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HANDBOOK ON MARINE RADIO COMMUNICATIONS AND RADIONAVIGATION EQUIPMENT. VOL. 2. RADIONAVIGATION EQUIPMENT

By

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[Book by Aleksandr Mustafovich Bayrashevskiy, Yuriy Yeliseyevich Gornostayev, Aleksandr Vasil'yevich Zherlakov, Aleksandr Anatol'yevich Il'in, Oleg Vasil'yevich Kononov and Nikolay Timofeyevich Nichiporenko, edited by Doctor of Technical Sciences, Professor A.V. Zherlakov; reviewers: engineers N.P. Malyshev and V.I. Shchepotin, Izdatel'stvo "Sudostroyeniye", 1979, 231 pages, 12,000 copies]

[Text] Basic information on modern radionavigation and radar equipment for maritime vessels is contained in this second volume of the handbook; the classification and characteristics are given for the instruments, as well as the complement and composition of the equipment and functional schematics of the units. The major requirements for the installation and operation of equipment under shipboard conditions are set forth.

The handbook is intended for a wide circle of engineering and technical workers in design and planning organizations, as well as specialists engaged in the operation of the equipment on seagoing and river fleet vessels and those of the Ministry of the Fishing Industry.

The handbook can also be useful to students in the higher educational institutes and technical schools, and students taking courses in marine training institutions for their course and diploma design work.

Foreword

Because of the rise in the tonnage and the increase in the speeds, sizes and inertia of modern vessels, the requirements place on marine navigation have increased substantially. The radionavigation instruments used on the ships of the merchant marine and fishing industry fleets are becoming extremely important, where these instruments make it possible to reduce the number of accidents which incur large material losses, and in some cases, create a real threat to safeguarding the environment.

Volume 2 of the handbook on marine equipment for radio communications and radio navigation is devoted to modern domestic radio navigation instruments used on ships of the merchant marine and fishing industry fleets. Functional and structural configurations are treated here, as well as the operational and technical characteristics and rules for technical operation of radio navigation instruments.

The shipboard oral indicating "Rybka" and "Barkas" radio direction finder as well as the visual dual channel "Rumb" radio direction finder are treated in Chapter 1.

Chapter 2 contains a description of the marine "Pirs-1D" and "Pirs-1M" display receivers which are used to determine the location of a vessel by means of signals transmitted by the shore stations of the "Decca" phase radio navigation system.

The marine KPI-5F display receiver used to determine the location of a ship based on signals from shore stations using the "Loran C" pulse-phase radio navigation system is treated in Chapter 3.

Descriptions of the marine "Lotsia", "Mius" and "Nayada" navigation radars and the "Okian" and "Okian-M" automated navigation radars are given in Chapters 4 and 5.

Specific features of the operation of "Istra" doppler navigation radars for measuring the berthing speed are treated in Chapter 6.

Chapter 7 is devoted to the marine "Mgla" infrared night vision scope and the "Gorizont" television system.

Each chapter of the handbook concludes with recommendations for the insulation, mounting and operation in a ship of the radio navigation instrument being discussed.

The development of ship navigation hardware in the last decade is characterized by the widescale introduction of digital computer equipment and the use of new principals for putting together complete sets of equipment which increase the operational capabilities of the instruments. The realization of digital processing circuitry for radio navigation data makes it possible to employ optimal processing techniques and represent the navigation information in a form convenient for the ship navigator.

Developmental work was completed and trial operation was started with the "Yenisey" radar set at the moment work was finished on this handbook. The development of situation displays using the "Briz-Ye" and "Kron" computers is drawing to a close; the production of these computers will start in 1981. Developmental work is underway at the present time on a more sophisticated "Biryus" navigation set.

Unfortunately, not all of these navigation sets have been included in this edition of the handbook. However, the authors have taken into account the trends noted in the development of ship navigation hardware and have attempted to give a more detailed treatment of those questions which will assist the reader in overcoming difficulties in studying radar-computer systems not included in this handbook.

The work was done by a collective of authors. Chapter 1 was written by O.V. Kononov, Chpater 2 by A.V. Zherlakov, Chpater 3 by Yu.Ye. Gornostayev, Chapters 4 and 6 by A.M. Bayrashevskiy, Chapters 5 and 7 by N.T. Nichiporenko and §4.2 by A.A. Il'in.

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PART ONE MARINE RADICNAVIGATION SYSTEMS

Marine radionavigation systems (MRS) are shipboard measurement equipment which serves to receive, process and display navigation information contained in electromagnetic field signals received either from radiation sources external to the ship or produced by shipboard radiation sources and reflected from external objects.

Radio navigation systems are used for the navigation of maritime transport and fishing industry ships, where these systems operate in the radio frequency bands shown in Figure B.1 (the boundaries of the frequency bands can be changed on the basis of international agreements).

The major tasks of navigation are solved by means of radionavigation systems: ship navigation from one region to another by the shortest, safest and most economically advantageous route. Of great importance in this case are problems of determining ship position at sea and the safe divergence from oncoming vessels. Radionavigation systems are also used when sailing in confined water (channels, narrow places, etc.), when docking large tonnage ships in ports, during oceanological, hydrographical and geodesic research at sea, when piloting ships through channels, sailing in ice, etc.

Radionavigation systems are recommended for maritime transport vessels, where these systems assure the determination of position with an accurracy, the values of which are given below:

Navigation Region	Precision in Determining Ship Position
Confined water	0.1-0.5 cable lengths
Coastal waters	0.1-0.25 miles
Open sea	1.0-2.0 miles

Radionavigation systems are classified according to several criteria. *Depending on the service region and the operating range (D)* they are subdivided as follows:

a) Close range navigation systems ($D \leq 100$ miles), coastal sailing, piloting a ship, docking, etc.

b) Intermediate operational radius systems ($D \leq 400$ miles);

c) Long range navigation systems (D = 1,500 to 2,500 miles);

d) Global systems (ranges encompassing all ship navigation regions of the world).

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Marine radionavigation systems, in being radio instrumentation equipment, are intended for determining the following *major navigation parameters:*

a) Directions (bearings, course angles, etc.);

b) Distances;

c) A linear combination of distances (difference or sum);

d) Speed;

e) Precise time.

The subsequent processing of these parameters determines the line of position of a ship at sea or its orientation relative to other ships or objects on shore.

A classification of marine radionavigation systems is given in Table B.1 as a function of the primary measurement and processing of the radio signals which contain information on the navigation parameters indicated above.

The navigation parameters measured by marine radionavigation systems are incorporated in radio signals which are mathematically described by the following expressions [1]:

$$e = W(r, \sigma, \varepsilon) E_m\left(t - \frac{r}{v}\right) \sin\left[\omega_c\left(t - \frac{r}{v}\right) - \psi_0\right], \quad (B.1)$$

where e is the electromagnetic field intensity at the installation point of the shipboard antenna;

$W(r,\sigma,\varepsilon)$ is the attenuation function for the intensity e due to the travel of signals over the path;

r is the distance between the shore station and the ship;

σ, ε is the effective conductivity and dielectric permittivity along the path respectively;

v is the radio wave propagation velocity;

E_m is the amplitude value of the field intensity;

ω_c, ψ_0 are the frequency and phase of the radio signals respectively.

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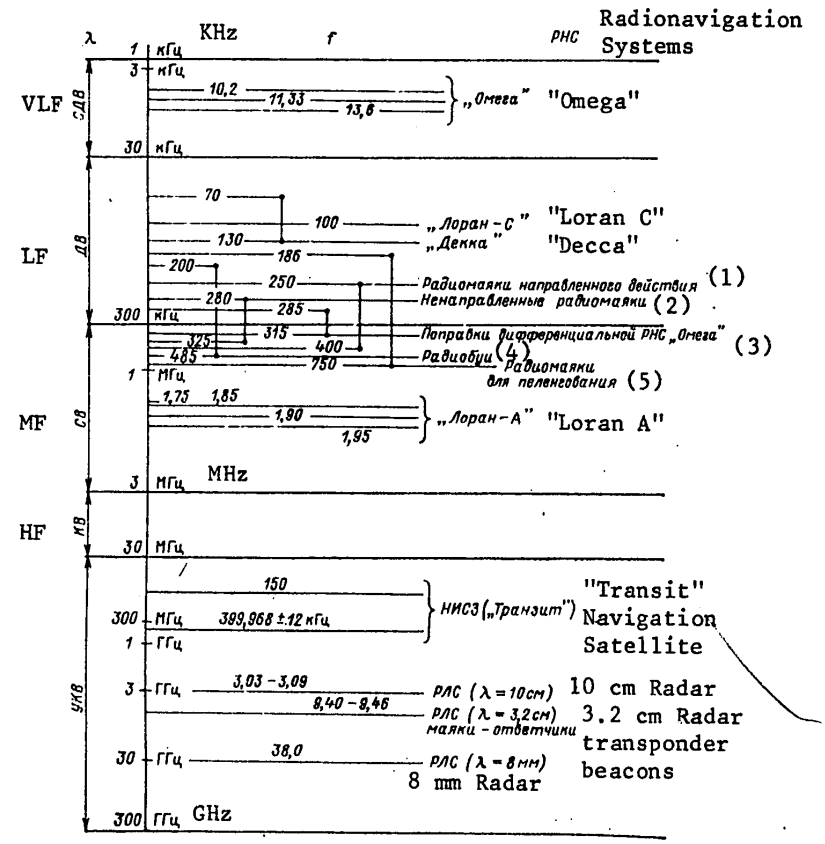

Figure B1. Band of frequencies used for radionavigation systems.

Key: 1. Directional radio beacons;
2. Omnidirectional radio beacons;
3. Corrections for the "Omega" differential radio navigation system;
4. Radio buoys;
5. Radio beacons for takin bearings.

Radionavigation systems are broken down into pulsed (the signals are transmitted at intervals separated in time, as pulses) and CW radionavigation systems, according to the nature of the transmitted and received signals (B.1).

TABLE B.1

Navigation Parameter Being Measured	Radionavigation System Classification	Name of the Shipboard Equipment
Direction	Goniometric	The "Rybka" and "Rumb" (visual dual channel) radio direction finders; the "Okean-M", "Lotsiya", "Don", "Mius", etc. radars.
Distance	Range finding	The "Omega" (range finding mode) radionavigation system display receivers, radars (see above) and "Al'fa", "Yenisey" and "Briz" collision warning systems
Difference in ranges	Difference range finding (radionavigation systems with time and frequency gating. Pulse-phase radionavigation systems)	"Pirs-1M", Pirs-1D", KPI-4, KPI-5F, "Omega" radionavigation display receivers and display receivers of satellite navigation systems.
Speed	Radionavigation systems and radars using the doppler effect	Navigation satellite display receivers (differential method), "Istra" radar (docking) and other radars (see above).
Time	-	"Omega", "Loran-C" and navigation satellite radionavigation system display receivers (in the precise time measurement mode).

The navigation parameter which is contained either in the time delay of the radio signals relative to each other (radio navigation systems using time gating, radars) or in the phase relationships of the received radio signals (phase radionavigation systems, radio range finders, etc.) is determined as a function of the measurement of the radio signal voltages (see B.1).

CHAPTER 1 GONIOMETRIC MARINE RADIONAVIGATION SYSTEMS

1.1. Marine Radio Direction Finders and Their Classification

Radio direction finder is the term for a radio receiving device which makes it possible to determine the direction of arrival of radio waves. The angle between the center line of a ship and the direction to a radio beacon, called the relative radio bearing (RKU), and the angle between true north and the direction to a radio beacon, called the observed radio bearing (RP) are determined using a radio direction finder.

Because of the simplicity of the device, the high reliability and the comparatively low cost, radio direction finders find wide applications in vessels of the maritime and fishing fleets.

Radio direction finders make it possible to solve the following navigational problems:

a) Determine the radio bearings to radio navigation beacons, omnidirectional radio stations and commercial fishing sonobuoys;

b) Pilot a ship using equal signal zones produced by directional radio beacons;

c) Take DF readings on ships transmitting distress signals.

Radio direction finders must be installed on all ships in accordance with international regulations to assure seafaring safety and protect human lives at sea.

Proper operation of a radio direction finder is possible when such factors as the following are taken into account, which degrade the accuracy of radio direction finding:

--The subjectivity in determining the audibility minimum of a signal;

--The necessity of carefully cancelling out the out-of-phase signal components ("an indistinct minimum");

--The influence of space radio waves at night ("the nighttime effect");

--The necessity of carefully determining and compensating for the radio deviation;

--The change in the position of the signal audibility minimum during maneuvering and rocking of the vessel.

Marine radio direction finders are broken down into aural and visual types according to the method of indicating the bearing.

In aural radio direction finders, a bearing is taken on radio beacons and radio stations aurally based on the minimum of the signal audibility. These types of instruments include radio direction finders with a rotating loop and goniometric radio direction finders.

The further development of radio direction finding equipment has led to the design of various types of radio direction finders with visual display of a bearing, of which the following find application at the present time:

--Automatic radio direction finders with a tracking goniometer search coil (ARP);

--Visual radio direction finders with cathode ray tube displays (VRP).

In automatic radio direction finders with a tracking system, it is necessary only to tune the receiver to the frequency of the radio beacon or radio station for which the DF bearing is being taken, after which the bearing is determined automatically. Radio direction finders of this type have substantial drawbacks which limit their application in ships of the maritime fleet. These include the following:

--The appearance of false bearing readouts in the presence of interference from radio stations on adjacent frequencies;

--The considerable inertia of the tracking system, which leads to direction finding errors when a vessel is rocking;

--The poor interference immunity, which causes arbitrary fluctuations of the meter in the pauses between radio beacon signals.

Visual radio direction finders with CRT displays are broken down into two types:

1) Dual channel visual radio direction finders with a CRT (DVRP);

2) Radio direction finders which sketch the directional pattern on the screen of the CRT (VRP).

At the present time, dual channel visual radio direction finders have become the most widespread on ships of the merchant marine, where these finders have the following distinctive features:

--The channels of the radio direction finder can be manually balanced using signals from the radio beacon on which the bearing is being taken;

--The capability of estimating direction finding quality;

--The existence of a narrow bandwidth in the receiver (300 to 600 Hz).

Single channel radio direction finders using CRT's with the directional pattern outlined on the screen have proven themselves quite well in operation, where these finders are distinguished by the following:

--Simplicity in taking a radio bearing;

--Low inertia of the bearing indication;

--The capability of estimating the direction finding quality.

1.2. The "Rybka" Marine Aural Indicating Radio Direction Finder

Function and Operational and Technical Characteristics

The "Rybka" aural radio direction finder is used on ships of the commercial fishing and merchant marine fleets, and makes it possible to do the following:

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--Determine radio bearings to navigation radio beacons, omnidirectional radio stations and fishing industry sonobuoys;

--Pilot a ship using equal signal zones produced by directional radio beacons;

--Take RDF bearings on ships transmitting distress signals.

The following are included in the basic equipment set of a radio direction finder: loop antenna, antenna mast, "inclined beam" or "whip" type omnidirectional antenna, goniometric receiver, radio operator signal panel and junction box.

The equipment complement of a radio direction finder depends on the structural design of the goniometric receiver unit, the diameter of the loop antenna, the type of selsyns used to track with the gyrocompass and the voltage of the shipboard power mains.

A type RA loop antenna is made from two mutually perpendicular shielded loops. The RA-1.2-4 loop has four turns with a diameter of 1.2 m while the RA-0.6-6 loop has six turns with a diameter of 0.6 m. The turns of the loop winding are housed inside shielding duraluminum tubes with a diameter of 30 mm. The upper loop assembly is made of an insulating material. The center taps of the winding are connected through capacitors to the chassis, something which makes it possible to check the insulation resistance of the loop circuit with respect to the loop housing without disconnecting the center tap of the loop winding.

The antenna mast is fabricated from duraluminum pipe with a diameter of 84/76 mm and a height of 1.6 m. The mast has an upper flange and guys with turnbuckles for fastening to a deck. The loop antenna is secured to the upper flange of the mast with bolts.

The "inclined beam" type omnidirectional antenna is made from copper antenna cable 6 to 8 m long.

The junction box is intended for connecting all of the cables to the goniometric receiver unit. To provide for spray protection, all of the cables are brought into the junction box through packing glands.

The goniometric receiving unit contains the receiver, the goniometric unit, the compensating device and the power supply.

The OP-120F converter converts the shipboard power mains direct current to single phase alternating current at a voltage of 127 V at a frequency of 50 Hz.

The signaling panel is intended for signaling the position of the ship antennas.

The overall dimensions of the components of the equipment set and their weight are given below:

	Overall Dimensions, mm	Weight, kg
The goniometric receiver	470 x 253 x 360	30
Loop antenna:		
600 mm diameter	680 x 680 x 900	14.5
1,200 mm diameter	1,280 x 1,280 x 1,592	21.5
Auxiliary antenna	6000	3
Signal panel	242 x 129 x 100	3.5
Antenna mast	1600	9
Storage battery	481 x 257 x 165	35
OP-120F inverter	314 x 178 x 234	12
Connecting cable	--	14

The "Rybka" radio direction finder has the following specific features:

a) It provides for radio direction finding at medium and intermediate wavelengths;

b) It is produced in a desk top and console design;

c) It is made with transistors, nuvistors and micromodules;

d) Provides for sensing by means of a meter with a pointer.

The major operational and technical specifications of the radio direction finder are given below:

Frequency bands which can be received:	
Medium wave, KHz	255 - 535
Intermediate wavelengths, MHz	1.60 - 3.35
Signal modes which can be received	A1, A2, A3
Mean arithmetic radio direction finding error, degrees, in the following frequency bands:	
255 - 535 KHz	1
1.6 - 3.35 MHz	3
Readout accuracy of a bearing on the scale, degrees	0.5
Sensitivity, microvolts:	
In the A2 and A3 modes for a signal/noise ratio of 3:1, in the following frequency bands:	
255 - 535 KHz	2
1.6 - 3.35 MHz	1
In the $A1_{narrow}$ mode for a signal/noise ratio of 15:1 in the following frequency bands:	
255 - 535 KHz	0.5
1.6 - 3.35 MHz	1
Channel selectivity, dB:	
Adjacent channel rejection for frequency offset of ± 10 KHz	50

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Image frequency rejection	60
Intermediate frequency rejection	60
Intermediate frequency bandwidth, Hz:	
Wide	5500
Narrow	300
Graduation error in the tuning scale, %	0.5
Manual gain control, dB	70
Electrical compensation for the radio deviation coefficient D* in the 255 - 535 KHz frequency band, degrees	±(2--20)
Length of the connecting feeders for the antenna, m:	
The D-1200 loop	15
Auxiliary	7
Antenna insulation resistance, MOhm	10
Power consumption:	
From the 127/220 VAC mains at a frequency of 50 Hz, VA	35
From the 24, 110 or 220 volt DC mains, watts	200
From the 24 volt emergency storage batteries, watts	30
Duration of continuous operation from the emergency storage batteries, hours	10
Rated operating life, hours	8,060
Weight of the complete radio direction finding set, kg	158

A block diagram of the "Rybka" radio direction finder is shown in Figure 1.1.

With the action of an electromagnetic field from a transmitting radio station, currents are induced in the loop and omnidirectional antennas of the radio direction finder which flow through the field coils of the goniometer and produce magnetic fields in them. An antiradar filter, a PLF, is used to eliminate interference from shipboard radars. A search coil rotates inside the field coils, where an e.m.f. is induced in the search coil which depends on the angle between the plane of the search coil and the resulting magnetic field of the goniometer. The voltage is fed from the main search coil to the input resonant circuit of the radio frequency amplifier, the UVCh, which consists of an amplification stage with a bandpass filter in the load and an aperiodic amplifier stage.

The voltage from the RF amplifier output and from the first local oscillator, G, is fed through a buffer aperiodic amplifier to the first ring mixer. The first intermediate frequency (IF = 1,198 KHz) is fed to the single stage amplifier for the first IF having a bandpass filter in the load, and then to a

*D is the quaternary ratio deviation coefficient.

second frequency converter consisting of a crystal controlled second local oscillator (1,413 KHz), an aperiodic buffer amplifier and a second ring mixer.

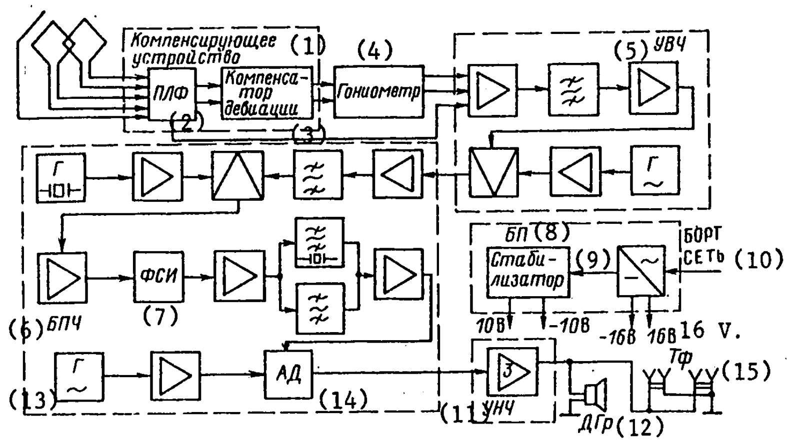

Figure 1.1. Block diagram of the "Rybka" radio direction finder.

Key:
1. Compensating unit;
2. Antiradar filter;
3. Deviation compensator;
4. Goniometer;
5. Radio frequency amplifier;
6. Intermediate frequency amplifier;
7. Lumped selectivity filter;
8. Power supply;
9. Regulator;
10. Ship power mains;
11. Audio amplifier;
12. Dynamic loudspeaker;
13. Oscillator;
14. AM detector;
15. Telephone headsets.

The second intermediate frequency of 215 KHz is fed from the output of the second ring mixer to a three stage second IF amplifier: the first stage has a lumped selectivity filter, a FSI; the second stage has a crystal filter (when a narrow bandwidth is used) or has a bandpass filter (when a broad bandwidth is used); and a third stage with a single tuned circuit in the load.

The second IF voltage is fed from the output of the third stage to the AM detector AD.

When receiving nondecaying A1 signals, the voltage from a third oscillator is additionally fed to the detector through an aperiodic buffer amplifier where the frequency of this oscillator varies in a range of 216 to 218 KHz. The audio-frequency output signal in this case is obtained as a result of the beat frequency resulting from the second intermediate frequency and the third oscillator frequency.

The audiofrequency signal from the detector output is fed to a three stage audiofrequency amplifier, the UNCh, the first two stages of which are designed in an aperiodic circuit configuration, while the output stage uses a push-pull transformer circuit. The amplified audiofrequency signal is fed to a dynamic loudspeaker, DGr, and two pairs of TA-56M type low impedance telephone sets.

The power supply BP provides for the operation of the radio direction finder from the 127, 220 or 24 volt AC mains, from 110, 220 or 24 volt DC mains as well as from the emergency 24 volt storage batteries.

The voltage of the shipboard power mains is fed through the mains filter and the SHIP POWER switch to the power transformer of the rectifier, which is designed in a bridge configuration with parametric voltage regulation.

The +16 and -16 V voltages for powering the relays and lighting circuits are taken directly from the rectifier, while the regulated +10 and -10 V voltages for powering the entire radio receiver circuit are taken from the parametric regulator.

Controlling the "Rybka" Radio Direction Finder

The operational controls and indicating dials used by the navigator when working directly with the radio direction finder are located on the front panel of the goniometric receiver (Figure 1.2).

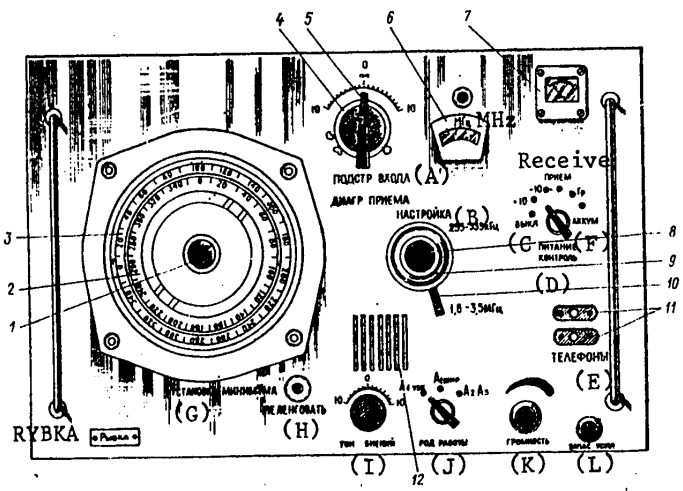

Figure 1.2. The front panel of the "Rybka" radio direction finder.

Key: A. Input fine tuning; Reception pattern;
B. Tuning;
C. Off;
D. Power check;
E. Telephone headsets;
F. Storage battery;
G. Set minimum;
H. Take bearing;
I. Beat frequency oscillator;
J. Operating mode: A_1 narrow; A_1 wide; A_2, A_3;

Key [cont.]: K. Volume;
L. Gain reserve [spline key operated RF gain control].

The DF BEARING signal light serves for monitoring the position of the shipboard antennas and comes on after they are isolated.

The SET MINIMUM control 1 is intended for rotating the sighting pointer to the position of the minimum of the radio beacon signal audibility.

The scale for the relative radio bearings, 2 (the stationary scale), with divisions of 1°, serves for reading out the relative radio bearing.

The scale for the observed radio bearings, 3 (the moving scale), with scale divisions of 1°, serves for reading out the observed bearings.

Control 4, INPUT FINE TUNING, is intended for fine tuning the radio direction finder to the radio beacon frequency based on the maximum loudness of the radio beacon call signs.

Switch 5, RECEPTION PATTERN, has four fixed positions and serves to switch the radio direction finder to the following modes: "watch duty reception", "direction finding", "sensing".

Frequency tuning scale 6 has numerical scale graduations for the medium wave band (outside scale) with intervals of 2 KHz, and intervals of 20 KHz for the intermediate frequency band (inside scale).

Meter 7 makes it possible to monitor the power supply voltage and visually observe the minimum of the radio beacon signal audibility.

The POWER SUPPLY CHECK switch has six fixed positions and serves to turn on the radio direction finder and check the supply voltages.

TUNING control 8 is intended for precise tuning to the radio beacon frequency using the frequency tuning scale or based on maximum audible loudness of the radio beacon call signs.

TUNING control 9 serves for coarse tuning to the radio beacon frequency using the frequency tuning scale.

Bandswitch 10 has two fixed positions:

Band I (medium wave): 255--535 KHz
Band II (intermediate wavelengths): 1.6--3.5 MHz.

Telephone jacks 11 serve for connecting two pairs of headsets.

The GAIN RESERVE control (spline key) is intended for changing the sensitivity of the radio direction finder.

The VOLUME control serves for continuous control of the volume of the radio beacon signal being received.

The OPERATING MODE switch has three positions. In the first two switch positions ("$A_{1\ narrow}$" and "$A_{1\ wide}$"), the telegraph signals of radio beacons and radio stations operating in the A1 mode are received, while in the third position, the signals of radio beacons and radio stations operating in A2 and A3 modes are received with a wide bandwidth.

Loudspeaker 12 serves for hearing the radio beacon signal.

The BFO control serves to obtain a desirable tone for the beat frequency in the headsets when receiving the signals of radio beacons operating in the A1 mode.

Controls which are not normally used during operation are placed under a cap on the front panel of the goniometric receiver, where these controls are used when preparing the radio direction finder for operation.

The SHIP POWER switch is used for selecting the power supply voltage.

The DEVIATION COMPENSATION switch makes it possible to compensate for the radio deviation coefficient D in a range of from -2° to 20°.

The ZERO SET control serves to match the scales of the radio direction finders to the gyrocompass repeater.

The GONIOMETER AXIS LOCK makes it possible to stop the goniometer rotor when zero setting the goniometer indicator.

Technical Operation Regulations

The following are to be done during watch duty reception:

--The Power Check switch is set in the "RECEIVE" position;

--Switch 5, RECEPTION PATTERN, is set in the "0" position;

--The OPERATING MODE switch is set in the "$A_{1\ wide}$" position when receiving the signals of radio beacons operating in the A1 mode, or in position "A_2A_3" when receiving the signals of radio beacons operating in the A2 or A3 modes;

--The bandswitch is set to the requisite position;

--The VOLUME control is set to the position in which noise is heard in the headsets;

--Using the coarse and fine tuning controls, one tunes to the frequency of a radio beacon for the maximum radio beacon signal loudness;

--Using the BEAT FREQUENCY OSCILLATOR control, the desirable beat frequency tone is obtained in the headsets;

--Maximum volume of the radio beacon signal is obtained by using control 4, INPUT FINE TUNING.

In the case of direction finding and sensing, the following are to be done:

--Switch 5, RECEPTION PATTERN, is set to the "∞" position;

--Using control 4, INPUT FINE TUNING, maximum volume is obtained;

--The pointer is set to the position of minimal radio beacon signal audibility with control 1, SET MINIMUM:

--The RECEPTION PATTERN switch 5 is set sequentially to the positions of the green and red cardiod patterns; if the least audibility is obtained in the red cardiod position, then the pointer must be rotated through 180°;

--Check the correctness of the sensing determination using the indicating meter when the POWER CHECK switch is set in the "receive" position. The green cardiod position of RECEPTION PATTERN switch 5 should correspond to the least deflection of the meter needle;

--Switch RECEPTION PATTERN switch 5 to the "∞" position and by alternately rotating the SET MINIMUM control and the RECEPTION PATTERN switch, obtain the lowest minimum of the audibility (the sharpest silence angle) and the minimal deflection of the meter needle in the "receive" position of the POWER CHECK switch;

--Determine the bearing (or the relative radio bearing) as the average arithmetical value of two readings made at the boundaries of the silence angle. For example: the silence angle is bounded by readings of 61 and 67°; the true reading will be (61° + 67°)/2 = 64°;

--After taking the readings, check the radio deviation correction using the residual radio deviation curve.

1.3. The "Barkas" Portable Marine Aurally Indicating Radio Direction Finder

Function and Composition of the Equipment Package

The "Barkas" portable radio direction finder is intended for small fishing vessels and makes it possible to do the following:

--Determine the radio bearings to navigation radio beacons and omnidirectional radio stations as well as fishing sonobuoys;

--Take radio bearings on ships transmitting distress signals.

The operational and technical characteristics of the radio direction finder are given below:

Received frequency bands:	
Medium wave, KHz	250 - 550
Intermediate wavelengths, MHz	1.6 - 3.35
Types of signals which can be received	A1, A2, A3, A3A, A3H
The precision in setting the tuning frequency, %	1
Mean arithmetic radio direction finding error, in degrees, in the following frequency bands:	
250 - 550 KHz	1

1.6 - 3.35 MHz	7
Sensitivity for reception with an omnidirectional antenna and a signal/noise ratio of 20 dB, in μV/m, in the following frequency bands;	
250 - 550 KHz	500
1.6 - 3.35 MHz	700
Channel selectivity in dB:	
Adjacent channel reduction for a frequency difference of ±10 KHz	40
Image frequency rejection	40
The intermediate frequency bandwidth in Hz	3000
Power consumption in watts	3
Continuous operational time from an 8KNG-Ts storage battery, hours	6
Mean time between failures, hours	1500
Weight of the radio direction finder, kg	7

The following are included in the delivered equipment set of the radio direction finder: the receiver and indicator unit, type TA-56M headsets, type 8KNGTs-1D storage batteries, a cable with a filter, a base and a charger and discharger unit.

A block diagram of the radio direction finder is shown in Figure 1.3.

The radio direction finder consists of the antenna rotating unit, the antenna amplifier, the radio receiver, the headsets TF and the KNGTs-1D type batteries or "Rubin-1" drycell.

The antenna rotating unit has two antennas: a directional antenna which takes the form of two mutually perpendicular ferrite rods with antenna coils wound on them, and an omnidirectional antenna in the form of a shortened whip with a capacitive load.

The antenna amplifier is designed in a resistance coupled amplifier configuration using a field effect transistor with a high input impedance, which provides for matching to the omnidirectional antenna. The amplifier load is the input resonant circuit consisting of an inductance coil and a variable capacitor. The signal from the input circuit is fed to the radio frequency amplifier input, where this amplifier is designed around a K2US241 integrated circuit with a bandpass filter as the load in the collector circuit.

The frequency converter and first local oscillator are designed around a single K2ZhA242 integrated circuit. The first local oscillator uses a capacitive feedback circuit. The voltage from the frequency converter is amplified by a four stage IF amplifier (the IF section), made using four identical K2US242 integrated circuits. The load of the first stage is an electromechanical filter

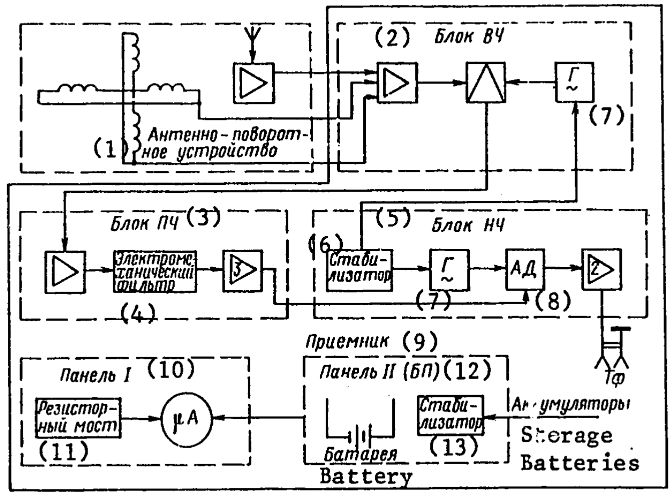

Figure 1.3. Block diagram of the "Barkas" radio direction finder.

Key:
1. Antenna steering unit;
2. Radio frequency section;
3. Intermediate frequency section;
4. Electromechanical filter;
5. Low frequency section;
6. Regulator;
7. Oscillator;
8. AM detector;
9. Receiver;
10. Panel I;
11. Resistor bridge;
12. Panel II (power supply);
13. Regulator

which governs the bandwidth and selectivity of the IF amplifier. The remaining three IF stages provide for the requisite gain in the channel.

The voltage from the output of the last IF amplifier stage is fed to an audiofrequency amplifier unit (the audiofrequency section). The following are assembled on the board for the audiofrequency section: a voltage regulator, the second local oscillator, the AM detector and an audiofrequency amplifier. The voltage regulator, which is designed around a K2PP241 integrated circuit, is intended for stabilizing the operating points of the radio frequency amplifier, converter and first local oscillator stages. The second local oscillator is intended for receiving A1 signals and restoring the carrier when receiving A3A and A3H signals. The oscillator is turned on when the radio direction finder operates in a telegraph mode and is designed around a K2ZhA242 integrated circuit using a crystal controlled oscillator.

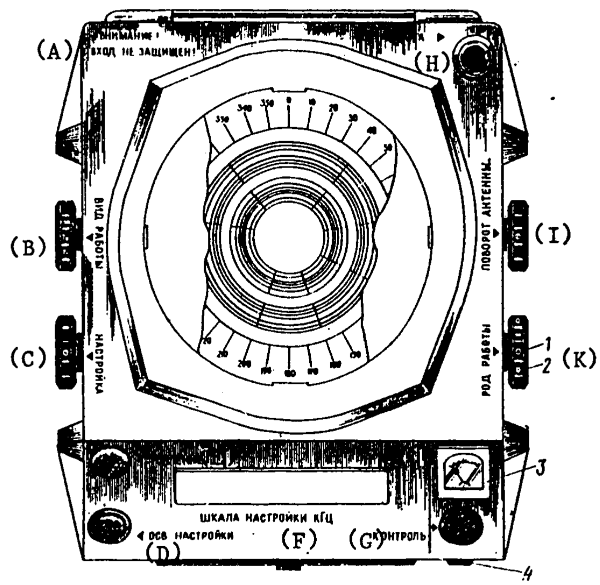

Figure 1.4. The front panel of the "Barkas" radio direction finder.

Key: A. CAUTION! INPUT NOT PROTECTED!
B. Signal mode switch;
C. Tuning;
D. Tuning light;
E. Gain control;
F. Tuning scale, KHz;
G. Monitor switch;
H. Azimuth scale light;
I. Antenna rotate;
K. Operating mode switch.

The detector stage combines the functions of an AM detector and a converter. In a telephone mode, it is used to segregate the envelope of amplitude modulated signals, while in a telegraph mode, it serves to obtain the beat frequency between the intermediate frequency and the second local oscillator. The detector is designed around a K2ZhA242 integrated circuit in a common emitter configuration. The detector load is the input impedance of the audio preamplifier. The audio amplifier consists of a preamplification stage, designed around transistors in a cascode circuit configuration, and a final stage using KT-312V transistors in a push-pull circuit. The audio amplifier is loaded into one pair of low impedance TA-56M headsets. A 200 μA microammeter is used to monitor the output voltage of the radio direction finder, where the audio frequency voltage detected by a diode and smoothed by a filter, which is located on panel I in the resistor bridge, is fed to the microammeter.

The power supply voltage is monitored by the microammeter, which is connected through an electrical scale extension circuit for the instrument, located on panel II.

The cover compartment of the radio direction finder is broken down into two parts. The voltage regulator which provides for operation of the radio direction finder from the ship batteries is housed in one portion while the back-up power source (a "Rubin-1" battery) is housed in the other section.

The front panel of the radio direction finder is shown in Figure 1.4. The operational controls, monitor and indicating instruments used by the operator when working directly with the radio direction finder are located on the face and side walls of the housing: the TUNING control, SIGNAL MODE switch, band-switch, AZIMUTH LIGHT button, ANTENNA ROTATE control, OPERATING MODE switch, the indicating meter 3, the MONITOR button, telephone jacks 4, the TUNING SCALE in KHz, the TUNING LIGHT button and the GAIN control. A 24 volt plug is placed on the back panel to connect the cable when getting power from shipboard storage batteries as well as two toggle switches: ON--OFF when powered from the ship-board storage batteries and INTERNAL-EXTERNAL when powered from the external source (shipboard storage batteries) or the internal source (two "Rubin-1" batteries).

Operating Modes

Watch Duty Reception. In this mode, the OPERATING MODE switch is in the "0" position. Only the signal from the omnidirectional antenna is used which is fed to the antenna amplifier and then through the switch to the input tuned circuit of the RF amplifier. The directional pattern of the antenna has the shape of a circle. In this mode, one tunes to the frequency of the transmitting radio station and listens to it.

Direction Finding Mode. In this case, the OPERATING MODE switch is in the "∞" position. The main directional antenna is used for reception. The signal from this antenna is fed through the switch to a balancing transformer and then to the input circuit of the RF amplifier. The antenna directional pattern has the shape of a figure eight. In this mode, one takes DF bearings on radio beacons and radio stations at the moment of the signal audibility minimum when rotating the ANTENNA ROTATE control.

Sensing. In this case, the OPERATING MODE switch is alternately set in positions 1 (red dot) and 2 (green dot). The signal from the auxiliary directional antenna is fed through the switch to the balancing transformer and then to the input circuit of the RF amplifier, while the signal from the nondirectional antenna is fed to the same input circuit directly through the switch. The signals from the auxiliary directional and omnidirectional antennas are added together. The resulting directional pattern has the shape of a cardiod, the minimum of which is shifted in space through 180°. The unambiguous direction to the radio station or radio beacon is indicated by the pointer of the colored marker which matches the color of the marker on the OPERATING MODE switch for which the output voltage and the audibility are a minimum.

Technical Operation Regulations.

During watch duty reception, the following is to be done:

--Set the OPERATING MODE switch to the "0" position;

--Set the SIGNAL MODE switch to the "Tg" ["telegraph"] position;

--Set the requisite band by means of switch 4;

--Set the GAIN control to the position for which noise is heard in the headphones;

--Tune to the frequency of the beacon on which a bearing is being taken using the TUNING control for the maximum signal loudness and maximum deflection of the meter needle.

When taking a bearing and making the sense determination, the following is to be done:

--Set the OPERATING MODE switch to the "∞" position;

--Using the ANTENNA ROTATE control, set the pointer to the position for minimal signal audibility from the radio beacon;

--Sequentially set the OPERATING MODE switch in the 1 (red dot) and 2 (green dot) positions;

--If the least audibility is obtained in position 1, then the pointer must be rotated through 180°;

--Determine the direction to the radio beacon using the color marker on the pointer, which matches the color of the marker on the OPERATING MODE switch for which the signal audibility is minimal;

--Throw the OPERATING MODE switch to the "∞" position and determine the boundaries of the silence angle;

--Using the azimuth scale, determine the relative radio bearing as the average arithmetic value of the two readings made at the boundaries of the silence angle;

--After taking the readings, take into account the radio deviation correction using the residual radio deviation curve.

1.4. The "Rumb" Dual Channel Marine Visual Radio Direction Finder

Function and Complement of the Complete Equipment Package

The visually indicating "Rumb" RDF is intended for merchant marine vessels and makes it possible to do the following:

--Determine radio bearings to navigation radio beacons and omnidirectional radio stations;

--Pilot ships using the radio signal zones produced by directional radio beacons;

--Take radio bearings on ships transmitting distress signals.

The composition of the equipment package of the radio direction finder depends on the variant of the receiver and indicator unit, the dimensions and type of the loop antenna as well as the presence of an antenna mast and the shipboard power mains voltage.

The basic radio direction finder package contains the following units: a loop antenna, an antenna mast, an "inclined beam" omnidirectional antenna, an antenna amplifier (AU), a receiver and indicator unit as well as a power supply and radio operator signal panel.

The "Rumb" radio direction finder has the following specific features:

1) It possesses "visual selectivity", which makes it possible to take bearings on the signals of two to three radio stations which simultaneously fall within the passband of the radio direction finder;

2) It makes it possible to continuously monitor the balance of the channels during direction finding;

3) Provides for nonsearch detection of radio beacon signals because of the use of a crystal controlled digital tuning display.

The major operational and technical characteristics of the radio direction finder are given below:

The frequency bands which can be received are:	
Medium wave, KHz	250 - 545
Intermediate wavelengths, MHz	1.6 - 2.85
Types of signals which can be received	A1, A2, A3
Precision in setting the frequency from the digital display, KHz	0.5
Mean square direction finding error, degrees, in the following frequency bands:	
250 - 545 KHz	1
1.6 - 2.85 MHz	3
Sensitivity when receiving with the 1,200 mm diameter loop, a feedline with a length of L = 30 m and a signal/noise ratio of 10:1, in μV/m, in the following frequency bands:	
250 - 545 KHz	25
1.60 - 2.85 MHz	25
Channel selectivity, in dB:	
Image frequency rejection	60
Intermediate frequency rejection	80
Intermediate frequency bandwidth, Hz:	
Wide band for the audio channel	3,000
Narrow band for the visual channel	500
Radio deviation compensation, in degrees, for the following coefficients:	
A	± 5
D	from -8 to +20
The length of connecting feedlines, in m, for the following antennas:	

Loop antenna	30 - 70
Auxiliary antenna	10
Antenna insulation resistance, MOhms	10
Power consumption from the 127/220 volt, 50 Hz mains, in VA	120
Weight of the complete radio direction finder set, in kg	96

A block diagram of the "Rumb" radio direction finder is shown in Figure 1.5.

The voltages from the longitudinal and transverse loop antennas are fed to the input unit of the display receiver. The input unit matches the antenna and feedline to the input amplifier of the radio frequency section, the BVCh, accomplishes the cross switching of the loop antennas between the I and II receiver-amplifier channels and amplifies the omnidirectional antenna signals.

A block diagram of the input section is shown in Figure 1.6. In the "bearing" operating mode, contacts two and three of relay R1 on board U1 open the omni-directional antenna circuit. In this mode, the signals are fed from the loop antennas to the diode switchers DK1 of board U1, which in the case of operation in the first band, are fed through the closed contacts 5 and 4, and 6 and 7 of relay R2 of board U2 and relay R2 of board U3 to the primary windings of transformers Tr2 and Tr4.

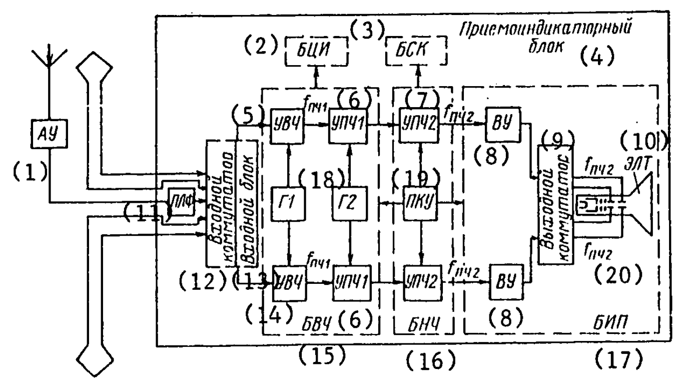

Figure 1.5. Block diagram of the "Rumb" radio direction finder.

Key:
1. AU = antenna amplifier;
2. BTsI = digital display;
3. BSK = audio channel section;
4. Receiver-indicator unit;
5. UVCh = radio frequency amplifier;
6. UPCh1 = intermediate frequency amplifier 1;
7. UPCh2 = intermediate frequency amplifier 2;
8. VU = output amplifiers;
9. Output switcher;

Key [cont.]: 10. ELT = cathode ray tube; 11. PLF = antiradar filter; 12. Input switcher; 13. Input section; 14. Radio frequency amplifier; 15. BVCh = radio frequency section; 16. BNCh = low frequency section; 17. BIP = bearing indicating block; 18. G1, G2 = local oscillators 1 and 2; 19. PKU = switcher circuit board; 20. Intermediate frequency 2.

In the second band, diode switchers DK1 of board U1 are connected through the closed contacts 5 and 4, and 6 and 7 of relay R1 of board U2 and relay R1 of board U3 to the windings of the matching transformers Tr1 and Tr3. The signal is fed from the output windings of transformers Tr2 and Tr4 when operating in the first frequency band and from the output windings of transformers Tr1 and Tr3 when operating in the second band through emitter followers EP3 and EP4 of board U4, and EP3 and EP4 of board U5 in the first case, and through emitter followers EP1 and EP2 of board U4 and EP1 and EP2 of board U5 in the second case to the corresponding selection and amplification channels of the high frequency section (see Figure 1.5). The diode switchers DK1 - DK2 of board U1 are switched by a square wave pulsed voltage at a frequency of 15 Hz, as a result of which the output windings of the transformers Tr1 and Tr3 are cross switched between inputs I and II of the amplifier channels.

In the "watch duty" and "check" operating modes, the signal is fed from the omnidirectional antenna through contacts 2 and 3 of relay R1 of board U1 to the input of the broadband amplifier, which consists of three stages and has as a load the primary windings of Tr1 and Tr2 of board U1.

The secondary windings of these transformers are connected to diode switcher DK2, and the subsequent signal path is analogous to the "bearing" mode.

The signals from the input section (see Figure 1.5) are fed to the radio frequency section, BVCh, which contains two identical amplifier stages for the signals from the longitudinal and transverse loop antennas. The radio frequency amplifier UVCh, which is incorporated in the radio frequency section, performs the following functions:

a) Provides for signal selection and amplification at the frequency which is tuned in;

b) Provides for image frequency and 750 KHz intermediate frequency rejection;

c) Converts the amplified signal f_1 to the first intermediate frequency f_{IF} = 750 KHz;

d) Controls the gain in steps.

A block diagram of the RF amplifier is shown in Figure 1.7. The RF amplifiers of the first and second amplification channels are made with two identical shielded strips. Two ganged sections of the five section block of variable

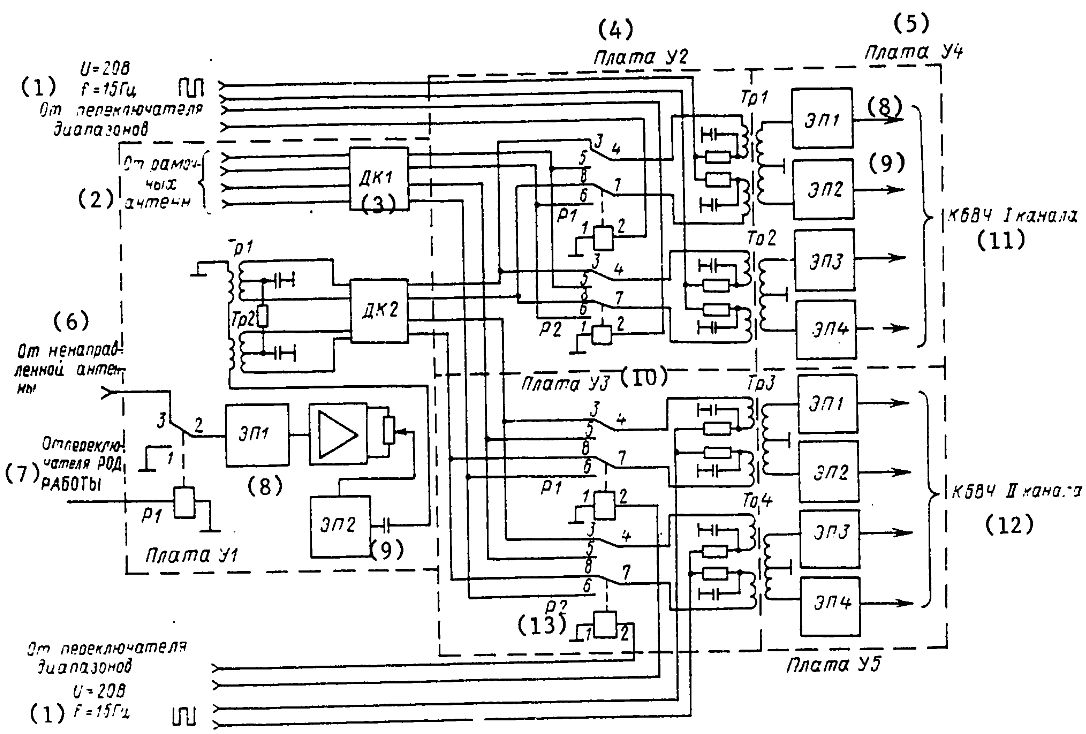

Figure 1.6. Block diagram of the input section.

Key: 1. U = 20 volts, f = 15 Hz, from the bandswitch;
2. From the loop antennas;
3. Diode switcher 1;
4. Board U2;
5. Board U4;
6. From the omnidirectional antenna;

Key [cont.]:
7. From the OPERATING MODE switch;
8. Emitter follower 1;
9. Emitter follower 2;
10. Board U3;
11. To the high frequency section [RF front end] of channel I;
12. To the high frequency section of channel II;
13. Relay R2.

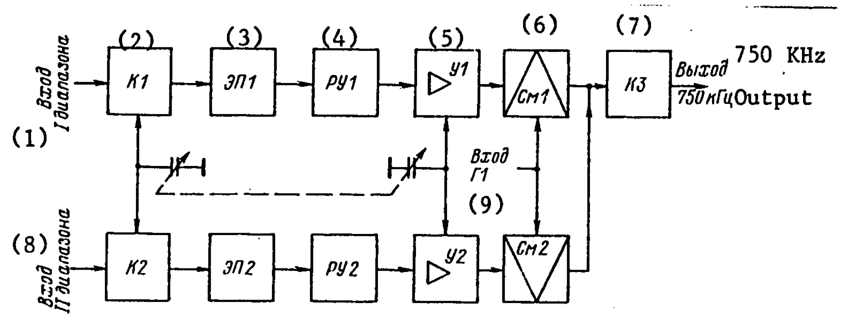

Figure 1.7. Block diagram of the RF amplifier.

Key:
1. Band I input;
2. Tuned circuit 1;
3. Emitter follower 1;
4. Gain control 1;
5. Amplifier 1;
6. Mixer 1;
7. Tuned circuit 3;
8. Band II input;
9. Heterodyne oscillator 1 input.

capacitors are used to tune the RF circuits for bands I and II in both channels.

The radio frequency signal is fed from the input section to the input resonant circuit K1 when band I is switched on (to tuned circuit K2 when band II is switched on). The signal at a frequency of f_1 which is segregated by tuned circuit K1 is fed to emitter follower EP1, then to the 1:10 step gain control RU1 and thereafter to amplifier U1, which is loaded into tuned circuit K3.

The signal from amplifier U1 and the signal from the first local oscillator G1 are fed simultaneously to the input of balanced mixer Sm1.

The converted signal at a frequency of f_{IF1} = 750 KHz is isolated in tuned circuit K3 and fed to the input of the first intermediate frequency amplifier board.

The first intermediate frequency amplifier UPCh1 (see Figure 1.5) performs the following functions:

a) Amplifies the IF1 signal;

b) Converts the amplified IF1 signal at f_{IF1} = 750 KHz to the IF2 signal: f_{IF2} = 33.3 KHz;

c) Provides for continuous gain control of the IF1 signal.

A block diagram of intermediate frequency amplifier 1 is shown in Figure 1.8.

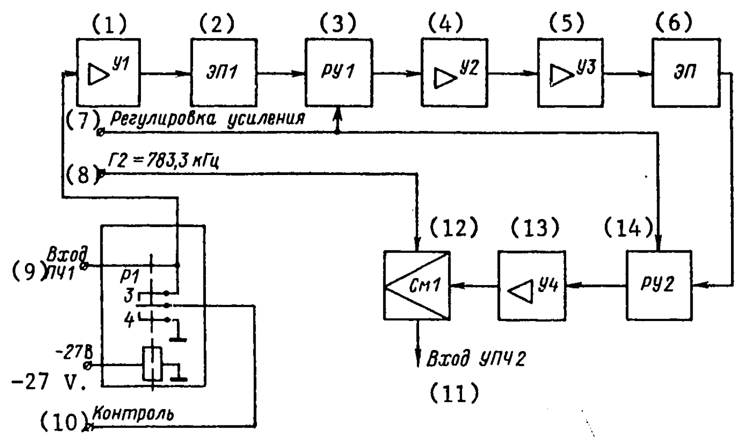

Figure 1.8. Block diagram of intermediate frequency amplifier 1.

Key:
1. Amplifier 1;
2. Emitter follower 1;
3. Gain control 1;
4. Amplifier 2;
5. Amplifier 3;
6. Emitter follower;
7. Gain control;
8. Local oscillator 2 = 783.3 KHz;
9. Intermediate frequency 1 input;
10. Monitor;
11. Intermediate frequency amplifier 2 input;
12. Mixer 1;
13. Amplifier 4;
14. Gain control 2.

In the "bearing" operating mode, the IF1 signal is fed from the output of mixer Sm1 to the amplifier stage U1, which is loaded into a resonant circuit, and then to emitter follower EP1, which matches the output impedance of the resonant circuit and the input impedance of gain control circuit RU1. Following the RU1 circuit, the signal is amplified by resistance coupled amplifiers U2 and U3 and thereafter fed to gain control circuit 2.

The signal level is continuously adjusted by a factor of 25 times in gain control circuits 1 and 2, RU1 and RU2.

The signal is fed from the output of circuit RU2 to tuned amplifier U4, which is loaded into a resonant circuit, and then to the mixer stage Sm1, to which the local oscillator signal of G2 is fed simultaneously. The signal is fed from the output of mixer stage Sm1 to the input of intermediate frequency amplifier 2.

In the "monitor" mode, relay R1 of the board for intermediate frequency amplifier 1 connects the inputs of the first intermediate frequency amplifiers of both amplifier channels in parallel.

The low frequency section (see Figure 1.5) performs the following functions:

a) Amplifies the IF 2 signals within a passband of 500 Hz (narrow band) and 3 KHz (broadband);

b) Generates the voltages which control the input and output switcher circuits, blank the trace and compensate for the D radio deviation coefficient;

c) Compensates for the D radio deviation coefficient.

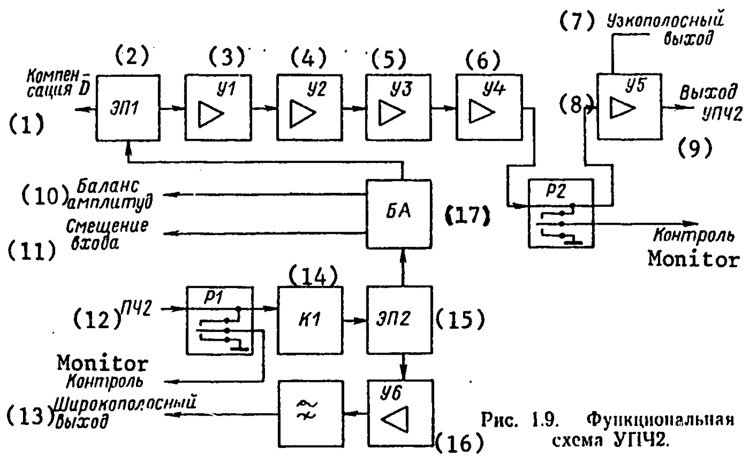

Рис. 1.9. Функциональная схема УПЧ2.

Figure 1.9. Block diagram of intermediate frequency amplifier 2.

Key:
1. D compensation;
2. Emitter follower 1;
3. Amplifier 1;
4. Amplifier 2;
5. Amplifier 3;
6. Amplifier 4;
7. Narrow band output;
8. Amplifier 5;
9. Intermediate frequency amplifier 2 output;
10. Amplitude balance;
11. Input bias;
12. Intermediate frequency 2;
13. Wide band output;
14. Tuned circuit 1;
15. Emitter follower 2;
16. Amplifier 6;
17. Amplitude balance circuitry.

The functional circuitry of the low frequency section consists of two boards for the intermediate frequency amplifiers (of the first and second channels), the switcher board, the PKU as well as the boards for the compensation of the D radio deviation coefficient (gain imbalancing of the channels).

A block diagram of the second intermediate frequency amplifier is shown in Figure 1.9. The IF2 signal is fed to tuned circuit K1 of the IF amplifier 2 board, which is the load for mixer Sm2 of the IF amplifier 1 board of the high frequency section.

The signal from tuned circuit K1 is fed through emitter follower EP2 simultaneously to amplifier U6 and to amplitude balancing circuit BA, which serves to equalize the gain in both channels.

Following amplifier U6, the signal is fed through a filter to the broadband output of the audio channel.

The signal is fed from the amplitude balancing circuit to the input of emitter follower EP1, and thereafter to the compensation circuitry for the radio deviation coefficient D and simultaneously to tuned amplifiers U1 - U3, with which the requisite passband is shaped and the requisite signal gain is obtained. The signal is fed from the output of resistance coupled amplifier U3 to resistance coupled amplifier U4 and then through relay R2 to the input of the tuned amplifier U5. Relay R2 is actuated in the mode when checking the operability of the indicator-receiver unit.

The signal is fed from amplifier U5 to the input of the bearing indication unit, BIP (see Figure 1.5), and to the narrow band output of the audio channel section, the BSK, which is intended for listening to the call signs of the radio beacons and radio stations operating in A1, A2 and A3 modes for which the bearings are being taken.

A block diagram of the audio channel section is shown in Figure 1.10. The signal is fed to the audio channel section via the two inputs for channels I and II when operating with a broadband response in the A2 and A3 modes, and via the single input when operating with a narrow bandwidth in the A1 mode.

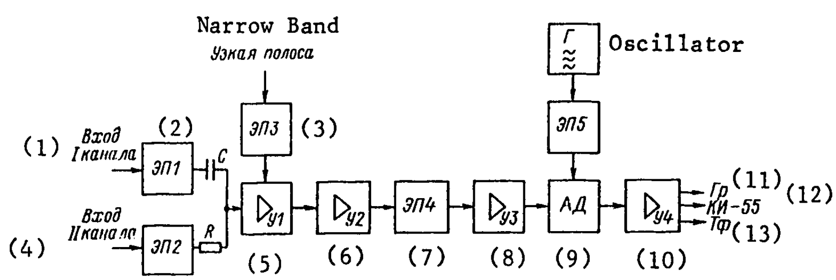

Figure 1.10. Block diagram of the audio channel section.

Key:
1. Channel I input;
2. Emitter follower 1;
3. Emitter follower 3;
4. Channel II input;
5. Amplifier 1;
6. Amplifier 2;
7. Emitter follower 4;
8. Amplifier 3;
9. AM detector;
10. Amplifier 4;
11. Loudspeaker;
12. KI-55;
13. Headsets.

In the case of A2 and A3 operation, the signals from both channels of IF amplifier 2 are fed separately to the inputs of emitter followers EP1 and EP2. The phases of the voltages fed via the two inputs, are shifted by 90° by a phase shifting R and C network prior to combining them, because of which, the intensity of the sum signal changes insignificantly for any course angle to the radio beacon on which a bearing is taken.

The sum voltage is fed from the phase shifting network to amplifier stages U1 and U2 with resonant circuits in the load, which together with the output tuned circuit of IF amplifier 2 provide for the specified passband.

The voltage is then fed to emitter follower EP4, and then to the untuned amplifier stage U3. The amplified voltage is detected by amplitude detector AD and fed to the audio amplifier U4, having outputs to a dynamic loudspeaker Gr headsets Tf and a KI-55 instrument.

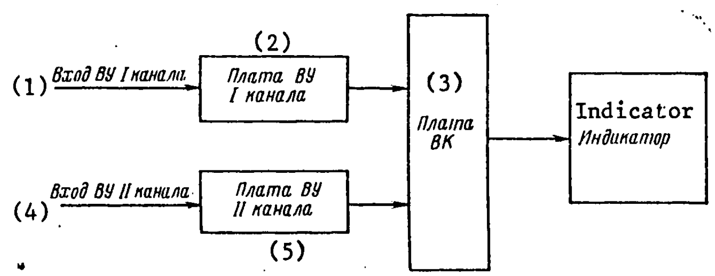

Figure 1.11. Block diagram of the bearing indicator unit.

Key:
1. Channel I output amplifier input;
2. Channel I output amplifier board;
3. Output switcher board;
4. Channel II output amplifier input;
5. Channel II output amplifier board.

When operating in the A1 mode, the voltages are summed beforehand in the IF amplifier 2 stages, and then the total voltage is fed to the input of emitter follower EP3. The voltage is amplified in stages U1 - U3 and fed to the AM detector AD. The voltage from the third local oscillator G is simultaneously fed to the detector through emitter follower EP5. A difference frequency signal is obtained as a result of the mixing of these voltages.

Following detection, the difference frequency voltage is fed to U4, with outputs for loudspeaker, headsets and the KI-55 instrument.

The bearing indication unit, BIP (see Figure 1.5), is intended for the power amplification of the IF 2 signals, the cross switching of the channels, the display of the bearing on the screen of the CRT and sense determination. A block diagram of the bearing indication unit is shown in Figure 1.11. The second intermediate frequency signal is fed from the low frequency section to the inputs of the output amplifier boards of the first and second channels.

The output amplifier consists of a preamplifier stage, a phase inverter stage designed in a push-pull configuration, and a final stage, also using a push-pull circuit.

The signals are fed from the output transformers of the output amplifier boards to the output switcher board (VK), which switches the output circuits of both amplifier channels synchronously with the corresponding switching at the input, which makes it possible to continuously monitor the balancing of the channels.

After passing through the diode switcher, the signals are fed from the output transformers to the deflecting plates, and from the sense determination transformers to the modulator for the CRT (see Figure 1.5).

An antiradar filter, PLF, is inserted in the circuit of the omnidirectional antenna to protect the receiver input against radar signals. A digital display unit, BTsI, is used to visually observe the tuning frequency.

Operating Modes

Watch Duty Reception. Operating mode switch 18 is in the "watch duty" position (Figure 1.12) [second position going clockwise]. Only the omnidirectional antenna is used for radio reception. One tunes to the radio beacon frequency.

DF Bearing Mode. Operating mode switch 18 is set in the "bearing" position [third position going clockwise]. The loop antenna is used for radio reception.

After fine-tuning the receiver and setting the gain, the channels are balanced by the two BALANCE controls, 7 and 8. Bearings are taken on radio stations and beacons in this mode.

Sense Determination. Operating mode switch 18 is set to the "bearing" position and the SENSE button is pushed on the BEARING POINTER control. The loop and omnidirectional antennas are used for radio reception. The quadrant corresponding to the direction to the radio beacon is traced on the screen of the CRT in this mode. The bearing ambiguity is resolved in this mode.

The Monitor Mode. Operational mode switch 18 is set in the "monitor" position [extreme clockwise position]. In this position, the operation of the set is checked periodically by means of the OPERATING CHECK and VOLTAGE CHECK switches and the meter 22.

Operating the "Rumb" Radio Direction Finder

The operational controls and readouts used by the navigator when working directly with the radio direction finder (see Figure 1.12) are located on the front panel of the receiver-indicator unit.

The SWITCHER OFF push button [28] serves for hearing the call-signs of the radio beacons more clearly.

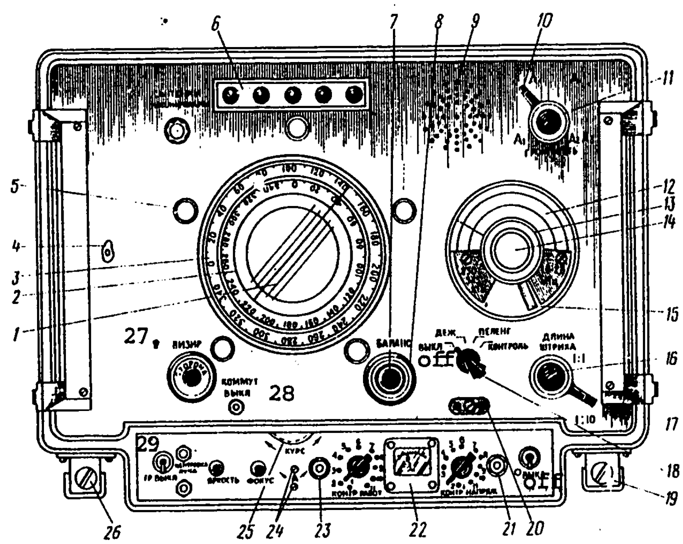

Figure 1.12. Front panel of the "Rumb" radio direction finder. [See text for key]

The SENSE pushbutton [in the center of control 27] is intended for resolving the ambiguity of the radio direction finder readout.

The BEARING POINTER control [27] serves for reading the relative radio bearing and the observed bearing.

Moving pointer 1 has five parallel lines for the correct alignment with the image on the CRT screen. The readout is accomplished using the center line of the pointer.

Control 4 for the D radio deviation coefficient compensation makes it possible to compensate in a range of from -8° to +20°.

The scale for the radio bearing angles (stationary scale 2) with scale divisions of 1° serves for reading the relative radio bearings.

The observed radio bearing scale (moving scale 3) with scale divisions of 1° serves for reading the observed bearings.

The monitor signal light for the position of the shipboard antennas, ANTENNAS ISOLATED, comes on after the isolation of the ship's antennas and the switch on the signal panel of the radio operator is set to the "take bearing" position.

Digital display 6 for the tuning shows the tuned frequency of the radio direction finder with a precision of 0.5 KHz.

The phase balance control 8, BALANCE, serves to equalize the phase shifts in both channels.

The gain balance control 7, BALANCE, is intended for equalizing the gains of both channels.

Loudspeaker 9 serves for listening to the radio beacons on which the bearing is being taken.

The switch A_1-A_2-A_3 (10) has four positions. In the first three switch positions, narrow band reception is used for the telegraph signals of radio beacons and radio stations operating in the A1 mode. In the fourth switch position, the signals of radio stations and radio beacons operating in the A2 and A3 modes are received with a wide bandwidth.

The VOLUME control 11 serves for the continuous adjustment of the volume of the signal being received.

The coarse tuning scale 12 has scale graduations for the medium wavelength band (the outside scale) at intervals of 50 Khz, and for the intermediate wavelength band at intervals of 0.2 MHz (inside scale).

The coarse tuning knob 13 serves for the rough tuning to the radio beacon frequency and has a pointer for presetting to the approximate frequency on the scale. The fine tuning knob 14 which is colocated with the coarse tuning control serves for the fine tuning to the radio beacon frequency either using the digital display or for a maximum of the ellipse or line image on the CRT screen, or based on the maximum loudness of the radio beacon call-signs.

Bandswitch 15 has two fixed positions:
"250 - 545 KHz" is band I (medium wave);
"1.6 - 2.8 MHz" is band II (intermediate wavelengths).

Operating mode switch 18 has four fixed positions and serves for switching the radio direction finder to the "watch duty reception", "DF bearing" and "check" modes.

The LINE LENGTH control 16 serves for continuous adjustment of the gain and obtaining the image of a line trace or ellipse with a length of 4 to 6 cm on the screen of the CRT.

The coarse gain attenuator 17 has two positions: "1:1" and "1:10". When the attenuator is switched from the "1:1" position to the "1:10" position, the signal gain is reduced by a factor of about 7 to 15 times.

Telephone jacks 20 are intended for connecting headphones.

The monitor and indicating controls not used during normal operation and which are used for monitoring the supply voltages, conditions in individual stages and detecting defects in both channels of the radio direction finder are located under a cover on the rear panel of the receiver-indicator unit (see Figure 1.12).

The OFF switch (deviation turned off) serves for disconnecting the elements which compensate for the radio bearing deviation coefficient D (present only in the radio direction finder variant having a loop antenna, arranged at an angle of 45° to the DP [middle-line plane]).

Pushbutton 21 for monitoring voltages makes it possible to monitor an additional six supply voltages and operating conditions of the stages.

The VOLTAGE CHECK switch serves for selecting the supply voltage or condition of the individual stages being monitored.

Meter 22 makes it possible to monitor the supply voltages and operational conditions of the stages. The normal mode corresponds to a deflection of the meter needle in a range of 60 to 80 scale divisions.

The OPERATION MONITOR switch serves to check the correctness of operation and detect defects in both channels of the radio direction finder.

Selsyn cutoff pushbutton 23 is used when matching to the gyrocompass repeater.

Control 24 for compensating for the A radio bearing deviation coefficient makes it possible to rotate the CRT in a range of $\pm 5°$ (it is first necessary to loosen the lock, and then make the adjustment).

The COURSE control 25 (setting the course) is intended for matching the radio bearing scale to the gyrocompass repeater.

The FOCUS, BRIGHTNESS and BEAM CENTERING controls serve to change the focusing, brightness and beam centering of the CRT respectively.

The SPKR OFF switch is intended for disconnecting the loudspeaker from the audio channel.

Screws 19 and 26 serve to fasten the housing to the shock absorbers.

The small lights 5 are intended for lighting the scales.

Technical Operating Rules

The following are to be done during watch duty reception:

--The operating mode switch is set in the "watch duty" position;

--The bandswitch is set to the requisite band;

--The A_1-A_2-A_3 switch is set in the position "A_2A_3" when receiving A2 and A3 signals, or in one of the three "A_1" positions when receiving A1 signals;

--The requisite loudness is set using the VOLUME and LINE TRACE LENGTH controls;

--One tunes to the frequency of the target radio beacon based on the maximum signal volume using the tuning controls;

--The desirable BFO tone is obtained in one of the three "A_1" positions using the A_1-A_2-A_3 switch.

The following are to be done when balancing the channels:

--Set the operating mode switch in the "bearing" position;

--A 5 to 6 cm image is obtained on the CRT screen using the TRACE LENGTH control and attenuator 17 (1:10);

--The two images on the CRT screen are combined using the combined BALANCE controls (7 for the gain and 8 for the phase shifts):

a) One line is obtained on the CRT screen as a result of the combining when receiving one signal;

b) When receiving out-of-phase signals, because of the influence of backscatter or multipath propagation, an ellipse is produced on the CRT screen as a result of the combining;

c) When receiving two signals which are close in frequency, one parallelogram is produced on the CRT screen as a result of the combining.

The following are to be done when taking a DF bearing and determining the sense:

--The operating mode switch 18 is set in the "bearing" position;

--One tunes to the frequency of the target radio beacon based on the maximum image on the CRT using the tuning controls;

--It is recommended that the position of attenuator 17 (1:10) be left unchanged when taking bearings on a group of radio beacons so as not to balance the channels anew;

--Set the POINTER control so that the line on the azimuth pointer dial is strictly parallel to the electronic trace or the major axis of the ellipse on the CRT screen;

--Press the SENSE button and determine the quadrant on the CRT screen within which the target radio beacon or radio station is located;

--Determine the bearing or relative radio bearing using that portion of the scale which is located within the quadrant obtained from the sense determination;

--After taking the readings, one must take into account the correction for the radio bearing deviation using the residual radio deviation curve.

The following are to be done in the monitor mode:

--Set the operating mode switch to the "monitor" position;

--Check the major voltages and currents using the monitor meter by means of the VOLTAGE CHECK switch;

--Check the major units of the indicator and compensate for the radio bearing deviation coefficients using the CRT screen and the OPERATING CHECK switch.

1.5. Requirements Placed on the Installation, Alignment and Operation of Marine Radio Direction Finders

A position is to be selected for the mounting of the antenna of a marine radio direction finder which is the most remote location from the metal parts of the vessel. Antennas for marine radio direction finders must be mounted as high as possible above the hull of the ship and as far as possible from pipes, masts, antennas and metal superstructures.

At medium wavelengths, the hull of the ship usually exerts the greatest influence on the amount of radio bearing deviation, while at short wavelengths, the masts, pipes and other antenna-like objects having a length of one-quarter or three-quarter wavelengths of the target radio station or radio beacon have the greatest influence.

Metal rigging within a radius of 9 m from the loop antenna is broken up into unequal sections with lengths of from 2 to 6 m using insulators. In the case where such segmentation is impossible, the rigging should be reliably grounded.

Having chosen several possible sites for the installation of the antenna system, it is expedient to use a portable radio direction finder to study them and select the position for which the radio deviation in the working frequency band is the least.

At short wavelengths, clear-cut silence angles should be obtained for bearing directions in all azimuths from 0° to 360° in an aural radio direction finder, narrow image ellipses should be obtained in the visual dual channel radio direction finder and clear-cut bearing readings should be obtained in other radio direction finding systems.

The longitudinal frame of the direction finder is positioned in the midline plane so that the engraving of the NOS [not further defined] is directed towards the bow of the ship. The height of the whip or the vertical projection of the slant antenna should run from 4 to 6 m. The distance between projections onto the horizontal plane of the loop antenna and the omnidirectional antenna should not exceed 6 m, otherwise the quality of direction sensing is degraded in the intermediate wavelength band. A spacing of the antennas is permitted in the vertical plane within the limits of the difference of the feedline lengths from the omnidirectional and loop antennas to the indicating receiver of no more than 4 m.

An antenna amplifier is used where the length of the cable to the indicating receiver unit is more than 8 m, regardless of the type of omnidirectional antenna. An antenna box is used only in the case where an inclined beam antenna is used with a feedline length of up to 8 m.

It is recommended that a receiver-indicator unit in a desk top design be set up on a desk, while the console design is to be mounted in a navigator's console.

The ground terminal must be connected to the hull of the vessel and the ground buses of the shock absorbers. The power supply is installed in a vertical position no further than 20 m from the receiver-indicator unit and is fastened without shock absorbers. The signaling panel is to be placed in the radio room in a vertical position, in a place convenient for actuation and observation.

After installing the radio direction finder, the insulation resistance of the antenna and feedline system is to be checked, the radio deviation is to be determined and compensated and the correctness of the connection of the power supply is to be checked and the unit is to be matched to the gyrocompass repeater. The insulation resistance of the antenna and feedline system is checked with a megohmmeter with a test voltage of 500 volts. The loop RF feeders are disconnected from the receiver-indicator unit and the megohmmeter measures the resistance between the center lead of the feedline and the chassis, which should be no less than 20 MOhms. A drop in the insulation resistance down to 10 MOhms is permitted at a temperature of 40° C and a humidity of 98%.

The correctness of the zero setting of the goniometer indicator is checked as follows. The ends of the loops are disconnected or shorted in the junction box and a bearing is taken on any radio station. When the relative radio bearing is other than 0° or 180°, the goniometer axis is locked with the GONIOMETER AXIS LOCK control, which is located under the cover on the cabinet of the goniometric receiver unit. The screw inserts are unscrewed with a special wrench, the MINIMUM SET control and the top cover are removed. The fastening screw is unscrewed and the azimuth pointer is set to 0° or 180°. After this, the loops are reconnected.

The determination of the radio bearing deviation can be accomplished several ways.

1. Using the radio transmitter of an auxiliary ship which makes a circle around the RDF ship. In this case, the ship for which the radio deviation is being determined remains in place. An auxiliary ship which continuously transmits radio signals at the working frequency of a radio beacon makes a circle around it at a range of 1.5 to 2 miles. At different relative bearings read out from 0° to 360° going clockwise, the relative radio bearing angles (RKU) from the RDF and the relative bearings (KU) from the azimuth circle of the compass are read out simultaneously at intervals of 10 to 15°. Then the value of the radio deviation is calculated for all relative bearing angles using the following formula:

$$f = KU - RKU \qquad f = КУ - РКУ, \tag{1.1}$$

the curve is plotted, and a radio deviation table is drawn up for the relative radio bearings at intervals of 10 to 15°.

2. Using a shore radio transmitter or radio beacon.

In this case, the ship for which the radio deviation is being determined approaches a shore radio transmitter (radio beacon) at a range of 1.5 to 2 miles and positions itself so that the radio wave intersects the shoreline at an angle close to 90°. Then the ship makes a circle and does the same things as in the first method. The radio deviation is a periodic function of the relative radio bearing, and for this reason can be represented by a Fourier series:

$$f = A + B\sin(\text{РКУ}) + C\cos(\text{РКУ}) + D\sin 2(\text{РКУ}) + E\cos 2(\text{РКУ}) + \ldots \quad (1.2)$$

[PKY = relative radio bearing (RKU)].

The coefficient A is called the circular coefficient, the coefficients B and C are the semicircular coefficients and D and E are the quadrantal coefficients [quadrantal DF error]. The values of the radio deviation coefficients depend on the type of secondary radiators and their position relative to the loops of the RDF. Metal structures, the vertical dimensions of which are considerably greater than the horizontal ones (masts, pipes, ship antennas) are called antenna-like secondary radiators. Metal structures which take the form of a closed resonant circuit for the induced current are called resonant circuit type secondary radiators. Such resonant circuits can be produced by the parts of metal rigging. The largest resonant circuit type radiator is the metal hull of a ship.

The A coefficient appears when the bearing readout pointer is set incorrectly and where resonant circuits are present, the planes of which do not coincide with the axis of the RDF loop.

The B coefficient is due to antenna-like secondary radiators located at the bow of a ship (+B) or at the stern (-B).

The C coefficient is caused by antenna-like secondary radiators, located either on the portside (+C) or to starboard (-C).

The D coefficient is caused by the ship's hull or by longitudinal and transverse resonant circuit type secondary radiators.

The E coefficient is caused by resonant circuit type secondary radiators arranged at an angle of 45° or 135° to the longitudinal axis.

Insulators are inserted to reduce the influence of secondary radiators in metal rigging, or, on the other hand, a reliable contact is made between the metal structures so as to eliminate the dependence of the level of the secondary field on climatic conditions.

The quadrant radio deviation coefficients have the greatest values.

The quadrantal radio deviation coefficient D is compensated in the "Rybka" aural radio direction finder in the first band in the following manner:

a) The value and sign of the radio deviation coefficient are determined;

b) The cover on the cabinet is removed from the goniometric receiver;

c) The DEVIATION COMPENSATION switch is set to the "+D2-8°", "+D8-20°", "-D2-8°" or "-D8-20°" position depending on the sign and magnitude of the D coefficient being compensated;

d) The locking screw is released and the adjusting screw of the variometer is rotated until the azimuth pointer line is set opposite the division corresponding to the value of the D coefficient being compensated;

e) The locking screw is clamped down and the cover of the case is closed.

The quadrantal radio deviation coefficient D is compensated in the "Rumb" visual radio direction finder in the medium wavelength band as follows:

a) The value and sign of the radio deviation coefficient are determined;

b) The image on the CRT screen is made equal to 5 to 6 cm using the TRACE LINE LENGTH control;

c) The double image is reduced to a line or an ellipse with a minor axis of minimal length by means of the the BALANCE control;

d) The operating mode switch is set to the "check" position;

e) The OPERATION CHECK switch is set to position "2";

f) The D coefficient compensation control is rotated so that the line or the major axis of the ellipse on the screen of the CRT is set at a relative radio bearing angle of $45° \pm D$.

After compensating for the quadrantal radio deviation coefficient D, the residual radio deviation is determined by the method treated earlier. The curve for the residual radio deviation is drawn on a special company blank form and is used for corrections during direction finding.

The power supply is turned on after checking the setting of the 220/127 volt plug in accordance with the mains voltage. In the case where a direct current main is used, the conformity of the type of voltage converter to the ship's power mains is also checked. The plug on the power supply should be set for 127 volts. Prior to turning the direction finder on, the input voltage switch on the power supply is set to the extreme left position, and after turning it on, the nomimal voltage is selected.

To match to the gyrocompass repeater, it is necessary to open the cover of the controls which are not used during normal operation, to cut off the power to the selsyn by pressing the button and set the radio direction finder scale in accordance with the gyrocompass readings by means of the existing control. With an increase in the gyrocompass bearing angle, the scale of the radio direction finders should rotate counter-clockwise.

Opposite rotation of the scale occurs because of the incorrect connection of the two wires to the selsyn rotor winding. With correct matching, the error in relative bearing angles from the radio bearing scale should not exceed $\pm 0.5°$.

CHAPTER 2 PHASE RADIONAVIGATION SYSTEMS

2.1. The Classification and Specific Features of Marine Phase Radionavigation Systems

Marine phase radionavigation systems are intended for determining a ship's position at sea. The phase radionavigation systems used in the merchant marine are difference range finding systems which measure the phase difference (the difference in the ranges) of the signals from shore transmitting stations operating in a CW mode. Phase radionavigation systems are broken down into frequency gating ("Pirs-1", "Decca") navigation systems and time gating ("Omega") radionavigation systems according to the manner of segregating the radio signals in the received channels of the shipboard indicator.

The "Decca" Phase Radionavigation System. The "Decca" radionavigation system is intended for determining a ship's position (lines of position) by means of measuring the difference in the ranges to shore transmitting stations operating in a CW mode using coherent electromagnetic oscillations (which are interrelated by an integer ratio). The operation of the system ("Decca" is a frequency gating navigation system) is based on the principle of measuring the phase relationships of the radio signals received by the marine indicating receivers in the long wave band of 85 to 135 KHz.

The shore stations (Figure 2.1) operate in a coordinated program, forming networks in which four stations are usually incorporated: the master, VShCh, and three slaved stations: VM1, VM2 and VM3.

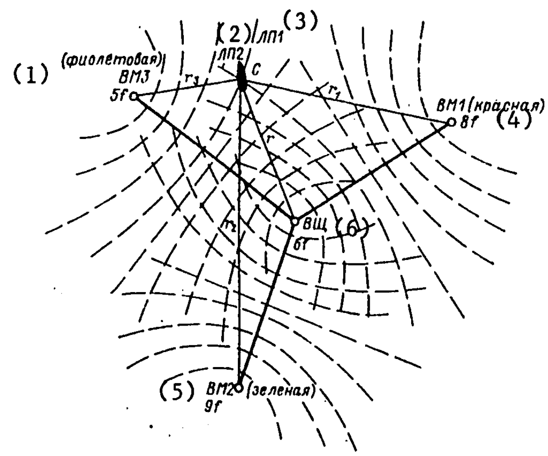

Figure 2.1. On the determination of the lines of position of a ship in the "Decca" radionavigation system.

Key: 1. Slaved station 3 (violet), 5f;
2. Line of position 2;
3. Line of position 1;

Key [cont.]: 4. Slaved station 1 (red), 8f;
5. Slaved station 2 (green), 9f;
6. Master station, 6f.

The shore stations, using CW operation (without call-signs), transmit radio signals at frequencies which are multiples of the base frequency of the network $\Omega = 2\pi f$: 6f (master), 8f (slave 1), 9f (slave 2) and 5f (slave 3). For convenience in identification, colors are assigned to the slaved stations (red, greed, violet).

All of the networks of the "Decca" radionavigation system (there are 49 networks in service at the present time) have alphanumeric designations from zero to ten and contain ten letters of the Latin alphabet in various combinations (for example, 3B, 6C, 10C, etc.).

If V is the propagation velocity of the electromagnetic oscillations (for the "Decca" radionavigation system, the computational velocity is equal to v = 299, 570 km $\cdot$ sec^{-1}), then the distances r and r_n from the master station and slaved stations 1-3 to the ship C are determined by the time delays $\tau = r/v$ and $\tau_i = r_i/v$ (i = 1, 2, 3) of the received radio signals:

$$U_{master} = U_{\text{ВЩ}} = U_m \cos 6\,\Omega\,(t - \tau);$$
$$U_{slave} = U_{\text{ВМ}} = U_n \cos n\,\Omega\,(t - \tau_i), \quad (2.1)$$

where U_m and U_n are the amplitudes of the radio signals received from the master and slaved stations; n is a coefficient which applies to the slaved stations and takes on values of 8, 9 and 5.

The transmission of the radio signals by the slaved stations is matched to the transmission of the radio signals by the master station. For simplicity in the discussions, we shall not consider the time delay in the transmission of the slaved station (baseline delay) with respect to the master station which occurs in this case, since the latter is taken into account in the design of the grid of isolines of the "Decca" radionavigation system which are plotted on the charts.

The received signals (2.1) in the shipboard indicating receiver are amplified and reduced to a single comparison frequency $M\Omega$ by means of multiplication by the coefficients M/6 and M/n, where the quantity M is the least dividend for 6 and n. Since n takes on values of 8, 9 and 5 for the slaved stations, then we have M equal to 24, 18 and 30 for the three pairs of stations (master and slave station 1, master and slave station 2, master and slave station 3).

Consequently, the signals (2.1), which are equated in amplitude and reduced to a single comparison frequency, assume the form:

$$U_{master} = U_{\text{ВЩ}} = U_0 \cos M\Omega\left(t - \frac{r}{v}\right);$$
$$U_{slave} = U_{\text{ВМ}} = U_0 \cos M\Omega\left(t - \frac{r_i}{v}\right), \quad (2.2)$$

where M sequentially takes on the values indicated above for the selected pairs of master and slaved stations.

The phase difference ψ of the received radio signals (2.2) is measured in the phase detectors (FD) in a marine indicating receiver:

$$\psi = M\Omega\left(t - \frac{r_i}{v}\right) - M\Omega\left(t - \frac{r}{v}\right) = M\Omega\frac{r - r_i}{v}. \quad (2.3)$$

Thus, the differences in the ranges $r - r_i$ between the ship C and the master and slaved stations or the lines of position, LP's, which are hyperbolas, at the intersection of which the ship is positioned, are determined in this case.

The phase measurement process for ψ is ambiguous, since only the fractional portion of the total cycle of change in the voltages (2.2) is determined in this case. For this reason, one must use the following instead of equation (2.3):

$$\psi = 2\pi N + \frac{2\pi}{\lambda_M}(r - r_i), \quad (2.4)$$

where N is an unknown number of total cycles of change in the voltages (2.2), determined in the process of eliminating the ambiguity (UM); λ_M is the comparison wavelength defined by the equality $\lambda_M = vT_M$.

What has been said can be illustrated by means of Figure 2.2. For the ships C1 and C2, which are located on line of position LP1 (a hyperbola), the measured phase difference is $\psi = 2\pi$. For the ship C3 (LP 0), the phase difference is $\psi = 0$. For ship C4, the phase meter readings yield the fractional portion of the period 2π, to which one must add one complete cycle of the frequency (N = 1).

The shortest distance d between adjacent hyperbolas with phase meter readings which differ by a complete period 2π is called the phase track width, while the shortest distance b between the master and slaved stations is called the baseline. The track width d is defined by the expression:

$$d = \frac{\lambda_M}{2\sin\frac{\gamma}{2}}, \quad (2.5)$$

where γ is the angle between the directions from the ship to the master and slaved stations. The least value of the track width occurs for a baseline of ($d_0 = \lambda_M/2$).

Eliminating the multiple value ambiguity (UM) of the phase measurements of ψ consists in determining the number of tracks (the number of complete cycles N). The lines of position (position of the ship) are determined by adding the number of complete cycles to the readings of the phase meters [see (2.4)].

The "Omega" Phase Radionavigation System. The "Omega" radionavigation system is intended for determining a ship's position (lines of position) by means of measuring the phase difference (range differences) to eight shore transmitting stations operating in an established CW mode.

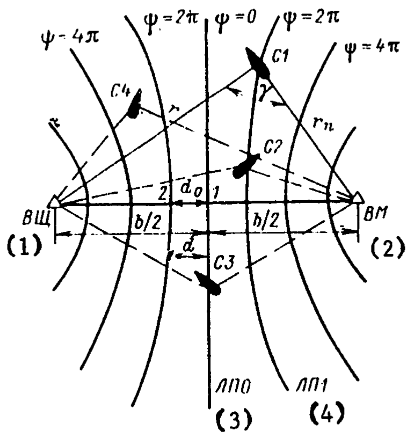

Figure 2.2. On the determination of the values of the phase difference ψ as a function of a ship's position.

Key:
1. Master station;
2. Slave station;
3. Line of position 0;
4. Line of position 1.

The "Omega" radionavigation system belongs to phase systems using time gating of the radio signals and is designed for determining the position of a ship in practically all of the navigating regions of the world. The position of the shore transmitting stations and the Latin indexes assigned to each station are shown in Table 2.1.

The operational principle of the "Omega" radionavigation system consists in determining the lines of position of a ship by means of measuring the phase difference ψ (the range difference $r_2 - r_1$) of the radio signals from two shore stations by means of the shipboard indicating receiver, and this regard, is similar to the operation of the "Decca" radionavigation system [see (2.4)], where:

$$\psi = 2\pi N + 2\pi \frac{r_2 - r_1}{\lambda_M}.$$

To eliminate the ambiguity of the readout, it is necessary to determine the integer number of tracks N, for which a special system operating mode is used.

TABLE 2.1.

Station Станция	Code Индекс Letter	Latitude Широта φ	Longitude Долгота λ
Норвежская (1)	A	66° 25′ 15″,0N	13° 09′ 10″,0Ost
Монровия (Либерия) (2)	B	6° 18′ 00″,0N	10° 40′ 00″,0W
Гавайи (3)	C	21° 24′ 16″,9N	157° 49′ 52″,7W
Северная Дакота (4)	D	46° 21′ 57″,2N	98° 20′ 08″,8W
о. Реюньон (5)	E	20° 58′ 26″,5S	55° 17′ 24″,2Ost
Аргентинская (6)	F	43° 03′ 12″,5S	65° 11′ 27″,7W
Тринидад (7)	G *	10° 42′ 06″,2N	61° 38′ 20″,3W
Японская (8)	H	34° 36′ 53″,3N	129° 27′ 12″,5Ost

* Станция G будет заменена станцией в Тихом океане.

*Station G will be replaced with a station in the Pacific Ocean.

Key:
1. Norway;
2. Monrovia (Liberia);
3. Hawaii;
4. North Dakota;
5. Reunion Island;
6. Argentina;
7. Trinidad;
8. Japan.

TABLE 2.2.

Станция Station	(1) Интервал передачи на частоте $f = 10{,}2$ кГц в одном цикле 10 с	(2) Продолжительность передачи, с
A (Норвегия) (Norway)	0,0–0,9	0,9
B (Либерия) (Liberia)	1,1–2,1	1,0
C (Гавайи) (Hawaii)	2,3–3,4	1,1
D (Северная Дакота) (North Dak.)	3,6–4,8	1,2
E (о. Реюньон) (Reunion Is.)	5,0–6,1	1,1
F (Аргентина) (Argentina)	6,3–7,2	0,9
G (Тринидад) (Trinidad)	7,4–8,6	1,2
H (Япония) (Japan)	8,8–9,8	1,0

Key: 1. Transmission interval at the frequency f = 10.2 KHz in 1 cycle of 10 seconds;
2. Duration of the transmission in seconds.

The radio signals are transmitted by the shore stations at frequencies of 10.2 KHz (9f), 11.33 KHz (10f) and 13.6 KHz (12f), which are multiples of the base frequency 1f = 1.133 KHz, i.e., in the infra-low frequency band (ILF).

The identification of the received signals in the shipboard indicating receiver is accomplished through the permanently established time pattern for their transmission by the shore stations, depicted in Figure 2.3. As can be seen from this figure, the time intervals for the transmissions of the stations (Table 2.2) have a strictly defined duration and set sequence, which makes it possible to establish precisely from which station the signals are incoming at the given point in time to the input of the shipboard indicating receiver.

The phase difference measurements are made at the single frequency of 10.2 KHz (the "navigation" mode), while the 11.33 and 13.6 KHz frequencies serve to eliminate the ambiguity (the UM mode).

The synchronization of the operation of the shore transmitting stations of the "Omega" radionavigation system with the standard precision universal time (Greenwich time) is accomplished through the use of high precision atomic oscillators with a relative frequency instability of 10^{-14}. For this reason, high stability crystal oscillators (the relative daily instability is 10^{-8}), which are used in marine indicating receivers, are synchronized with the precise time signals of the shore stations of the "Omega" radionavigation system, which increases the reliability of the phase measurements and makes it possible to obtain precise readouts of Greenwich time (the precision time measurement mode).

To transmit the special measurement signals, the shore stations transmit additional frequencies in intervals free of the major frequency transmissions (see the hatch-marked portions of the diagram in Figure 2.3), which can be used in the range finding mode to determine a ship's position (the operational mode called "po-po").

TABLE 2.3.

Radionavigation System (РНС)	Frequency (Частота)			(4) Ширина d точной дорожки на базе, мили	(5) Режим УМ*	
	(1) излучения береговых станций	(2) расчетная (базисная)	(3) определяющая сетку точных изофаз (точных дорожек)		(6) первая ступень	(7) вторая ступень
«Декка» "Decca"	6f (ВЩ) (red) 8f (ВМ1 — красная) 9f (ВМ2 — зеленая) (green) 5f (ВМ3 — фиолетовая) (purple)	1f ≈ 14,2 кГц 14.2 KHz	24f (ВЩ — ВМ1) 18f (ВЩ — ВМ2) 30f (ВЩ — ВМ3) ВЩ = master station	d_1 = 0,236 (437 м) d_2 = 0,316 (585 м) d_3 = 0,189 (350 м)	d_1 = 0,713 мили miles (1,32 км) d_2 = 0,634 мили miles (1,174 км) d_3 = 1,14 мили (2,112 км)	d = 5,67 мили miles (10,5 км)
«Омега» "Omega"	9f — 10,2 кГц 10f 11,33 кГц 12f 13,6 кГц	1f = 1,133 кГц 1.133 KHz	10,2 кГц ВМ = slaved station	8,0	d = 24 мили (для 3f = 3,4 кГц) (for 3f = 3.4 KHz)	d = 72 мили (для 1f = 1,133 кГц) (for 1f = 1.133 KHz)

* Для приемоиндикатора «Пирс-1».
*For the "Pirs-1" Display Receiver

Key:
1. Transmissions of the shore stations;
2. Computational (base) frequency;
3. Frequency determining the grid of precise isophases (precision tracks);
4. Width d of a precision track on the baseline, miles;
5. Ambiguity elimination mode*;
6. First stage;
7. Second stage.

Eliminating Multivalue Ambiguity in Phase Radionavigation Systems. Phase radionavigation systems using frequency or time gating (the "Decca" and "Omega" radionavigation systems) have readout ambiguity in the readings of the phase indicators. The UM mode - ambiguity elimination in the operation of marine indicating receivers - is used to eliminate this. In this mode, the phase measurements of the radio signals of the shore stations are made at lower frequencies than the major frequencies used for determining the lines of position of a ship.

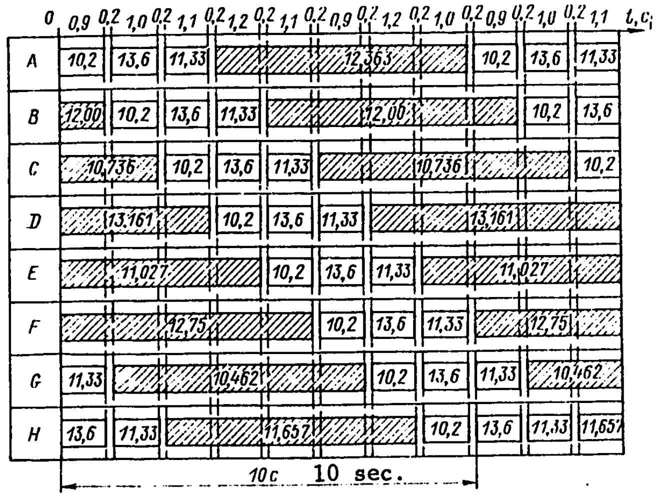

Figure 2.3. Time diagram of the radio signal transmission cycle by the shore stations of the "Omega" radionavigation system.

In the "Omega" radionavigation system, the shore stations transmit additional frequencies of 11.33 and 13.6 KHz for the ambiguity elimination mode besides the main frequency of 10.2 KHz. Phase measurements are made in this mode in a marine indicating receiver either at the difference frequency of 3.4 KHz (the first ambiguity elimination stage), formed by the difference between the 13.6 and 10.2 KHz frequency, or at a frequency of 1.133 KHz (the second ambiguity elimination mode), formed by the difference between the 11.3 KHz frequency and the main 10.2 KHz frequency.

The readouts recorded in this case from the indicators show the measured phase difference ψ_g (the difference in the ranges to the shore stations), just as for the main navigation frequency of 10.2 KHz (see Figure 2.2). The difference consists in the fact that during phase measurements at lower frequencies (3.4 or 1.13 KHz), the width of the tracks d ("coarse" tracks) is several times greater than the width of the precision tracks formed during measurements at the main frequency of 10.2 KHz. Values of the track widths of phase radionavigation systems are given in Table 2.3 for measurements at different frequencies. The fact is that during phase measurements in the ambiguity elimination mode at the 3.4 KHz frequency, the width of the coarse track at the base is equal to 24 miles, i.e., is three times greater than the width of the precision track of d = 8 miles.

To eliminate the ambiguity (determine the number N of the precision track when using charts with the isophase grid drawn on them), one works from the presupposition that the ship's location is known from other navigational determinations with a precision of no less than 12 miles (half the width of the coarse track), and for this reason, the number of the coarse track is known beforehand.

Consequently, in the case of phase measurements using the "Omega" radionavigation system indicating receiver at a frequency of 3.4 KHz, the fractional part of the coarse track width is determined which is applied to the chart taking into account the requisite corrections, laying off the distance from the known isophase line of the coarse track. In this way the number of the precision track is determined which corresponds to measurements at the main frequency of 10.2 KHz and the ambiguity is eliminated.

Ambiguity elimination can also be accomplished by a closure technique where the ship's position is known sufficiently precisely from navigational determinations or the coordinates of the location when leaving port are known, etc.

The ambiguity is eliminated in basically the same way in the "Decca" radionavigation system indicating receivers where the phase measurements are performed at a frequency of 1f ≈ 14.2 KHz.

2.2. The "Pirs-1D" Marine Indicating Receiver

The "Pirs-1D" marine indicating receiver is intended for determining a ship's position at sea using the radio signals of the "Decca" phase radionavigation system.

The major technical specification for the indicating receiver are given below:

Supply voltage, volts	127 or 220 volts AC
Power mains frequency, Hz	50
Power consumption, V · A	400
Maximum temperature range, °C	from -10 to +50
Humidity range, %	95 - 98
Type of antenna	Vertical
Antenna height, m	$\geq$ 4
Number of working frequencies	63
Diurnal stability of the crystal oscillator	$(2\text{--}3) \cdot 10^{-7}$
Number of received channels	5
Band of frequencies which can be received, KHz	70--130
Overall weight, kg	80.5

Operational Principle of the "Pirs-1D" Indicating Receiver. The "Pirs-1D" marine indicating receiver has increased interference immunity and operational reliability thanks to the use of a highly stable crystal master oscillator, OG, in the instrument as well as narrow band crystal filters in the measurement channels.

Electromechanical compensation-tracking systems are used in the indicating receiver, the elevated inertia of which as compared to the interference which changes rapidly with time which accompanies the signals received from the master and slave stations, assures low frequency filtering of possible errors in the phase measurements.

A measurement principle which is different from that of the foreign "Decca" radionavigation system indicating receivers is used in the "Pirs-1D" instrument, where this principle consists in reducing the radio signals from the master station at a frequency of 6f to frequencies of 8f, 9f and 5f of the slave stations and then measuring the phase difference ψ due to this at the nf frequencies of the slave stations.

A block diagram of the "Pirs-1D" indicating receiver is depicted in Figure 2.4.

The Synchronization Channel. The master oscillator, OG, which is installed in a thermostatically controlled chamber, generates a highly stable reference voltage at $6F_0$, which is fed in the synchronization channel to the FAPCh [phase locked loop, PLL] - a system for automatically fine tuning the phase and frequency of the reference voltage $6F_0$ to the phase and frequency of the radio signals from the master station. On the other hand, the radio signals of the master station at 6f received by the ship's antenna A are fed following preamplification in the RF amplifier to the mixer Sm, where the intermediate frequency 6F is segregated out. The synchronization channel and measurement channels of the indicating receiver are tuned to constant intermediate frequencies of 100, 133.3, 150 and 83.3 KHz. This is achieved through the use of a heterodyne frequency oscillator G, which generates a highly stable voltage at one of 63 frequencies (6Δ), which are linearly related to the transmission frequency of the master station of the selected network of the "Decca" radionavigation system. The noise immunity during reception is also boosted through the use of narrow band crystal filters which are tuned to the intermediate frequency.

The following voltage is fed to the input of the phase locked loop system following the mixer, crystal filter and intermediate frequency amplifier, the UPCh:

$$U_{6F} = U_0 \cos\left(6\,\omega t + 6\,\Omega \frac{r}{v}\right), \qquad (2.6)$$

where 6ω corresponds to the intermediate frequency of 6F while 6Ω (r/v) is the phase shifts produced as a result of the time delay τ during the transmission of the radio signals from the master station to the ship [see (2.1)].

The master station signals 6f received on the ship can be considerably influenced by interference of various kinds (for example, atmospherics, etc.), which are of a random nature. A certain portion of this interference can pass through the 6F crystal filter. For this reason, the continuous fine tuning of the frequency and phase of the reference voltage at $6F_0$ from the highly stable master oscillator OG to the phase and frequency of the 6F voltage from the master station has the advantage that by virtue of the considerable inertia in the elements of the PLL tuning system, the latter practically does not respond to rapid random changes (as a result of the action of interference) in the received signals. Along with this, the reference voltage $6F_0$, which is tuned to the phase and frequency of the 6F signals from the master station will not contain this random interference and is subsequently used for the phase measurements.

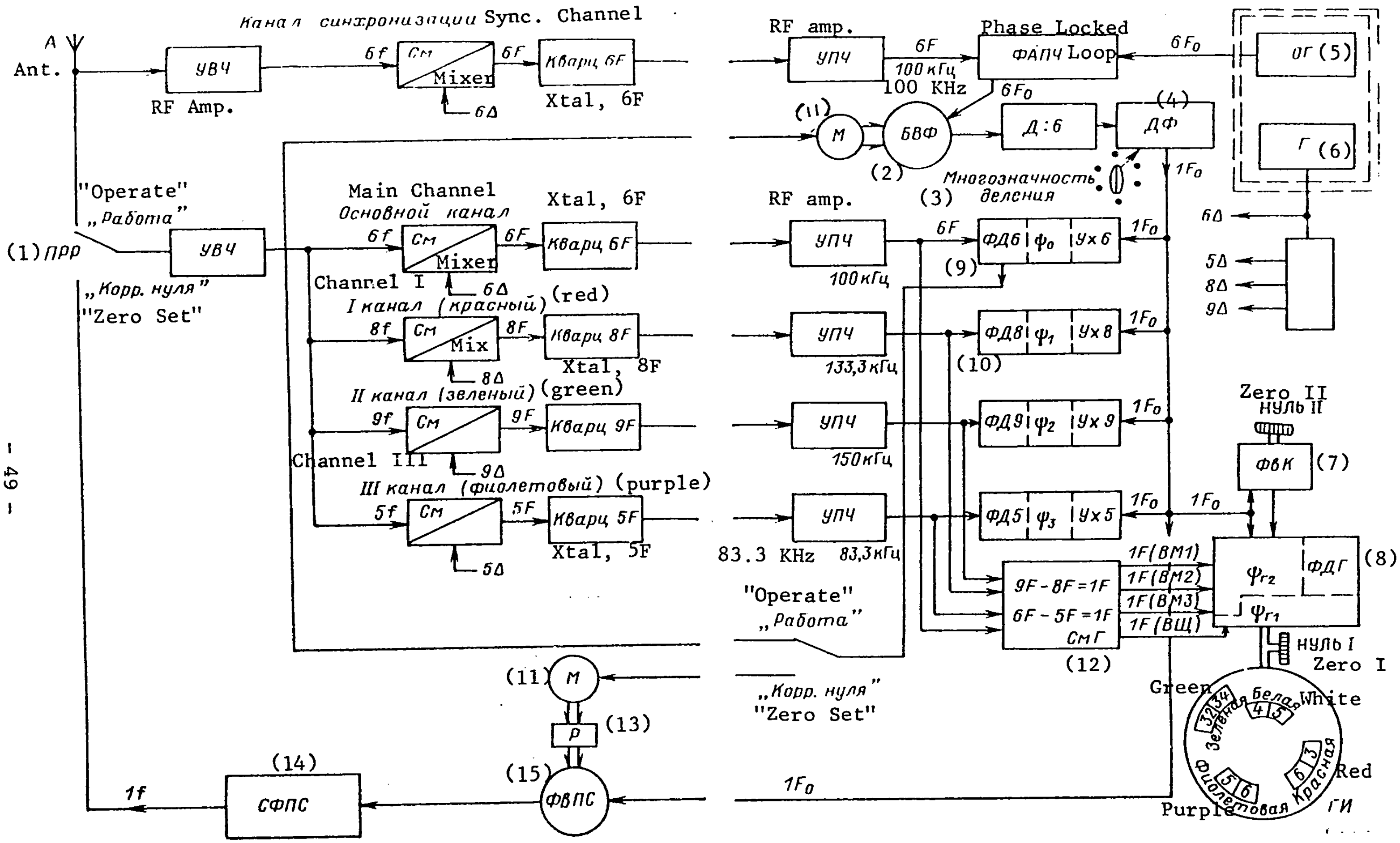

Figure 2.4. Block diagram of the "Pirs-1D" indicating receiver.

Key:
1. Operating mode switch;
2. Master phase shifter;
3. Division factor;
4. Discrete phase shifter;

Key [cont.]:
5. Master oscillator;
6. Oscillator;
7. FvK [?channel phase shifter?];
8. FDG [?oscillator phase detector?];
9. Phase detector 6;
10. Phase detector 8;
11. Motor;
12. SmG [?local oscillator mixer?];
13. Reduction gearing;
14. SFPS [not further defined];
15. FVPS [not further defined].

The $6F_0$ voltage from the PLL passes through the divider D:6, where the ambiguity which occurs in the value of the phase during division is eliminated by a special discrete phase shifter, DF.

The Main Channel. The main channel of the indicating receiver is intended for fine tuning the phase of the reference frequency $1F_0$ to the phase of the master station signal 6f. The operation of this channel increases the reliability of all of the phase measurements, since the reference voltage at $1F_0$ which is fed from the PLL circuitry through the master phase shifter unit, the BVF, the divider D:6 and the DF discrete phase shifter is then used in all operating modes of the instrument both as the original master voltage which "remembers" the phase of the master station, the VShCh.

The main channel unit is similar to the synchronization channel unit. At the output of this channel, the intermediate frequency 6F is fed to the phase detector FD6, to which the master voltage $6F_0$ is also fed which is obtained by multiplying the reference voltage $1F_0$ by six. Where there is a phase difference ψ_0 between the voltages cited here, the compensation-tracking system fine tunes the phase of the $6F_0$ voltage (and consequently also the phase of the $1F_0$ voltage) to the phase of the 6F voltage of the master station.

The reference voltage $1F_0$, which is tuned in the main channel to the master station phase, has the form:

$$U_{1F_0} = U_0 \cos\left(\omega t + \Omega \frac{r}{v}\right). \qquad (2.7)$$

The Phase Difference Measurement Channels. The "Pirs-1D" indicating receiver is designed to determine a ship's position (lines of position) by means of finding the phase differences ψ_1, ψ_2 and ψ_3 for the master and slaved station signals in all three measurement channels (red, green and violet). The processes which take place in this case are similar. For this reason, we shall consider only the operation of channel I: the red channel.

The radio signals received by antenna A from slave station 1 [see (2.1)] are:

$$U_{8f} = U_0 \cos 8\,\Omega\left(t - \frac{r_1}{v}\right)$$

and following preamplification in the RF amplifier are fed to the mixer, where they are mixed with the frequency 8Δ of the local oscillator. The 8F intermediate frequency is fed to phase detector FD8 after passing through the crystal filter and the IF amplifier, the UPCh:

$$U_{8F} = U_0 \cos\left(8\,\omega t + 8\,\Omega \frac{r_1}{v}\right). \qquad (2.8)$$

On the other hand, the voltage $1F_0$ [see (2.7)], which is fine tuned to the phase of the master station, is fed to the Yx8 multiplier:

$$U_{8F_0} = U_0 \cos\left(8\,\omega t + 8\,\Omega \frac{r}{v}\right). \qquad (2.9)$$

Reference voltage (2.9) is also fed to the red channel phase detector FD8. The compensation-tracking system measures the phase difference ψ_1. In accordance with equations (2.8) and (2.9), this phase difference is equal to:

$$\psi_1 = 8\,\Omega \frac{r - r_1}{v}, \qquad (2.10)$$

which makes it possible to find one line of position for a ship.

The measurements of the phase differences ψ_2 and ψ_3 in the green and violet channels are made just as was explained above for the red channel.

The Measurement of the Phase Difference ψ by the Compensation-Tracking System. Measurements of the phase differences ψ between the master and the slave stations are made in the measurement channels of the "Pirs-1D" indicating receiver. Compensation-tracking systems are used for this purpose (Figure 2.5), which consist of phase shifters, phase detectors, motors and precise indicators (phase meters). The tracking systems in the measurement channels are distinguished only by the use of reducers with different transmission ratios, and for this reason, it is sufficient to treat the operation of such a system for only 1 (the red) channel.

The reference voltage $1F_0$ is fed to the times eight multiplier, Yx8, and then the $8F_0$ voltage is fed through the phase shifter Fv8 to phase detector FD8. The mismatch voltage which is proportional to the phase difference ψ_1 between the $8F_0$ voltage (tuned to the phase of the master station) and the 8F voltage (having the phase of the signals from slaved station 1) is produced in this detector. This mismatch voltage is fed from phase detector FD8 to the motor M, which turns phase shifter Fv8 through the reducers as well as the pointers (large and small) of the precise red indicator, the TIK.

The phase shifter Fv8 changes the phase of the $8F_0$ voltage until the mismatch in phase detector FD8 is compensated. The readout is made from the TIK precise indicator, where the large pointer indicates the fractional portion while the small pointer indicates the whole number of periods (tracks) of the measured phase difference ψ_1 [see (2.10)].

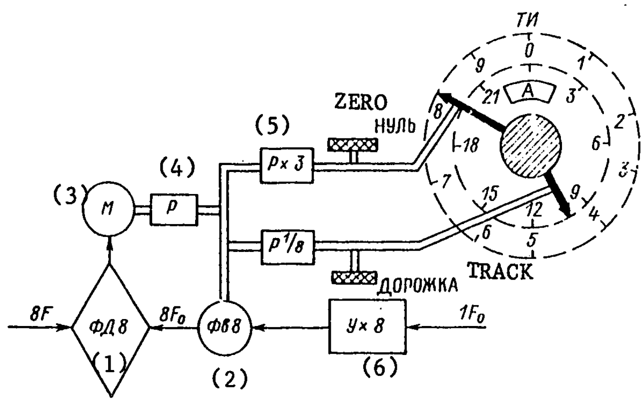

Figure 2.5. The compensation-tracking system for phase measurements ("Pirs-1D").

Key:
1. Phase detector 8;
2. Phase shifter 8;
3. Motor;
4. Reducer;
5. Step-up gearing (x3);
6. x8 multiplier.

Thus, to determine a ship's position (lines of position), measurements of the phase differences ψ_1, ψ_2 and ψ_3 are made in the three measurement channels. These measurements are made at frequencies of 8Ω, 9Ω and 5Ω [see (2.10)]. In order to have the capability of utilizing navigation charts with the "Decca" radionavigation system hyperbola grids drawn on them, it is necessary to convert the readouts of ψ_1, ψ_2 and ψ_3 to the readings of the "Decca" radionavigation system indicating receivers which measure the phase differences at the comparison frequencies of MΩ = 24Ω, 18Ω and 30Ω [see (2.2)]. For this purpose, the readouts of the phase differences ψ_1, ψ_2 and ψ_3 in the "Pirs-1D" are transmitted to the large pointers through the step-up gearing (by factors of 3, 2 and 6 times in channels I, II and III respectively) (8Ω · 3, 9Ω · 2 and 5Ω · 6), while they are transmitted to the small pointers, which calculate the whole number of periods N (tracks) through step-down reducers (by factors of 8, 9 and 5 times).

Consequently, the rotation angles of the small pointers of the TIK [precision red indicator], TIZ [precision green indicator] and TIF [precision violet indicator] are M times less (24, 18, 30) than the rotation angles of the large pointers and one revolution of the small pointers corresponds to M revolutions of the large pointers, i.e., contains 24, 18 or 30 tracks (one revolution of the large pointer corresponds to a phase difference change of 2π: by one track).

The track zone in the "Decca" radionavigation system is the term for the number of tracks in one revolution of the small pointer. Thus, for the TIK precise red channel indicator, 24 tracks are contained in the track zone, etc. An additional internal scale with 10 Latin letters A, B, C, D, E, F, G, H, I and J is used to identify the zones (see Figure 2.5), to which the small pointer of the precision red indicator is coupled through a step-down 1:10 reducer.

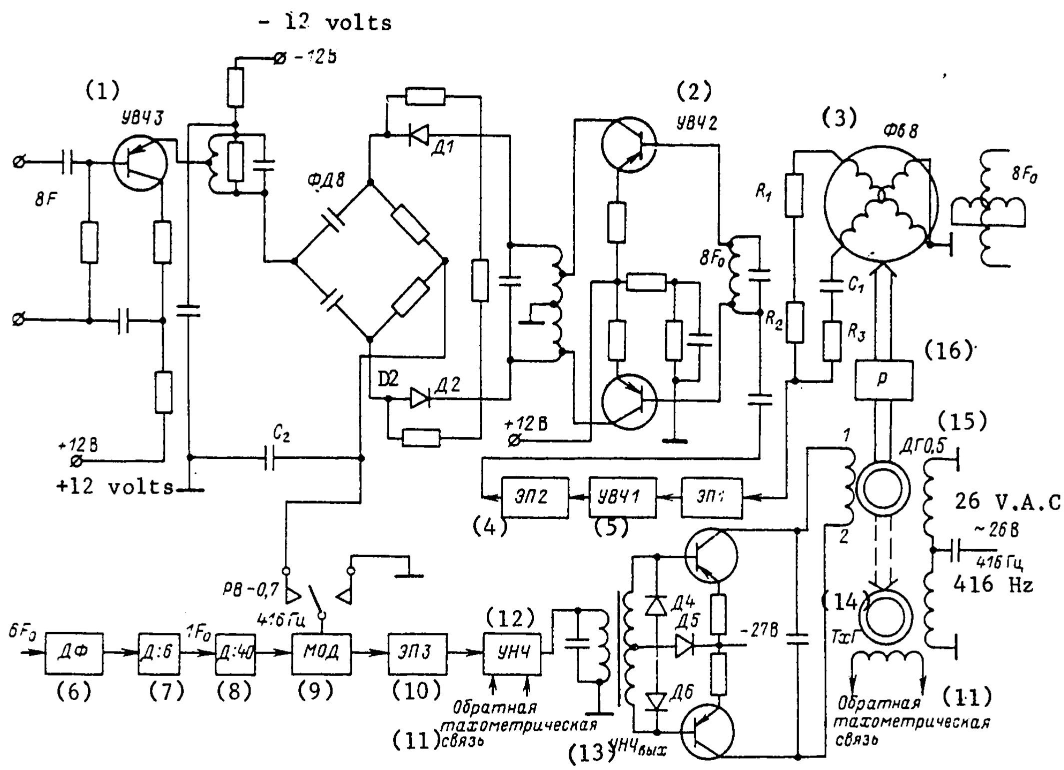

Figure 2.6. Basic electrical schematic of the phase difference ψ measurement circuitry in the "Pirs-1D" indicating receiver.

Key:
1. RF amplifier 3;
2. RF amplifier 2;
3. Phase shifter 8;
4. Emitter follower 2;
5. RF amplifier 1;
6. Discrete phase shifter;
7. Divide by 6;
8. Divide by 40;
9. Modulator;
10. Emitter follower 3;
11. Tachometric feedback;
12. Low frequency amplifier;
13. Output low frequency amplifier;
14. Tachogenerator;
15. DG 0.5 electric motor;
16. Reducer.

For convenience in identifying the readings taken from the precise indicators, the scale divisions for the small pointers of the red channel are graduated from 1 to 23 (24 divisions, including the 0 graduation); the green channel is graduated from 30 to 47 (18 divisions, including the 30 graduation); and the violet channel is graduated from 50 to 79 (30 divisions, including the 50 graduation). The stable positions of the phase shifters to which the small pointers must be set in the "zero set" mode are indicated by large numbers on these scales (for example, the numbers 3, 6, 9, 12, 15, 18 and 21 in Figure 2.5).

A basic electrical schematic of the phase difference ψ measurement circuitry of the "Pirs-1D" indicating receiver is shown in Figure 2.6. The reference voltage $8F_0$, which is obtained by multiplying $1F_0$ by 8, is fed to the stator windings of the phase shifter Fv8 (a BIF 0.19 type). Voltages are induced in the rotor windings of Fv8 which are proportional to the sine and cosine of the rotor rotation angle. After summing in a quadrature circuit consisting of resistors R_1-R_3 and capacitor C_1, the voltage $8F_0$ is phase shifted through an angle which depends on the rotor rotation angle. The $8F_0$ voltage then passes from phase shifter Fv8 through the emitter followers EP1, EP2, RF amplifiers 1 and 2 and is fed to phase detector FD8.

On the other hand, the 8F voltage from the slave station 1, VM1, is fed to this same phase shifter following amplification in RF amplifier 3. Phase detector FD8 is a summing bridge configuration, and for this reason, taking into account the action of diodes D1 and D2, we obtain a DC mismatch voltage across capacitor C_2 which is proportional to the phase difference ψ_1 between the voltages 8F and $8F_0$. The mismatch voltage is fed from capacitor C_2 through protective relay RV-0.7 to the modulator MOD, where it is modulated with a frequency of 416 Hz, obtained by dividing the reference $1F_0$ voltage by 40.

The mismatch voltage is fed from the low frequency output amplifier, $UNCh_{vykh}$, to the control winding 1-2 of motor DG 0.5 after passing through emitter follower EP3 and several low frequency amplifiers, UNCh's. This motor rotates phase shifter Fv8 through the reducer R until the mismatch voltage is cancelled. At the same time, the motor rotates the rotor of the tachogenerator TkhG, which generates a negative feedback voltage which is applied to the low frequency amplifier to stabilize the operation of the DG 0.5 motor. We will note that relay RV-0.7 actuates in the ambiguity elimination mode (UM) and disconnects the modulator, MOD, from the circuit of phase detector FD8, so as not to introduce errors into the readings of the precise indicators.

Eliminating Ambiguity in the "Pirs-1D" Indicating Receivers. The phase measurements of ψ [see (2.4)] have an ambiguity of $2\pi N$, where N is the number of complete periods (tracks) determined in the ambiguity elimination mode. The identification of the track number N consists in finding the correct readout using the small pointers of the precise indicators. An additional indicator (phase meter) GI is used for this in the "Pirs-1D" indicating receiver (see Figure 2.4), where this meter is also called the "coarse" track indicator, which makes phase measurements only at the frequency 1F (or 1f).

The master and slaved shore stations of the "Decca" radionavigation system transmit radio signals in accordance with the special MP [multipulse] or MP + V time diagram for the ambiguity elimination mode.

The time pattern for the MP + V transmissions of "Decca" radionavigation system shore stations (the mixed transmission cycle) is shown in Figure 2.7. The transmission cycle begins at the outset of each minute with a short interruption in the transmission of the master station (depicted in the figure with a thick line), after which, the master station transmits signals simultaneously on frequencies of 5f and 6f for 0.45 sec (from 0.15 to 0.6 sec), while the first slave station 1 (red) transmits on frequencies of 8f and 9f. Then the second pause in the transmission of the master station follows in the 10th second, after which this station transmits signals on four frequencies (5f, 6f, 8f and 9f) for 0.45 sec (from 10.15 to 10.6 sec).

Then follows the third brief interruption in the transmission of the master station, and the first slave station 1 (red) transmits signals at frequencies of 5f, 6f, 8f, and 9f for 0.45 sec (from 12.65 to 13.1 sec). The master station does not operate during this time interval. Then, as can be seen from the time pattern for master station transmissions, depicted in the figure with the thick line, there follows a fourth pause in the operation of the master station, and the second slave station 2 (green) transmits at four frequencies (5f, 6f, 8f, and 9f) between 15.15 and 15.6 sec (for 0.45 sec), while the master station does not operate during this period.

The fifth interruption in master station transmissions occurs prior to the transmission of the 5f, 6f, 8f and 9f ambiguity resolution signals by the third slaved station 3 (violet), which follow from 17.65 to 18.1 sec (for 0.45 sec). In this time interval, the master station also does not operate.

After 20 seconds have elapsed following the short term interruption in transmissions, the master station transmits frequencies of 5f and 6f in the time interval from 20.15 to 20.6 sec (for 0.5 sec) and simultaneously with it, the second slaved station 2 (green) transmits frequencies of 8f and 9f.

A similar phenomenon occurs after 40 seconds have elapsed, with the only difference that simultaneously with the master station which transmits signals at frequencies of 5f and 6f, no longer the second slave station transmits the signals at frequencies of 8f and 9f, but rather the third slave station 3 (violet).

It is important to note that the transmission cycles for the ambiguity resolution signals by the shore stations of the "Decca" radionavigation system are of a symmetrical uniform nature and take place both with a repetition period of one minute (this cycle is conventionally designated with the letter V) and with a repetition period of 20 seconds (the multipulse, MP, transmission cycle). The essence of the more reliable technique of ambiguity resolution, UM, by means of using the multipulse mode consists in the fact that in marine indicating receivers using this mode (the "Pirs-1M", etc.), the 1f signals

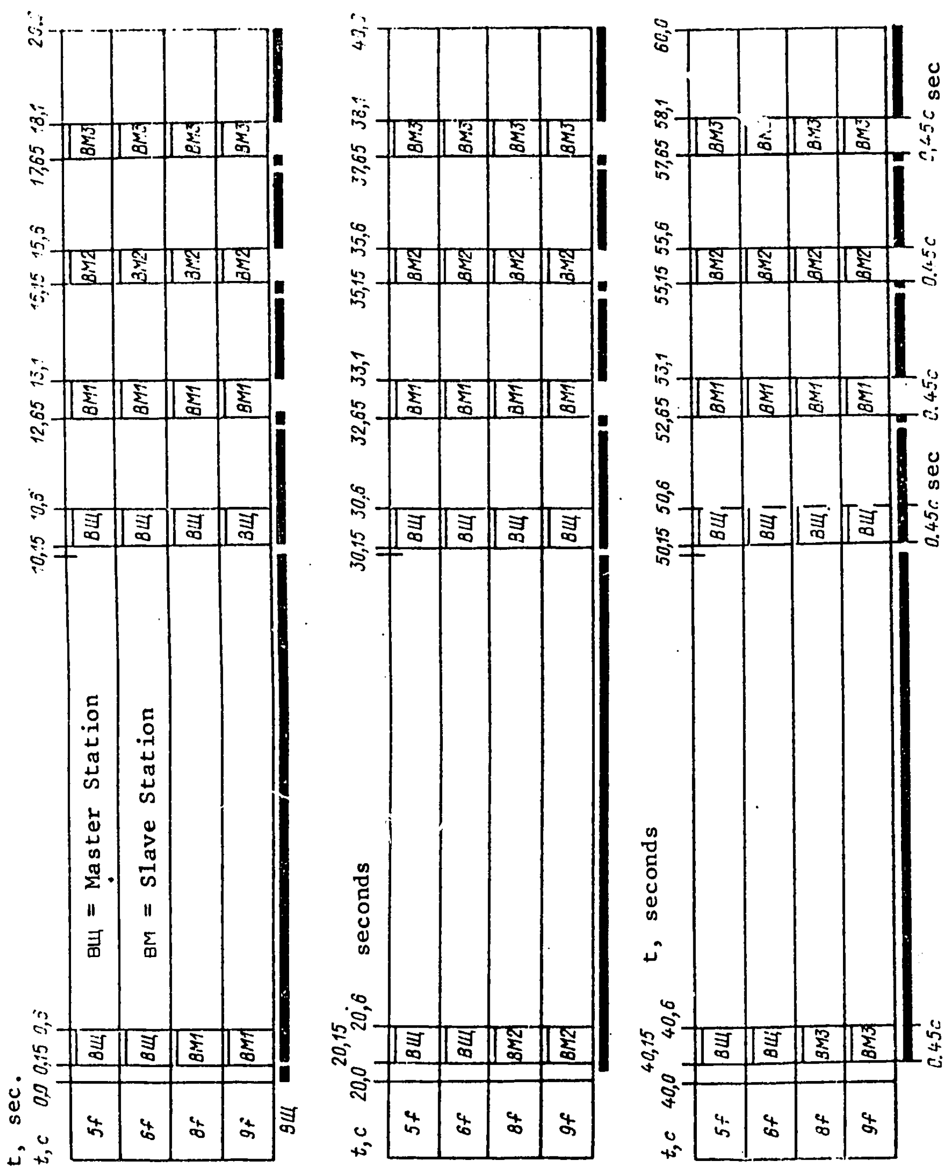

Figure 2.7. Time diagram of the MP+V transmission of the shore stations of the "Decca" radionavigation system in the ambiguity elimination mode.

are segregated from the sum of all four frequencies (5f, 6f, 8f and 9f) transmitted simultaneously for 0.45 sec by each station in the network. The V and MP cycles are easily distinguished in Figure 2.7, since the time intervals of station operation in the V mode are depicted in the left half of the figure, while the multipulse mode is shown in the right half.

The V transmission cycle is used in old models of indicating receivers and makes it possible to resolve the ambiguity once per minute. When the MP transmission cycle is employed, the ambiguity is resolved for each pair of stations three times per minute.

The ambiguity resolution process consists of two stages (see Figure 2.4).

The first ambiguity resolution step consists in accounting for the additional phase shift introduced into the $1F_0$ reference voltage when the master oscillator OG voltage at $6F_0$ is divided by 6, where this oscillator is designed in a phased lock loop configuration in each synchronization channel to fine tune to the phase and frequency of the master station. This additional phase shift will be a multiple of 60° and is determined by the quantity $z(2\pi/6)$, where z is an unknown integer, which can assume values from zero to five (z = 0, 1, 2, 3, 4, 5). To eliminate the ambiguity in the division and reduce the number z to zero, the master station signals at frequencies of 5f and 6f are used in the transmission cycle for the ambiguity resolution signals (see Figure 2.7).

These signals which are received by the antenna of the ship's indicating receiver (see Figure 2.4), following conversions in the main and violet channels, are fed to the mixer SmG following the intermediate frequency amplifier; the 1F difference frequency voltage is generated in the mixer. The 1F voltage is then fed to the phase detector FDG of the compensation-tracking system, to which the reference voltage $1F_0$ is also fed, which contains, as was indicated above, the phase shift of $z(2\pi/6)$ from the multivalued ambiguity of the division of the phase of the reference voltage $6F_0$ by 6.

The phase metering device $\psi\Gamma_1$ measures the phase shift $z(2\pi/6)$ or the difference voltages 1F and $1F_0$, and the readout on the white scale of the GI [coarse track indicator] will not be equal to zero. This scale is graduated in numbers z from zero to five. By rotating the DIVISION AMBIGUITY control clockwise, which has six positions, and the discrete phase shifter DF coupled to it, the phase of the reference voltage $1F_0$ is changed in portions which are multiples of 60° until the complete compensation for the phase shift $z(2\pi/6)$. The reading of the white scale division of the coarse track indicator in this case will be equal to zero, and the first stage in the resolution of the ambiguity is completed.

The second stage of ambiguity resolutions [see (2.4)] consists in determining the track number from the precise indicators, i.e., the number $2\pi N$ of the total cycles of measuring the phase difference ψ. The 8f and 9f signals transmitted simultaneously for 0.45 sec by each slave station are used for this (see Figures 2.4 and 2.7).

Thus, the 8f and 9f signals of slave station 1 are used when resolving the ambiguity for the red indicator, the TIK [precise red indicator]. These signals will be picked up by the antenna, and after undergoing conversion in the red and green channels by means of frequency gating, they are fed to mixer SmG. The difference frequency 1F is segregated in the mixer SmG, where this frequency has a phase shift corresponding to the time delay r_1/v with the passage of the radio signals over the distance r_1 from slave station 1 to the ship. The voltage 1F is fed to the phase detector FDG. On the other hand, the reference voltage $1F_0$, which is tuned to the phase and frequency of the master station, is also fed to phase detector FDG. The compensation-tracking system, the action of which is similar to that which was described above, measures the phase difference $\psi_{\Gamma 2}$ in the voltages 1F and $1F_0$, and a readout appears on the red scale of the coarse track indicator, the GI, which corresponds to this phase difference. It is important to note that the measurement of the phase difference $\psi_{\Gamma 2}$ is accomplished at the base frequency 1F (1f), and therefore [see (2.4)]:

$$\psi_{\Gamma 2} = 2\pi N_1 + 2\pi \frac{r_1 - r}{\lambda}, \tag{2.11}$$

where λ is the wavelength correponding to the base frequency 1f ≈ 14.2 KHz; N_1 is the unknown number of complete cycles of change in the phase difference $\psi_{\Gamma 2}$. The measured phase difference $\psi_{\Gamma 2}$ likewise has an ambiguity of $2\pi N_1$. The hyperbolic grid of isolines plotted using formula (2.11) forms the so-called "coarse" tracks, the width of which is several times greater than the width of the precision tracks (see Table 2.3). Given the condition that the ship's position at sea is known with an error of no more than three miles, i.e. with a greater precision than half of the width of a coarse track, for which the reckoning or determination of the position by other navigation instruments is used, the number N_1 of the coarse track will be known beforehand. For this reason, the reading taken from the red scale of the coarse track indicator makes it possible to find the number N of the precision track. For this, the small pointer of the TIK precision indicator (red channel indicator) is set in accordance with the reading of the red scale of the GI [coarse track indicator] and the ambiguity in the phase measurements of ψ_1 is thereby eliminated.

Similar operations must also be carried out to eliminate the ambiguity in the readings of the precise indicators for the green and violet channels. For this, the green and violet scale readings of the coarse track indicator are set on the TIZ and TIF [green and violet precision indicators] (in the green and violet channels), by turning the small pointers of these indicators manually to the corresponding divisions. After setting the small pointers of the precision indicators, the ambiguity resolution is considered completed.

Eliminating the Phase Shifts Produced in the Measurement Circuits of the "Pirs-1D" Indicating Receiver (Zero Setting). In the "zero set" mode, possible undesirable phase shifts in the signals of the master and slave stations are eliminated in the measurement channels of the indicating receiver. A special SFPS circuit (see Figure 2.4) generates test signals (called pilot signals) in the form of a train of short pulses with a repetition rate of 1f, which are fed to the measurement channels in the "Pirs-1D" receiver. If during the passage of the 1f signals voltages appear by virtue of the properties and engineering features of the electronic circuits used in the instrument, where these voltage give evidence of the appearance of phase differences, then the readings of the precision and coarse indicators are corrected.

The processes which take place in the indicating receiver in the "zero set" mode are conveniently broken down into three steps.

The first step in the process consists in tuning the phase of the pilot signals to the phase of the master station signals at the output of the main channel. As can be seen from Figure 2.4, in the "zero set" position of the operating mode switch, the pilot signals at 1f from the SFPS [pilot signal generating] circuitry are fed through the RF amplifier to the circuitry of the main channel. Because of the presence of narrow band filters in this channel, the 6f frequencies are segregated from the 1f frequencies, where the former have the appropriate phase. The 6f signals are fed to the mixer Sm, where they are mixed with the 6Δ frequency of the local oscillator and are then fed through the crystal filter and the intermediate frequency amplifier to the main channel phase detector FD6.

On the other hand, because of the action of the synchronization channel and the FAPCh system [phase locked loop frequency and phase control system], the $6F_0$ ($1F_0$) reference voltage is fed to this phase detector FD6, where this voltage is tuned to the phase and frequency of the master station. The mismatch voltage corresponding to the phase difference between 6F (1f) and $6F_0$ ($1F_0$) is fed from phase detector FD6 to motor M of the compensation-tracking system, which rotates the pilot signal phase shifter FvPS until this phase difference is equal to zero. The tuning of the 1f pilot signal phase to the phase of the master station signals (the phase of the $1F_0$ reference voltage signals) is accomplished in this way.

The second stage of the process in the "Pirs-1D" indicating receiver in the "zero set" mode consists in taking into account possible additional phase shifts in the measurement channels and eliminating possible errors in the readings of the precision track indicators. In this case, the 1f signals, which are tuned to the phase of the reference voltage $1F_0$ signals, are fed from the pilot signal generator through the RF amplifier to the measurement channels (red, green, violet). Because of the presence of narrow band filters in these channels, the 8f, 9f and 5f harmonics are segregated from the 1f signals, where the former have the same phase as the 1f signals. The segregated signals then pass through the mixers Sm, the crystal filters, the intermediate frequency amplifiers and are fed to the appropriate phase detectors. On the other hand, the reference voltage $1F_0$ signals are fed to these same phase detectors where these signals are tuned to the phase and frequency of the master station. It is easy to see that the differences in the mismatch voltages produced in the phase detectors correspond to possible phase shifts in the 1f pilot signals because of their passage through the components of the measurement channel circuits, and consequently, will be a source of errors in the precise phase measurements. To take these errors into account, the

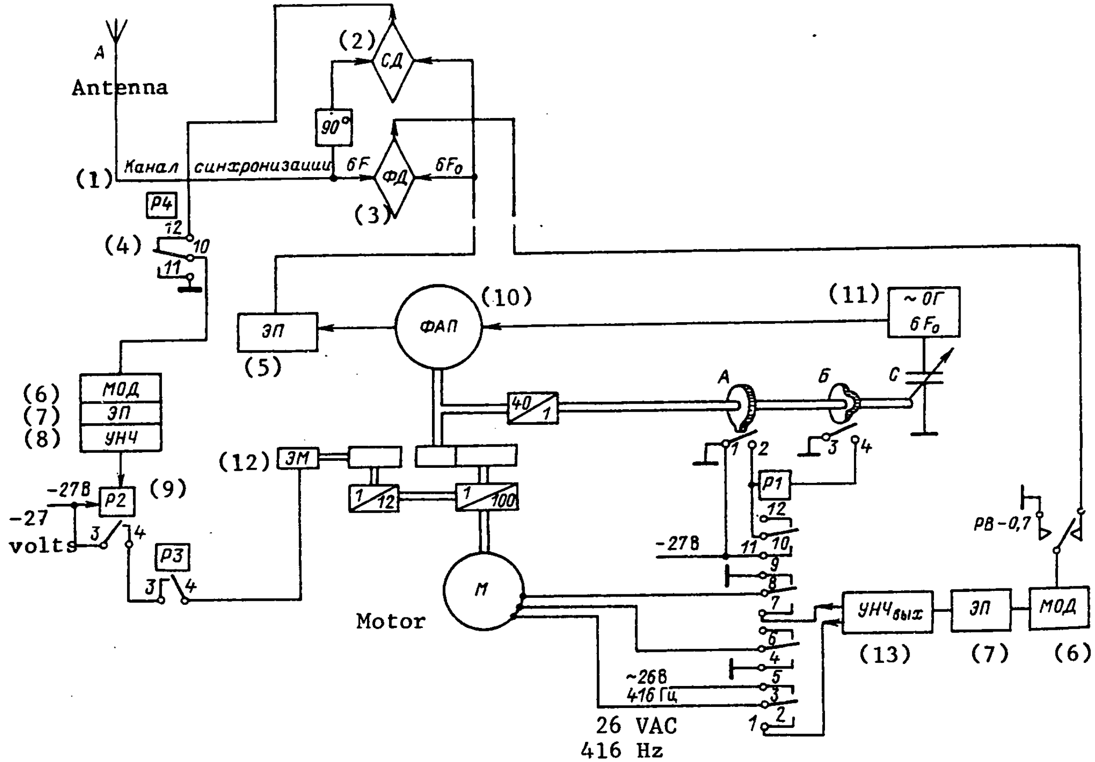

Figure 2.8. Basic schematic of the automatic phase and frequency control circuitry of the "Pirs-1D" indicating receiver.

Key:
1. Synchronization channel;
2. Synchronous detector;
3. Phase detector;
4. Relay R4;
5. Emitter follower;
6. Modulator;
7. Emitter follower;
8. Low frequency amplifier;
9. Relay R2;
10. Phase shifter;
11. Master oscillator, $6F_0$;
12. Electromagnetic clutch;
13. Low frequency output amplifier.

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large pointers of the precision track indicators are set on the zero graduations, while the small pointers are set to any large division on the inside scale.

The third step in the "zero set" process consists in taking into account possible errors due to supplemental phase shifts when the radio signals pass through the measurement channels of the indicating receiver during phase measurements with the "coarse" indicator, the GI. At first, the additional phase shift with the passage of the pilot signals through the main and the violet channels is taken into account. In this case, by pressing the ZERO I control, the 6F and 5F (6f and 5f) are fed to the mixer SmG [coarse track indicator mixer] from the main and violet channels, which produce the difference frequency 1F (1f). The latter is fed to the FDG phase detector [coarse track phase detector], to which the reference voltage $1F_0$ is also fed. With the appearance of an additional phase difference between the 1F and $1F_0$ voltages, the reading on the white scale of the coarse indicator will differ from zero. A zero reading is to be set on this scale using the ZERO I control.

Then the additional phase difference with passage of the 9F and 8F (9f and 8f) pilot signals through the green and red measurement channels is taken into account. By pressing the ZERO II control, the indicated frequencies are fed to the SmG mixer, while their 1F difference frequency is fed to the FDG [coarse track phase detector]. On the other hand, the $1F_0$ reference voltage is fed to this same phase detector, the FDG, through an additional phase corrector, the FvK, which is inserted when the ZERO II control is pressed. With the appearance of the phase difference between 1F and $1F_0$, a mismatch voltage is produced in the coarse track phase detector and the white scale reading will not be equal to zero. This phase difference is taken into account by means of the FvK phase shifter using the ZERO II control until the zero reading appears on the white scale.

The FAPCh [Phase Locked Loop] System for Tuning the Phase and Frequency of the $6F_0$ Reference Voltage to the Phase and Frequency of the 6F Voltage of the Master Station, the VShCh. A two stage (primary and secondary) frequency control system using a compensation-tracking system is employed in the "Pirs-1D" indicating receiver in the FAPCh system, which consists of a master crystal oscillator OG (Figure 2.8), a phase shifter FAP, a motor M (a DG-05TA type) and a variable capacitor C. After the instrument is turned on, a voltage of -27 V is fed through contacts 3 and 4 of relay RZ to electromagnetic clutch EM, which actuates, disconnecting the step-down 1/12 reducer from the motor M, and the latter operates through the 1/100 step-down reducer (the broad operating bandwidth of the FAPCh [PLL frequency and phase control]). Simultaneously, a voltage of 26 VAC at a frequency of 416 Hz is fed through contacts 2/5 and 8 and 9 of relay R1 to motor M. The latter starts to rotate and turns the phase shifter FAP through the reducer, and couples the rotation through the additional 40/1 step-down reducer to cams A and B of variable capacitor C, returning it to the initial position. It is important to note that relay R1 actuates only with the simultaneous closure of contacts 3 and 4, and 1 and 2, which contact cam B with a broad projecting lug and cam A with a narrow tooth-like projection respectively, the position of which corresponds to the initial position of the capacitor C. With the actuation of relay R1, capacitor C will be in the initial position, which also corresponds to the first stage in the automatic frequency control of the phase locked loop system.

The actuation of relay R1 connects the windings of the motor M through contacts 1, 2, 5, and 4, and 7 and 8 to the output of the output amplifier. In this case, the mismatch voltage between the reference $6F_0$ voltage fed from the thermostatically controlled master oscillator OG through phase shifter FAP and the emitter follower EP to the phase detector FD, and the 6F voltage of the master station, which is also fed to the phase detector through the synchronization channel, is fed from the low frequency output amplifier to the control windings of the motor M. In the process of subsequent automatic frequency control (the second stage), when the mismatch voltage appears in phase detector FD, the motor M rotates the phase shifter FAP and the variable capacitor C until the phase and frequency of the $6F_0$ voltage is completely synchronized with the 6F voltage from the master station.

The second synchronization stage takes place within the range of rotation of the capacitor C limited by the rotation of the cam with the broad lug. When outside of this range, contacts 3 and 4 of relay R1 are open, relay R1 is de-energized and the automatic frequency control process starts anew by means of rotating capacitor C to the initial position, as was described above. With the completion of the automatic frequency control and synchronization process for the $6F_0$ and 6F voltages (the mismatch voltage from the phase detector will be equal to zero in this case), the maximum voltage will be picked off of the synchronous detector SD. This voltage is fed through the breaking contacts 10 and 12 of relay R4 and the controller (modulator, emitter follower, low frequency amplifier) to relay R2, which actuates, opening contacts 3 and 4 in the power supply line for the electromagnetic clutch EM. The motor M turns on to rotate the phase shifter FAP through the step-down 1/100 and 1/12 reducers with an overall transfer ratio of 1:1,200 (the narrow operating bandwidth of the PLL frequency and phase control). The PLL system shifts from the search mode to the mode of tracking the phase and frequency of the master station signals. In this case, the completion of the automatic frequency and phase control synchronization process will be clearly seen from the blinking light on the scales of the precision track indicators.

2.3. The "Pirs-1M" Marine Indicating Receiver

The modernized "Pirs-1M" marine indicating receiver differs in its structural design from the "Pirs-1D" in the use of the MP [multipulse] mode in ambiguity resolution (UM). The reliability of ambiguity resolution is increased in this way, especially with an increase in the distance of the ship from the transmitting stations of the selected network of the "Decca" radionavigation system. A block diagram of the instrument is shown in Figure 2.9. In the multipulse ambiguity elimination mode, each station in a network of the "Decca" radionavigation system transmits signals at frequencies of 6f, 8f, 9f, and 5f simultaneously at intervals of 20 seconds (see Figure 2.7). By summing them, one can segregate the fundamental frequency 1f from which the number of tracks N is identified.

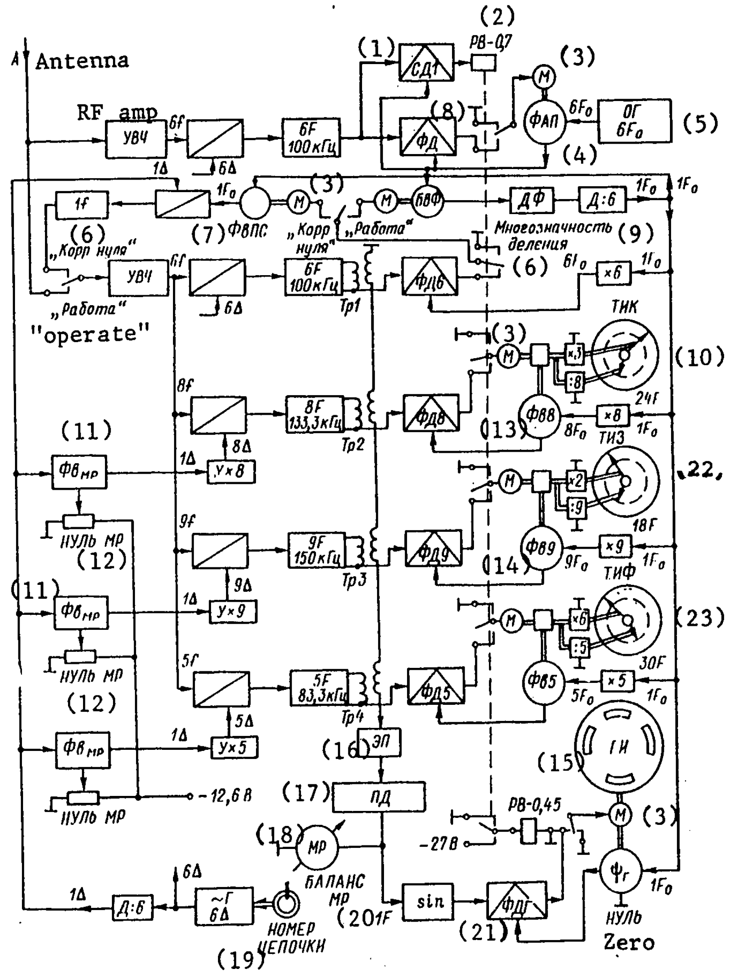

Figure 2.9. Block diagram of the "Pirs-1M" indicating receiver.

Key:
1. Synchronous detector 1;
2. Relay RV-0.7;
3. Motor M;
4. Phase shifter;
5. Master oscillator, $6F_0$;
6. "Zero set";
7. FVPS = pilot signal phase shifter;
8. Phase detector;
9. Ambiguity division;
10. TIK = red channel precise track indicator;
11. Varicap multipulse phase shifter;
12. Multipulse zero set;
13. Phase shifter 8;
14. Phase shifter 9;
15. GI = coarse track indicator;
16. Emitter follower;
17. PD = peak detector;
18. Multipulse control;
19. Network number;
20. Multipulse balance;
21. FDG = coarse track phase detector;
22. TIZ = green channel precise track indicator;

Key [cont.]: 23. TIF = violet channel precise track indicator.

The signals cited here are picked off from the secondary windings of transformers Tr1--Tr4 inserted in the circuits of all of the measurement channels in the "Pirs-1M" indicating receiver. The voltage obtained is fed through the emitter follower EP to the peak detector PD, which limits the voltage on the down side, where the short width pulses with a repetition rate of 1F are also segregated out. These pulses are then converted to sine waves at the same frequency and fed to the phase detector FDG [coarse track phase detector]. On the other hand, the reference voltage $1F_0$ is fed to the phase detector from phase shifter ψ_Γ. Using the phase measurements made by means of the compensation tracking system, which consists of the FDG phase detector, the phase shifter ψ_Γ and the motor M, the ambiguity is resolved as was explained above using the readings of the GI [coarse track indicator] scales.

A provision is made in the "Pirs-1M" indicating receiver for the adjustment of the mutual phase relationships between the received 6f, 8f, 9f and 5f signals, since it is possible to segregate the synthesized 1F voltage from the sum of the four frequencies cited above given the condition that the latter do not undergo any additional phase shifts when passing through the corresponding measurement channels.

The phase relationships are adjusted in the "zero set" mode by means of changing the phase of the local oscillator frequencies at 8Δ, 9Δ and 5Δ, for which three varicaps Fv_{MP} [multipulse phase shifter] are used, the supply voltage to which is delivered through the MULTIPULSE ZERO potentiometers.

The maximum deflection of the MULTIPULSE BALANCE meter needle corresponds to the isolation of the synthesized 1F frequency, and consequently, the subsequent reliable elimination of the ambiguity in the phase measurements.

The "Pirs-1M" indicating receiver set contains four units with the following overall dimensions and weight (without the matching parts of the connectors):

--The receiver (P): 425 x 682 x 225 mm, 32 kg;

--The block of indicators (BI): 440 x 403 x 406 mm, 22 kg;

--The power supply (BP): 477 x 379 x 231 mm, 25 kg;

--The antiradar filter (PLF): 76 x 48 x 335 mm, 1.4 kg.

The following are included with the equipment set of the "Pirs-1M" indicating receiver (Figure 2.10):

--Fault detecting instrument (PON);

--Kit of spare parts, tools and accessories (19 modules);

--Technical description;

--Connecting cables.

A general view of the block of indicators of the "Pirs-1M" instrument is shown in Figure 2.11. The following are arranged on the front panel of the block of indicators: the scales of the precise indicators, the TI (E is for the red, A is for the green and C is for the violet); WHITE, RED, VIOLET and GREEN scales of the GI [coarse track indicator]; the ZERO and TRACK setting controls for the pointers of the precision track indicators; the ZERO set control for the WHITE scale of the coarse track indicator; the NETWORK NUMBER switch for selecting the network number; the OPERATING MODE switch; the HEAT signal light for the thermostat heating system; the DIVISION AMBIGUITY switch; the ILLUMINATION control for adjusting the filament current of the scale lighting lamps; the D-PRESS button for operation in the combined variant; the meter indicator for the multipulse phase balance; the controls for correcting the phase of the local oscillator frequencies of the individual channels (K is for the red, Z is for the green and F is for the violet); the light indicating switch for the coarse track indicator.

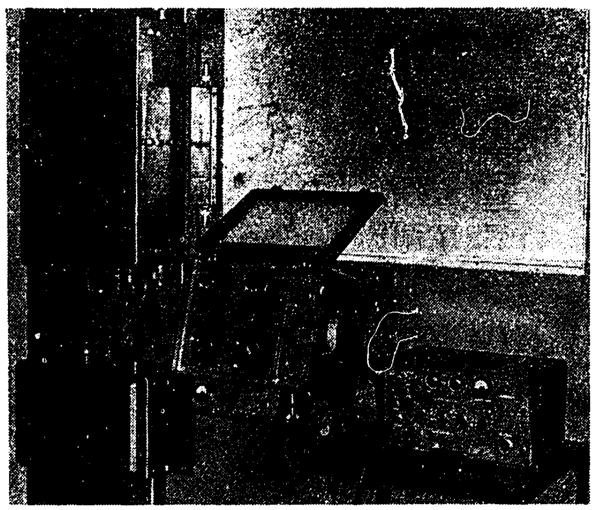

Figure 2.10. The complete equipment complement of the "Pirs-1M" indicating receiver with the fault detection instrument.

For convenience in operating the instrument on board ship, a fault detection instrument (PON) is used in the "Pirs-1M" indicating receiver. The amplitude and frequency, as well as the pulse width of the signals being checked, which are picked off from the corresponding monitor plug connectors of the "Pirs-1M" indicating receiver are monitored by means of the fault detection instrument (Figure 2.12).

The main technical specifications for the fault detection instrument are given below:

Maximum measurable signal voltages	Up to 10 volts
Range of measurable frequencies	25 Hz--25 KHz

Signal pulse widths which can be measured at levels of 0.7 to 1.5 volts	800 μs--800 ms
Deviation of signal amplitudes from the nominal values	±(20--25)%
Duration of continuous operation	6 hours
Supply voltage	127 VAC, 220 VAC, ±5%
Power mains frequency	40 Hz, 400 Hz, ±2%
Power consumption	40 VA
Weight of the instrument	7 kg
Overall dimensions	346 x 223 x 212 mm

The following components are placed on the front panel of the fault detection unit (see Figure 2.12): toggle switch B1, ON-OFF, for turning the instrument on and off; the 127 volt - 220 volt - control for setting the supply voltage; the POWER male connector for the supply voltage input; switches B2, B3 and B4 for setting the test programs; the MEASUREMENT - RESET counter toggle switch; the FREQUENCY CHECK two place counter (the lamps L1 and L2 are dekatrons); the AMPLITUDE CHECK meter; the CALIBRATE control for the meter; the TEST monitor socket for the fault detection instrument; and a 0.5 amp fuse.

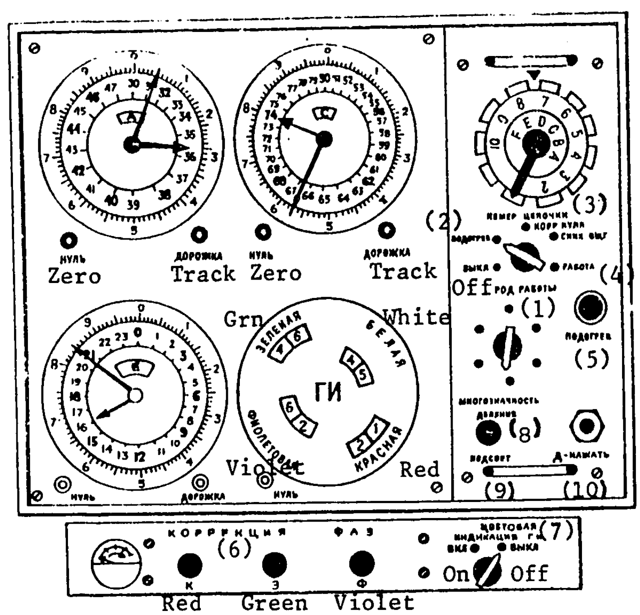

Figure 2.11. The indicator block of the "Pirs-1M" instrument.

Key: 1. Operating mode;
2. Heat;
3. Network number; zero set; master station coarse track sync;

Key [cont.]: 4. Operate;
5. Heat [indicating light];
6. Phase correction;
7. Coarse track indicator scale lighting: on - off;
8. Division ambiguity;
9. Scale lighting;
10. D-press.

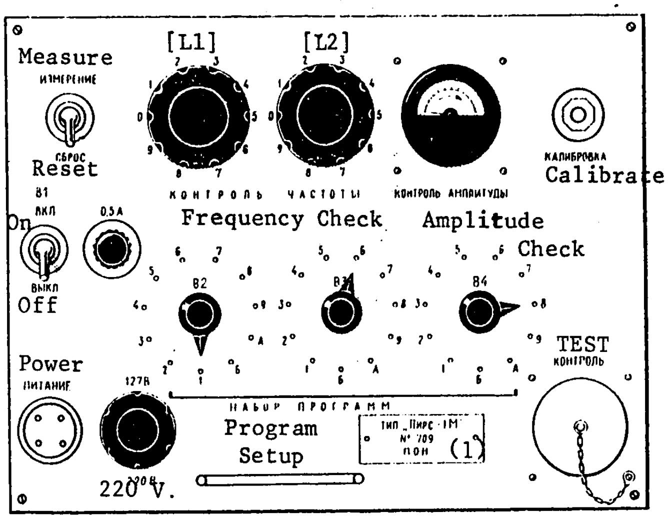

Figure 2.12. Exterior view of the fault detection instrument.

Key: 1. Type "Pirsl-1M", No. 709, PON [fault detection instrument].

A block diagram showing the amplitude testing of signals is depicted in Figure 2.13. The signal being checked is fed through switch B2 to the modulator MOD, where it is modulated with an AC voltage at a frequency of 400 Hz, which is fed through the matching emitter follower EP from a push-pull multivibrator. Then, the signal being checked passes through an amplifier circuit and limiter O, and is fed to the meter I. Based on the deflection of the meter needle, one can judge whether the signal amplitude falls in the specified range. A signal with a deviation of $\pm$(20 - 25)% of the nominal value is considered normal, i.e., within the range of the first - sixth scale divisions. Signals being monitored with voltages of up to 10 volts are checked with limiting with respect to the maximum. For this, a voltage of -12.6 volts is fed to the limiter through switch B4 in the "A" position.

A provision is made in the instrument for calibrating the meter I in a calibrator K. The calibrating voltage of 0.6 volts is fed through switch B2. With the deflection of the meter needle I from the fourth scale division, the needle is returned to this position with the CALIBRATE control, for which a voltage of -12.6 volts is fed through the potentiometer. When calibrating the meter, program 41B is set with controls B2, B3 and B4 (see Figure 2.12).

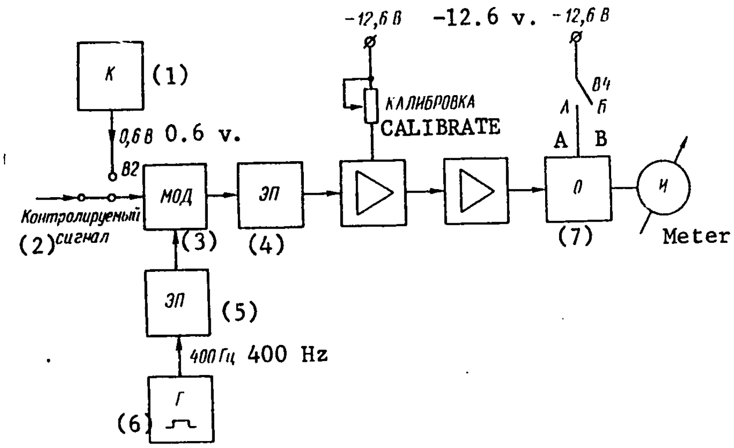

Figure 2.13. Block diagram of the circuitry for signal amplitude testing.

Key:
1. Calibrator;
2. Signal being checked;
3. Modulator;
4. Emitter follower;
5. Emitter follower;
6. Pulse generator;
7. Limiter.

The frequency or width of the signal pulses is checked in accordance with the block diagram shown in Figure 2.14 and consisting of the channel for the frequency being measured, a reference frequency channel, a counter, reset and triggering devices as well as a controller.

The basic function of the circuitry consists in generating a time interval equal to the duration of one period of the frequency being studied or width of the pulse being checked, and turning on an electronic switch, K1, for this amount of time in the reference frequency channel. The measurement process consists in modulating (quantizing) the generated time intervals with the reference frequency pulses and calculating the number of these pulses with a two place decimal counter, which registers the value of the measured frequency or the width of the signal pulse being studied.

Frequency Measurement. The frequency being measured (at a level of 0.7 volts) is fed through switch V2a to the input of the channel for the frequency being measured. It is then routed through the matching emitter follower EP7, amplifier U7, and emitter follower EP8 to Schmidt trigger Tg6, where it is converted to pulses, the width of which is equal to the period of the frequency being measured. It is then fed through the D:8 divider and emitter follower 9 to the wafers V2g and V2v of switch V2. When measuring a frequency, switch V2 is set in the "6" or "7" position.

The electronic switch K1 in the reference frequency channel is controlled through emitter follower EP6 by Schmidt triggers Tg4 and Tg5 of the controller.

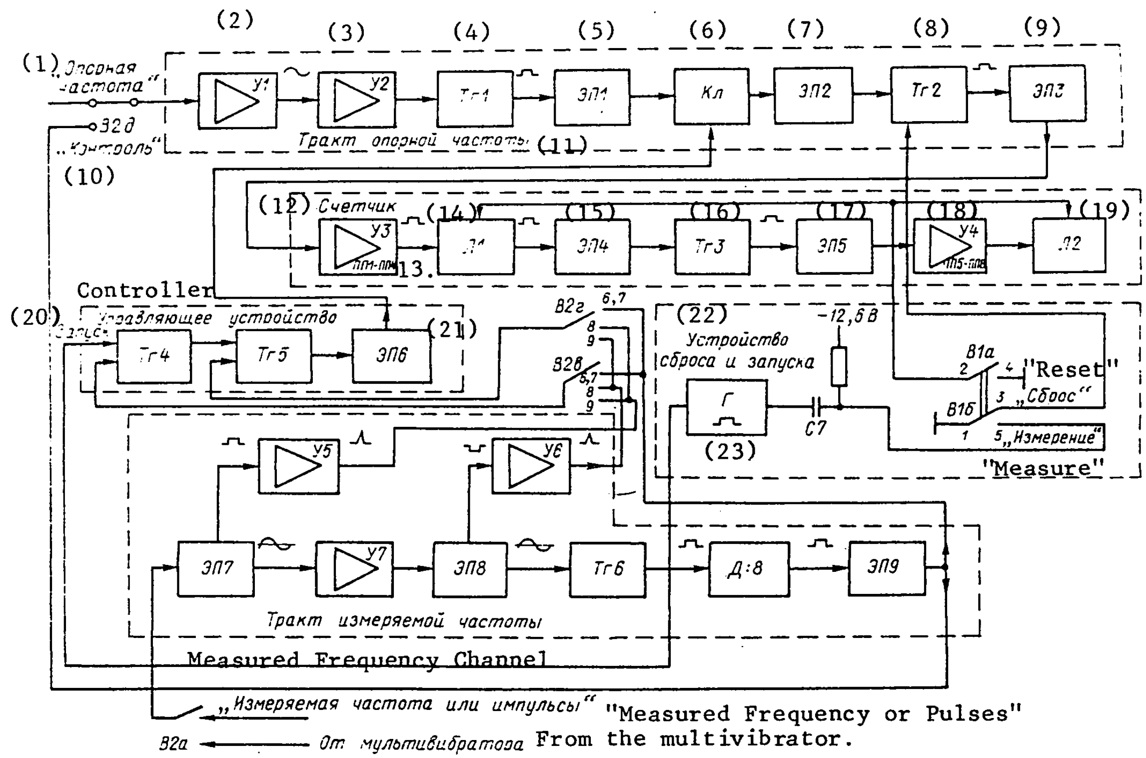

Figure 2.14. Block diagram of the circuitry for signal frequency and pulse width testing.

Key:
1. "Reference frequency";
2. Amplifier 1;
3. Amplifier 2;
4. Schmidt trigger 1;
5. Emitter follower 1;
6. Electronic switch;
7. Emitter follower 2;
8. Schmidt trigger 2;
9. Emitter follower 3;
10. "Test", V2d;
11. Reference frequency channel;
12. Counter;
13. Amplifier 3, PP1-PP4;
14. Dekatron 1;
15. Emitter follower 4;
16. Schmidt trigger 3;
17. Emitter follower 5;
18. Amplifier 4, PP5-PP8;
19. Dekatron 2;
20. Start;
21. Emitter follower 6;
22. Reset and triggering unit.

When switch V1 is set in the "reset" position, the dekatrons L1 and L2 of the counter are switched to the initial position, and the flip-flops of Tg2 [Schmidt trigger 2] - the divider in the reference frequency channel, are set to the position for half of a readout unit, which makes it possible to avoid the readout error of ±1 in the case of a multiple ratio of the reference frequency and the frequency being measured.

When switch V1 is set to the "Measure" position, a triggering signal is fed from biased multivibrator G to flip-flop Tg4, the flip-flop reverses its state, also shifting flip-flop Tg5 which is coupled to it to the new state. The pulse of the frequency being measured then incoming from emitter follower 9 shifts flip-flops Tg4 and Tg5 to the state where the feed of the blocking voltage through emitter follower 6 to the electronic switch is terminated. The switch turns on and passes the reference frequency pulses, which pass through switch V2d, amplifiers U1 and U2, Schmidt trigger Tg1, emitter follower 1, the electronic switch K1, emitter follower 2, the flip-flop divide by 8 divider Tg2 and emitter follower 3. The two place decimal counter (dekatrons L1 and L2) count the number of reference frequency pulses. The next regular pulse then coming from emitter follower 9 of the channel for the frequency being measured shifts the flip-flops Tg4 and Tg5 of the controller to the opposite state, the switch is cut off and the pulse counting is terminated. With the arrival of the next triggering pulse, the measurement process is repeated.

Measuring Signal Pulse Width. Measurements of signal pulse widths are made by feeding the pulses to be tested (at a level of no less than 2.5 volts) through switch V2a to emitter follower 7 and then to amplifier U5. Simultaneously with this, the pulses are fed through amplifier U7, where they are inverted, and emitter follower 8 to amplifier U6. Positive pulses are taken from amplifiers U5 and U6, where the pulse from the negative leading edge of the input pulse is taken from U5 and the pulse from the positive leading edge of this pulse is taken from the output of U6. To measure the width of a positive pulse, switch V2 is set in the "8" position, and when measuring a negative pulse, it is set in the "9" position. The pulses being measured are then fed to flip-flops Tg4 and Tg5, and the measurement process takes place just as in the case of frequency measurement.

In the autocheck mode, the program number is set at 41B and a 400 Hz voltage is fed through switch V2a into the channel for the frequency being measured, where this voltage following conversion is fed from the output of emitter follower 9 to switch V2d for the input of the reference frequency channel. The counter readings should change continuously in this case. When the program is set at 51B, the counter readout should not change.

The set of test programs and the readings of the AMPLITUDE CHECK indicator and the FREQUENCY CHECK counter are given in the operating instructions for the "Pirs-1M" indicating receiver.

2.4. Requirements Placed on the Installation, Alignment and Operation of Indicating Receivers Under Marine Conditions

The "Pirs-1M (or D)" indicating receiver is installed in a heated room in a location convenient for servicing and use, while the indicator block, the BI, is installed close to the operating position of the navigator (in a bulkhead or on a navigator's table), and the receiver P and power supply BP are installed in an insulated room at a distance of no more than 40 m (Figure 2.15) from the indicator block. Moreover, when laying out the individual instruments included in the complete indicating receiver package, one takes into account the maximum permissible distances which depend on the design characteristics of the connecting cables. The positions of the connectors (up or down) in the installation of the instrument are shown in Figure 2.15. It is permissible to replace the KNRE and KNRETE type cables with cables having the same number of cores, the same cross-sections and similar shielding. If the units of the "Pirs-1M" indicating receiver are located at distances of no more than 2.5 m from each other, then it is possible to use cables supplied by the manufacturing plant as part of the complete equipment package.

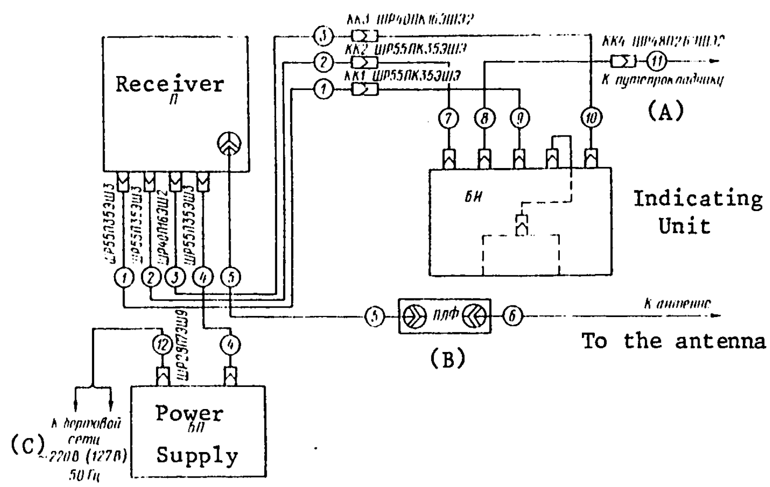

Figure 2.15. Schematic showing the electrical connections for the "Pirs-1M".

Key: A. To the map tracer;
B. Antiradar filter;
C. To the ship power mains, 220 VAC (or 127 VAC), 50 Hz.

A vertical marine omnidirectional antenna with a length of from 4 m to 6 m is used to receive radio signals from the stations of the selected network of the "Decca" radionavigation system. If the antenna has a length of more than 6 m, then it is permissible to incline it to the horizontal by no less than 80°. The capacitance of the antenna feedline should not exceed 2,350 picofarads.

The antenna is to be located far away from the antennas of the ship's radio transmitting equipment and fastened sufficiently tightly, since its rocking can introduce additional errors into phase measurements.

Номер кабеля Cable No.	Марка и сечение Type and Cross-section	Длина, не более Length, no more than:
1	КНРЭТЭ 37 × 1 мм²	(1 + 9) 40 м
2	КНРЭТЭ 37 × 1 мм²	(2 + 7) 40 м
3	КНРЭТЭ 14 × 1 мм²	(3 + 10) 40 м
4	КНРЭТЭ 33 × 1 мм²	5 м
5	РК-75-7-12 (РК-120)	1 м
6	РК-75-7-12 (РК-120)	(5 + 6) 30 м
7	КНРЭТЭ 37 × 1 мм²	2,5 м
8	КНРЭТЭ 24 × 1 мм²	2,5 м
9	КНРЭТЭ 37 × 1 мм²	2,5 м
10	КНРЭТЭ 14 × 1 мм²	2,5 м
11	КНРЭТЭ 24 × 1 мм²	--
12	КНРЭ 3 × 3,5 мм²	10 м

The checking of the operational status of the "Pirs-1" indicating receiver is accomplished under marine conditions when using the instrument for navigation, as well as for preventive purposes every 200 hours of operation, but no less often than once every three months.

The fault detection instrument is used in the "Pirs-1M" indicating receiver to check the power supply circuits (test the power supply voltages of the instrument), the indicator block (check the reference frequencies) and the receiver (check the reference frequency, intermediate frequency voltages, etc.). The set of test programs and permissible values of the deviations in the voltages being checked are given in the operating instructions for the instrument.

In the case where defects are found which cannot be successfully eliminated under shipboard conditions, the instrument is to be repaired and aligned by specialists of the electronics radionavigation service for shipping.

The readiness of the "Pirs-1M" indicating receiver for use is established during the start-up of the instrument and the subsequent performance of the following operations (see Figure 2.11):

1. One hour before the start of operation of the instrument, throw the OPERATING MODE switch to the "heat" position.

The thermostat of the crystal oscillator unit is heated, which is attested by the fact that the green monitor lamp HEATING is on. When the requisite temperature is reached (after 20 to 30 minutes), the light goes off. It is possible for the light to come on repeated for short periods of time (1 to 5 minutes) during the process of the subsequent adjusting of the thermostat temperature.

2. The twin NETWORK NUMBER switch is set to the number (outside scale) and letter (inside scale) chosen from the network chart for the "Decca" radionavigation system.

3. The OPERATING MODE switch is set in the "Zero Set" position. After 1 to 3 minutes, the scale lighting for the E, A and C precision track indicators should begin to blink and there should be continuous illumination of the WHITE scale for the coarse indicator, where these are evidence of the completion of the process of fine tuning the master oscillator to the phase and frequency of the master station of the network.

4. The greatest deflection of the phase balance meter needle is achieved by rotating the PHASE CORRECTION after pressing the K, Z and F [red, green and violet] controls.

5. Using the ZERO and TRACK controls, the large pointers are set to zero on the outer scale while the small pointers are set to any of the large numbers on the inner scales of the precise E, A and C indicators after these controls are pressed. The zero graduation on the WHITE scale of the coarse indicator is set using the ZERO control.

6. Having set the control to the ON position, turn on the light display for the scales of the coarse indicator, the GI [coarse track indicator].

7. The OPERATING MODE switch is set in the "Sinkh VShChG" ["coarse track master station synchronization"] position. The WHITE scale of the coarse indicator, which has divisions of 0, 1, 2, 3, 4 and 5 will be illuminated for 2.5 seconds every 20 seconds. It is necessary to take the reading of the WHITE scale which should be set equal to zero.

8. Rotate the DIVISION AMBIGUITY switch clockwise by the number of divisions corresponding to the noted reading of the WHITE scale, making the reading of this scale equal to zero.

9. The OPERATING MODE switch is set in the "operate" position.

The small and large pointers of the E, A and C precise track indicators, in rotating, will come to stable positions which make it possible to record the corresponding readings, since the scales of these indicators are continuously illuminated. The RED, GREEN and VIOLET scales of the coarse indicator are illuminated for 2.5 seconds each during a single cycle of 20 seconds in step with the time pattern for the ambiguity elimination in the following sequence: red, green and violet. The readings of the small pointers of the E, A and C precise indicators are matched to the readings of these scales of the coarse indicator at the moment they are lighted up. For this, for example, the small pointer is set to the reading of the division of the inside scale equal to the readings of the RED scale in accordance with the reading recorded from the RED scale of the coarse indicator using the TRACK control of the E precise track indicator. Similar operations in determining the number of the precise track (the setting of the small pointers) are also carried out for the A and C precise indicators. In the "operate" mode, the WHITE scale is not lighted.

The track zone is set by means of the TRACK control by rotating the small pointer through that whole number of revolutions for which the letter designating the given zone appears in the cutout in the dial plate of the precise track indicator. In this case, the numerical index of the zone is determined from the "Decca" radionavigation system chart on which the dead reckoning position of the ship is drawn.

10. The pointer readings are taken from the precise indicators and the corresponding lines of position are drawn on the navigation chart with the "Decca" radionavigation system hyperbola grid drawn on it.

During the first hour of operation, it is necessary to take care that the readings of the small pointers of the precise track indicators do not differ from the readings of the corresponding scales (RED, VIOLET, GREEN) of the coarse indicator. Where necessary, the readings of the small pointers are to be corrected every 30 minutes with a subsequent increase in this interval up to 2 to 3 hours.

With a change in the number of the "Decca" radionavigation system network, the operations presented above are repeated, starting with paragraph 2.

CHAPTER THREE. PULSE AND PULSE-PHASE RADIONAVIGATION SYSTEMS

3.1. The Classification and Specific Features of Marine Pulse and Pulse-Phase Radionavigation Systems

Marine pulse and pulse-phase radionavigation systems (IFRNS) are a means of long range radio navigation and are intended for determining a ship's position at great distances from shore with a precision which assures navigational safety when sailing the in the open sea. The "Loran-A" pulse radionavigation system and "Loran-C" pulse-phase system are the ones most widely used for the purposes of marine navigation [5, 6]. These systems make it possible to measure the difference in the distances from a ship to two stationary points: a pair stations which synchronously transmit radio pulses. For a known radio wave propagation velocity, v, a definite time difference Δt between the instants of arrival of the radio signals from the shore stations corresponds to a particular difference in the distances Δr. This time difference is called the radio navigation parameter and is measured by means of a shipboard indicating receiver. The geometric locus of points of equal difference in the distances from a ship to two stations forms an isoline in the form of a hyperbola on the surface of the earth. Thus, these radionavigation systems belong among difference-ranging, or hyperbolic systems according to the kind of geometric quantity being measured.

Ship position is determined by the intersection of the two hyperbolas, corresponding to the differences in the distances to the two pairs of shore stations. Each pair of stations consists of a master (VShCh) and a slave (VM) station, separated by a distance which is called the baseline b. The master stations start the transmission of the radio pulses with a repetition period (repeating rate) T at a carrier frequency of f, while the slaved stations receive these pulses and synchronously retransmit them with a certain time delay t_d.

The "Loran-A" radionavigation system is a system with unsynchronized (independent) baselines, since each pair of stations transmits radio pulses with a repetition period T and a carrier frequency f, which differ from the pulse repetition period and carrier frequency of the other pair.

Two or more pairs of stations can be combined in a network, and in this case, their carrier frequencies are chosen the same. In this case, the master or slave stations are set up at one point, while in other cases, the master station of one pair is colocated with the slave station of another pair, etc. The baseline length for the majority of station pairs amounts to 300 to 350 miles.

At the present time, three carrier frequency channels are used for system operation in the medium wave band: 1. 1,950 KHz; 2. 1,850 KHz and 3. 1,900 KHz. The repetition periods (repetition rates) of the radio pulses are combined in three groups, designated by the letters H (high), L (low) and S (special). Each group consists of eight monotonically increasing (recurrent) repetition periods designated by ordinals numerals N from 0 to 7. The precise value of any of the 24 repetition periods T, expressed in microseconds, is determined by the following expressions:

$$T_H = (300 - N)\,100 \text{ мкс};$$
$$T_L = (400 - N)\,100 \text{ мкс};$$
$$T_S = (500 - N)\,100 \text{ мкс}.$$

The number of the frequency channel, the group of frequencies and the number of the recurrent repetition period (frequency) or correspondingly the first, second and third symbols in designating the pairs of stations. For example, the designation 1S5 defines a pair of stations operating in the first frequency channel (1,950 KHz) with a recurrent value of the repetition period of 49,500 microseconds from the S group of repetition periods.

The possibility of identifying the signals from the master and slave stations within a single pair is accomplished because of the presence of a common delay t_d in the moment of the transmission of the master station signal with respect to the point in time of the transmission of the radio pulse from the slaved station:

$$t_d = t_b + t_k + t/2$$

where t_b is the radio pulse travel time from the master to the slave station;

t_k is the code delay which serves to change the readout of the navigation parameter in accordance with a specified program;

T/2 is the delay in the radiation of the signal by a time equal to half of the repetition period.

At any point in the working zone of the system, the master station pulse is always received earlier than the signal from the slave station, earlier by an amount less than T/2; a unique readout of the navigation parameter is achieved in this way.

The "Loran-C" pulse-phase radionavigation system is a system with synchronized (dependent) baseline. The shore stations of the system are combined into networks, each of which consists of a master station M and several slave stations (from two to five), which are conventionally designated with the letters W, X, Y and Z. All of the stations in the network operate with the same signal repetition period on one carrier frequency. The transmission of the signals by the slaved stations is strictly synchronized with the master station signals. The synchronization is accomplished both with respect to the envelopes of the radio pulses and the high freuency modulation phase.

A pulse train transmission mode is used to boost the average power of the transmitted signals to increase the system operational range (Figure 3.1). The packets (trains) of slave station pulses consist of eight pulses with a period of 1,000 microseconds. Besides the eight main pulses with a period of 1,000 microseconds, there is also a ninth pulse present in the pulse train of the master station, where this pulse is set off from the preseding pulse by 2,000 microseconds. This pulse, which is called the marker pulse, serves for the identification of the master station signals as well as for the transmission of service information to the slaved stations.

Phase coding of the pulses is introduced in order to eliminate the influence of the space waves of the multiple reflection of each preceding pulse in a train on the subsequent surface pulse which occurs in the pulse train mode. The essence of phase coding consists in the fact that the initial phase of the radio pulses in a train is shifted through 180° in accordance with a law which is different for the odd and even trains. As a result of the alternate period storage of the pulse trains, the sum of the components in the output voltage, which are due to the space waves noted above, becomes equal to zero. The phase coding of the pulses in a train also facilitate the automatic identification of the signals of a master station and the tracking of it in the case of noise levels elevated above the signals.

All of the "Loran-C" radionavigation system networks operate on one carrier frequency in the longwave band: 100 KHz. The signals of the various networks are identified based on the repetition period T of the radio pulses. The repetition periods are combined in groups designated as S, SH, SL and SS, each of which consists of eight recurrent periods with ordinal numbers of 0 to 7. The precise values of the repetition periods are defined by the relationships:

$$T_S = (500 - N)\,100 \text{ мкс}; \qquad T_{SL} = (800 - N)\,100 \text{ мкс};$$
$$T_{SH} = (600 - N)\,100 \text{ мкс}; \qquad T_{SS} = (1000 - N)\,100 \text{ мкс}.$$

[MKC = microseconds]

The signals of the slaved stations in one network are identified based on their time position relative to the master station signals. The arrangement sequence (in the general case) is as follows: W, X, Y, Z. The values of the code delays, t_k, introduced at the master stations, are chosen so that the pulse trains of each slave station can appear only in a definite time interval segment relative to the pulse train from the master station. For this reason, the readouts of the navigation parameter for each pair will fall in their own specified range.

The groups of repetition rages and the number of the recurrent frequency are included in the designation of a network. For example, SL-7 defines the "Loran-C" radionavigation system network operating with a pulse repetition period of 79,300 microseconds from the group of SL repetition periods. The conventional designation of a network is supplemented with the corresponding letter to designate one of the stations in a network (M for the master and W, X, Y or Z for the slaved stations).

The "Loran-C" radionavigation signals are not only used for solving navigation problems, but also for transmitting precise time signals.

Marine receiver-indicators are intended for the measurement of a radionavigation parameter: the time difference Δt between the moments of arrival of radio pulses from the master and slave stations.

In the "Loran-A" pulse radionavigation system receiver-indicators, the quantity Δt is measured by a pulse technique: by means of matching the envelopes of the edges of the radio pulses. In the case of a signal to noise ratio of five, the mean square measurement error σ does not exceed ±1 μsec. The pulse measurement technique is sometimes limited when working with "Loran-C" radionavigation signals. Such a measurement technique is realized in the first type of indicating receivers [5], which include the KPI-4 equipment.

The capabilities of pulse-phase radio navigation systems can be more fully realized only in indicating receivers which utilize additional information on the phase of the radio signal. Such devices include the second type of indicating receivers with visual matching of the edges using the high frequency pulse modulating frequency (ML-100), with automatic phase tracking and visual matching of the envelopes of the leading edges (KPI-5F), as well as the third type of indicating receivers with automatic measurement of the phase difference of the carriers at a "singular" point in the radio pulses and using automatic signal search where the noise level exceeds the signal level (TDL-601). The third type of indicating receivers realizes the major advantages of pulse-phase radionavigation systems: they have high measurement precision and unambiguous readouts; they execute a signal search in the presence of noise. Marine indicating receivers, as a rule, are designed for operation in both long range radionavigation systems.

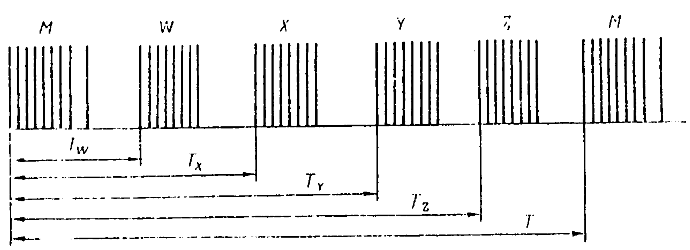

Figure 3.1. On the determination of the operational mode for the transmission of pulse-phase radionavigation system signals.

The sequential resolution of the following major problems precedes the obtaining of a readout of the radionavigation parameter from a pair of pulse or pulse-phase radionavigation stations:

1. The tuning of the indicating receiver to work with the signals of the selected pair of radionavigation stations.

2. The detection of the signals from the selected pair and the identification of the radio pulses from the master and the slaved stations.

3. The identification of the type of signals received from each shore station.

4. Measuring the radionavigation parameter using the most suitable portions of the edges of the radio pulses.

5. Recording the readout, and if necessary, correcting the values of the time difference with a correction for the radio wave propagation conditions.

Simplified variants of indicating receivers have become extremely widespread in the merchant marine: equipment of the first and second types. In such equipment, the problems enumerated above are solved by the operator and the measurement results depend to a considerable extent on the level of his training and acquired practical operating skills.

To tune the indicating receiver, the operator switches to the requisite frequency band and sets in the designations for the selected pair of stations with the corresponding switches located on the front panel of the indicator.

The signals from the pair of stations are detected and identified visually on the screen of the CRT. With correct setting of the switches, signals from a pair of "Loran-A" radionavigation station and a network of "Loran-C" radionavigation stations stand still on the horizontal sweep line, while the signals of the other pairs of "Loran-A" stations or "Loran-C" networks move at different rates to the right or to the left along the sweep lines.

The signals from the master and slave stations of the "Loran-A" radionavigation systems are recognized using the following rule: the signals are to be placed on different sweep lines so that the top pulse is to the left of the bottom pulse. Then the top pulse will be the signal from the master station and the lower one the signal from the slave station.

In "Loran-C" radionavigation systems, the master station pulse train is recognized from the presence in the train of the ninth marker pulse, while the pulse packets of the slave stations are recognized based on their timewise position on the sweep lines relative to the master station pulse train. To facilitate the identification operation, it is recommended that a reading be set beforehand in the readout unit which corresponds to the calculated line of position. Then, if the master station signal is set on the stationary pedestal at the start of the upper sweep line, the moving pedestal appears at the point where the signal of the corresponding slave station is located.

The identification of the type of received signal (surface, space, combination) is one of the most important operations, which has a significant influence on the measurement results. It should be carried out taking into account the specific

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features of radio wave propagation in the working band of the radionavigation system based on data on the range to the shore station, the propagation path, the season of the year and time of day, as well as information on the mutual position of the pulses on the CRT screen, their shape and time stability.

When space wave signals are used for the measurements, the resulting readout is to be corrected with the appropriate correction for propagation conditions, taken from the radionavigation chart.

In the "Loran-A" radionavigation system, surface waves are received during the day [6] with propagation over the sea at ranges of up to 600-700 miles from shore stations with powers of 100 to 160 KW and at distances of up to 800 to 900 miles in the case of 1 MW stations. At night, because of the increase in the level of atmospheric noise, the reception range is reduced to approximately 500 miles. The reception range is sharply reduced in the case where land areas are encountered over the propagation path.

Space waves usually appear one to two hours before sunset, and are observed during the entire night and one to two hours after sunrise. In the winter, ionospheric signals are observed around the clock at middle and high latitudes, with the exception of two to three hours near noon.

Of the different kinds of ionospheric signals (E_1, E_2, D, F_1 and F_2), the more stable E_1 waves received at distances of up to 1,400 to 1,500 miles from land stations are used for position determinations. As compared to a surface wave, the amplitude of an ionospheric wave increases, while the time delay decreases with increasing range to the shore station.

At distances starting at 300 to 500 miles, a composite signal is received which is formed by the interference of the surface and ionospheric waves. As a rule, the envelope of this signal has a "double peak" shape. Measurements using the composite signal require the greatest care, since in the case of small surface wave amplitudes, as well as with the influence of "splitting" phenomena of the leading edge and fading of the space wave, the "double peak nature" of the resulting pulse can be poorly pronounced, something which makes it difficult to ascertain the portion of the edge corresponding to the surface wave.

In the "Loran-C" radionavigation system, the reception range for surface waves in the case of propagation over the sea depends primarily on the transmitted radio pulse power, the level of atmospheric noise and the degree of influence of ionospheric waves at the reception point [5].

Space waves at a frequency of 100 KHz exist at all times of the day. An exception is only the low latitudes ($\phi < 30°$), where daytime reflections are absent during the summer. The amplitude of the E_1 ionospheric wave rises up to the amplitude of the surface wave at distances of approximately 500 miles during the day and 400 miles at night with time delays equal to about 50 and 70 microseconds respectively. With a further increase in the range to the shore station, the amplitude of E_1 radio pulses begins to exceed the amplitude of surfaces waves, while the delay in the arrival time of the reflected pulses, in falling off, tends towards constant values of 54.1 microseconds at night and 38.1 microseconds during the day. Doubly reflected radio signals conventionally designated as E_2 appear at the same time.

It can be seen from an analysis of long wave band radio wave propagation conditions that regardless of the time of day, starting at distances of 300 to 400 miles, one must anticipate the reception of a composite signal caused by the interference of surface and space wave radio pulses. The waveform of the envelope of the resulting radio pulse is governed in the general case by the ratio of the amplitudes and high frequency modulation phase difference. Working with the composite signal entails considerable difficulties, as a rule, due to the complexities of the visual recognition of the portion of the pulse edge which is due to the surface wave.

Starting at ranges of 900 miles, the E_1 component will predominate in the envelope of the resulting pulse, and with a certain amount of care, measurements can be made just as in the case of purely reflected signal.

3.2. The KPI-5F Indicating Receiver

The KPI-5F indicating receiver is intended for the determination of a ship's position using "Loran-A" and "Loran-C" radionavigation system signals, as well as domestic pulse-phase radionavigation systems by means of using charts with a hyperbolic grid or special tables.

Three units are incorporated in the indicating receiver set: the radio receiver, the indicator unit and a synchronous filter. Additionally, the product complement includes sets of interchangeable and spare parts, tools and accessories.

The major operational and technical characteristics of the indicating receiver are given below:

Type of Indicating Receiver	Semi-Automatic, with Visual Search and Matching of the Signals on the CRT Screen
The number of station pairs which can be processed simultaneously	1
The mean square instrument error in the measurements of the navigation parameter for a signal/interference ratio of 3, in microseconds:	
At medium wavelengths	0.7
At long wavelengths	0.3
Receiver sensitivity for a signal/internal noise ratio of unity, with respect to the peak values within the receiver passband, microvolts:	
In the long wave channel	7 and 14
In the medium wave channel	5 and 10
(For feedline lengths of 5 m and 10 m respectively)	

[Table, continued]:

Type of Indicating Receiver	Semi-Automatic with Visual Search and Matching of the Signals on the CRT Screen
Receiver bandwidth at the 0.5 KHz level:	
At long wavelengths	20 ± 3
At medium wavelengths	17 ± 5
Gain control range, in dB, no less than:	
Manual	100
Balance	60
Probability of correct elimination of the ambiguity in the phase measurements for a signal/interference ratio of three, no less than	0.95
Time for measuring the navigation parameter based on the signals from one pair of stations, in minutes, no more than	1.5

A simplified block diagram of the KPI-5F indicating receiver is shown in Figure 3.2.

In terms of the principle for the realization of the navigational data, the indicating receiver belongs among single channel devices with visual signal search and superposition of their edges on a CRT screen [5].

The measurement of the navigational parameter, the time difference between the moments of arrival of the master and slave station signals, is accomplished by the compensation technique which consists in replacing (compensating for) the time interval being measured with an artificially introduced time delay which is equal to it. This delay is inserted by means of a variable delay circuit and is read out from the display. The equality of the time interval being measured and the delay being generated is determined based on the coincidence of the leading edges of the pulses on the CRT screen. To improve the measurement precision, a provision is made in the indicating receiver for an automatic tracking system. Tracking is accomplished in the operation of the "Loran-A" radionavigation system using the doubly differentiated envelopes of the signals. In the "Loran-C" radionavigation system, the tracking uses the zero crossing points (with respect to the phase) of the pulse RF modulating frequency. By means of matching the edges of the envelopes and the CRT screen, uniqueness in the phase readout is achieved with a precision of half of the RF pulse modulating period.

A self-monitoring mode is provided in the indicating receiver for checking the operability of the equipment. The operability is monitored on the CRT screen, as well as on the inidicating display.

The radio receiver (RPU) is intended for the selective reception of the radio-navigation system signals from the background of interference and for amplifying

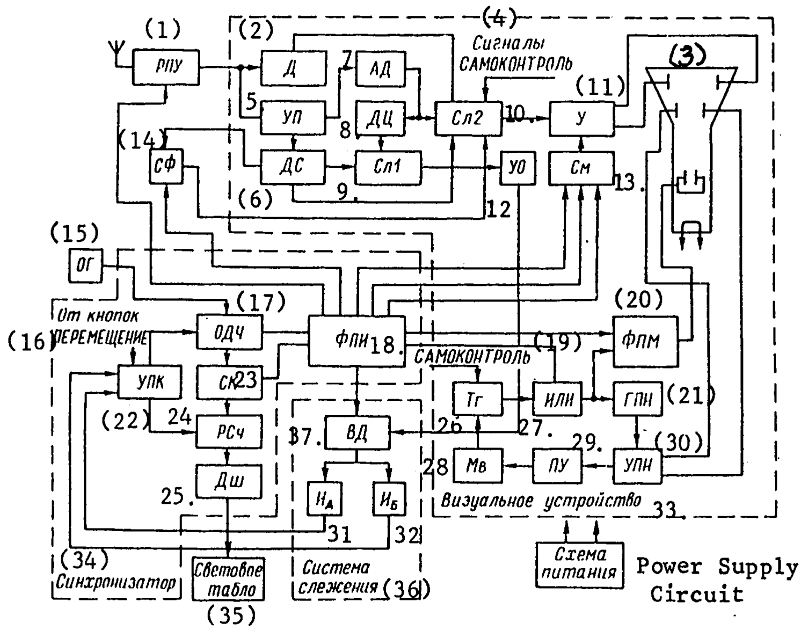

Figure 3.2. Simplified block diagram of the KPI-5F indicating receiver.

Key:

Key:
1. RPU = receiver;
2. D = divider;
3. Cathode ray tube;
4. Self-test signals;
5. UP = Preamplifier;
6. DS = RF signal decoder;
7. AD = AM detector;
8. DTs = double differentiating network;
9. Sl1 = selector 1;
10. Sl2 = selector 2;
11. U = output amplifier;
12. UO = amplifier-limiter;
13. Sm = limitier;
14. SF = synchronous filter;
15. OG = master oscillator;
16. From the SHIFT buttons;
17. ODCh = master frequency divider;
18. FPI = pulse train driver;
19. Self-test;
20. FPM = strobe and tracking marker driver;

[Key to Figure 3.2, continued]:

21. GTN = sawtooth voltage generator;
22. UPK = channel shift control circuit;
23. SK = code comparator;
24. RSch = bidirectional counter;
25. Dsh = decoder;
26. Tg = flip-flop;
27. ILI = OR gate;
28. Mv = biased flip-flop;
29. PU = threshold gate;
30. UPN = push-pull sawtooth voltage amplifier;
31. I_A = A integrator;
32. I_B = B integrator;
33. Visual display unit;
34. Synchronizer;
35. Digital display;
36. Tracking system;
37. VD = time discriminator.

them up to the levels needed for normal operation of the indicator. A block diagram of the receiver is shown in Figure 3.3.

The unit has two operating bands: long wave and medium wave, as well as fixed tuning to the frequency of the operating channels. The radio receiver is remote controlled.

The long wave channel of the receiver uses a direct amplification circuit configuration for a frequency of 100 KHz. The 0.5 level bandwidth is 20 ± 3 KHz. A provision is made for the capability of operationally tuning the selective circuits ± 9 KHz off of the center frequency, something which improves the conditions for recognizing the type of radio pulse being received (surface, ionospheric, composite).

The medium wave channel of the receiver is a superheterodyne circuit. The intermediate frequency is 465 KHz. The bandwidth at the 0.5 level amounts to 17 ± 5 KHz.

In the long wave channel, as well as in the IF channel for the medium wave band, amplitude-phase and phase equalization respectively are used for the frequency characteristics. This made it possible, along with retaining the high selectivity rejecting signals of radio services on adjacent frequencies, to increase the rise time of the radionavigation system pulses at the receiver output, and as a consequence, to increase the resolution of the indicating receiver with respect to ionospheric signals.

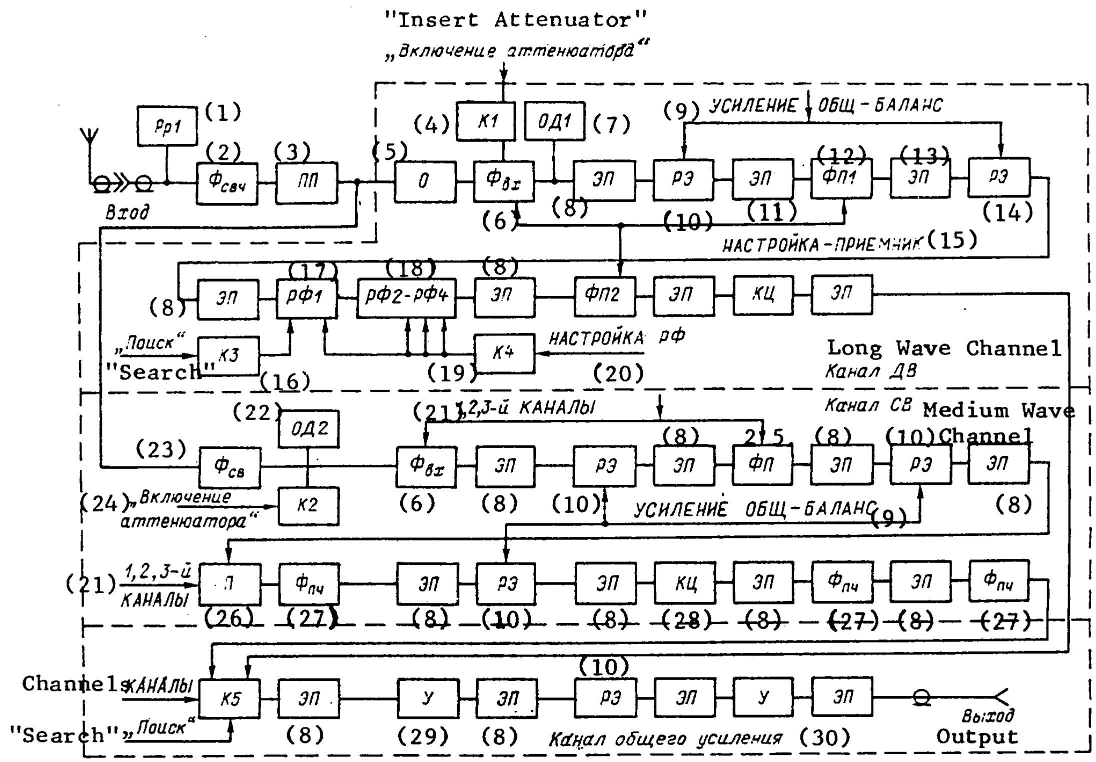

Figure 3.3. Block diagram of the radio receiver.

Key:
1. Rr1 = discharger 1;
2. Fsvch = microwave RF filter;
3. PP = tuning circuit board;
4. K1 = switcher 1;
5. O = limiter;
6. Fvkh = input filter;
7. OD1 = diode limiter 1;
8. EP = emitter follower;
9. OVERALL GAIN--BALANCE;
10. RE = electronic gain control;
11. EP = emitter follower;
12. FP1 = bandpass filter 1;
13. EP = emitter follower;
14. RE = electronic gain control;
15. TUNE--RECEIVER;
16. K3 = switcher 3;

[Key to Figure 3.3, continued]:

17. RF1 = rejection filter 1;
18. RF2-RF4 = rejection filters 2 - 4;
19. K4 = switcher 4;
20. Rejection filter tuning;
21. Channels 1, 2 and 3;
22. OD2 = diode limiter 2;
23. Medium wave filter;
24. "Attenuator On";
25. FP = bandpass filter;
26. P = convertor;
27. F_{pch} = intermediate frequency filter;
28. KTs = amplitude-phase correction circuit;
29. U = amplifier;
30. Common amplifier channel.

The signal from the antenna and feedline assembly is fed to the receiver through an RF connector. To protect the front end stages against the effect of high power interference from shipboard radio transmitters, radars, etc., the circuitry contains a discharger Rr1, a microwave filter F_{svch}, a diode thyristor limiter O and two diode limiters (OD1 and OD2). The actuation threshold of the thyristor circuit is about 20 volts, while the threshold for the bilateral diode limiters is 2 volts each.

When operating in the longwave band, the signal is fed to the input filter, F_{in}, in the form of a tuned circuit formed by the inductance of a coil, the capacitance of the antenna, the distributed capacitances of the feedline and wiring, as well as the capacitances of the tuning circuit board PP and the semiconductor control capacitors, the varicaps. The varicaps provide for the capability of continuous tuning of the resonant circuit by ± 9 KHz from the carrier frequency of the pulse-phase radionavigation system signals. The control voltage is fed to the varicaps by means of a potentiometer which is coupled to the RECEIVER--TUNE control, which is located on the front panel of the indicating receiver. An input signal attenuator is located on the input filter circuit board, where this attenuator is made in the form of a capacitive voltage divider with an attenuation coefficient of five.

The RF signal is fed through the emitter follower EP from the output of the filter to the electronic gain control RE. Gain control is accomplished by changing the internal resistance of the field effect transistor channels with the action of the regulating picked off of the potentiometers of the OVERALL--GAIN----BALANCE INDICATOR. The electronic gain control is matched by the emitter follower to the bandpass filter FP1, formed by a pair of overcoupled resonant circuits. The signal is fed through the emitter follower from the output of the filter to the electronic gain control circuitry (RE) and then through the emitter follower to rejection filters RF1--RF4, which suppress the four sinusoidal interference components with frequencies in a band of from 85 to 135 KHz. Continuous tuning of the rejection filters is accomplished by means of feeding voltage to the varicaps which are picked off of the TUNE RF1-RF4 potentiomters, which are located on the front panel of the indicator. These same voltages are simultaneously fed to the switcher circuit K4, which serves to maintain the Q of the resonant circuits of the rejection filters constant within the working band of frequencies. In the "RF" position of the CHANNELS switch, the "Search" instruction is fed to switcher K3, based on which RF1 is switched over to the noise gating mode. The remaining rejection filters can operate only in a suppression mode.

Then the signal is fed through the emitter follower to the second bandpass filter FP2, which is similar to bandpass filter FP1. The RF signal is fed from the filter output through the emitter follower to the amplitude-phase equalization circuit, the KTs, and then through electronic switch K5 to the common amplification channel for the long wave and medium wave bands. Bandpass filters FP1 and FP2 are tuned by means of varicaps, which play the part of tuned circuit capacitors, and are ganged with respect to frequency for tuning the input resonant circuit.

When operating in the medium wave band, the signal from the output of the tuning circuit board PP is fed to the broadband dual tuned circuit bandpass filter, F_{SV} [$F_{medium\ wave}$], which attenuates the signals of radio services on adjacent frequencies. When the ATTENUATOR toggle switch is switched on on the indicator, the input resonant circuit in the bandpass filter is shunted by means of electronic switch K2, which provides for the attenuation of radionavigation system signals by approximately 20 dB. The signals are then fed to the input filter F_{in} in the form of a single resonant circuit, and then through the emitter follower to the electronic gain control RE. The RF signal is fed from the output of the gain control circuit through the emitter follower to the bandpass filter FP_{SV} [medium wave bandpass filter], which takes the form of a three section resonant circuit filter with external capacitive coupling. The frequency tuning of the filter is accomplished by means of feeding fixed voltages to the varicaps on instructions from the CHANNELS switch in the "RF" [rejection filter], "DV" [long wave], and "SV-1,2,3" [medium wave bands 1, 2, 3]. After passing through the emitter follower and the electronic gain control RE, the signal is then fed through an emitter follower to the frequency converter P to convert the received signal to the 465 KHz intermediate frequency signal. The converter is designed in a combined mixer and local oscillator configuration. The frequency produced by the local oscillator is crystal controlled. The switching of the local oscillator frequencies is accomplished by means of switching in the appropriate crystal by means of the electronic switchers. The load on the frequency converter is the intermediate frequency filter F_{IF}, which is formed by a pair of coupled tuned circuits with external capacitive coupling. The filter is tuned to a frequency of 465 KHz, and the signal is fed from its output through the emitter follower EP and the electronic gain control to the phase correction circuitry, and then on to two identical intermediate frequency filters, which are isolated from each other by means of emitter followers. The filters are designed in a TM section bandpass filter configuration. The signal is then fed through the electronic switcher K5, which is controlled by instructions from the CHANNELS switch to the common broadband amplification channel for the medium wave and long wave bands. This amplifier chain contains two amplifiers U and an electronic gain control RE. These stages are matched to each other by means of emitter followers EP.

The signal is then fed to the output emitter follower which matches the output of the receiver to the RF cable through which the RF pulses are fed to the indicator unit.

The subsequent processing of the radio signals received from the shore radio stations is accomplished in the indicator unit for the purpose of measuring the radionavigation parameter.

The complement of the indicator (see Figure 3.2) includes the master oscillator OG, synchronizer, visual display, tracking system and power supply circuitry.

The series produced "Giatsint" master oscillator (IG2.210.100) is used as the master oscillator in the KPI-5F, the 5 MHz frequency of which is established with a precision of $\pm 1 \cdot 10^{-7}$ after 15 minutes and $\pm 1.5 \cdot 10^{-8}$ after two hours.

The operational time diagram for the indicator which is governed by the synchronizer is intended for the solution of the following problems:

1. Synchronize the repetition rate of the CRT sweep with the repetition rate of the signals from the shore stations.

2. Generate a pulse train for the measurement and readouts of the navigation parameter.

3. Generate auxiliary sequences of individual pulses and trains needed for the operation of the indicating receiver.

Included in the complement of the synchronizer (see Figure 3.2) is a master frequency divider ODCh, a code comparison gate SK, a bidirectional counter RCch, a decoder Dsh, a channel shift control circuit UPK and a pulse train driver FPI.

The master frequency divider generates the sequence of channel A pulses (the master station channel) from the sinusoidal voltage from the master oscillator where this pulse train has a repetition period T equal to the repetition period of the individual packets of radio pulses received from the shore stations, as well as a series of reference pulse trains for channel A which are needed for the operation of the indicating receiver.

To measure the time delay of the slave station signal relative to the signals from the master stations, the synchronizer generates a sequence of channel B pulses (slave station), the time position of which can be shifted relative to the channel A pulses by an interval fixed with a precision of 0.1 microseconds in a range of 10,000 to 70,000 microseconds. This problem is solved by a digital variable delay circuit by means of comparing the number codes of the frequency divider and the bidirectional counter, and generating the output signals at the points in time when the codes match [5]. In the initial state, the code of some number is stored in the bidirectional counter. The number code in the decades of the master frequency divider are periodically changed during the process of dividing the voltage incoming from the master osicllator. At the points in time when the number code written in the master frequency divider coincides with the

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number code written in the bidirectional counter, reference sequences of channel B pulses are generated at the output of the code comparison circuit.

The channel shift control circuitry provides for the capability of moving the channel A and B pulse sequences in time at different rates relative to the shore station signals, as well as moving the channel B pulse train relative to the channel A pulse train by means of changing the division coefficients in the master frequency divider and the state of the bidirectional counter.

The pulse sequence driver generates the sequences of pulses needed for the operation of the receiver, the visual display and the tracking system from the reference A and B channel sequences.

The decoder Dsh is intended for representing the number stored in the bidirectional counter in a decimal code for display.

A block diagram of the synchronizer is shown in Figure 3.4. The master frequency divider ODCh consists of the limiter-amplifier UO, seven frequency dividers (DCh1-DCh7) and four drivers (Fr9-Fr-12).

The limiter-amplifier provides for negative and positive peak limiting of the 5 MHz sinusoidal voltage and reduces it to a level which assures normal operation of the first frequency divider.

The first frequency divider (DCh1) is designed as a digital phase shifter. It divides the master oscillator frequency by five and makes it possible to phase shift the output pulses in any direction in a discrete step of 0.1 microsecond upon instructions from the channel shift control circuit. The five subsequent frequency dividers (DCh2-DCh6) are designed with identical circuits having division factors of 10 and are intended for dividing the frequency down to a level equal to the repetition rate of the shore station RF pulses. For the selected values of the division factors, the pulse repetition period at the output of DCh6 [frequency divider 6] is 100,000 microseconds, i.e., corresponds to the repetition period of the group SS "Loran-C" radionavigation system signals.

The repetition rates corresponding to the five groups of frequencies other than the lowest frequency group SS (the H, L, S, SH and SL), are generated by means of master frequency driver circuits (Fr12) by means of reducing the division coefficient of the sixth frequency divider. The values of the recurrent repetition rates are generated by means of the supplemental frequency driver circuit Fr10 by changing the division factor of the fourth frequency divider in the "Loran-C" mode and the third and fourth frequency dividers in the "Loran-A" mode.

Frequency divider DCh7 having a division coefficient of eight generates the signals needed to assure the specified shift rates for the reference pulse trains of both channels.

Driver Fr9 generates the channel A pulse train with a repetition period of 10 microseconds, having the capability of being shifted in time in discrete steps of 0.1 microseconds.

Driver Fr11 generates signals with repetition periods of P/2 and T, needed for the operation of pulse train driver and channel shift control circuits, as well as for the generation of the recurrent frequencies.

The bidirectional counter RSch consists of six identical bidirectional counters having a scaling factor of ten each (six decades). The number stored in each of the first five decades is changed by means of the channel B shift circuit (FP-B), while the numbers stored in the sixth decade is changed with the action of the signal from the channel B set circuit (Ust-B). The codes of the numbers written in bidirectional counters RSch2-RSch6, are compared with the number codes written in the corresponding decades of the master frequency divider (DCh2-DCh6) by means of five AND gates of equal capacity included in the code comparison circuit SK.

The signals from the bidirectional counter flip-flops and the series of pulse trains from the digital phase shifter are fed to the input of drivers Fr7 and Fr8. These devices are included in the complement of the code comparison circuitry and generate the channel B pulse trains with periods of 1 and 10 microseconds, the time position of which can be set relative to the corresponding channel A pulse sequences in discrete steps of 0.1 microseconds. The pulse train from the outputs of the equal value gates and drivers Fr7 and Fr8 are fed to pulse train driver as the channel B reference sequences.

The decoder Dsh consists of six identical decoding circuits, each of which makes it possible to display a decimal number on the seven segment display corresponding to the code of the number stored in the bidirectional counter decade coupled to it.

The channel shift control circuit UPK consists of the channel A and B shift drivers (FP-A and FP-B), which provide for the dropout of the master frequency divider and the bidirectional counter with different repetition periods which depend on the positions of the MASTER FREQUENCIES, SUPPLEMENTAL FREQUENCIES, and SWEEP switches. Reducing the repetition period of the dropout pulses leads to an increase in the shift speed of the reference sequences of channels A and B. The dropout commands can arrive at the UPK [channel shift control circuit] from the SHIFT pushbutton switches or from the tracking system SS.

The channel shift control circuitry also includes the channel B set circuit (Ust-B), which provides for the elimination of possible intrusions of channel B time sequences in certain states of the bidirectional counter, and additionally sets the initial value of the requisite delay of the channel B sequences taking into account the specific operational features of the "Loran-A" and "Loran-C" radionavigation systems.

The pulse train drive FPI consists of three registers (Rg1-Rg3), three time gates (S11-S13), setting pulse drivers for the first and second registers (Fr1 and Fr2), driver Fr6 for the ZONE A and ZONE B pulses, pedestal generating circuits (Fr3) and pulse decoders (Fr5), as well as a pulse driver Fr4 for the tracking system SS, the visual display unit VU, the receiver RPU and the synchronous filter SF. All of the output signals of the pulse train driver are produced from the pulse trains generated by the registers.

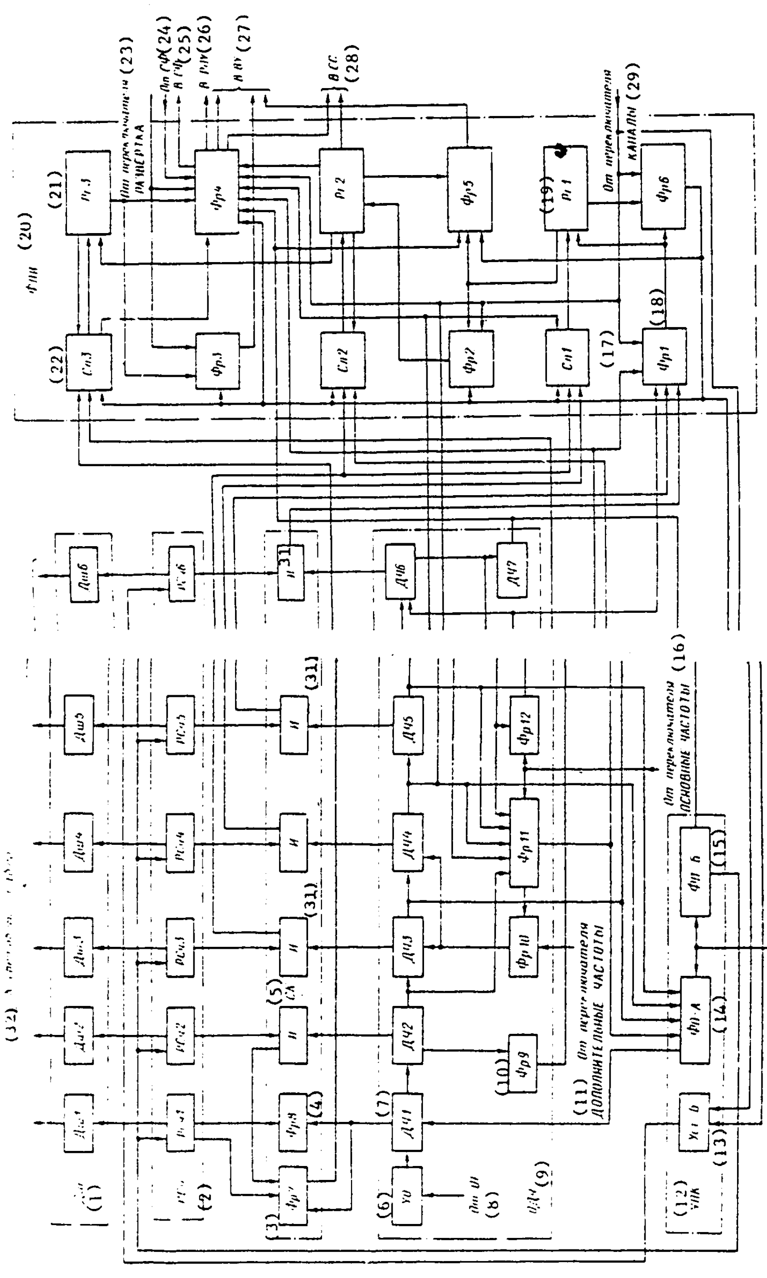

Figure 3.4. Block diagram of the synchronizer.

Key to Figure 3.4.:

1. Dsh = decoder;
2. RSch = bidirectional counter;
3. Fr7 = driver 7;
4. Fr8 = driver 8;
5. SK = code comparator;
6. UO = limiting amplifier;
7. DCh1 = frequency divider 1;
8. From the master oscillator;
9. ODCh = master frequency divider;
10. Fr9 = driver 9;
11. From the SUPPLEMENTAL FREQUENCIES switch;
12. UPK = channel shift control circuit;
13. Ust-B = channel B set circuit;
14. FP-A = channel A shift driver;
15. FP-B = channel B shift driver;
16. From the main frequencies switch;
17. S11 = selector 1;
18. Fr1 = pulse driver for register 1;
19. Rg1 = register 1;
20. FPI = pulse train driver;
21. Rg3 = register 3;
22. S13 = selector 3;
23. From the SWEEP switch;
24. From the SF [synchronous filter];
25. To the synchronous filter;
26. To the RPU [receiver];
27. To the VU [visual display unit];
28. To the SS [tracking systeml;
29. From the CHANNELS switch;
30. From the SHIFT pushbuttons and toggle switch;
31. I = integrators;
32. To the digital display.

The visual display unit (VU) (see Figure 3.2) is intended for solving the problems of radionavigation system signal detection and recognition, monitoring the execution of the measurements of the navigation parameter and the setting for the automatic tracking radio pulses. The visual display unit is additionally used in a "self testing mode". Included in the visual display unit besides the CRT and its power supply circuits are circuits for generating the signals for the CRT, a synchronous filter and a tracking system, as well as sweep generating circuitry.

The sweep generating circuit consists of a biased flip-flop Mv, a flip-flop Tg, an OR gate, a sawtooth voltage generator GPN, a push-pull sawtooth voltage amplifier UPN, a threshold gate PU, as well as a strobe and tracking marker driver FPM.

In the "operate" mode, the repetition rate of the sweep and its duration are governed by the sync pulses which are supplied from the pulse train driver of the synchrnoizer and fed through the OR gate, where these trigger the sawtooth voltage generator. The generated pulses are amplified in the sawtooth voltage amplifier and fed to the horizontal deflection plates of the CRT.

In the "Self testing" mode, the sawtooth voltage generator is triggered by a flop-flop, which in turn is actuated by pulses from the test points in the indicating receiver. The duration of the sweep in this case is governed by a threshold gate to which sawtooth pulses are fed from the push-pull sawtooth voltage amplifier. When they reach the threshold value, the biased flip-flop is triggered, which uses its own pulses to return flip-flop TG to the initial state.

The strobe and tracking marker driver serves to obtain square-wave positive polarity pulses, which turn on the CRT during the forward trace of the beam, and also generate a negative marker, which marks the position of the tracking pulse on the CRT screen. The strobe and tracking marker pulses are fed to the modulating grid of the CRT.

The signals fed to the vertical plates of the CRT are produced in the signal driver for the CRT, which consists of the preamplifier UP, the divider D, the amplitude detector AD, the decoding circuit DS, the double differentiating network DTs, the limiting amplifier UO, the mixer Sm, the final amplifier U and two switching circuits (gates) Sl1 and Sl2.

The kind of signal at the vertical plates of the CRT depends on the positions of the SWEEP and TEST switches, which feed instructions to gate Sl2. Five sweeps of different lengths at a repetition rate equal to the repetition rate of the shore station pulses are produced on the screen of the CRT. With the first and second sweep rates, the radio signals from the receiver output are fed to the vertical plates through divider D, gate Sl2 and final amplifier U.

The first sweep (the longest one), the duration of which is equal to the repetition period of the ground station signals, serves to solve the problem of detecting and identifying the signals and presetting them on the auxiliary rectangular pulses: the pedestals. By means of the separation pulses, the sweep line is broken down into two parts with a length of T/2 each, which are reproduced on the CRT screen in the form of two [horizontal] lines. This increases the sweep scale with a constant working tube diameter and simultaneously provides for the possibility of identifying the master and slave station signals when working with the "Loran-A" radionavigation system.

The second sweep (of shorter duration) with a duration of 8,790 microseconds is intended for the more precise placement of the signals on the peaks of the pedestals and the preliminary amplitude equalization (balancing) of the signals. The auxiliary pedestals and sweep segregation pulses, which are fed to the vertical plates of the CRT along with the radionavigation system signals, are generated in the synchronizer SPI [pulse train driver] and are fed to final amplifier U after they are mixed in the mixer Sm. The divider D serves to adjust the input signal level of the final amplifier.

For the third sweep rate, the envelopes of the radio signals detected by amplitude detector AD are fed through gate Sl2 to the CRT. This sweep is of even shorter duration, 390 microseconds, because of which a large scale image of the pulse signals is achieved. With the third rate, the lower and upper sweep lines are combined, the signal type is identified (surface, ionospheric, combination), and the pulse amplitudes are balanced more precisely and the edges of the envelopes of the master and slave signals are combined.

The shift pulses which move the sweep lines down along the vertical for more complete utilization of the working area of the CRT screen are fed from the synchronizer through the mixer Sm and the final amplifier U to the vertical plates.

There are two more sweep rates which are used when working with the "Loran-C" radionavigation system. The fourth sweep with a duration of 50 microseconds is intended for checking the correctness of the signal decoding. In this case, the radio pulses are fed from the radio signal decoder DS through gate Sl2 to the screen of the CRT. The CODE 1 - CODE 2 toggle switch (see Figure 3.7b) serves to control the decoding circuitry.

With the fifth sweep rate ("FO"), the correctness of the resolution of the phase readout ambiguity is checked by means of combining the edges of the radio pulse envelopes segregated from the signal and noise mixture by the synchronous filter SF on the screen of the CRT. The duration of the fifth sweep is equal to the duration of the third.

In the "self testing", the signals being tested are fed from the test points of the indicating receiver through gate Sl2 to the CRT screen.

The signals for the tracking system are switched by means of the gate circuit Sl1. In the "Loran-C" mode, the decoded radio signal from the decoding circuit is fed through gate Sl1 to limiting amplifier UO. In the "Loran-A" mode, the twice differentiated envelope of the radio pulse from the differentiating network DTs is fed to the limiting amplifier.

The tracking system (SS) provides for automatic tracking of master and slave station signals. The major elements of the tracking system are the time discriminator and two integrators I_A and I_B. The signals from the limiting amplifier of the visual display unit are fed to one input of the time discriminator. The tracking pulses from the synchronizer pulse train driver are fed to the second input. The time discriminator determines the amount and sign of the mismatching of the tracking pulses and the signals from the visual display unit.

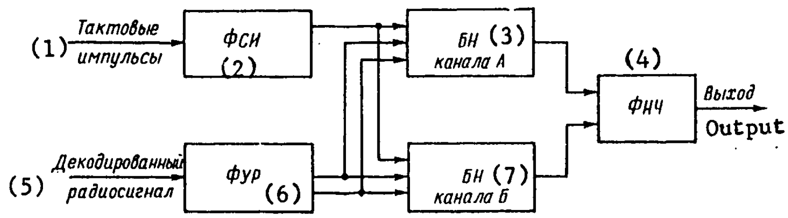

Figure 3.5. Block diagram of the synchronous filter.

Key: 1. Clock pulses;
2. Strobe pulse generator;
3. Channel A store;
4. Low pass filter;
5. Decoded radio signal;
6. Radio signal phase inverting amplifier;
7. Channel B store.

The error signal integrators for channels A and B take the form of bidirectional counters, which calculate the difference in the samples of the positive and negative mismatched signs. If the absolute value of the difference in the samples reaches a number which overflows the bidirectional counter, then a pulse will be fed from the output of the integrator to the synchronizer, the action of which causes the tracking pulses of the corresponding channel to shift in the direction of a reduction in the amount of the mismatch.

When receiving master station pulses, the error signal acts through the channel shift control circuitry, UPK, on the digital phase shifter of the master frequency divider, tuning the repetition rate of the tracking pulses from the synchronizer to the repetition rate of the signals from the shore station, i.e., automatic frequency control is realized in the tracking circuit using the master signals.

When receiving slave station signals, the error signal acts through the channel shift control circuit on the first bidirectional counter of the synchrnoizer and shifts the tracking pulses in time till they match the "singular" points of the slave station signals.

The synchronous filter SF is intended for segregating the leading edges of the "Loran-C" master and slave station pulses from the mixture of signals and noise.

A block diagram of the synchronous filter is shown in Figure 3.5, while the time diagrams which explain its operation are presented in Figure 3.6.

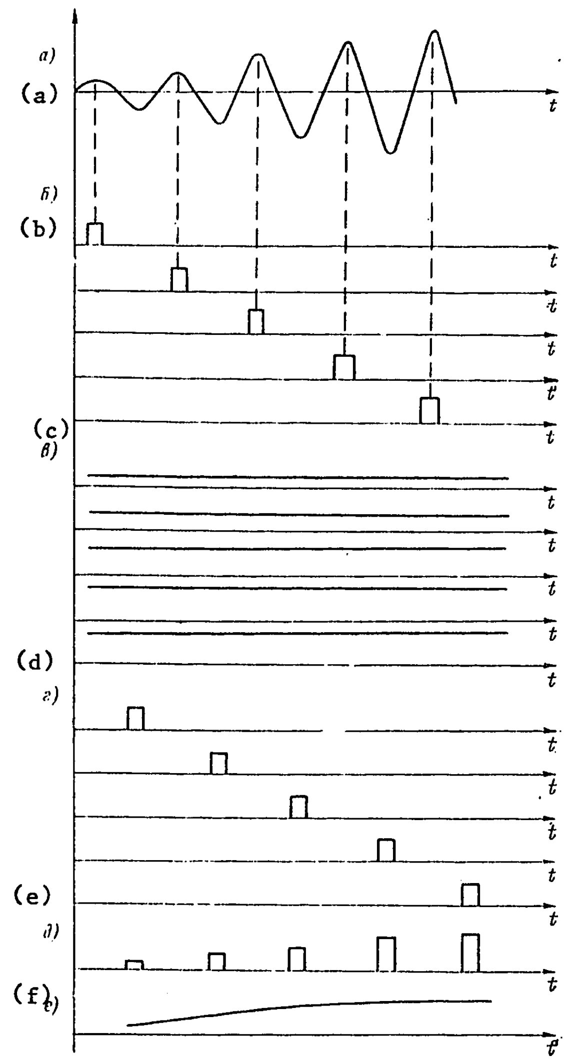

Figure 3.6. Time diagrams for the operation of the synchronous filter: a. The RF signal; b,d. Strobe pulses; c. Voltage across the store capacitors; e,f. Voltage at the input and output respectively of the low pass filter.

The complement of the synchronous filter includes a phase inverting RF signal amplifier FUR, a strobe pulse driver FSI, two stores BN for channels A and B as well as a low pass filter FNCh.

The operational principle of the synchronous filter is based on charging 15 storage capacitors, which are connected by means of switching circuits to the radio signal source at the points in time corresponding to the maximum of the positive and negative half-waves of a radio pulse. The envelope of the radio signal is generated from the voltages stored by the capacitors by means of time gating and filtering the sequence of gated-out voltages by means of a low pass filter.

The inverted and non-inverted radio pulses are fed from the outputs of the phase inverting amplifier to the signal inputs of the stores for channels A and B. Simultaneously, the strobe pulses which are formed from the clock pulse train are fed from the strobe pulse driver circuit to the blocks of stores, where these strobe pulses determine the moments of connection of the storage capacitors to the radio signal source. Two groups of capacitors (eight capacitors in the first and seven in the second) are used for gating the noninverted and inverted radio signal sequences, and two corresponding strobing pulse trains are generated, which move with a shift of 5 microseconds, i.e., by the amount of a half-period of the RF pulse modulation frequency.

The timewise sequential connection of the groups of storage capacitors to the low pass filter is accomplished by means of these same two strobing pulse trains. The strobing pulses of the second group are used to connect the first group of stores, while the strobing pulses of the first group are used to connect the second group of stores to the low pass filter. Because of this technique of connecting the storage capacitors to the low pass filter, the radio signal envelope produced by them proves to be delayed in time relative to the envelope at the output of the phase inverting amplifier by a half-period of the RF pulse modulation frequency.

The electrical power supply circuit is intended for providing power to the KPI-5F indicating receiver from the alternating current mains at a frequency of 50 ± 2.5 Hz and a voltage of 127 or 220 volts with fluctuations of ±10%.

The power supply circuit complement includes eight power supplies which produce 10 DC voltage and 1 AC 6.3 volt square wave to power the CRT filament. The main technical specifications of the power supplies are given in Table 3.1.

The power supplies are designed in a transformer--rectifier--filter--regulator circuit configuration and are protected against short circuits in the load circuitry.

The 1,500 volts and -1,500 volts needed to power the CRT circuits are obtained by converting the regulated DC voltage at 27 volts to an alternating current square wave at a frequency of about 10 KHz. The voltage for powering the CRT filament, as well as the voltages fed to the two high voltage 1,500--1,500 volt rectifiers, designed in four-stage multiplier circuit configurations are picked off of the converter output.

TABLE 3.1

Unit Using Power	Output Voltage, Volts	Load Current, Milli-amperes	Ripple, %, No More Than	Total Instability, % No More Than
Synchronizer, tracking system and digital display	+5	3,000	2.0	5
Visual display	+12.6	80	0.1	-
	+100	60		-
	-12.6	20		1.0
Radio receiver	-12.6	140	0.05	-
	-50	60		-
Master oscillator, visual display and converter for the high voltage rectifier	+27	400	-	-
CRT	+1,500	0.15	-	10
	-1,500	1.0	-	-
	6.3	100	-	-
Synchronous filter	-20	50	0.1	5

3.3. Recommendations for the Installation of the Indicating Receiver on a Ship

An overall view of the KPI-5F indicating receiver set is shown in Figure 3.7.

The indicating receiver is produced in two colors: set OTs1.400.120 is gray-blue, while set OTs1.400.120 is of an ivory color.

The equipment is powered from the AC mains at 127/220 volts, 50 Hz. Where the requisite power is lacking on a ship, one can use DC mains at 220, 110 or 24 volts with the appropriate converters, the presence of which is stipulated when ordering the product. The mounting and installation of the converters is accomplished in accordance with the documentation supplied with them. The supply mains voltage may be measured with a Ts413 multimeter or one of a similar class of precision which is no worse than 2.5. Deviations in the supply mains voltage and frequency deviations not exceeding $\pm 10\%$ and $\pm 5\%$ respectively are permitted.

The overall dimensions and weight of the units of the equipment set are given in Table 3.2.

TABLE 3.2

Name of the Unit	Designation	Overall Dimensions, mm			Weight, kg, No More Than
		Depth	Width	Height	
Radio receiver	OTs2.003.025	218	450	165	8
Indicator (with frame)	OTs2.043.004	530	515	235	30
Synchronous filter	OTs2.067.360	257	228	140	3.5
Set of tools, spare parts and accesories	OTs4.070.228	504	406	166	8

It is necessary to observe the following major requirements when laying out the equipment set:

1. The radio receiver is to be installed no more than 5 m from the antenna input in an internal compartment of the ship, assuring free access to the connector. The unit is mounted horizontally on brackets or on a bulkhead, providing in this case for the possibility of sliding unit out of the housing and removing the cover from the chassis block.

2. The indicator unit is placed in the navigator's compartment in the immediate vicinity of the position where the navigation work is done, assuring free access to the controls which are located both on the front panel and on the side. A provision is to be made in the installation of the indicator for the possiblity of removing the cover and sliding out the circuit boards for repair.

3. The synchronous filter is housed in the navigator's compartment at a distance of no more than 3 m from the indicator on a desk or bulkhead. When installing the filter, a provision should be made for the possibility of removing the covers.

3.4. Main Operating Rules for the KPI-5F Indicating Receiver

The Arrangement and Designation of the Meters and Controls. The major meters and controls are located on the front panel of the indicator, while the controls which are not normally used in operation are located on the right side wall. The controls and meters are enumerated in Table 3.3 , with the functions performed by them also indicated.

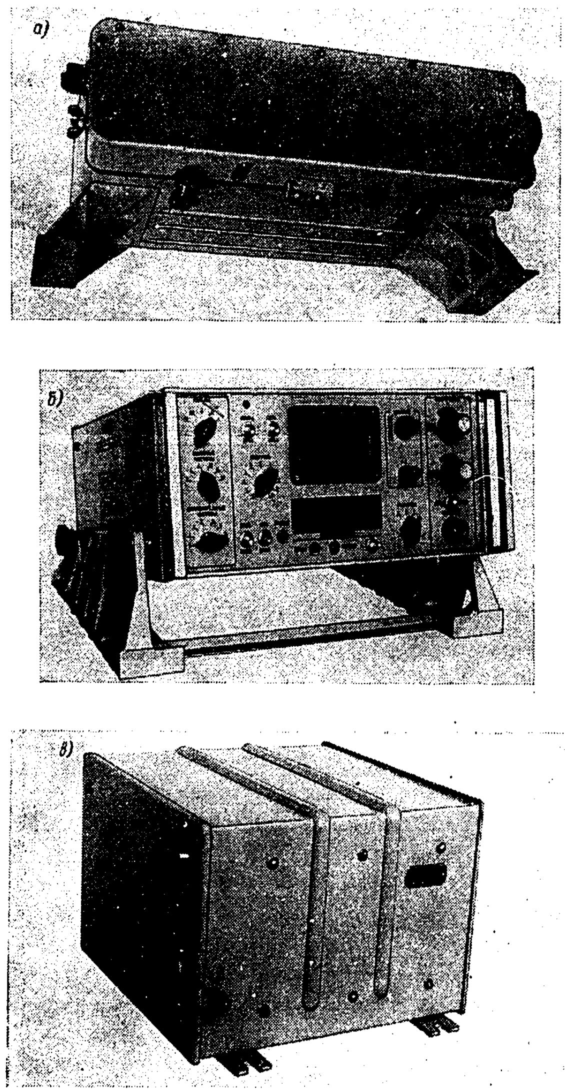

Figure 3.7. General view of the equipment complement of the KPI-5F indicating receiver.
Key: a. Radio receiver; b. Indicator unit; c. Synchronous filter.

TABLE 3.3

Meters and Controls	Functions Which Are Performed
CRYSTAL - OFF toggle switch	Turning the master oscillator on and off
WHITE CRYSTAL light	Signaling the heating of the master oscillator (the light goes out)
MAIN POWER - OFF toggle switch	Turning the indicating receiver on and off
TUNE - RECEIVER potentiometer	Tuning the receiver in the long wave band ±9 KHz from the carrier frequency of the shore station. Identifying surface and space waves
The TUNE RF-1, RF-2, RF-3, RF-4 [rejection filters 1-4] potentiometers	Suppressing interference from broadcast, telegraph and special stations in the long wave band
TEST switch	Checking the operation of the major units of the indicating receiver
The CHANNELS switch [bandswitch] (RF, DV, SV-1, 2, 3) [rejection filter, long wave, medium wave bands 1, 2 and 3]	Narrow band interference search in the "RF" position. Turning on "Loran-A" channels 1, 2 and 3 in the medium wave mode and "Loran-C" in the long wave mode
MAIN FREQUENCIES switch	Selecting the main repetition rate of the radio pulses
SUPPLEMENTAL FREQUENCIES switch	Selecting one of eight recurrent repetition rates of the radio pulses
SWEEP switch (1, 2, 3, 4, FO)	Changing the sweep rate, switching the synchronous filter to the "FO" position [ambiguity resolution of the phase readout]
ATTENUTATOR - OFF toggle switch	Reducing the amplitude of the received signal
GAIN - BALANCE potentiometer	Equalizing the amplitudes of a signal pair
The GAIN - COMMON potentiometer	Adjusting the amplitudes of the master and slave station signals
The GAIN - FO potentiometer	Adjusting the amplitude of a signal pair in the "FO" position of the SWEEP switch
CODE 1 - CODE 2 toggle switch	Decoding pulse-phase radionavigation system signal packets
AFC - OFF toggle switch	Actuating synchronization on the master station signals and tracking of the slave station signals

TABLE 3.3

Meters and Controls	Functions Which are Performed
The SHIFT (TO THE LEFT - TO THE RIGHT) pushbuttons and the A-B toggle switch	Shifting the radionavigation system signals and pedestals with respect to the sweep lines
READOUT pushbutton	Turning the digital display on when taking a reading
The FOCUS potentiometer	Focusing the image on the CRT screen
The BRIGHTNESS potentiometer	Adjusting the image brightness
Digital display	Indicating the reading in microseconds
The cathode ray tube	Visual display of the signals

Preparing the Indicating Receiver for Operation. Prior to starting operation, the position of the controls and meters of the indicating receive must be checked and set to the initial positions:

--The POWER MAINS - OFF toggle switch in the "Off" position;

--The CRYSTAL - OFF toggle switch in the "Off" position;

--The CHANNELS switch [bandswitch] in any position;

--The TEST switch in the "0" position;

--The AFC - OFF toggle switch in the "AFC" position;

--The A-B toggle switch in the "A" position;

--The OVERALL GAIN potentiometer is rotated counterclockwise to the stop (in the extreme left position);

--The equal channel gain mark on the GAIN - BALANCE potentiometer control is set in the upper vertical position;

--The equal channel gain marker on the GAIN - FO potentiometer control is set in the upper vertical position;

--The SWEEP switch is set in position "1";

--The TUNE RF-1, RF-2, RF-3 and RF-4 potentiometers are set in one of the extreme positions;

--The ATTENUTAOR - OFF toggle switch is set in the "Off" position;

--The 0 mark on the TUNE - RECEIVER potentiometer control is set opposite the mark on the front panel.

The Procedure for Turning the Indicating Receiver On and Off. The indicating receiver is turned on in the following sequence:

1. Some 15 to 20 minutes prior to starting operation, turn on the heat for the master oscillator, for which the CRYSTAL - OFF toggle switch is set in the "Crystal" position. The small flight light comes on, which signals the heating of the thermostate of the master oscillator. After 10 to 15 minutes the light goes out and will come on again as necessary to automatically maintain the specified temperature in the thermostat.

2. The POWER MAINS - OFF toggle switch is set in the "Mains" position after the master oscillator is heated up. After 1 to 2 minutes, two sweep lines with two rectangular pedestals should appear on the screen of the CRT (in position "1" of the SWEEP switch).

The indicating receiver is turned off in the following sequence:

1. The POWER MAINS - OFF toggle switch is set in the "Off" position;

2. The CRYSTAL - OFF toggle switch is left in the "Crystal" position if the indicating receiver is being turned off for less than one hour;

3. The POWER MAINS and CRYSTAL toggle switches are turned off sequentially when the equipment is shut down for a long time.

Measurements Using "Loran-A" Radio Navigation System Signals. The operations are performed in the following sequence:

1. The indicating receiver is prepared for operation.

2. The master oscillator thermostat heating is turned on for 15 to 20 minutes prior to the start of operation.

3. Using radionavigation suppor data for the navigation region and the radionavigation chart or special tables, two (or more) pairs of radionavigation system stations are selected.

Based on preliminary information on the ship's position and the radio wave propagation conditions, the possible type of signals incoming from each of the stations of the selected pairs is determined beforehand.

4. Tune the indicating receiver for operation with the first pair, for which:

--Set the CHANNELS switch in the "SV-1" ["medium wave 1"], "SV-2" or "SV-3" position, corresponding to the first symbol (number) in the designation of the selected pair of "Loran-A" radionavigation system stations;

--Set the MAIN FREQUENCIES switch in the "H", "L" or "S" position, corresponding to the second symbol (letter) in the designation of the selected pair of "Loran-A" radionavigation system stations.

5. Set the POWER MAINS -- OFF toggle switch in the "Power Mains" position. After two sweep lines with two rectangular pedestals appear on the CRT screen, use the BRIGHTNESS and FOCUS potentiometer controls to adjust the brightness and clarity of the image.

6. Solve the problem of detecting the signals of the selected pair of stations, for which the OVERALL GAIN potentiometer control is used to adjust the gain of the receiver so that two stationary radio pulses (when receiving surface waves) or two series of stationary pulses (in the presence of ionospheric waves) - the signals of the selected pair of stations - are clearly seen against the noise background in the sweep lines.

To facilitate the problem of detecting stationary pulses of a pair in the presence of considerable interference, it is recommended that the signals which are being detected be made to move and stop by briefly pressing one of the SHIFT buttons.

7. Solve the problem of identifying the master and slaved station signals from the arrangement of the pulses on the sweep lines. The pulses should be on different sweep lines, where the pulse on the upper line should be to the left of the one on the lower. With this arrangement, the upper pulse is the master station signal while the lower pulse is the slave station signals. If the signals are incorrectly arranged, one of the SHIFT buttons is to be pressed. Observing the motion of the signals, release the button at the moment they are correctly arranged.

8. Arrange the master and slave station pulses at the peaks of the stationary and moving pedestals respectively, for which:

--Press one of the SHIFT buttons (TO THE LEFT or TO THE RIGHT). While observing the shift in the signals release the button at the moment when a single pulse (surface wave reception) or the first of a series of pulses (where space waves are present) of the master station are at the peak of the stationary pedestal near its leading edge;

9. Set the A - B toggle switch in the "B" position. Push the TO THE LEFT or TO THE RIGHT button. While the observing the shift in the moving pedestal, release the button at the moment when the leading edge of the pedestal comes up and touches from below the single pulse or the first of the series of pulses (where ionospheric waves are present) of the slave station.

9. Using the GAIN - BALANCE potentiometer control, set the amplitudes of the first of the series of visible pulses approximately equal to the height of the pedestals.

10. Set the SWEEP switch in position "2". The peaks of the pedestals stretched out in two horizontal lines with the radio pulses on them will be

seen on the screen. Taking into account the data obtained in performing paragraph 3 of these instructions, set about the visual adentification of the type of signals being received (surface wave, ionospheric, composite).

11. Using the TO THE LEFT or TO THE RIGHT control, bring the pulse or series of pulses of the slave station precisely underneath the master pulse (or series of pulses).

12. Set toggle switch A - B in position "A" and using the TO THE LEFT button, move the radio pulses to the start of the horizontal lines.

13. Set the SWEEP switch in the "3" position. The sweep lines on the CRT screen will merge into a single line. The stretched video pulses of the master and slave stations will be seen. A dark vertical marker in the left portion of the sweep indicates the position of the tracking pulses of the tracking system.

14. Taking the specific features of "Loran-A" radionavigation system radio wave propagation into account, continue the visual identification of the type of signals received from the master and slave stations. Primary attention is to be concentrated on the leading edges of the pulses (the leading edges of the first in the series of pulses where space waves are present). To ascertain a possible weak surface component in the leading edge of an ionospheric E_1 signal, the OVERALL - GAIN potentiometer control is to be used to increase the receiver gain and carefully study the initial portion of the leading edge for the presence of a break in the envelope.

15. Set the A - B toggle switch in the "B" position, and using the TO THE LEFT and TO THE RIGHT buttons, match up the initial portions of the leading edges of the master and slave signals. Using the GAIN - BALANCE potentiometer, simultaneously equalize the leading edges of the pulses up to their peaks (in the case of surface waves or pure space waves) or up to the breaks in the envelopes (when working with composite signals).

Note: When working with E_1 waves, the matching of the leading edges is to be accomplished at the moment the phenomena of leading edge splitting and pulse fading are finished.

16. Press the READOUT button and take a reading of the navigation parameter in microseconds from the digital display.

In the case of measurements using space waves, the reading must be corrected with a correction for the radio wave propagation conditions, which is taken from the radionavigation chart or from tables.

17. To obtain the second line of position, similar measurements are to be performed using the second pair of "Loran-A" system stations.

18. To establish automatic tracking of master and slave surface wave signals, the A - B toggle switch is to be set in position "A" and the TO THE LEFT or TO THE RIGHT button is to be used to match the 0.5 level of the leading edge of the combined pulses with the dark vertical marker.

Measurements Using "Loran-C" Radionavigation System Signals. The operations are performed in the following sequence:

1. Prepare the indicating receiver for operation.

2. Turn on the master oscillator thermostat heating 15 to 20 minutes prior to starting operation.

3. Choose two (or more) pairs of stations from the "Loran-C" radionavigation system network from a radionavigation chart or special tables, using radio-navigational data for the navigating region.

Based on the preliminary information, determine the possible types of waves arriving from each of the stations of the selected pairs beforehand.

4. Tune the indicating receiver to the signals of the selected network for operation, for which the following is done:

--Set the CHANNELS switch in the "RF" ["rejection filter"] position;

--Set the MAIN FREQUENCIES switch in the "S", "SH", "SL" or "SS" positions, depending on the designation of the network selected for operation;

--Set the SUPPLEMENTAL FREQUENCIES switch in one of eight fixed positions, corresponding to the number included in the designation of the network selected for operation.

5. Set the POWER MAINS - OFF toggle switch in the "Power Mains" position. After the two sweep lines with the two rectangular pedestals appear on the CRT screen, adjust the brightness and clarity of the image using the BRIGHTNESS FOCUS potentiometers.

6. Solve the problem of detecting the signals of the selected network of the "Loran-C" radionavigation system, for which the OVERALL - GAIN potentiometer is used to adjust the receiver gain so that the stationary packets (train) of radio pulses of the master and slave stations are clearly seen against the background of interference on the sweep lines. The master station pulse train consists of nine pulses, while the master station trains consist of eight pulses each. The pulse trains of other networks move to the right or to the left along the sweep lines at different rates.

7. The interference status is estimated on the CRT screen. When there is interference from broadcast, telegraph as well as special stations, the interfering signals are to be suppressed using the rejection filters. The rejection filters are tuned in the following order:

a) The OVERALL - GAIN potentiometer is used to adjust the gain so that the band of interference is equal to the pedestal amplitude;

b) The RF-1 [rejection filter 1] is tuned to the frequency of the first interfering signal, for which, the maximum level (thickness) of the interference trace on the CRT screen is achieved by rotating the TUNE RF-1 potentiometer control;

c) Suppress the first interference signal, for which the TUNE RF-2 potentiometer is rotated and the position is found for which the amplitude of the interference is sharply reduced;

d) By rotating the TUNE RF-1 potentiometer control, seek out the second possible interference signal and suppress it with the RF-3';

e) By rotating the TUNE RF-1 potentiometer control, seek out the third possible interfering signal and suppress it with RF-4;

f) Tune RF-1 to the frequency of the fourth possible interfering signal; Set the CHANNELS switch in the "DV" ["long wave"] position; in this case, the RF-1 is switched from the "search" mode to the "suppress" mode, which is accompanied by a reduction in the amplitude of the fourth interfering signal;

Note: The process of suppressing interference must be accompanied by visual monitoring of the level of the useful signal pulse trains; where possible, one is to avoid tuning the rejection filters to frequencies close to the carrier frequency of the radio pulses, something which can reduce their amplitudes and distort waveforms.

8. Position the pulse trains from the master and slave stations at the peaks of the stationary and moving pedestals respectively, for which the following are done:

--Using the OVERALL - GAIN potentiometer control, the amplitude of the pulse train from the master station is set equal to the pedestal height;

--The A - B toggle switch is set in position "A";

--One of the SHIFT buttons is pressed (TO THE LEFT or TO THE RIGHT); Observing the motion of the signals, release the button at the moment when the first eight pulses of the master station pulse train are located at the peak of the stationary pedestal;

--Set the A - B toggle switch in the "B" position; press one of the SHIFT buttons (TO THE LEFT or TO THE RIGHT) and move the moving pedestal underneath the selected pulse train for the determination of the slave station line of position so that the eight pulses of the pulse train appear at the peak of pedestal.

9. Set the SWEEP switch in position "2". Two sweep lines will be seen on the CRT screen which are determined by the peaks of the pedestals with eight radio pulses in each horizontal line.

10. By pressing one of the SHIFT buttons (TO THE LEFT or TO THE RIGHT) arrange the eight radio pulses on the lower sweep line (slave station signals)

precisely underneath the eight pulses on the top sweep line (master station signals).

11. Set the A - B toggle switch in position "A". By pressing one of the SHIFT buttons (TO THE LEFT or TO THE RIGHT), set the first radio pulses of the pulse trains at the origin of the sweep lines.

12. Set the SWEEP switch in position "3". One sweep line with two signals formed by the superimposition of the envelopes of the eight pulses from the master and slave station pulse trains will be seen on the CRT screen.

13. Taking into account the data obtained in the execution of paragraph 3 of these instructions, set about the visual identification of the type of signals received from the master and slave stations. Special care should be taken in performing this task when working in the region of a mixed signal. To facilitate the identification of the portion of the edge of the resulting pulse corresponding to a surface wave under conditions of in-phase addition of forward and reflected signals, one is to begin to slowly rotate the RECEIVER potentiometer control, accompanying it with the visual monitoring of the shape of the initial portion of the edge of the radio pulse. The moment of the transition from the surface to the composite signal should be indicated in this case by the appearance of a wavy variation ("steps") on the monotonically rising envelope.

14. Press one of the SHIFT (TO THE LEFT or TO THE RIGHT) buttons and bring the center of the signal edge portion selected for the measurements using the master station signal up to the dark vertical marker of the tracking point.

15. Switch the A - B toggle switch to the "B" position. Using the GAIN - BALANCE potentiometer, set the slope of the slave station signal edge portion selected for the measurements parallel to the corresponding portion of the edge of the master station signal.

16. Press one of the SHIFT buttons (TO THE LEFT or TO THE RIGHT) and match the master and slave station signal edge portions selected for the measurements.

17. Check the decoding of the radio pulses, for which the SWEEP switch is set in position "4". One sine wave should be seen on the CRT screen (the signals are decoded). If two sine waves which are out of phase are seen on the CRT screen (the signals are not decoded), then the CODE 1 - CODE 2 toggle switch must be set in the next position and one must check to see that the radio signals have been decoded.

18. Set the SWEEP switch in the "FO" position (phase readout). The envelopes of signals with a triangular waveform from the synchronous filter output will be observed on the CRT screen.

19. Using the SHIFT buttons (TO THE LEFT or TO THE RIGHT) and the FO GAIN potentiometer, match the leading edges and amplitudes of the triangular images.

20. Press the READOUT button and take the readings from the digital display. If the reading was obtained using space waves, it must be corrected with the appropriate correction determined from a chart or by means of special tables.

21. To obtain the second line of position, it is necessary to perform the operations indicated in paragraphs 8 through 20 of these instructions.

PART II MARINE NAVIGATION RADARS

Marine navigation radars (SNRLS) have taken over the leading position at the present time in ship navigation and navigation safety equipment. Despite the fact that the first experiments in detecting ships were performed in the USSR as early as 1936 [4], radars began to find wide scale applications in navigation only at the end of the 1940's and the start of the 1950's.

Marine navigation radars or ship radar* is the term for the radioelectronic device intended for the detection and determination of the coordinates and parameters of motion of various objects on land (shore) and on water by means of the reflection, reradiation or inherent radiation of the objects (the targets) of electromagnetic (radio) waves. A radar object (target) is any physical body or group of bodies, the electrical and magnetic properties of which differ from the environment in which the radio waves propagate. Under sea navigation conditions, such objects are ships, navigation markers (buoys and spar buoys), the shoreline, various water surface obstacles, shore structures, etc.

Useful information on the radar target is supplied by the radio signals which arrive from it at the radar set. Depending on the origin of these signals, radars are broken down into passive and active types. A passive radar system is used to receive signals produced by thermal radio emission. For this reason, passive radar is frequently called passive thermal radar.

A passive system radar contains a pencil-beam receiving antenna, a receiver and a display unit. Passive radars are used in ship navigation to receive the electromagnetic energy radiated by the sun, the moon and the stars. Marine radio sextants operate on this principle.

An active radar system can operate with either a passive response (primary radar) or an active response (secondary radar).

A passive response radar contains a radio transmitter, transmitting and receiving antennas, a radio receiver and a display. The energy of the direct or probe signals radiated by the antenna, in propagating in a specified direction, is reflected from the objects and impinges on the receiver input. The reflected signals, amplified by the receiver, are fed to the display where they are converted to a form convenient for obtaining information on the received signals.

Active radar with an active response differs from the passive response in that a transceiver or radar transponder is present in the target or point which is specified beforehand.

A radar transponder is a device in which, with the arrival of "interrogation" radar signals, response signals are transmitted in the form of code combinations

*In American and English literature: radar (radio detection and ranging).

of sufficient power. The response signals make it possible to not only detect and determine the coordinates of a poorly reflecting target or point where the radar transponder is set up, but also to identify the object. Radar transponders, designed for joint operation with ship navigation radars, have been given the name of radar transponder beacons (RMO).

Radars are classified not only according to the origin of the radar signals, but also according to the type or structure of the probe signals (the signals irradiating the targets). Depending on the type of signals, radars are broken down into pulse and CW types. A pulse radar periodically transmits short microwave (SVCh) pulses, while it receives the pulse signals reflected from the targets in the gap between the probe pulses. The reflected pulse signal from each target is delayed with respect to the probe signal by the time $t = 2D/c$, where D is the distance to the target (the range); c is the radio wave propagation velocity. The range is determined from this time interval, $D = ct/2$, while the direction to the detected target (the azimuth) is determined by means of the pencil-beam antenna.

Where several targets are present, the received returns will be shifted in time and direction depending on the range and azimuth to these objects. The specific feature of pulsed radar operation noted here makes it possible to rather simply observe several objects simultaneously which are located within the operating radius of the radar. Display techniques using cathode ray tubes (ELT) [CRT's] used in pulsed radars or automatic ranging systems for one or more targets also facilitate this. The advantages of a pulsed radar also include the comparative simplicity in the utilization of the same antenna for both transmission and reception of the radar signals.

Drawbacks to pulsed radars are the necessity of using large peak powers for the probe pulses, the complexity of determining the rate of motion of objects, the impossibility of measuring very small ranges and the relatively large minimum operating range of the radars, which depend on the pulse width, the minimum value of which is limited by the frequency spectrum width and the transient process times in the equipment.

Despite the drawbacks noted here, the advantages of the pulse technique make a 360° scan mode possible for marine navigation radars. The CW system is used at the present time in navigation equipment for the measurement of the docking speed of ships. For this purpose, an unmodulated CW system is used which is known under the name of the Doppler-Belopol'skiy system. The operational principle of this system consists in the fact that the frequency of returns in the case of the relative motion of the target and the radar differs from the frequency of the probe signals by an amount which depends on the radial velocity of the relative motion of the radar and the target.

CHAPTER 4 MARINE PULSED NAVIGATION RADARS

4.1. The Specific Features of Pulsed Radars and Their Technical and Operational Characteristics

Pulse marine navigation radars (ISNRLS) are used in navigation for the detection, coordinate determination and determination of the parameters of the motion of various water and shore targets, the shoreline and other obstacles which are capable of reflecting the energy of the probe signals to the radar. The resolution of these problems makes it possible to assure navigation safety when ships are located in narrow straits and other confined waters, the safe passing of ships in the case of reduced or limited visibility, as well as the determination of a ship's position based on known shore or floating reference points and by means of specially set up radar transponders.

Pulse marine navigation radars should possess sufficient resolution, precision in the measurement of ranges and directions to targets being detected as well as minimal overall dimensions and weight of the entire installation, assuring the following in this case:

--Azimuthal plan position indication, which makes it possible to monitor the surrounding surface situation within a specified operating radius;

--The orientation of the image of the returns from the targets on the indicator screen both relative to the course of the ship (the middle line plane) and relative to the meridian (true north);

--Reliable detection of both large and small low lying surface objects (buoys, small boats, various obstacles) where clutter is present from an agitated sea surface, or hydrometeors (rain, fog, snow, etc.);

--A target detection range independent of the amplitude of the rocking of the ship;

--The reproduction on the indicator screen of both the relative and true motion of the targets;

--Operational reliability and servicing simplicity.

A block diagram of a pulsed radar with plan position indication is shown in Figure 4.1. The circuit complement includes the following major components or units:

a) A synchronizer, which generates the triggering pulses to control the radar circuitry (one operational cycle of the radar, the duration of which is called the repetition period corresponds to each triggering pulse);

b) A pulse modulator which generates modulating pulses of a specified width τ_p and amplitude, which control the microwave generator;

c) A microwave generator which produces high power microwave pulses, the width of which is governed by the width of the modulating pulses;

d) The antenna and feedline, which consists of a pencil-beam antenna and a waveguide line; the antenna has a beaver-tail directional pattern, i.e., a narrow pattern in the horizontal plane (0.7 to 0.5°) and a relatively wide pattern in the vertical plane (18 to 25°), which assures the requisite precision in the measurement of azimuths and reduces the influence of the ship's rocking on the radar detection range;

e) An antenna switch with a very fast response, which at the moment the probe pulse is generated connects the antenna to the transmitter and protects the receiver input against the high power pulse of the microwave generator, and after the probe pulse is completed, connects the antenna to the receiver input until the generation of the next probe pulse;

f) A receiver which amplifies the received signals and transmits them to the display in the form of video pulses;

g) A two dimensional plan position indicator (IKO) [PPI], which converts the received return voltage to a visible image on the CRT screen. Magnetically controlled CRT's with brightness modulation of the electron beam are used for this purpose in the display. The received signals increase the brightness of the screen at the point corresponding to the azimuth of the detected target and its range on the range scale.

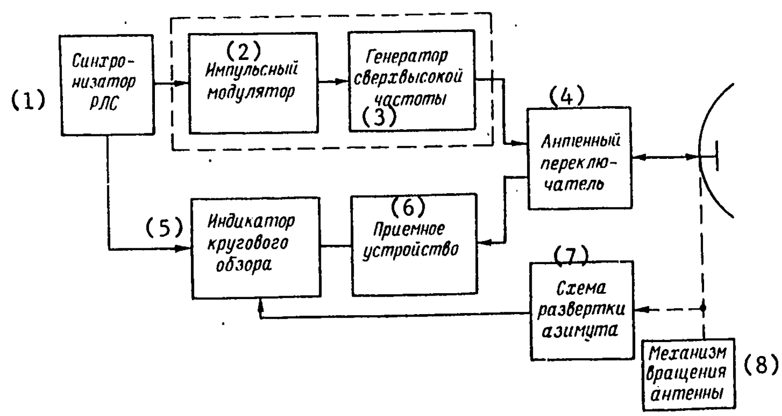

Figure 4.1. Block diagram of a pulsed radar.

Key:
1. Radar synchronizer;
2. Pulse modulator;
3. Microwave frequency generator;
4. Antenna switch;
5. Plan position indicator;
6. Receiver;
7. Azimuth sweep circuitry;
8. Antenna rotating mechanism.

Mechanical and electronic cursors are used to read the azimuths. The ranges to targets are read out by means of special electronic range markers, which are fixed (NMD) or moving (PMD). With the rotation of the radar antenna (by means of a special mechanism), these markers create fixed range rings (circles) (NKD) and a moving range ring (PKD) on the CRT screen.

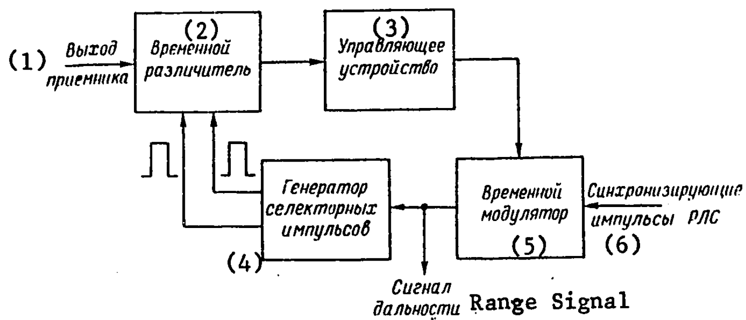

Figure 4.2. Block diagram of an automatic range tracking system.

Key:
1. Receiver output;
2. Time discriminator;
3. Controller;
4. Strobe pulse generator;
5. Time modulator;
6. Radar synchronizing pulses.

The plan position display is assured through the creation of radio circular scanning of the electron beam of the CRT. The radial range sweep is produced by deflecting windings, through which a sawtooth waveform current is passed. Circular sweep of the CRT beam can be obtained in two ways: by rotating the deflecting windings about the neck of the CRT synchronously and in phase with the rotation of the antenna or by creating a rotating magnetic field by means of two stationary, mutually perpendicular deflecting windings.

The following are used to couple the antenna to the indicator: a selsyn tracking transmission system (SSP); sine-cosine rotating transformers (SKVT); turning or rotating transformers (VT), etc. The orientation of the signal image on the PPI screen with respect to north is assured by tracking the azimuth sweep circuit with the ship course indicator: the gyrocompass.

The signals can be displayed either in a relative motion (OD) or true motion (ID) mode. In the first case, the origin (center) of the circular radial scan, which marks the position of the ship on the PPI screen, coincides with the center of the screen and remains constant when the ship moves. Because of this, the images of stationary objects move on the screen at a speed proportional to the speed of the ship, while images from moving objects move with the relative speed of the objects and the speed of the ship itself. Such a display mode complicates the identification of stationary and fixed targets, makes it difficult to determine the true direction and speed of other ships, etc.

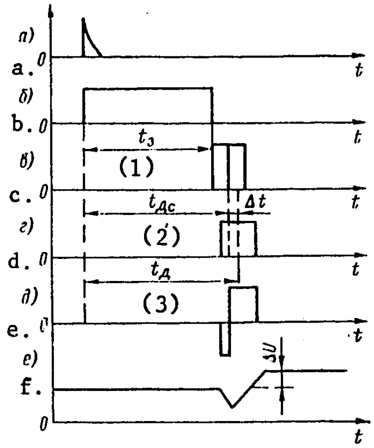

Figure 4.3. Time graphs of automatic range tracking circuit operation.

Key: 1. $t_z = t_{delay}$;
2. $t_{ds} = t_{discriminator}$;
3. t_d.

To change a display over to a true motion indicating mode, it is necessary to subtract the vector for the motion of the ship itself from the relative motion vector. This is achieved in technical terms by having the PPI circuitry supplemented with a special device: a true motion display accessory, which converts the electrical log and gyrocompass data to the appropriate signals which move the origin of the circular-radial sweep on the PPI screen in the direction of the ship's motion and at a rate proportional to its speed. Upon reaching the edge of the screen, the origin of the sweep is automatically (or manually) and rapidly returned to the initial position at the opposite edge of the screen, changing the image of the surrounding area. To preclude log and gyrocompass errors, a provision is made for manual correction of the ship course and speed data in the true motion display circuitry.

When the origin of the range sweep is shifted relative to the center of the screen, the azimuth reading is taken by means of an electronic azimuth cursor (EVN), which takes the form of a second sweep line which can be rotated manually in a range of 360°.

A system for automatic range tracking (ASD) and automatic azimuth tracking (ASN) of targets is used in automated navigation radars to solve the problem of passing and preventing the collision of ships. A block diagram of an automated range tracking circuit is shown in Figure 4.2, while the time traces of the change in the voltages in the elements of this system are shown in Figure 4.3. The radar sync pulses (graph a) control the operation of the time modulator (see Figure 4.2), which generates the delay voltage pulses t_z [1] (graph b). The trailing edge of these pulses triggers the strobe pulse generator (range strobes), shifted in time with respect to each other by the amount of their width (graph c). The strobe pulses and video pulses of the received returns (graph d) are fed to the time discriminator. The time discriminator compares the overlap areas of the video pulse and the strobe pulses and generates an error voltage (graph e), which is proportional to the difference in the areas being compared. The error signal is fed to a controller which generates a control signal voltage ΔU (graph f). The latter, in acting on the time modulator, changes the width of its delay pulse t_z so that the timewise mismatch Δt which is equal to $\Delta t = t_d - t_{ds}$ is reduced and tends to a low value equal to the tracking error.

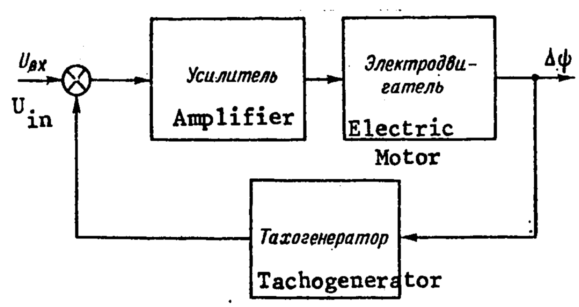

Figure 4.4. Block diagram of an electromechanical integrator.

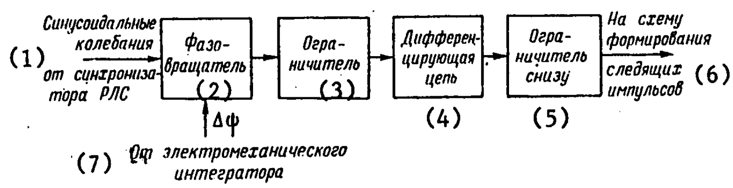

Figure 4.5. Phase meter circuit of a time modulator.

Key:
1. Sinusoidal waveforms from the radar synchronizer;
2. Phase shifter;
3. Limiter;
4. Differentiating network;
5. Negative peak clipper;
6. To the tracking pulse generating circuitry;
7. From the electromechanical integrator.

Electronic and electromechanical integrating circuits are used as the controller. A block diagram of an electromechanical integrator is shown in Figure 4.4. The integrating element is an AC or DC electric motor. The angular speed of the motor is proportional to the applied voltage, while the shaft rotation angle Δψ is proportional to the integral of the input voltage. A feedback network, designed around a tachogenerator for the appropriate type of current, differentiates the output signal. The resulting voltage is compared with the input, and their difference acts on the electric motor until the output signal is precisely proportional to the integral of the input signal, while the voltage difference goes to zero.

Time modulators (VM) take the form of delay circuits which can be made in the form of devices which generate variable width voltage pulses (multivibrators, phantastrons, etc.) or pulses of constant width, which are delayed relative to the sync pulses by an amount of time governed by the integrator control signal. An example of the latter type of time modulator is a phase metering circuit (Figure 4.5) consisting of a phase shifter and the driving stages. The sinusoidal waveforms from a radar synchronizer are fed through a phase shifter to a limiter. The rectangular pulses obtained after limiting are differentiated, and after negative peak clipping, the spiked positive polarity pulses control the strobe pulse generator, which can be designed in a delayed blocking oscillator circuit configuration. The time delay t_z of the peaked pulses is realized by a phase shifter for which the phase output signal is proportional to the integrator rotor rotation angle $\Delta\psi$. The value of the time delay is defined by the expression:

$$t_z = [t_{delay}] = (\phi/2\pi)T$$

where ϕ is the phase change created by the phase shifter;
T is the period of the sinusoidal oscillations driving the phase shifter.

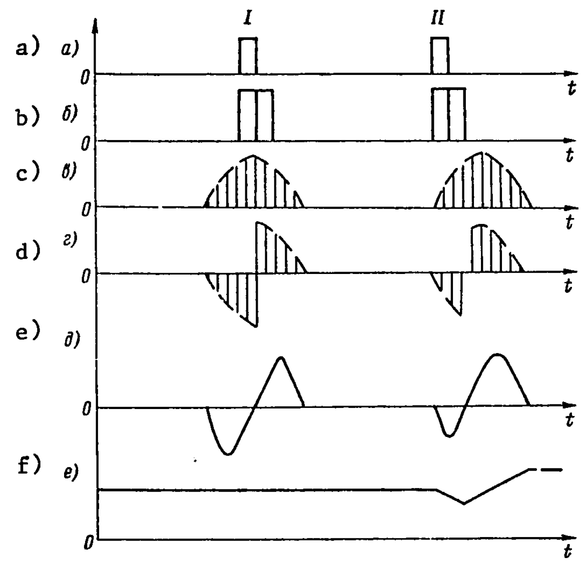

Figure 4.6. Time graphs showing the operation of an automatic azimuth tracking circuit.

Automatic azimuth tracking with simultaneous scanning of the surrounding space is accomplished using the same technique as in the case of automatic range tracking. The basic difference consists first of all in the fact that the tracking signal is not a single pulse, but rather a pulse packet which is reflected from the target during the rotation of the antenna in the horizontal plane; secondly, the arrival period of the pulse packets is determined by the circular scanning time in azimuth. Graphs of the processes in an automatic azimuth tracking system are shown in Figure 4.6. When the axis of the antenna directional pattern coincides with the direction for which there is a special marker on the azimuth circle of the antenna rotating mechanism, then a special contact is closed and the azimuth readout pulse generator or bearing strobe generator is turned on (graph aI). With the action of these pulses, the strobe pulse generator is actuated (graph bI). When the center of the return signal packet (graph cI) coincides with the center of the strobe pulses, the return pulse packet is divided in half (graph dI) and the to'al voltage at the output of the time discriminator is equal to zero (graph eI), because of which the control voltage at the integrator output does not change (graph fI). If the target shifts relative to the position of the azimuth marker in the antenna mechanism, then the center of the strobe pulses will not match the center of the return signal packet (graph cII). Then a mismatch voltage will appear at the output of the time discriminator (graph eII), which will increase the control voltage of the integrator (graph fII), and as a result, the integrating electric motor will turn the azimuth marker through the mismatch angle.

The operational characteristics of a marine navigation radar are as follows: the maximum detection range, the minimum detection range, the resolution, the precision of range and angular coordinate measurements and the operational reliability.

The maximum range depends on the power potential of the radar, the effective back-scatter cross-section of the target, the energy losses in the atmosphere, the influence of water surface returns, and is limited in practice by the radar visibility range for surface targets, which is determined by the propagation properties of ultrashort waves (UKV) [VHF].

The potential detection range (the radar range in free space) is defined by the formula:

$$D_{max} = \sqrt[4]{\frac{P_и G_A^2 S_{эф} \lambda^2}{P_{пр\ min} (4\pi)^3}},$$

where P_i is the pulse power of the probe signals;
G_A is the directional gain of the antenna;
S_{eff} is the effective radar cross-section of the target;
$P_{rec\ min}$ is the receiver pulse sensitivity;
λ is the radar wavelength.

When $\lambda < 10$ cm, the energy of the radar signals is attenuated in oxygen, water vapor and hydrometeors. For this reason, the radar detection range is reduced and will be equal to:

$$D'_{max} = D_{max} e^{-0.115 \alpha_з D'_{max}}, \qquad (4.1)$$

where α_3 is the attenuation coefficient of the atmosphere, which depends on the wavelength and the condition of the atmosphere, in dB/km.

When using radar on low lying surface targets, the return from the water surface sharply reduces the radar range. In this case, the radar detection range is determined from the formula:

$$D''_{max} = \sqrt[8]{\frac{P_и G_A^2 S_{эф} 4\pi (h_1 h_2)^4}{p_{пр\ min} \lambda^2}},$$

where h_1 is the height at which the radar antenna is mounted;
h_2 is the height of the surface target.

Besides the return energy, the water or ground surface also exerts an influence on the radar range because of its curvature. It is known that at ultrashort wavelengths, especially at centimeter wavelengths and shorter, the capability of radio waves of bending around the convex surface of the earth is very poorly pronounced. For this reason, radar detection range of surface targets is limited by the radar visibility range (in kilometers), which is equal to:

$$D_0 = 4{,}12\left(\sqrt{h_1} + \sqrt{h_2}\right)$$

(where h_1 and h_2 are expressed in meters).

The minimum radar range is determined by the probe pulse width:

$$D_{min} = 300\tau_i \qquad D_{min} = 300\,\tau_{и}$$

(where τ_i is the pulse width is microseconds; D_{min} is the minimum range in m), and depends on the so-called radar dead zone, which is determined from the formula:

$$D_{dead\ zone} = h_1/\tan\theta/2 \qquad D_{м.з} = \frac{h_1}{\mathrm{tg}\,0/2},$$

where θ is the width of the antenna directional pattern in the vertical plane.

The range resolution of a radar is characterized by the minimum distance ΔD between adjacent targets, located on the same azimuth, for which it is possible to observe them separately and determine their coordinates. The spacing ΔD depends on the pulse width, the electron spot diameter d_π on the CRT screen and the range scale (the distance being measured) of the indicator D:

$$\Delta D = \frac{c\,\tau_{и}}{2} + \frac{d_{п}}{l_{р}} D,$$

where c is the radio wave propagation velocity; l_p is the length of a range sweep line.

The directional (azimuth) resolution of a radar is determined by the minimal angle Δα between adjacent targets located at the same range from the radar, for which it is possible to observe them separately and determine their coordinates. The angle Δα depends on the width of the antenna directional pattern in the horizontal plane α°_{hor}, the spot diameter and the distance r from the center of the sweep to the target blip on the CRT screen:

$$\Delta\alpha^{\circ} = \alpha^{\circ}_{гор} + 57{,}3\,\frac{d_{п}}{r}.$$

The coordinate measurement precision is characterized by the size of the errors when making readings with the radar. They can occur because of waveform distortions in the pulsed signals, inaccuracy in taking the radio wave propagation velocity into account as well as the influence of interference, instrument errors, limited resolution of the observer's organs of vision, etc.

The potential range measurement precision depends on the waveform and width of the probe pulses as well as the interference level. The mean square potential error of a range measurement is defined in accordance with the formula:

$$\delta_{п} = \frac{c\tau_{и}}{\sqrt{\pi q_0}},$$

where q_0 is the ratio of the signal energy to the interference energy at the receiver output.

The potential mean square azimuth measurement error is determined by the width and shape of the antenna directional pattern in the horizontal plane as well as the ratio of the signal energy to the interference energy at the receiver input:

$$\varphi^{\circ}_{п} = \frac{\alpha^{\circ}_{гор}}{\sqrt{\pi q_0}}.$$

Operational reliability characterizes the capability of a radar of performing the function assigned to it under actual operating conditions. It is usually expressed as the number of operating hours between two successive failures.

The main technical characteristics of a marine navigation radar are: the wavelength (pulse modulation frequency); the pulse repetition rate; the transmitter power; the receiver sensitivity and bandwidth; and the width of the probe pulses. The technical characteristics or the parameters are chosen based on the requirements placed on the radar operating characteristics.

The wavelength of a marine navigation radar is chosen taking into account the following tasks: providing for pulsed radar operation with a short pulse width (0.05-1 μsec); obtaining high antenna directivity in the horizontal plane without excessively increasing the antenna dimensions; assuring the detection of both large and small low-lying surface targets within the specified operational radius of the radar; providing for the requisite radar detection range where energy is absorbed in the troposphere (oxygen, water vapor) and in hydrometeors (rain, fog, etc.). Working from these conditions, the 3 centimeter band has become the most widespread for navigation radars (a wavelength of 3.2 cm). In individual cases, a 10 centimeter radar is used to reduce energy absorption in the troposphere and reduce clutter from precipitation and rain clouds.

The choice of the pulse repetition rate is conditioned by the unambiguous determination of the range and effectiveness of detecting targets in a circular scanning mode. The following are considered in this case: the duration of the forward trace for the range sweep; the rotational speed of the antenna and the width of the antenna directional pattern in the horizontal plane.

The maximum pulse repetition rate is determined from the formula:

$$F_{p\ max} = F_{и\ max} = \frac{c}{2{,}5\, D_{max}},$$

where D_{max} is the maximum range on the indicator scale.

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The minimum repetition rate is found from the condition:

$$F_{p\ min} = 6nN_{min}/\alpha^{\circ}_{hor} \qquad F_{\text{и}\ min} = \frac{6nN_{min}}{\alpha^{\circ}_{\text{гор}}},$$

where N_{min} is the minimum number of reflected pulses in a packet (it should be no less than 10 to 15); n is the antenna rotational speed, r.p.m.

The working repetition rate is chosen from the condition:

$$F_{p\ min} < F_p < F_{p\ max}. \qquad F_{\text{и}\ min} \leqslant F_{\text{и}} \leqslant F_{\text{и}\ max}.$$

A distinction is drawn between the pulse power P_p and the average power P_{avg} of the radar transmitter, which are related by the following equation:

$$P_{avg} = P_p \tau_p F_p \qquad P_{\text{ср}} = P_{\text{и}} \tau_{\text{и}} F_{\text{и}}.$$

The receiver sensitivity and bandwidth are some of the most important characteristics, since along with the transmitter power, they determine the radar detection range and the quality of the pulse signal.

The sensitivity characterizes the ability of the receiver to receive and detect weak returns with a specified probability under conditions of interference produced by the internal noise of the receiver. It is expressed as the minimum received signal power at the input to the receiver, which is equal to:

$$P_{rec\ min} = N_n mk_0 \Delta f_{rec} \qquad P_{\text{пр}\ min} = N_{\text{ш}} mk_0 \Delta f_{\text{пр}},$$

where N_n is the noise factor of the receiver;
- m is the discrimination coefficient (the minimum signal power to noise power ratio at the receiver output which is necessary to isolate the useful signal);
- k is Boltzman's constant, equal to $k = 1.37 \cdot 10^{-23}$ J/deg;
- $T_0 = 300°$ K;
- Δf_{rec} is the receiver bandwidth.

Receiver sensitivity is expressed in units of power (fractions of a watt) or decibels:

$$P_{rec\ min} = 10\ \log(P_{ref}/P_{rec\ min}),\ \text{dB}, \qquad P_{\text{пр}\ min} = 10\ \lg \frac{P_{\text{оп}}}{P_{\text{пр}\ min}}\ \text{дБ},$$

where P_{ref} is the reference power level, usually 1 watt.

Radar receiver bandwidth should not be very narrow so as not to cause pulse signal distortions. On the other hand, too wide a bandwidth increases the internal noise and thereby reduces the receiver sensitivity. In practice, the bandwidth of a marine navigation radar receiver is chosen from the condition:

$$\Delta f_{\text{пр}} = \frac{1,2 \div 1,37}{\tau_{\text{и}}} + 2\Delta f_s,$$

where Δf_s is the residual error in tuning the local oscillator of the automatic frequency control system of the receiver.

The major parameters of a radar antenna are: the directional pattern width of the antenna in the horizontal α_{hor} and vertical θ planes at the half power points (at the 0.5 level); the directional gain G_A and the degree or amount of sidelobe suppression.

The antenna directional gain is equal to:

$$G_A = 4\pi/\alpha_{hor}\theta. \qquad G_A = \frac{4\pi}{\alpha_{\text{гор}}\theta}.$$

If α_{hor} and θ are expressed in degrees, then:

$$G_A = \frac{41253}{\alpha^{\circ}_{\text{гор}}\theta^{\circ}}.$$

The degree of sidelobe suppression is expressed in decibels and is characterized by the ratio γ of the maximum sidelobe power P_b to the power of the main lobe P:

$$\gamma = 10 \log(P_b/P), \text{ dB}.$$

To assure normal operation of a marine navigation radar, the sidelobe level should be 20 to 30 dB below the level of the main lobe.

4.2. The "Lotsiya" Marine Navigation Radar

The "Lotsiya" marine navigation radar (SNRLS) is intended for installation on vessels of port services, auxiliary services and technical fleets, on low tonnage hydrofoils as well as for a standby radar on large tonnage seagoing vessels [11].

The "Lotsiya" marine navigation radar contains the following units: the antenna (L1), the transceiver (L2), the indicator (L3), the power supply (L4), the control console (L5), a power inverter, a rectifier and a regulator for the ship power.

The radar station equipment complement also includes the installation set for mounting the waveguide channel, the set of waveguide sections, the set of spare parts, tools and accessories as well as the set of interconnecting cables.

The unit can be powered from three sources: 24-27, 110 or 220 volts DC; 115 volts AC at 400 Hz and 220/380 volts three-phase AC at 50 Hz.

The "Lotsiya" marine navigation radar has the following operational and technical parameters:

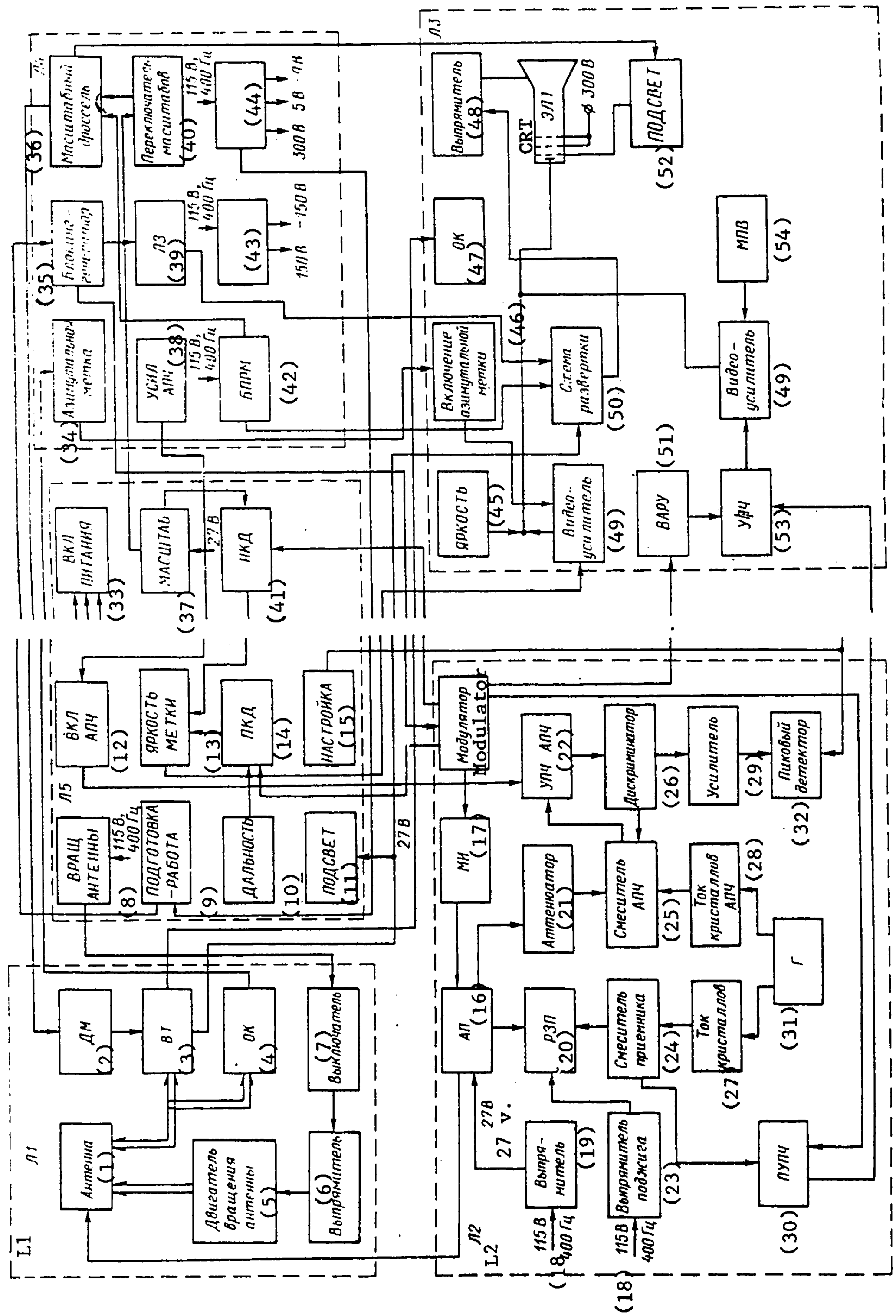

Figure 4.7. Block diagram of the "Lotsiya" marine navigation radar.

Key:
1. Antenna;
2. Diode clamping bridge;
3. Rotating transformer;
4. Deflecting coils;
5. Antenna rotation motor;
6. Rectifier;
7. Cutoff switch;
8. ANTENNA ROTATE, 115 volts, 400 Hz input;
9. PREPARE FOR OPERATION;
10. RANGE;
11. SWEEP INTENSIFIER;
12. AFC ON;
13. CURSOR BRIGHTNESS;
14. MOVING RANGE RING;
15. TUNE;
16. Antenna switch;
17. Magnetron RF generator;
18. 115 volts, 400 Hz;
19. Rectifier;
20. Receiver front-end protective discharger;
21. Attenuator;
22. Intermediate frequency amplifier AFC;
23. Ignition rectifier [for discharger];
24. Receiver mixer;
25. AFC mixer;
26. Discriminator;
27. Crystal current;
28. AFC crystal current;
29. Amplifier;
30. Intermediate frequency preamplifier;
31. Local oscillator;
32. Peak detector;
33. POWER ON;
34. Azimuth marker;
35. Blocking oscillator;
36. Scale choke;
37. SCALE;
38. AFC amplifier;
39. Delay line;
40. Scale switch;
41. Fixed range ring;
42. Modulator and sweep power supply panel;
43. Rectifier, 115 VAC, 400 Hz in, +150, -150 volts out;
44. Rectifier, 115 v, 400 Hz in, 300 volts, 5 volts and -9 volts out;
45. BRIGHTNESS;
46. Azimuth marker switching;
47. Deflecting coils;
48. Rectifier;
49. Video amplifier;
50. Sweep circuit;
51. Automatic time gain control;
52. Brightener;
53. IF amplifier;
54. MPV [expansion unknown].

Maximum detection range*, miles:	
A shore 60 m high	12-14
Ship with a displacement of 700 tons	6.6
Average sea buoy	1.3
Minimum detection range, meters	35
Maximum range determination error, percent of the maximum value of the indicator scale:	
On the 4, 8 and 17 mile range scales	2
On the 0.5, 1 and 2 mile range scales	35 m
Maximum azimuth determination error, degrees	1.5

*For a waveguide length of up to 10 m and an antenna mounting height of 7 m above sea level.

Range resolution, in m, no worse than	35
Angular resolution on the 4 mile scale, degrees, no worse than	2
Carrier frequency (3.2 cm wavelength), MHz	9,375 ± 45
Probe pulse width, microseconds:	
On the 0.5, 1 and 2 mile range scales	0.12
On the 4, 8 and 16 mile range scales	0.3 ± 0.1
Pulse repetition rate, pul/sec:	
On the 0.5, 1 and 2 mile scales	1,600 ± 200
On the 4, 8 and 16 mile scales	500
The pulsed transmitter power, KW:	
On the 0.5, 1 and 2 mile scales	2.5
On the 4, 8 and 16 mile scales	4.5
Pulse sensitivity of the receiver, in dB relative to the 1 mW level	88
Receiver intermediate frequency, MHz	30
Receiver bandwidth, MHz	13.5
Antenna directional pattern width at the 0.5 level relative to the maximum power, degrees:	
In the horizontal plane	1.7
In the vertical plane	18 ± 2
Sidelobe attenuation, in dB, no less than	23
Antenna rotational speed, r.p.m.	20 ± 4
Diameter of the indicator screen, mm	108*
Antenna gain	700
Indicator range scales**, miles	0.5, 1, 2, 4 8 and 16
Interval between fixed range ring markers on the 0.5 mile scale, miles	0.1
Power consumed from the ship's power mains, watts	500
Continuous operating time, hours	24
The time before the radar is ready after being turned on, minutes	4
Permissible ambient temperature variations, °C:	
For the L1 unit [antenna]	-40 to +50
For the other units	-10 to +50

*The indicator screen diameter with the removable lens is increased.

**Only the moving range ring is used on the 1 to 16 mile scales.

Permissible relative air humidity at +40° C, %	95-98
Permissible ship angle of heel, degrees	45
Permissible variations in the ship power parameters, %:	
For the DC and AC voltages	±10
At the 50 Hz frequency	±5
At the 400 Hz frequency	±2
Permissible wind load on the antenna, m/sec	50

A block diagram of the "Lotsiya" marine navigation radar is shown in Figure 4.7. The synchronization of the radar circuit is accomplished from a blocking oscillator, which controls the operation of the sweep generator of the indicator L3 through a delay line and directly controls the magnetic modulator of the transmitter L2. The mutual relationships between the remaining elements can be seen from the block diagram itself.

The antenna unit (unit L1) consists of the antenna, the RF section, the SL-369 antenna rotation motor, the motor power rectifier, the OK bearing (azimuth) marker contactor group, the 6VTI-1TV type rotating transformer (VT), the DM diode clamping bridges and the supplemental toggle switch for actuating the antenna rotation.

A DC voltage is fed to the motor winding from the rectifier, which is designed around 2D202Zh type diodes in a bridge configuration. The antenna is rotated through a reducer with a gear ratio of 1:250. The rotating transformer provides for the synchronous rotation of the sweep on the plan position indicator screen (PPI) with the rotation of the antenna. The rotating transformer rotor is coupled to the rotating shaft of the antenna through a reducer with a ratio of 1:1. A current is induced in the stator windings of the rotating transformer which is proportional to the sine and cosine of the antenna rotational angle.

The high frequency section of unit L1 consists of the radiating system (the antenna) and the waveguide channel. The slot type antenna contains a rectangular cross-section waveguide of 28.5 x 12.6 mm with inclined slots cut in the narrow wall, which shape the antenna directional pattern in the horizontal plane. The slots are separated from each other by metal partitions which form ultimate waveguide filters to suppress the vertical field component. A horn reflector shapes the directional pattern in the vertical plane. The horn is covered with a dielectric fairing to protect against the external environment. The overall standing wave ratio (KSV) [SWR] of the antenna is no more than 1.4. The change in the SWR with the rotation of the antenna does not exceed 0.1. The maximum of the antenna directional pattern is deflected from a normal to the antenna aperture by an angle of 5°24'.

The rotating junction of the antenna waveguide channel consists of fixed and moving sections. The stationary section takes the form of a rectangular waveguide 23 x 10 mm in cross-section with circular flanges. The moving section consists of brackets and waveguides which are connected to the antenna. There is an air gap of 0.2 mm between the stationary and rotating sections. Electrical contact is achieved in the gap by means of a choke groove. Energy transmission stability is assured between the sections through the presence of a coupling stub.

The transceiver (unit L2) consists of the following: a magnetic modulator, the RF generator (magnetron) MI, the antenna switch AP, the intermediate frequency preamplifier PUPCh, the local oscillator and the automatic frequency control circuit APCh [AFC].

The thyristor type magnetic modulator has a series charging resonant circuit, three compressor stages, a shaping line and a pulse transformer. The first type A compression stage (section) produces voltage pulses with a width of 22 μsec, the second type B stage produces pulses with a width of 1.7 μsec and the third type A compression stage produces pulses with a width of 0.12 or 0.3 μsec. An MI-158-1 pulsed magnetron is used in the transmitter.

The ferrite antenna switch has a broadband receiver protection discharger RZP of the RR-83A-1 type, equipped with a preheater with a thermal regulator. The discharger contains a firing electrode which is supplied from a firing rectifier at a voltage of 600 to 800 volts.

The local oscillator G takes the form of a reflective K-27 klystron. The intermediate frequency preamplifier contains two stages using a dual tuned circuit configuration with 6Zh1B vacuum tubes. The gain of the IF preamplifier is no less than six for a bandwidth of no less than 10 MHz. The signals are fed to the amplifier input from the balanced mixer of the receiver in which D405V and D405BP microwave (SVCh) diodes are used.

The AFC system operates in a dual channel circuit configuration with a balanced mixer, similar to the receiver mixer, using D405A and D405AP microwave diodes. The AFC channel includes the following: a two stage IF amplifier using 6Zh1P-YeV vacuum tubes, a discriminator using stagger tuned resonant circuits with a 6Kh2P-YeV twin diode; a controller which contains a DC amplifier using a 6NZP "triple triode" vacuum tube and a peak detector using 2D105 silicon diodes.

In structural terms, the L2 unit takes the form of a hermetically sealed cylinder with exterior annular cooling fins. The cap of the cylinder is a facing panel, which supports all of the structural components through the chassis. The high voltage elements of the transmitter - the magnetron oscillator MI and the modulator - are housed in a separate high voltage compartment of the transceiver. A packet with drying silica gel is included in a special lattice work cartridge to reduce the humidity in the unit.

The indicator (unit L3) contains the following: the cathode ray tube ELT [CRT], the high voltage rectifier, the deflection coils OK, the sweep generation circuitry (sweep assemblies), the main IF amplifier, the video amplifier, forward trace sweep intensifier and other components of the display circuitry.

The amplified signals from the targets are fed from the output of the IF preamplifier to the input of the intermediate frequency amplifier. The amplified and detected signals from the IF amplifier output are fed to the video amplifier input. The fixed range ring, moving range ring (from the L5 unit [control console]) and the azimuth (bearing) marker voltage pulses are fed to the input of the second video amplifier channel. The amplified signals from the targets, the fixed and moving range ring markers as well as the azimuth marker signals are fed from the output of the video amplifier to the cathode of the CRT. Also fed to this point is the screen brightness control voltage. The forward trace sweep intensifier voltage pulses are fed to the CRT modulator.

The power supply (L4) contains a distribution box, a sweep scale panel, a sweep and modulator supply panel, a panel of +300, +5 and -9 volt rectifiers, a panel of +150 and -150 volt rectifiers as well as the synchronizer panel.

The distribution box serves for electrically connecting the radar assemblies which are located in different units as well as the electrical interconnection of all of the units to each other. The complement of the box includes the following: the connecting circuitry with the output plugs, the power switching circuit, a portion of the azimuth (bearing) marker generating circuit, thermal time delay relay, filter capacitors for the sweep and modulator power supply rectifiers as well as a fan for ventilating the unit.

The sweep scale panel is intended for switching the circuits which generate the sweep scale. The +27 v voltage from the SCALE switch, located in unit L5, is fed to the windings of one of the relays, which connects the appropriate sections of the scale choke in the sweep generator circuit.

The BPRM modulator and sweep power supply panel (block) is intended for supplying a DC voltage of 80 to 150 volts for the indicator sweep as well as the modulator. It consists of the sweep supply rectifier, the modulator supply rectifier and the current protection. The sweep supply rectifier is designed in a bridge circuit using 2D202Zh diodes. The modulator supply rectifier is likewise designed in a bridge circuit using 2D202Zh diodes. The current limiting circuitry protects the components of the sweep and modulator circuits when the permissible current values of the load are exceeded.

The +150 and -150 volt rectifier panel contains rectifiers designed in a semiconductor bridge configuration.

The +300, +5 and -9 volt rectifier panel contains a +300 volt rectifier in a bridge configuration with an electronic regulator using 6S19P-V, 6Zh5B-V and 6G5B-V vacuum tubes using a KTs402Zh rectifier; the +5 volt rectifier is a full wave rectifier using a KTs402I rectifier with regulation provided by a D815A zener diode. The -9 volt rectifier is likewise designed in a full-wave configuration using a KTs402I rectifier with regulation supplied by a D815G zener diode.

The synchronization panel contains a locking oscillator designed around a 6N17B-V vacuum tube operating in a self-oscillating mode. The blocking oscillator synchronizes the operation of the radar units. To compensate for the delay in the modulator, the indicator sweep circuitry is triggered through a delay line LZ. The AFC gain is controlled by means of a potentiometer which regulates the grid bias of the IF amplifier tube of the AFC system.

The monitor and control console (unit L5) includes the monitor, control and fixed and moving range ring marker generator panel. The unit has the following controls: radar power on and off switches, antenna rotation switch, brightness controls for the range marker, PREPARE-OPERATE transmitter on switch and indicator switch, brightness controls for the illumination of the range scales, operational control of the AFC (turning on the AFC, manual frequency control, tuning), range scale switching (scale adjustment), as well as time delay adjustment of the moving range ring and its measurement.

The power inverter (IS-24/27) is intended for converting the 24 or 27 volt DC to 115 volts AC at 400 Hz unregulated with a capacity of up to 230 VA; as well as 115 volts, 400 Hz regulated with a capacity of up to 140 VA. The complement of the IS-24/27 inverter includes: the power unit, the master oscillator, the control unit, the AC voltage regulator, the 27 volt rectifier and the ventilation fan.

The power unit takes the form of a parallel inverter (a DC power to AC power converter) using controlled PTL-50-2 thyristor rectifiers with external excitation. The thyristors are controlled (excited) from a GZ-400 master oscillator, which generates square wave pulses with a positive amplitude of 8 volts.

The master oscillator is designed in a push-pull configuration with transformer coupling (a blocking oscillator) using P215 transistors. To improve the frequency stability, power is supplied to the oscillator through a compensation type voltage regulator, the circuit of which employs P213, MP25B, MP104 transistors and silicon D818B and D814B zener diodes.

The BU1 control block consists of an electronic time delay relay and a voltage discriminator. The control unit provides for either local or remote triggering of the inverter, protects the external voltage source and thyristors against a short circuit current, and automatically switches the taps of the output windings of the power transformer in the case of a considerable change in the supply voltage.

The 27 volt rectifier is designed in a bridge configuration using 2D202V silicon diodes. The presence of a 27 volt rectifier with a general supply mains voltage of 27 volts is due to the requirement of isolating the output voltages of the inverter from the supply mains voltage, which increases the operational reliability of the radar.

The ferroresonant regulator is intended for stabilizing the 115 volt, 400 Hz output voltage. Normal operation of the regulator is assured with a load current of up to 1.25 amps. In the case of a greater value of the load current, the output voltage falls off smoothly.

The fan located inside the inverter promotes the maintenance of a constant temperature within the inverter housing.

The IS-110 and IS-220 power inverters convert the DC voltage of the ship's mains at 110 V or 220 V to 115 volts at 400 Hz. The following are generated at the inverter output: 115 volts, 400 Hz unregulated with a capacity of up to 230 VA; 115 volts, 400 Hz regulated, with a capacity of up to 140 VA, and a DC voltage of 27 volts at a power of up to 80 watts. The following are included in the inverters: the power section, the master oscillator, the control block (BU2 for the IS-110 inverter and BU3 for the IS-220), interference protection filters, and AC voltage regulator and a 27 volt rectifier.

The ship mains power rectifier (unit V27) is used to power the "Lotsiya" marine navigation radar from the ship's three-phase AC voltage of 220 V or 380 V at 50 Hz. The unit takes the form of a three-phase rectifier using VKD25-1B silicon rectifiers, and an IS-24/27 power inverter with a DC voltage of 24 or 27 volts.

The ship's mains power regulator (the LS unit) is intended for powering the station from the AC mains voltage at 115 volts, 400 Hz and has the following output voltages: 115 V, 400 Hz unregulated with a capacity of up to 230 VA; 115 V, 400 Hz, regulated with a capacity of up to 140 VA and a DC voltage of 27 V at a power of up to 80 watts. The LS unit contains a power transformer, ferroresonant regulator, and a duty bridge rectifier using 2D202V silicon diodes.

The overall dimensions of the radar units and the values of their weight are given below:

L1	1,481 x 393 x 357 mm; 24 kg
L2	295 x 295 x 397 mm; 12 kg
L3	581 x 352 x 205 mm; 12 kg
L4	264 x 320 x 180 mm; 12 kg
L5	274 x 274 x 133 mm; 3.5 kg
IS-24/27	520 x 370 x 190 mm; 30 kg
V27	520 x 370 x 190 mm; 30 kg
LS	340 x 200 x 165 mm; 7 kg
IS-110	520 x 370 x 190 mm; 30 kg
IS-220	520 x 370 x 190 mm; 30 kg

The "Lotsiya" marine navigation radar is located and installed on a ship taking into account its operational convenience and the specific features of the operation of its units. The L1 unit [antenna] is mounted on a special mast or platform at a height which precludes the possibility of the appearance of shaded sectors and the irradiation of the ship's crew by the electromagnetic field on open spaces of the deck and superstructures. The L3 and L5 units [indicator and control console] are housed in the bridge (near the helm) or in the navigator's compartment. The L3 unit can be fastened to a desk, in a bulkhead or built into the ship control console. The L5 unit should be installed in the immediate vicinity of the L3 unit. The L2 and L3 units can be located in any dry room. The L2 unit should be installed only horizontally. When installing the L4 unit, it is necessary to assure access to the fuses and the COURSE MARKER potentiometer, which are located on the facing deck panel. The IS, V27 and LS units are installed in equipment rooms. It is also permissible to locate these units in the navigator's room and the bridge.

When installing the units, a provision should be made for the capability of free access to the fuses and controls of the units, as well as for opening the covers and the ventilation openings. It is not permissible to place the V27 and LS units in rooms with a corrosive or dusty environment, or to cover them during operation with covers or heat insulating objects. The L2, L3 and L4 units are mounted on type APN shock absorbers while the V27, LS and IS units are mounted on AKSS-10M shock absorbers. The chassis of all of the units should be reliably grounded.

The units are electrically interconnected by means of cables in strict conformity with the marking on the cable plug connectors and the units. The cable from the ship power mains to the inverter or the LS and V27 units is run directly in the ship. All the remaining cables and the matching part of the connector for the inverter and the LS and V27 units are supplied as part of the radar package. The length of the cable from the L1 unit to the L3 and from the L3 to the L4 should be minimal. Otherwise, there is the danger of distortion of the sweep on the 0.5 mile range scale.

The waveguide channel is composed of standard waveguide sections. The quantity and designation of the waveguides are stipulated when ordering. The number of bends in the waveguide line should be no more than five. The maximum length of the waveguide channel should not exceed 10 m.

It is recommended that the "Lotsiya" marine navigation radar be controlled and its operating modes checked in the following order.

The ON-OFF toggle switch on the control console is set in the "On" position. The green light comes on in this case on the control console. After one minute, the main supply voltages for the radar are checked with the meter: +115, +27, -150, +300, and +150 volts, for which the CHECK switch is set in the appropriate positions. After two to four minutes, the presence of the sweep and modulator voltages is checked. If these voltages fall in the nominal range (are within the specified sectors of the meter), then the PREPARE - OPERATE toggle switch is set in the "Operate" position, while the CHECK switch is set in the "TM" position. In this case, a red light should come on, on the control console, while the magnetron current should correspond to the nominal value.

By continuously rotating the BRIGHTNESS control on the indicator in a clockwise direction, a clear-cut sweep line is set on the CRT screen. By rotating the

MARKER BRIGHTNESS control on the control console, bright fixed range ring marker points are made to appear on the sweep line. By turning the GAIN control clockwise on the indicator, receiver noise is made to appear on the sweep line. Having checked for the absence of foreign objects within the radius of rotation of the antenna, the ANTENNA ROTATE toggle switch on the control console is set in the "On" position. The sweep line on the indicator screen should rotate clockwise in this case.

The SCALE switch on the control console is set sequentially in the "1", "2", "4", "8" and "16" (miles) positions, and by turning the control for the range readout mechanism on the control console, the presence of the moving range ring marker on each range scale is checked. Having set the moving range ring marker at the edge of the CRT screen, the conformity of the scale readings of the range meter to the set scale is also checked.

TABLE 4.1.

Unit in which the Controls Are Located	Designation of the Controls	Initial Position
L5 [control console]	VKL-VYKL [ON-OFF]	Center
L5	PODGOTOVKA-RABOTA [PREPARE - OPERATE]	"Prepare"
L5	MASSHTAB [SCALE]	"0.5 miles"
L5	KONTROL' [CHECK]	"115 v"
L5	VRASHCH ANT - VKL [ANTENNA ROTATE - ON]	"Rotate"
L5	APCH - RRCH [AFC - MANUAL FREQ CONTROL]	"Manual freq control"
L5	NASTROYKA [TUNE]	Center
L5	YARKOST' METKI [MARKER BRIGHTNESS]	Extreme left
L5	DAL'NOST' [RANGE]	Any
L5	PODSVET [BRIGHTENER]	Center
L3 [indicator]	USILENIYE [GAIN]	Extreme left
L3	VARU [TIME AGC]	Extreme left
L3	PODSVET [BRIGHTENER]	Center
L3	YARKOST' [BRIGHTNESS]	Extreme left
L3	KURS OTM - VKL [AZIMUTH MARKER - ON]	"Azimuth marker"
L3	MPV - VYKL [MPV - OFF]	"Off"

TABLE 4.1. [cont.]

Unit in which the Controls Are Located	Designation of the Controls	Initial Position
L1 [antenna]	ANTENNA - VKL [ANTENNA - ON]	"On"
LS [regulated ship power supply]	PITANIYE - VKL [POWER - ON]	"Power"
LS	MESTNOYE - DISTANTS [LOCAL - REMOTE]	"Remote"

Notes: 1. The SCALE switch should be turned only after first pressing it.
2. If when the PREPARE - OPERATE toggle switch is set in the "Operate" position, there is no magnetron current or beam sweep on the screen of the CRT, then it is necessary to set the toggle switch in the "Prepare" position, to press and release the SCALE switch and again throw the toggle switch to the "Operate" position.

The SCALE switch is set in the "4 miles" position, and by smoothly turning the VARU [time AGC] control on the L3 unit (the indicator), the presence of shading of the CRT screen in a radius of no less than 3 miles is checked. By successively setting the CHECK switch in the "TK-1" and "TK-2" positions, and by turning the TUNE control, blips from targets are made to appear on the indicator screen in any of the range scales and at the nominal value of the crystal current (within the range of the corresponding sector of the meter). Optimal tuning is maximum image brightness of the pips on the indicator screen from the most distant targets.

The APCh - RRCh [AFC - MANUAL FREQUENCY CONTROL] toggle switch is set in the "AFC" position. In this case, the brightness of the signals returned from the targets should not change on the indicator screen and the crystal current level should not exceed the nominal values when the TUNE control is rotated 90° to the left and to the right of the set value.

To shut the radar down, the PREPARE - OPERATE toggle switch is set in the "Prepare" position. The ON - OFF toggle switch is depressed on the control console and it is set in the "Off" position. The POWER - ON toggle switch on the LS unit is set in the "Power" position (when the radar is equipped with a LS unit).

All of the radar controls are set in the initial position in accordance with Table 4.1 prior to starting the radar up.

Prior to turning on a new radar or following a long term down time, a careful visual inspection is to be made of the radar, the correctness and reliability of the unit connections are to be checked as well as the integrity of the mechanical structures of the housing, the front panels of the units, the presence and conformity of the fuses to the nominal values and the correctness of the joining of the antenna to the waveguide.

When the equipment is provided as a complete package with the IS-24/27 unit in conjunction with the V27 unit, the AUTOMATIC-MANUAL toggle switch in the inverter is set in the "Manual" position. Depending on the ship mains voltage, as well as the length of the cable between the V27 and IS-24/27, it is permissible to switch the 24 - 27 volt toggle switch to the position for which the unregulated output voltage of 115 volts will fall in a range of 115 volts ± 5 %.

The tuning and adjustment of the "Lotsiya" marine navigation radar are carried out when parts and assemblies are replaced which have exhausted their service life, after eliminating defects, etc. The list of checks and adjustments after the replacement of main units, panels, assemblies and parts of the radar is given in Table 4.2 of [11].

The procedure for some of the radar adjustments during operation on board ship is given below.

The antenna is adjusted while the ship is standing at the dock. The following procedure is recommended for the antenna adjustment work. Using an optical sight, the center line of the ship is lined up with any clearly visible reflecting target on the radar screen which is located at a distance of 0.7 to 1 mile. The ANTENNA ROTATE - ON toggle switch on the control console is set in the "Antenna rotate" position while the SCALE switch is set in the "1 mile" position. By turning the antenna manually, a return from the selected target is made to appear on the sweep line.

Rotating the POINTER [azimuth pointer] control on the L3 unit, the mechanical line of sight is matched to the zero graduation on the azimuth scale of the indicator. The cover on the antenna assembly is opened up, the fastening screws for the rotating transformer are loosened and the sweep line on the PPI screen is made to match the mechanical sighting line by means of rotating the rotating transformer housing. Then the housing of the rotating transformer is secured with the screws and the drive section is pressed down until it engages the gear wheel. The AZIMUTH MARKER ON toggle switch on the L3 unit is set in the "On" position. The antenna horn is rotated in a small range from the zero position, and by rotating the shaft on its axis, the electronic azimuth marker is made to match the mechanical sighting line. One is to make sure that the target marker appears precisely on the electronic course marker. The antenna cover is closed and the screws are tightened down. The ANTENNA ROTATE - ON toggle switch on the L5 unit is set in the "On" position and the matching of the azimuth marker with the zero graduation of the azimuth scale of the indicator and the target located on the midline of the ship is checked once again.

The operation of the controls is checked by switching the appropriate controls of the radar in operation. In this case, the correct output of instructions and response of the radar circuit components should correspond to each position of the controls.

The time the high voltage has been turned on is checked by simultaneously throwing on the ON-OFF toggle switch on the control console and the second meter. The CHECK switch is set in the "sweep voltage" position. The second meter is turned on at the moment the sweep voltage appears. The warm-up time should fall in a range of 2 to 4 minutes after turning the station on.

TABLE 4.2

Units, Panels or Components Being Replaced	Checks and Adjustments
Unit L1 [antenna]	Check and adjust the sweep amplitude, align the antenna, as well as the position and amplitude of the azimuth marker.
Unit L2 [transceiver], klystron, magnetron	Check and adjust the magnetron current, the crystal current, the radar range or sensitivity, the AFC system and the tuning of the local oscillator.
Unit L3 [indicator]	Check and adjust the sweep amplitude, the tracking precision of the sweep line, the range scales and the time AGC.
Unit L4 [power supply]	Check and adjust the magnetron current, range scales, sweep amplitude and AFC system.
Unit L5 [control console] or the moving range ring panel	Check the calibration precision of the moving and stationary range ring markers.
The power inverter IS and the V27 unit [ship power mains rectifier] or the LS unit [regulated ship power supply]	Adjust the regulated 115 volts and the 400 Hz frequency.
Modulator	Check the magnetron current.
The IF preamplifier and IF amplifier panels	Check the radar range or sensitivity, the action of the time AGC, the AFC system; adjust the blanking pulse.
CRT or deflecting systems	Check the operation of the beam controls, the horizontal sweep line precision, the range scales and the sweep amplitude; adjust the sweep center.
RF front end or protective discharger for the receiver	Check the range or sensitivity of the radar as well as the crystal currents

The corresponding voltages and currents are checked by means of AC and DC volt meters, which are connected to the corresponding jacks of the test box, which are in turn connected to the connector of unit L4 [the power supply]. The voltages should fall in the following ranges: -9 (8.7 to 11) volts; +5 (4.5 to 5.7) volts; -150 volts +1%; +150 volts +3%; +300 volts, ±1%; U_{razv} = 80 to 150 volts; U_M = 80 to 150 volts; 115 volts regulated ±2%; 115 volts unregulated, ±10%; 27 volts ±10%.

In the case of nonconformity of the 115 volts regulated and 115 volts unregulated, one must check the frequency and ripple of the ship power mains voltage. In the case of nonconformity of the +300 volts, one must adjust the REG +300 V potentiometer in the L4 unit.

The adjustment of the sweep brightness and the illumination of the control console and indicator scales is checked by rotating the BRIGHTNESS and BRIGHTENER controls on the indicator in a clockwise direction, as well as the ILLUMINATION control on the control console. In this case, the brightness of the sweep and the illumination lamps should rise smoothly.

When checking the centering of the indicator sweep, the SCALE switch on the control console is set in the "4 miles" position and the ANTENNA ROTATE - ON toggle switch is set in the "On" position. The origin of the sweep should describe a circle, the center of which coincides with the intersection of the pointers on the mechanical scale of the indicator with a precision of 2 mm.

If the displacements of the center exceed the indicated amount, then an adjustment is made, for which the fastening screws for the magnet holder are loosened, the sweep is turned on and the SCALE switch is set in the "4 miles" position. The antenna rotation is actuated. The centering magnet is rotated about its center and about the opening of the pipe with a screwdriver and the origin of the sweep is matched up with the intersection of the azimuth pointer. The clamp screws for the magnet and the fastening screws for the plate are tightened down.

The tracking accuracy of the sweep line is checked by rotating the antenna manually through intervals of 30° each on its azimuth scale and comparing the sweep positions on the indicator screen in this case. The ANTENNA ROTATE - ON toggle switch is set beforehand to the "antenna rotate" position. The mismatching between the antenna position and the sweep line should not exceed 1.7°. In the case of a larger value of the mismatch angle, the system is aligned by rotating the housing of the rotating transformer about its axis. Because of the fact that the axis of the antenna directional pattern, as was noted above, deviates from the normal to the plane of the antenna by 6°, an antenna rotation angle of 6° clockwise is taken as zero on the azimuth scale of the indicator.

The tuning of the radar after replacing the magnetron or klystron when on board ship is accomplished using radar returns by connecting the L2 unit to the waveguide channel through a coaxial waveguide line which is included in the kit of spare parts, tools and accessories [11]. The oscilloscope input is connected to the IF AMPLIFIER OUT radiofrequency connector on the L3 indicator. Synchronization is accomplished from the PULSE BLANKING connector on the front panel of the L2 unit. The TUNE control on the control console is set in the center position, the AFC - MANUAL FREQUENCY CONTROL toggle switch is set in the "Manual Control" position, and the PREPARE - OPERATE toggle switch is set in the "Operate" position. The ZONE potentiometer in the L2 unit is set in the center position.

By turning the mechanical tuning screw of the klystron clockwise from the stop, the maximum number of returns is made to appear on the oscilloscope screen, as well as the maximum amplitude of the returns from the most remote target. In this case, the crystal current level should be a maximum. If when rotating the mechanical tuning screw of the klystron no signals are obtained or the crystal current does not have a maximum value, then the ZONE potentiometer is to be turned and the tuning of the klystron with the screw repeated. It must be kept in mind that when rotating the mechanical tuning screw of the klystron clockwise, two maxima may be observed: the first corresponds to the tuning of the klystron to the working frequency, while the second corresponds to the image frequency.

4.3. The "Mius" Marine Navigation Radar

The "Mius" marine navigation radar is intended for installation on vessels with a registered tonnage of 300 reg. tons and more. The equipment complement of the radar includes the following units: A - the antenna and waveguide assembly, P - the transceiver, I - the indicator, R - the repeater, V - power rectifier, S - the power converter.

Depending on the type of shipboard power voltage, the repeater and power converter units have the following differences: for a DC mains voltage of 110 or 220 volts: R (= 110, 220 volts), S (= 110 volts) and S (= 220 volts); for single phase AC mains at a voltage of 220 volts, 400 Hz: R (220 VAC, 400 Hz), S (220 VAC, 400 Hz); for three-phase alternating current power mains at a voltage/380 volts, 50 Hz: R (3 x 220/380 VAC, 50 Hz). The V unit is used only for a shipboard three phase AC power mair at a voltage of 220/380 V, 50 Hz.

Besides the units enumerated above, the radar set contains: a waveguide channel installation set; a callibrated delay cable; a set of spare parts, tools and accessories; a power switcher; and a GPVMZ-25 multisection type rotary switch. The operational and technical characteristics (parameters) of the radar are given below:

Wavelength, cm	3.2
Transmitter pulse power, KW	7
Pulse sensitivity of the receiver, dB	120
Range scales, miles	0.4, 0.4R, 0.8; 1, 6, 4, 8, 16, 24
Intervals between range rings, miles	0.4/0.2, 0.8/0.2, 1.6/0.4, 4/1, 8/2, 16/4, 24/4
Probe pulse width in microseconds, on the following range scales in miles:	
0.4, 0.8, 1.6, 4	0.1
8, 16, 24	0.3
The pulse repetition rate, pulses/sec, on the following range scales, in miles:	
0.4, 0.8, 1.6, 4	3,000
8, 16, 24	2,000
Receiver bandwidth, in MHz, for pulse widths of:	
0.1	12
0.3	4
Intermediate frequency, MHz	60
Antenna directional pattern width at the half power level, °:	
In the horizontal plane	1.1
In the vertical plane	20
Degree of suppression of the sidelobes, in dB, no worse than	25
Rotational speed (scan speed) of the antenna, r.p.m.	17 ± 2

Maximum error in the determination of the range to targets by means of the moving range ring (pointer), no more than, on the following scales:	
0.4, 0.8, 1.6 miles, in m	65
4.8, 16, 24 miles, in % of the range scale	2.5
Mean square direction (azimuth) measurement error, °, no more than	1
Azimuth resolution on the 1.6 mile scale, degrees, no worse than	1.2
Range resolution, m	25
Minimal detection range for an antenna height of 15 m and a waveguide channel length of 10 m, in meters	30
Maximum target detection range, in miles:	
Ship with a displacement of 3,000 tons	10
Average sea buoy without a reflector, 3.2 meters hight	1.8
Maximum error in the transmission of the course angles of the antenna to the indicator sweep system, in °, no more than	1
Diameter of the CRT screen*, in mm	180
Power consumption, in KW, no more than	0.7
Warm-up time for the radar after being turned on, min	4
Operational reliability per failure, in hours	300

The composition of the units of the "Mius" radar is shown in Figure 4.8.

Block P1 in unit P is the modulator; it generates modulated voltage pulses with widths of 0.1 and 0.3 microseconds and an amplitude of 6 KV to control the operation of the magnetron oscillator.

Micorwave (SVCh) block P2 contains an antenna switch, receive (intermediate frequency) and automatic frequency control (APCh) [AFC] mixers, a K-94 klystron local oscillator and other components needed for the transmission, reception and conversion of the returns to the 60 MHz intermediate frequency.

Block P3 is the receiver and provides for the amplification of the intermediate frequency pulses, detection, amplification of the video pulses and the transmission of the amplified signals to the video mixer I3.

Block P4, the AFC, maintains the intermediate frequency of 60 MHz of the receiver constant when the magnetron or klystron frequency deviates from the minimum value.

Block P5 is a +27 and ±110 volt rectifier.

Block P6 contains two rectifiers for a voltage of -300 volts and a protection circuit.

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*A lens is used which increases the image size up to 230 mm.

Block P7 consits of +350 volt and +50 volt rectifiers.

Block P8 contains -40 and -12.6 volt rectifiers as well as a voltage regulator.

Block P9 consists of a -100/-150 volt rectifier, a voltage switching relay and a protection circuit.

Block P10 is an analyzer to check the operability of the radar circuitry.

Block P11 is a monotor block.

Block I1 of unit I is the range sweep block of the CRT indicator.

Block I2 generates the fixed range markers (NKD).

Block I3 is the video mixer.

Block I4 is the +14 KV high voltage rectifier for the anode supply of the indicator CRT.

Block I5 contains the elements necessary for range measurements (range pointer) and azimuth measurement (mechanical azimuth pointer) as well as the scale mechanism, the monitor circuitry for the power characteristics of the station, etc.

Block I6 generates the cursor or range ring (PKD) [moving range ring].

The CRT unit contains an 18LM58 cathode ray tube, the deflecting system, focusing system, the electronic beam sweep centering circuitry and the course marker circuit.

PU is the radar operational control console (panel).

The S unit converts the DC voltage of the ship's mains or the output voltage of unit V to an alternating single phase regulated voltage at 220 volts, 400 Hz. When the radar is powered from ship's AC power at 220 volts, 400 Hz, this voltage is regulated and filtered in the S unit.

Unit V contains a -200 volt rectifier, protection circuitry, a monitor circuit, an industrial interference filter and a radar actuating circuit. Block R1 of unit R is a course angle or bearing repeater.

Block R2 performs the function of a mismatch signal amplifier.

Block A1 of unit A is the antenna.

Block A2 is the drive for rotating the antenna. The following subblocks are included in A2: A2/1 is a reducer; A2/2 is a rotating microwave junction; A2/3 is a remote azimuth transmission unit.

Block A3 is a test antenna.

The antenna and waveguide assembly (unit A) is a slotted antenna, and as usual, takes the form of a waveguide horn radiator. The slotted waveguide traveling wave radiator with an array of filters generates the antenna directional pattern in the horizontal plane. The horn shapes the directional pattern in the vertical plane. The probe signal energy is radiated and the return signals are received by means of oblique slots, cut in the narrow wall of a rectangular waveguide with a cross-section of 28.5 x 12.6 mm. An absorbing load of carbonyl iron is fastened at the end of the radiator. The slots are separated from each other by metallic partitions, which form off-mode waveguide filters to suppress the vertical field component. There is a standard flange at the input end of the waveguide. The radiating aperture of the antenna is hermetically sealed with a dielectric plug of PS-4 plastic foam.

To control the antenna directional pattern in the horizontal plane there are three regulating screws, which make it possible to bend the waveguide radiator in the horizontal plane within a certain range. The maximum of the antenna directional pattern is deflected from the normal to the antenna aperture by 6°.

When powered using 110 volts DC, a SL-661 type electric motor is used to rotate the antenna. A SL-661/R type electric motor is used for 220 volts DC. A APN-11/2 synchronous electric motor with a short-circuited rotor is used for ship's power that is three-phase 220/380 volts AC at 50 Hz. In the case of ship's power at 220 volts AC, 440 Hz, a SL-661 electric motor is installed in block A2 and powered from the rectifier in the R unit.

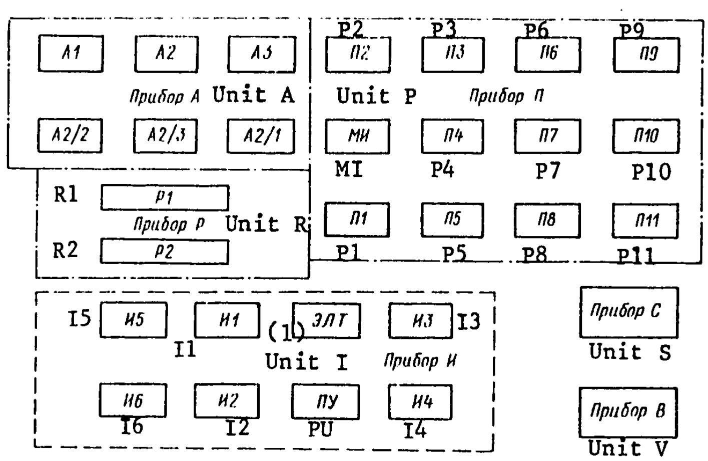

Figure 4.8. The composition of the blocks of the "Mius" marine navigation radar unit.

Key: 1. Cathode ray tube;
Unit A = antenna and waveguide assembly;

Key [cont.]: Unit P = transceiver;
Unit R = repeater;
Unit I = indicator;
Unit S = power converter;
Unit V = power rectifier.

[See text for detailed key]

The rotating coupling A2/2 is used to join the rotating antenna to the stationary waveguide line. The transmitter energy excites oscillations in the coaxial line through the rectangular waveguide. The center conductor of the line is the exciting stub for the waveguide which is coupled to the antenna. The ball shaped end of the stub makes it possible for a specified frequency spectrum to pass through the rotating junction.

The angular position of the antenna (A2/3) is transmitted to the R unit by means of a 5BVT rotating transformer, which is coupled by a gear transmission to the antenna shaft. To check the precision of the tracking system and the antenna adjustment, a removable scale mechanism with a rotation scale of 10° and scale graduations of 0.1° is installed in the A2 unit. To generate the course marker, a special contact device is mounted on the antenna shaft: an attachment in the form of a contact drum with two brushes, which make contact once per antenna revolution and switch a circuit which drives the course marker on the CRT screen.

A test antenna (block A3) is used to monitor the power characteristics of the radar. It is made in the form of a pyramidal hermetically sealed horn, fastened by means of a bracket on the antenna rotation drive housing. The dimensions of the horn aperture and its position relative to the main (slotted) antenna are chosen so that the attenuation in the antenna--horn space amounts to 29 dB. In order to assure the requisite delay of the monitor signal relative to the probe pulse, block A3 is coupled to the transceiver (unit P) by a calibrated delay line (cable) of fixed length.

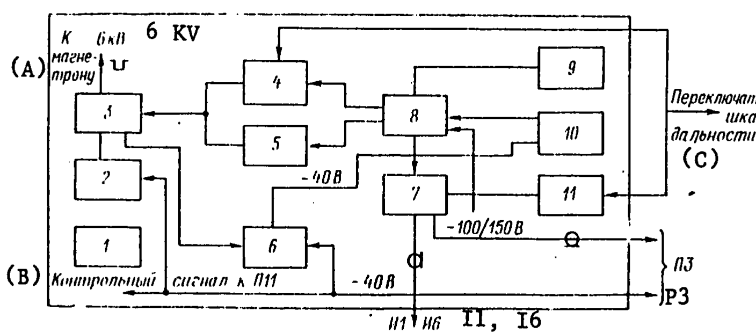

Figure 4.9. Block diagram of the modulator.

Key: A. To the magnetron;
B. Monitor signal to P11 [monitor block of the transceiver];
C. Range scale switch.

The "Mius" radar transmitter consists of a modulator (block P1) and a type MI-507 magnetron oscillator. A block diagram of the modulator is shown in Figure 4.9. The modulator is designed using a thyristor-magnet configuration (a magnetic modulator). The modulator complement includes: master oscillator 10, the converter and first pulse compression stage 8, the second compression stage 5 for the generation of modulating pulses with a width of 0.1 μsec, stage 4 for generating 0.3 μsec pulses, sync pulse generator 7, pulse transformer 3, relay 11 for switching the pulse repetition rate, pulse voltage divider 2, protective relay 6, interference filters 1 and magnetron current control circuit 9.

The master oscillator generates positive voltage pulses to trigger the converter stage of the magnetic modulator. It consists of a self-excited transistor blocking oscillator, a slaved blocking oscillator and an emitter follower using two transistors connected in parallel.

The converter stage and the first compression stage convert the -100/150 volts DC of the power supply to positive pulses with a width of about 1μsec. In the case of operation on the 0.4, 0.8, 1.6 and 4 mile range scales, the pulses are transmitted from the first compression stage to the second and compressed to a width of 0.1 μsec. The resulting pulses are fed to a pulse transformer, stepped up to a voltage of 6 KV, and having a negative polarity, are applied to the magnetron cathode. When the radar operates on the 8, 16 and 24 mile range scales, the pulses are fed from the first compression stage to the shaping circuit (stage) by means of a long line, which creates voltage pulses at the output with a width of 0.3 μsec, which are transmitted to the pulse transformer input.

The sync pulse generating circuit triggers the sweep block I1 (of the indicator), the range cursor generation block I6 and the time AGC generating stage, block P3. The magnetron current regulating circuit provides for a continuous change in the magnetron current in a range of from 1 to 1.5 mA. The protection relay which actuates if the magnetron current exceeds the nominal value by approximately three times serves to protect block P1 against a short circuit in the magnetron. The pulse repetition rate switching circuit (relay) changes the repetition rate: the repetition rate and width of the probe pulses as a function of the selected range scale of the indicator.

Microwave block P2 includes the following: a ferrite circulator, which in conjunction with a gas discharger, forms the antenna switch; the converter for converting the microwave returns to the 60 MHz intermediate frequency; the converter for the difference frequency between the magnetron and the klystron local oscillator to control the AFC circuit. A block diagram of the P2 block is shown in Figure 4.10. The microwave oscillations generated by the magnetron are fed to unit A (the antenna) through a directional coupler and a ferrite circulator. The directional coupler is made with crossed waveguides which are coupled at the common wall. The ferrite circulator contains two 120 degree tees, which form four arms, which route the magnetron power to the antenna in the "transmit" mode. The receiver is protected against the high power magnetron pulses by a broadband RIl discharger with a firing electrode to which a voltage of -600 volts is fed. When the radar returns are received, the energy is routed by the circulator into the receive channel. The isolation between the transmit and receive channels of the circulator is 20 dB. The energy losses during transmission amount to no less than 0.5 dB and less than 1 dB during reception. The effect of spurious signals on the receive channel is eliminated by means of an electromagnetic shielding shutter which automatically shorts the waveguide line when the radar is switched off.

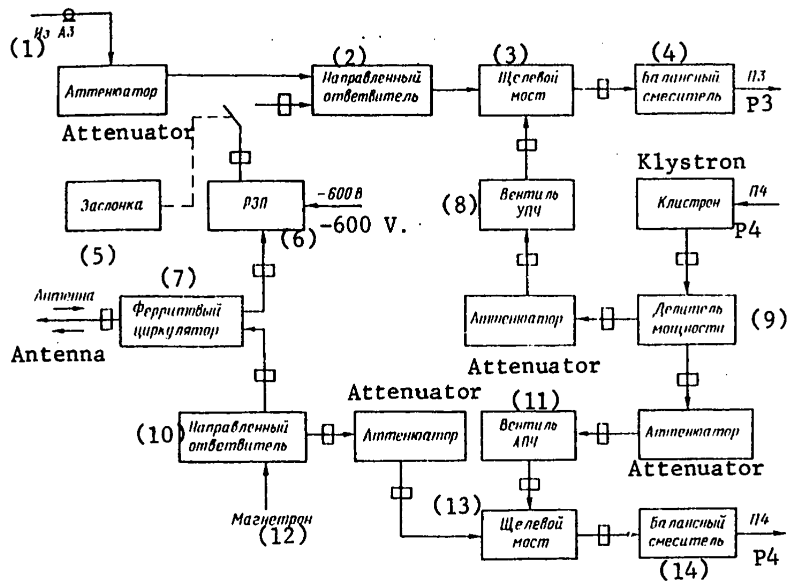

Figure 4.10. Structural configuration of block P2.

Key:
1. From A3 [test antenna];
2. Directional coupler;
3. Slotted bridge;
4. Balanced mixer;
5. Electromagnetic shielding shutter;
6. Receiver protection discharger;
7. Ferrite circulator;
8. Intermediate frequency amplifier isolator [sic];
9. Power divider;
10. Directional coupler;
11. AFC isolator;
12. Magnetron;
13. Slotted bridge;
14. Balanced mixer.

The received radar returns are fed from the ferrite circulator through the open receiver protective discharger RZP, the directional coupler and the slotted bridge to a balanced mixer. The output of the K-94 klystron is also fed to this same point through a power divider, attenuator, ferrite isolator, intermediate frequency amplifier and slotted bridge. The 60 MHz intermediate frequency is fed from the output of the balanced mixer to block P3 of the receiver for amplification.

The local oscillator output is simultaneously fed through the power divider, attenuator, ferrite isolator of the AFC and the slotted bridge to the balanced AFC mixer. The attenuated output of the magnetron is also fed to this same point through the directional coupler, attenuator and slotted bridge. The difference frequency between the klystron and magnetron, which appears at the output of the AFC mixer, is transmitted to unit P4, the automatic frequency control circuitry. The requisite isolation is achieved between the AFC and IF amplifier mixers by inserting ferrite isolators. In the "monitor" operating mode, an electromagnetic shielding shutter is used to block the receiver channel against magnetron probe pulses getting through to the IF amplifier mixer, where these pulses leak through the RZP receiver protection discharger. The signals from the monitor antenna (block A3) are fed through the attenuator and slotted bridge to the input of the IF amplifier mixer.

The receiver (block P3) contains the input circuit for matching to the mixer, a multistage intermediate frequency amplifier, which is broken down into linear amplifier stages and has a logarithmic gain response; a video amplifier, a differentiating network (differentiator), and an emitter follower. Moreover, the complement of the receiver includes the following: a time AGC circuit, a stage for monitoring the feed of the signal to the monitor block, a switching circuit for actuating the differentiator, switching the IF amplifier bandwidth and switching the time constant of the differentiating network.

To reduce the noise, the receiver front end is designed around a 6S51NV nuvistor triode. The second and third stages use 6E12NV nuvistor tetrodes. All three stages operate in a linear mode. The receiver bandwidth is varied in the second stage. When working with 0.1 μsec pulses, the bandwidth of the IF amplifier is 20 to 25 MHz. When the pulse width is 0.3 μsec, the IF amplifier bandwidth is reduced down to 5 to 7 MHz. The remaining 10 IF amplifier stages have a logarithmic amplitude response and are designed in a circuit for the sequential addition of the detected pulses in a summing delay line. All of the stages of the logarithmic IF amplifier have a dual resonant circuit configuration similar to the first three stages and are designed around 6E12NV nuvistor tetrodes. The signals from the output of the IF amplifier are fed to a two stage video amplifier, which in addition to amplifying, differentiates the video pulses and transmits them to unit I, as well as feeds out negative polarity video pulses to the monitor system.

The automatic frequency control block P4 includes the following: three intermediate frequency amplifier stages, a discriminator, an emitter follower, a video preamplifier, a first channel amplifier and peak detector, a second channel amplifier and peak detector, a AFC test oscillator, as well as a klystron tuning panel. The first two IF amplifier stages use 1 T313V transistors in a two tuned circuit configuration. The third IF amplifier stage has a single tuned circuit configuration using a transistor of the same type. All three IF amplifier stages are looped by negative feedback.

The phase discriminator is designed around D18 diodes. The emitter follower uses a P416B transistor and matches the high output impedance of the discriminator to the low input impedance of the video preamplifier which uses a P416B transistor also. Following conversion in the AFC mixer, the difference frequency between the magnetron and the klystron is amplified by the IF amplifier stages and is fed to the discriminator. If this frequency differs from the intermediate frequency (60 MHz), then error signal video pulses will appear at the discriminator, the amplitude and polarity of which depend on the magnitude and sign of the deviation of the difference frequency from the nominal value.

The error signal pulses are fed from the discriminator output through an emitter follower to the input of the video preamplifier. Following preamplification, depending on the polarity, the video pulses are fed to a particular main amplifier channel which uses MP25B transistors, are detected by the appropriate peak detector, converted to a positive or negative polarity DC voltage depending on the error sign and are used to control the frequency of the klystron local oscillator. The AFC test oscillator generates a period sequence of radio pulses modulated at frequencies of 54 and 66 MHz, which correspond to the maxima of the discriminator characteristic. These RF pulses are fed to the input of the AFC block along with the difference frequency between the magnetron and the klystron, and produce a control voltage of about 24 volts at the output of the AFC block, which is monitored by metering instruments in the P11 block.

There are five blocks of rectifiers incorporated in unit P.

Block P5 contains the 110 and +27 volt rectifiers. The first of them is designed in a bridge circuit configuration using D231 diodes and is designed for a load current of up to 0.3 amps. The +27 volt, 1.21 amp rectifier is likewise designed in a bridge circuit using D231 diodes, and is equipped with a capacitive filter for smoothing the rectified voltage ripple. A 115 volt, 400 Hz voltage is likewise picked off from the output of block P5 to power the electric clocks.

Block P6 has the following rectifiers: -300 volts, 0.05 amps; -500 volts, 0.0001 amps; -420 volts, 0.006 amps; -500 volts, 0.006 amps. On the whole, block P6 takes the form of two series connected -300 volt rectifiers, designed in a bridge circuit using D211 diodes. A voltage divider is used to obtain the -420 and -500 volts. The existing protection circuit disconnects the -300 and 220 volts, 400 Hz from a number of circuits when the -420 and -500 volts is lost.

Block P7 has the following rectifiers: +400 volts, 0.007 amps and +50 volts, 0.215 amps. The +400 volts is obtained by means of the series connection of the 350 and 50 volt rectifiers. Both rectifiers are designed in a bridge circuit configuration and use D226 and D211 diodes respectively.

Block P8 consists of -40 volt, 0.6 amp and -12.6 volt, 0.25 amp rectifiers. Both rectifiers are designed in a bridge circuit configuration using D231 diodes and have compensation type regulators for the rectified voltage with the regulating and amplifying elements connected in series.

Block P9 takes the form of a -100 volt, 0.61 amp or -150 volt, 0.42 amp rectifier. The voltages are switched by means of a special relay in the rectifier circuit and the switching depends on the modulator operating mode (block P1). The rectifier is designed as a bridge circuit using D235B diodes. It has a special circuit for overload protection. The operational monitoring of the P3 block is accomplished using the voltages fed to the radar monitor system.

The operational analyzer for the blocks (block P10) monitors and analyzes the operability of the P1, P3, I1, I2, I3 and I6 blocks and feeds out GOOD signals to monitor block P11. Moreover, block P10 generates the modulating pulses for the AFC test oscillator in block P4.

Blocks P1, I1, P2 and I6 are monitored with respect to the output pulse amplitudes. Under normal operating conditions, the negative polarity voltage pulses being monitored are fed with an amplitude of no less than 1 volt to block P10. The width and repetition rate of these pulses are governed by the range scale and the block being checked.

Blocks P3 and I3 are monitored with respect to the noise voltage level at the block output. Under normal conditions, a negative DC voltage of no less than 0.5 volts is fed to block P10. The check voltage is generated by means of transducers and normalizers in the appropriate blocks, with the exception of block P1. The check pulse for this block, the amplitude of which should be no less than 30 volts, is normalized in block P11. As can be seen from the functional block diagram, the check pulses of the blocks are are fed to an emitter follower and expander through a functional block fault detector. The emitter follower, along with eliminating the influence of the input impedance of block P10 on the blocks being monitored, expands the width of the pulses being checked out to 5 μsec. The negative polarity pulses from the output of the emitter follower are fed to an amplitude gate. The gate generates and feeds from its output negative voltage pulses with a width of no less than 5 μsec, given the condition that the amplitude of the pulses of the blocks being monitored is no less than the specified level. The gated pulses are then fed to the normalizer, which generates negative voltage pulses with a width of 15 to 20 μsec and an amplitude of about 6 volts.

The normalizer pulses are converted in an integrator to a DC voltage which powers a relay winding. When the relay actuates, the power circuit for the GOOD signal light is closed in P11, the unit which signals the good operating condition of the blocks. The DC voltage is also monitored through the fault search unit (P11), from which the DC voltage is fed to the converter. The converter, which is controlled by a master oscillator, generates a negative pulse voltage with a width of 3 μsec at a repetition rate of 4,000 pulses/sec and an amplitude proportional to the DC monitor voltage.

The voltage pulses are fed from the output of the converter through block P11 to the input of the emitter follower-expander, and then, just as in the preceding case, through the amplitude gate, normalizer, and the integrator to the signalling indicator for good operating condition of the blocks (P11).

A self-checking mode is provided in block P10. For this purpose, a negative DC voltage of about 0.5 volts, which is the monitor voltage, is fed from the self-checking signal generating circuit through block P11 to the converter. The subsequent signal path for the check signal is similar to that for the operation of blocks P10 and P11 when checking the DC voltages.

The modulating pulses to control the test oscillator of the AFC block are generated by a special generating circuit to which positive voltage pulses are fed from the master oscillator. Structurally speaking, the P10 block is made on a printed circuit board, enclosed in the base housing made of sheet aluminum alloy. Sockets are located on the side walls of the housing for checking the block supply voltages, the DC voltages of blocks P3, I3 and self-checking as well as the pulsed voltages of blocks P1, I1, I2 and I6. Block P11 (the monitor panel) is structurally made in the form of a panel of plexiglass, on which the meters, switches and other elements are mounted. Block P11 monitors the operability of blocks P4-P9 and I4, and also indicates the operability of all of the replaceable blocks and certain assemblies in the radar. The switching of the parameters of the assemblies and blocks being monitored is accomplished by means of manual contact switches. The operable condition indicators for the P1, I1, I2, I3 and I6 blocks are light indicators using special lamps. The operability indicators for blocks P4-P9 and I4, as well as for the magnetron, klystron, discharger and IF amplifier and AFC crystals are meters.

Block I1 of unit I (the indicator) is the sweep unit (Figure 4.11). It generates the following: the range sweep current pulses, the forward sweep trace brightening voltage pulses; and the I2 block triggering control voltage pulses. The width of the indicated pulses is determined by the range scale and is shown in Table 4.3.

TABLE 4.3.

Range Scale Шкала дальности, мили Miles	Длительность импульсов, мкс Pulse Width, microseconds	(1) Частота следования импульсов, имп./с
0,4P, 0,4, 0,8	12	3000
1,6	22	
4	51	
8	100	2000
16	200	
24	300	1000

Примечание. Амплитуда импульсов подсветки прямого хода развертки положительной полярности составляет 20 В; запуска блока И2 отрицательной полярности — не менее 9 В; контроля — не менее 1,5 В.

Note: The amplitude of the positive forward sweep trace brightening pulses is 20 volts; the block I2 negative polarity triggering pulses are no less than 9 volts; the monitor pulses are no less than 1.5 volts.

Key: 1. Pulse repetition rate, pulses/sec.

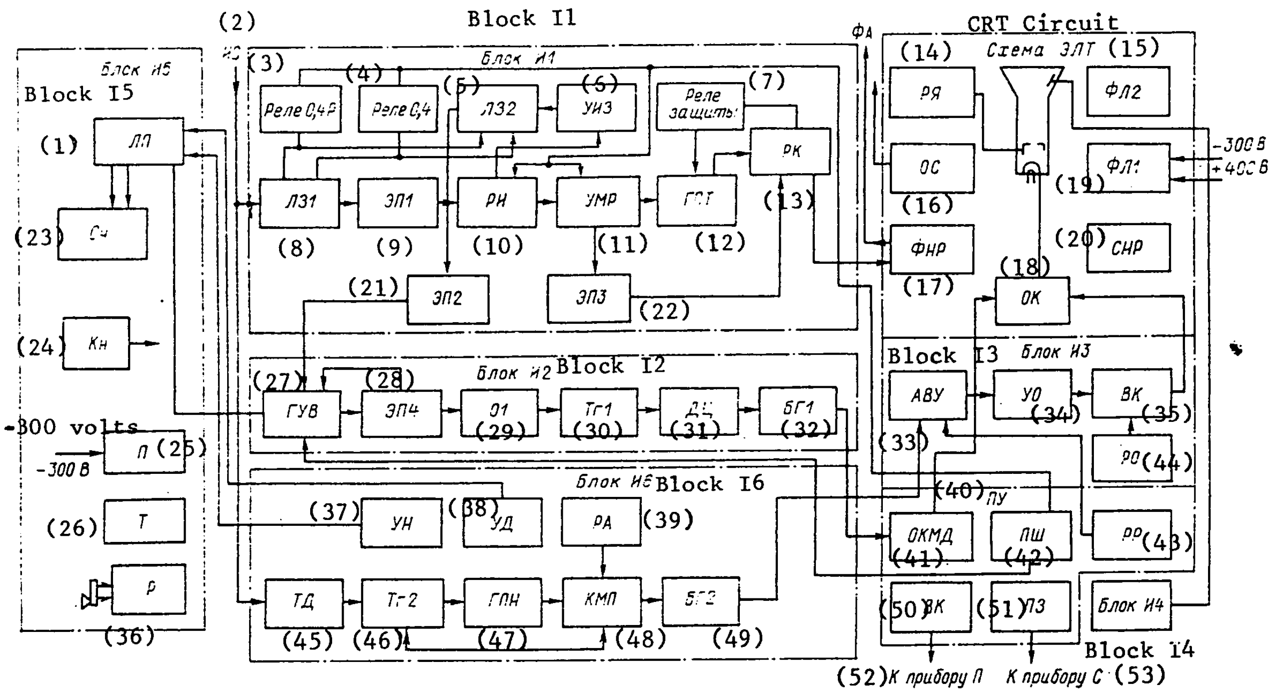

Figure 4.11. Block diagram of unit I.

Key:
1. LP = linear potentiometer;
2. IS = sync pulses;
3. 0.4 R [range switching] relay;
4. 0.4 relay;
5. LZ2 = delay line 2;
6. UI3 = pulse amplifier 3;
7. Protection relay;
8. LZ1 = delay line 1;
9. EP1 = emitter follower 1;
10. RI = pulse expander;
11. UMR = sweep power amplifier;
12. GPT = sawtooth current generator;
13. RK = switching relay;
14. RYa = brightness control;
15. FL2 = electron beam focusing element 2:
16. OS = deflecting system;
17. FNR = sweep origin clamp circuit;
18. OK = deflecting coils;
19. FL1 = focusing element 1;
20. FNR = sweep origin shift elements;
21. EP2 = emitter follower 2;

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Key [cont.]:
22. EP3 = emitter follower 3;
23. Sch = (range pointer) counter;
24. Kn = [power parameter test] pushbutton;
25. P = potentiometer;
26. T = toggle switch [ANTENNA ROTATE - OFF];
27. GUV = shock excitation oscillator;
28. EP4 = emitter follower 4;
29. O1 = limiter 1;
30. Tg1 = Schmidt trigger 1;
31. DTs = differentiating network;
32. BG1 = Blocking oscillator 1;
33. AVU = antilogarithmic video amplifier;
34. UO = limiting amplifier;
35. VK = circuit for turning the radar on and off;
36. R = reducer;
37. UN = zero set control;
38. UD = maximum range set control;
39. RA = amplitude control [for the output pulses of the blocking oscillator];
40. PU = control panel;
41. OKMD = circuit for turning on the range and course markers;
42. PSh = scale switch;
43. RR = discrimination control [resolution];
44. RO = [expansion unknown];
45. TD = transformer differentiator;
46. Tg2 = Schmidt trigger 2;
47. GPN = sawtooth voltage generator;
48. KMP = comparator;
49. BG2 = blocking oscillator 2;
50. VK = circuit for turning on the radar;
51. PZ = interference protection circuit;
52. To unit P;
53. To unit F.

The synchronizing pulses, IS, are fed from block P1 through delay line LZ1, emitter follower EP1 using a 27301A transistor to the pulse expander RI: a multivibrator designed around P416B transistors. The control pulses are fed from the multivibrator output to trigger pulse amplifier UIZ of block I2 designed around a MP10A transistor, as well as to the sweep power amplifier UMP which uses P605 transistors. The amplified pulses are then fed to the sawtooth generator GPT for the 0.4R and 0.4 mile scales as well as the sawtooth generator for the 0.8--24 mile scales. The resulting sawtooth current is fed from the output of both generators through the switching relay RK of the output stages, the circuit for clamping the sweep origin FNR and the antenna phase shifter FA to the deflecting system of the CRT, which consists of two mutually perpendicular windings.

Block I2 for generating the stationary range markers (rings) is controlled by the triggering pulses of the multivibrator through a trigger pulse amplifier UIZ, the delay line LZ2 and emitter follower EP2. These pulses are fed to the shock excitation oscillator GUV designed around a MP10A transistor, which generates a sinusoidal voltage, the frequency of which is determined by the range scale. This voltage is fed through emitter follower EP4 using a

MP10A transistor and limiter O1 using a D311A [diode] to Schmidt trigger Tg1, which is designed around P416 transistors. The rectangular voltage pulses generated by the Schmidt trigger, are differentiated (by means of the DTs [differentiating network]), and the peaked negative pulses trigger the slaved blocking oscillator BG1 designed around a P416 transistor which generates the stationary range markers.

Block I3 is a video mixer and consists of an antilogarithmic video amplifier AVU using a 2T301D transistor; the limiting amplifier UO uses a 2T301D transistor and the output stage VK is designed around 2T301D transistors. Block I3 generates the antilogarithmic amplitude response for the video signals, amplifies, limits the RO [expansion unknown] and feeds the signals to the CRT along with the course marker signals OK, and mixes the video signals with the stationary range marker (NKD) pulses and the range cursor pulses (PKD).

The control panel PU contains the following: the OKMD circuit for turning on the course and range markers; the scale switch PSh; the discrimination control circuit RR; the circuit for turning on the interference protection PZ and the circuit for turning on the radar VK.

Block I4 takes the form of a +14 KV high voltage rectifier to supply the second anode of the CRT. The rectifier is designed as a voltage tripler using selenium TVS-7-19M rectifiers.

Block I5 is intended for the readout of the angular coordinates (bearings and course angles) as well as the range to targets. The block contains a system of two scales: stationary with divisions of 0 to 360° and moving with divisions of 0 to 180° to starboard and to port; a range pointer counter SCh with a reducer R, which is coupled to a linear potentiometer LP; the ANTENNA ROTATE - OFF toggle switch T; the potentiometer P in the STANDBY P4 mode, and the pushbutton Kn for monitoring the power parameters.

Block I6 generates the voltage pulses for the range pointer with a width of 0.06 μsec and an amplitude of 2 volts, as well as the voltage pulses for monitoring block I6. The block circuitry contains the following: transformer differentiator TD; flip-flop Tg2 using 2T301D transistors; a sawtooth voltage generator GPN using a 2T301D transistor; a comparator KMP using a 2T301D transistor in conjunction with D223A diodes and an output blocking oscillator BG2 using a P416B transistor. The circuit is equipped with the following controls: the amplitude control RA for the output pulses of the blocking oscillator, the maximum range set control UD and the zero set control UN.

The CRT circuitry contains the following: the deflection system OS, the sweep origin clamp circuit FNR, the electron beam focusing elements FL1 and FL2, the beam brightness controls RYa and the components for shifting the sweep origin SNR. As was noted, the deflection system consists of two stationary windings, the magnetic axes of which are shifted through 90° (sine and cosine deflecting coils). The clamping circuit for the sweep origin has two clamping bridges, through which the corresponding windings of the rotating transformer and the deflecting coils OK are coupled together. An armored magnet and a magnetic conductor which encircles the neck of the CRT serve as the elements for shifting the sweep origin. The sweep is centered by rotating the magnet about its own axis. The video pulses of the target returns are fed to the cathode of the CRT through video mixer I3, along with the stationary range marker and electronic range cursor pulses and the course marker voltage pulses. The forward sweep trace brightener pulses and the negative beam brightness control voltage are fed to the CRT modulator.

Unit R relays the antenna angular position data, interfaces the radar with the gyrocompass and controls the orientation of the image on the CRT screen. Block R1 relays the course angle and bearing, and orients the image on the radar screen with respect to course and meridian. Block R2 is the mismatch signal amplifier.

The V unit (power rectifier) is intended for converting the shipboard three-phase 220/380 volts AC at 50 Hz to 220 volts DC to power unit S. The complement of the V unit includes: the circuit for turning the radar on; the main 220 volt rectifier; the protection circuitry when the shipboard power is cut off; the shipboard power mains voltage monitor circuit.

Unit S (the power converter) converts the 110 and 220 volts DC or the 220 volts, 400 Hz AC shipboard power to an alternating regulated voltage of 220 volts at 400 Hz with a sinusoidal waveform. To convert the DC voltage, the unit S contains the following: a master oscillator, a thyristor inverter, an AC voltage regulator, a filter for the fundamental frequency, a circuit for automatically turning the radar on, and a master oscillator monitor circuit (block S1). The following are used in unit S for the conversion of the input voltage of 220 volts AC at 400 Hz: an AC voltage regulator, a fundamental frequency filter, and a circuit for automatically turning the radar on. In both cases, there are industrial interference filters at the input.

When ship's DC power is applied to unit S, the master oscillator of block S1 generates two pulse trains, which are shifted relative to each other by half a period. The pulse repetition rate is 400 to 500 pulses/sec with a width of 300 to 500 μsec; the voltage amplitude is no less than 10 volts. The master oscillator pulses are fed to an inverter, which is designed in a push-pull configuration using thyristors. The rectangular waveform output voltage is fed from the inverter output to a regulator, which uses direct current saturable reactors, is stepped up by an autotransformer and is then fed to the first harmonic filter. The regulated sinusoidal voltage is fed directly to the rectifiers of the first power supply stage and the filament transformers, as well as through the circuit for automatically turning on the radar to the rectifiers of the second power supply stage.

When a ship's voltage of 220 volts at 400 Hz is applied to unit S, the voltage is fed through an industrial interference filter directly to the AC voltage regulator.

The specific features of the operation of the units and their operational convenience is taken into account when setting up and installing the "Mius" radar equipment. Unit A must be installed at a height of no less than 5 m above the waterline, assuring circular scanning of the antenna. One is to avoid hot gases and fuel particles exhausted from a smokestack falling on the antenna. The P and I units are housed in the pilot house or navigator's compartment. Depending on the installation variant, the I unit can be fastened to a bulkhead, on an overhead ceiling or on the deck of the deckhouse. The P unit is to be installed in such a way that the distance from the deck to the upper part of the unit is 1.6 m. Unit S can be placed in any dry room where the spacing from the deck to the upper part of the unit housing is 1.6 to 1.8 m. The spacing between the walls of the units and other ship equipment should be no less than 30 cm, and no less than 80 to 100 cm between the units and a bulkhead of a ship.

The power supply characteristics, overall dimensions and weight are given below:

Unit A	2,430 x 895 x 440 mm; 68 kg
Unit P	464 x 304 x 643 mm; 54 kg
Unit I	380 x 660 x 800 mm; 41 kg
Unit S (220 volts DC)	413 x 239 x 560 mm; 33 kg
Unit S (110 volts DC)	413 x 239 x 560 mm; 33 kg
Unit S (220 volts AC, 400 Hz)	290 x 198 x 428 mm; 15 kg
Unit V	393 x 281 x 573 mm; 38 kg
Unit R (110 volts DC)	366 x 286 x 525 mm; 29 kg
Unit R (220 volts DC)	366 x 286 x 525 mm; 29 kg
Unit R (220 volts AC, 400 Hz)	366 x 286 x 525 mm; 29 kg
Unit R (220/380 volts AC, 50 Hz)	366 x 286 x 525 mm; 29 kg
Unit K (110 volts DC, 220 volts DC)	230 x 380 x 170 mm; 5 kg
Unit K (220 volts AC, 400 Hz)	230 x 380 x 170 mm; 8 kg
Unit K (220/380 volts AC, 50 Hz)	230 x 380 x 170 mm; 5 kg
The cabinet of spare parts, tools and accessories	446 x 455 x 1170 mm; 90 kg
The GPVME-25 multisection type rotary switch	140 x 204 x 145 mm; 1.75 kg
Installation set	30 kg

The control of the "Mius" radar is broken down into the operational control and installation alignment.

The following are done during operational control: turning the radar on and off; turning the range and course markers on and off; adjusting the signal resolution and image contrast; measuring ranges to objects (targets); measuring the course angles and bearings to targets; switching the orientation of the image on the CRT screen; controlling the interference suppression.

Installation alignment and adjustment provides for the following operations: interfacing the radar with the gyrocompass; matching the image to the gyrocompass reading; mechanical and electrical alignment of the klystron; stand-by fine tuning of the klystron frequency; setting the duration of the time AGC; setting the gating level of the time AGC; adjusting the magnetron current; adjusting the illumination brightness of the CRT screen; adjusting the brightness of the range markers; focusing the CRT beam; centering the image sweep on the CRT screen; setting the signal limiting level; adjusting the brightness of the range pointer; zero setting the range pointer; switching the antenna rotation; switching the power feed to the tracking system.

Operational control is realized in the following manner:

1. To turn the radar on, the RADAR ON-OFF toggle switch on the indicator control board is set in the "On" position. In this case, one of the windows with the numbers for the scale and the range markers should light up on the control panel.

2. After 3 to 5 minutes have elapsed, a light with the label TRANSMITTER should light up on the control board of unit I, which signals that the modulators and other circuits of the radar are turned on.

3. While monitoring radar operation, make the following checks:

a) For the presence of range sweep on all scales and its threshold brightness;

b) The presence of noise and signals on the indicator screen as well as the variation in them by adjusting the DISCRIMINATION potentiometer;

c) Matching the centers of the plan position sweep and the azimuth cursor on the indicator screen;

d) The image quality of the range markers (MD) and course marker (OK); the OFF-OK-OK, MD toggle switch is set in the "OK, MD" position; in this case, the course marker should read zero on the stationary scale of the azimuth circle when the image is oriented with respect to the course heading;

e) The presence of the range cursor marker (VD) and its brightness;

f) The system f.r monitoring the power parameters of the radar (KEKh), for which one of the range scales (up to 4 miles) is set, the CHECK POWER CHARACTERISTICS button is pressed, which is located under the cover of the control board on unit I, and one makes sure that a check signal is present in the form of an arc (90° to 140°), positioned at an angle of 180° relative to the line of the course marker and separated from the probe pulse by 1 to 3 mm (to improve conditions for observing the power characteristic monitoring signals, it is recommended that the range marker be turned off);

g) The relative precision in matching the range markers and range pointer by means of comparing (colocating) the range pointer with each range marker (the readings taken from the counter should not differ from the values of the distances indicated by the range markers by more than specified in the radar station data sheet).

4. The image on the PPI screen is matched to the gyrocompass, for which the following is done:

a) The IMAGE ORIENTATION SWITCHING toggle switch is set in the "On Meridian" position;

b) The OPERATE - MATCH TO GYROCOMPASS switch is set in the "Match to Gyrocompass" position;

c) Using a special key, the value of the course heading taken from the gyrocompass repeater or its central unit is set on the course scale in unit R;

d) The OPERATE - MATCH TO GYROCOMPASS switch is thrown to the "Operate" position;

e) The special key is removed;

f) The requisite operating mode is set (with respect to the course heading or the meridian).

5. In the presence of sea wave or atmospheric precipitation clutter, the INTERFERENCE SUPPRESSION AND SIGNAL DIFFERENTIATION toggle switch is turned on. This toggle switch is also turned on where it is necessary to boost the range resolution of objects (targets).

6. The DISCRIMINATION control is used to achieve the most complete and clear image of the returns (from the objects or targets) against the background of noise or interference.

7. The radar set is turned off by setting the RADAR ON-OFF toggle switch in the "Off" position.

The operational status of the radar is monitored and a preventive check of the monitor system is made by means of a built-in test system (VSK) for when the radar set is turned on. The checks are made from the panel of the monitor block P11, which is located on the cover of unit P, in the sequence indicated by the symbols: △1 - △2 - △3 - △4 - △5, going clockwise.

All of the switches on the monitor panel, the switch on the klystron tuning panel of unit P and the switch on the front panel of unit V should be in the extreme left position prior to making the checks. Before making the checks, one must make sure that the fuses at the inputs to the power supplies are good based on the fact that none of the signal lights above the fuses are on in section △1 of the monitor panel. Lights coming on when a fuse is good is evidence of a defective power supply. The location of the defective source is indicated by the lable under the signal lights.

The 220 volt, 200 Hz regulated II shipboard power main, as well as the voltages produced by rectifiers P5 and P9 as well as I4 are to be checked on the monitor panel of unit P, for which the following is done:

a) Set the switch located at the boundary of the △2 - △3 section to the △2 position;

b) By switching the POWER SUPPLY MONITOR control in a clockwise direction, make sure that in all positions, the meter needle of the meter located in 2 , falls within the range of the corresponding colored sector. The location of a defective block is indicated by the lable opposite the control of the POWER SUPPLY MONITOR switch.

Check the operability of the blocks in the △3 section of the radar by rotating the SEARCH switch clockwise. The status of the corresponding block is registered by signal lights with the labels GOOD or BAD. The location of a defective block is indicated by the label opposite the switch control in each of its positions. In the "SK" position of the SEARCH switch, the operability of block P10 is monitored as well as section △3 of block P11. After completing the checks of the blocks, the SEARCH switch is to be set in the initial position "radar operate". The NONOPERATIONAL RADAR MODE display should go out.

To check the operability of block P4, make sure beforehand that when the CHECK BLOCK P4 switch is in the "operate" position, the pointer of the meter located in section △4 , points to zero. By switching the CHECK BLOCK P4 control sequentially to the "check I" and "check II" positions, one is to make sure that the pointer of the meter falls in the range of the right side sector for the "check I" position and the left sector for the "check II" position. The RADAR NONOPERATIONAL MODE display should be on, on the monitor panel. The departure of the meter needle outside the range of a sector signals the defectiveness of block P4. Set the CHECK BLOCK P4 switch in the "operate" position. In this case, the RADAR NONOPERATING MODE display should go out. If the display does not go out, one must check the position of the FREQUENCY TUNE MODE switch on the klystron tuning panel, which should be in the "AFC operate" position.

Check the operability of the individual functional assemblies, for which the following is done:

a) The switch located at the boundary of the △2 and △5 sections is set in position △5 ;

b) By rotating the CHECK ASSEMBLIES (current) switch clockwise, one is to make sure that the pointer of the meter in each switch position falls within the range of the colored sector.

Check the operability of unit V. In the case where the EMERGENCY MODE signal light is on; immediately turn the radar off with the RADAR ON-OFF toggle switch located on the front panel of unit I, and check the ship mains voltage based on the lighting of the signal lamps with the SHIP MAINS ON label. A failure of the lamps to light indicates that voltage is not being fed to unit V from the ship mains.

Check the level of the ship mains voltage in each phase, for which it is necessary to set switch V1 sequentially in the IF, IIF and IIIF positions. In these switch positions, the pointer of the meter should fall within the range of the sector. If this meter does not show readings or the meter needle goes outside the sector limits, one must check the phase voltages at the test jacks G1, G2, G3 and G4 of unit V by means of the 4313 instrument. The voltage level can differ from the nominal value by no more than 10%.

Check that the contactor fuse is good from the failure of the DEFECTIVE CONTACTOR FUSE signal light to come on.

In the absence of sweep rotation on the CRT screen, one is to make sure of the operability of unit R, for which the following must be done:

a) Check for the presence of the power supply voltage of the tracking system of unit R from the lighting of the POWER light. The failure of the lamp to light indicates that the 220 volt, 400 Hz, reg. I voltage is not being fed to unit R from S;

b) Check that the fuse in the 220 volt, 400 Hz, reg. I circuit is good based on the lighting of the 400 Hz, 220 volt signal lamp;

c) Check that the fuse for the drive power rectifier is good from the lighting of the RECTIFIER signal light (for the variant of unit R which is designed for power from a 220 volt at 400 Hz ship power main);

d) Check that the fuses in the antenna motor are good based on the lighting of the ANTENNA MOTOR signal lights;

e) Open the cover of the unit and check the position of the toggle switch in the "amplifier" position;

f) Remove block R2 from the unit and place it with another from the spare parts, tools and accessories kit; if the tracking system does not operate afer R2 is replaced and the sweep line does not rotate, the power circuit of the actuating motor with the marking M5 in block R1 is to be checked, as well as the electrical connections of the rotating transformers in block A2 and R1.

If with a change in the course heading of the ship, the course marker does not move on the screen of the indicator or the scale in unit R remains stationary, one must check the position of the OPERATE - MATCH TO GYROCOMPASS SWITCH. This switch should be in the "operate" position.

4.4. The "Nayada" Series of Marine Navigation Radars

The "Nayada" series of marine navigation radars (SNRLS) consists of four radar sets: the "Nayada-1", "Nayada-2", and "Nayada-4" [sic] with different characteristics and functional capabilities.

The equipment composition of the "Nayada" marine navigation radar series is given in Table 4.4, while the operational and technical characteristics of the radar [8] are given below:

TABLE 4.4

Unit Designation	Unit Code	"Nayada-1"	"Nayada-2"	"Nayada-3"	"Nayada-4"
Antenna with a beam width of:					
1°	A	1	-	-	-
0.7°	A	-	1	1	1
Indicator	I	1	1	1	2
True motion unit	D	-	-	1	2
Transceiver	P	-	-	-	-
Reflective overlay plotting board	N	-	1	1	1
Repeater	R	-	-	-	1
Static converter	S	1	1	1	-
Rectifier	V	1	1	1	-
Portable test meter	K	1	1	1	1
Type ATO and APO electric machine voltage converter		-	-	-	1
Spare parts and accessories	ZIP	1	1	1	1

Wavelength, cm	3.2
PPI sweep frequency, r.p.m.	19
Width of the antenna directional pattern in the horizontal plane, degrees:	
"Nayada-1"	1
"Nayada-2", "Nayada-3" and "Nayada-4"	0.7
The same, in the vertical plane, degrees	20
Diameter of the 31LM5V CRT screen, mm	310
Range scale, miles	0.5, 1, 2, 4, 8, 16, 32, 64
Intervals between range markers, miles	0.25, 0.5, 1, 2, 4, 8, 8
Probe pulse width, microseconds, on the following scales, in miles:	
0.5, 1 and 2	0.07
4 and 8	0.25
16, 32 and 64	0.7
Pulse repetition rate, pulses/sec, on the following scales, in miles:	

0.5, 1 and 2	3,000
4 and 8	1,500
16 and 32	750
64	500
Transmitter pulse power, KW	15
Pulse sensitivity of the receiver, dB/W	120
Switchable bandwidths of the receiver, MHz	14 and 6
Receiver intermediate frequency, MHz	60
Minimum detection range for an antenna height of 15 m and a wavelength of 10 m, no worse than, in m	30
The range resolution on the 0.5 mile scale, no worse, in m	20
Azimuth resolution on the 2 mile scale, in degrees	1.6 or 2.1
Maximum azimuth measurement error, in degrees, using the following pointers:	
Electronic	0.5
Mechanical	1.0
Maximum range measurement error, no more than, on the following scales:	
0.5, 1 and 2 miles, in m	50
The remainder, in percent of the range scale	1.0
Maximum error in the motion of the marker for the radar's own ship in the true motion mode:	
Angular error, in degrees	2.5
Speed error, in percent	5.0
Antenna directional gain, in relative units	1,200 and 1,800
Video amplifier bandwidth, MHz, no less than	12
Width of the range cursor pulses, microseconds	0.07/0.3
Width of the heading cursor on the PPI screen, in degrees, no more than	1
Antenna dimensions, in mm:	
Aperture	2,386-3,427
Sweep radius	1,230-1,760
Maximum waveguide channel length, m	20
Detection range for an antenna height of 15 m, in miles, no less than:	
Of an average sea buoy without a reflector	3.5
A 5,000 ton ship	17
Mean time between failures, hours, no less than	250
Average repair time, minutes, no more than	30
Continuous duty time, hours	24
Radar warm-up time, minutes	4
Power consumption, in KW, no more than:	
"Nayada-1"	1.2
"Nayada-2"	1.3
"Nayada-3"	1.5
"Nayada-4"	2.75

Distinctive features of the "Nayada" marine navigation radars as compared to other modern nonautomated marine navigation radars (the "Lotsiya", Kivach", "Mius") are:

--The capability of displaying the surface situation on the PPI screen both in a relative motion mode (OD) and in a true motion mode (ID);

--The capability of measuring the angular coordinates of targets both with a mechanical and with an electronic pointer with a digital azimuth counter;

--The possibility of operationally displacing the center (origin) of the PPI sweep by two-thirds of the radius of the screen both in the true and relative motion modes, which makes it possible to increase the radar scan range in a selected direction without changing the range scale;

--The capability of solving navigational problems by means of graphical plots on a mirror overlay plotting board (unit N) using the current radar situation which is reflected on it from the indicator;

--Using an interface unit: a repeater (unit R), which provides for the multiplication and generation of interface signals needed for the use of a second display, as well as for interfacing additional indicators of other types and designations;

--The presence of a special de-icer in the antenna rotation drive which reduces the danger of antenna icing under conditions of sharply reduced temperatures;

--Higher range and azimuth resolution because of the shortening of the probe pulse width down to 0.07 microseconds, the narrowing of the antenna directional pattern width in the horizontal plane down to 0.7 degrees and the use of a CRT with improved resolution in the indicator.

As can be seen from Table 4.4, the "Nayada-1" marine navigation radar has an antenna with a directional pattern width in the horizontal plane of 1 degree (a directivity coefficient of 1,200 [front to back ratio]). In contrast to the "Nayada-1", the "Nayada-2" marine navigation radar includes an antenna with a narrower directional pattern in the horizontal plane, equal to 0.7 degrees) a directivity coefficient of 1,800); it is equipped with an overlay mirror plotting board (unit N) for graphical plots under a removable viewing hood; a more powerful electric motor is installed in the antenna rotation drive. The "Nayada-3" marine navigation radar differs from the "Nayada-2" marine navigation radar in the presence of an additional unit: a true motion unit (unit D). In contrast to the "Nayada-3", the "Nayada-4" marine navigation radar has the following: a second indicator which is used as a slaved unit; a second D unit; a repeater (the coupling unit R), which provides provides for the functioning of the second unit. All of the "Nayada" series radars can operate with an "Al'fa" [8] ship collision danger warning unit. The radars are intended for installation on ships with a gross register tonnage of 500 r.p. and higher.

The "Nayada" marine navigation radar can be powered from ship's mains at 110 and 220 volts DC, or with alternating three-phase 220/380 volts at 50 Hz. The units of the radar are powered from static converters (unit S) or from electrical machine sets ("Nayada-4") with a regulated 220 volts AC at 400 Hz. When the radar is powered with 220/380 volts AC at 50 Hz, the radar equipment complement additionally includes a ship power voltage rectifier (unit V).

The antenna rotation motor drive is powered directly from the ship mains through unit I, in which a motor protection block is located (block ZD), which disconnects the power when an excessive overload occurs.

When ordering the equipment, it is recommended that one use the decimal numbers of the "Nayada" marine navigation radar units and assemblies, which are listed below [12].

Unit A with an antenna directional pattern width in the horizontal plane of 1°, for ship's power mains of 110 volts DC is designated by the decimal number LA2092032; for 220 volt DC mains, the number is LA2092033-01; for ship power mains of 220/380 volts AC at 50 Hz, the designation is LA2092033-02.

Unit A with an antenna directional pattern width in the horizontal plane of 0.7° for ship's mains of 110 volts DC is designated LA2092032; for ship's mains of 220 volts DC, it is LA2092032-01; and for three-phase 220/380 volts AC at 50 Hz, the designation is LA2092032-02.

Unit P has the decimal number LA2000010; unit I (console type) is LA2043008; unit I (control panel type) is LA2043018; unit D (console type is LA2300058; unit D (control panel type) is LA200065; unit N is LA2317000; unit S (110 volts DC) is LA3211005G4; unit S (220 volts DC) is LA3211007G4; unit R is LA2300057; unit V is LA3215065G4; and individual ZIP [spare parts, tools and accessories kit] is LA100063; unit K is LA2761088; and the delay cable is LA4350050.

The "Nayada" marine navigation radar has a unit for monitoring the power characteristics and checking that the radar units and assemblies are in good condition.

The "Nayada" marine navigation radar can be interfaced to the "Kurs-3", "Kurs-3M", "Kurs-4", "Kurs-4M", "Kurs-5", "Amur-3" and "Vega" ship gyrocompasses. The "Nayada-3" and "Nayada-4" radars are coupled to MGL-25 and LG-2 logs to provide for a true motion display mode. The coupling to the gyrocompasses is made through BS-404AN and SS-150 selsyns with a rotation scale division of 1°; they are coupled to the logs through BS-404AN selsyns with a scale division of 0.2 knots. The power is supplied to the selsyns from the gyrocompass and the log.

The overall dimensions and wieght of the units are given below:

Unit A (1°)	554 x 2,400 x 833 mm; 73.5 kg
Unit A (0.7°)	554 x 3,430 x 833 mm; 102 kg
Unit I	985 x 526 x 550 mm; 105 kg
Unit D	1,180 x 520 x 305 mm; 61 kg
Unit P	840 x 601 x 390 mm; 92 kg

Unit N	80 x 400 x 400 mm; 5 kg
Unit R	460 x 255 x 139 mm; 7 kg
Unit S (110 volts DC)	795 x 480 x 289 mm; 64 kg
Unit S (220 volts DC)	795 x 480 x 289 mm; 61 kg
Unit V	600 x 443 x 288 mm; 50 kg
Unit K (without bag)	130 x 260 x 130 mm; 2.5 kg
Unit K (with bag)	150 x 400 x 150 mm; 3.5 kg
Spare parts, tools and accessories with unit K	1,430 x 660 x 405 mm; 160 kg

A block diagram of the "Nayada-3" radar is shown in Figure 4.12.

The antenna unit (Unit A) consists of the antenna rotation drive (block PA), the main antenna (block AR) and the monitor antenna (block AK) in a waterproofed design. The main antenna is a slotted type with a horizontally polarized field. The antenna aperture in the horizontal plane for the 0.7° directional pattern is 3,427 mm with a sweep radius of 1,760 mm; for the 1° pattern, it is 2,386 mm and the sweep radius is 1,230 mm. The monitor antenna is made in the form of a sectoral horn with a waveguide to coaxial transition junction. It is rigidly fastened to the housing of the drive by means of a bracket. The antenna rotation drive for all types of radars is standardized, and consists of a reducer which rotates the microwave junction, course angle and course marker transducers and anti-icing heaters. The antenna rotation motor is fastened to the antenna drive on the outside and can be changed to match the ship mains voltage and antenna type. The slot antenna horn is hermetically sealed with a radiotransparent dielectric, made of fiberglass with a wire grid to compensate for the microwave energy reflected from the dielectric. The "Nayada" marine navigation radar antenna is designed for supporting wind loads at wind speeds of 50 m/sec and has an ultimate strength for wind velocities of up to 70 m/sec.

The transceiver (unit P) includes the following: the microwave block, the intermediate frequency amplifier block, the video pulse processing block VI, the microwave generator circuitry (the magnetron oscillator MI), the transmitter modulator block MP, the block of modulator filters FM, the tuning and metering block NK, the automatic frequency control block APCh [AFC], and the power rectifier blocks V1-V4. Besides the blocks enumerated above, the complement of unit P also includes the control circiutry for starting up the transmitter, the circuit for switching the magnetron filament voltage, the voltage monitoring sensors, a fan, an electrical time counter and other components.

Besides the modulating pulses widthds of 0.7, 025 and 0.07 microseconds, the magnetic thyristor type transmitter modulator also generates synchronizing pulses which control the operation of the receiver (the time AGC circuit) and the indicator, as well as the modulator metering pulses. The DC voltage for powering the modulator comes from rectifier VI which is a V-180-240-1 type and which produces a regulated -180 volts at the output for a load current of 0.45 A or -240 volts for a load current of 0.35 A and a stabilization factor of no less than 50.

The microwave frequency generated by the magnetron with the action of the modulating pulses is fed to the microwave block and through a directional coupler and ferrite circulator to the output of unit P. A portion of the probe pulse energy is fed through a directional coupler, attenuator and slotted bridge to the AFC mixer channel and is used for automatic frequency control of the Klystron local oscillator of the receiver. The energy of the received returns is fed from the output of unit A (block AR) to the microwave block, is converted to the 60 MHz intermediate frequency and fed to the IF amplifier block of the receiver, which is designed in a superheterodyne configuration with a logarithmic amplitude response. The detected intermediate frequency signals are fed to the video amplifier block VI, are amplified up to a level of 0.35 to 2.2 volts and fed through an emitter follower via a cable to the video signal mixer block SVS of unit I [the indicator].

The time AGC voltage is also produced in the video pulse processing block, where this voltage can be controlled with respect to pulse width and level, and is then fed to the linear stages of the IF amplifier block.

The signal received by the monitor antenna are fed to the receive channel of the microwave block in the overall radar set operational monitoring mode (KOR). Built in metering of the operation of the magnetron, the klystron, the protective discharger for the receiver (RZP), the IF amplifier and AFC crystals is used in unit P, while the operation of the AFC unit is metered, etc. The monitoring is accomplished by means of a meter built into the tuning and metering block NK using the "go -- no go" principle. Moreover, there are special monitor lights for the fuses in the input circuits of the power supplies for the unit. A portable meter (unit K) is used to check the remaining replaceable blocks and assemblies of unit P. The modulator filter block FM eliminates radio reception interference which arises because of the high power pulse signals of the transmitter. The V-300/600-1 type rectifier V2 powers the klystron circuits, the CRT, the ignition of the receiver protection discharger, as well as the radar actuation and time delay relays. Type VK-12.6/27/50-1 rectifier V3 powers the blocks and assemblies of unit B. Rectifier V4, which is a V-27-3-1, produces a voltage of +27 volts in unit P.

he indicator (unit I) incorporates the sweep generator block GR, the azimuth cursor generator block VN, the range cursor control block UVD, the moving range cursor block PVD, the block for the fixed range markers MD, the video signal mixer block SVS, the sweep coordinator block KR, the block for switching the clamping bridges KMF, the motor protection block ZD, the tracking system amplifier block USS, the output sweep stage VKR, the azimuth cursor VT, the diode bridges for cursor sweep DMV, the image orientation circuitry OI, a type VK-12.6/27/50-2 rectifier V5, which produces a regulated 12.6 volts at the output as well as a regulated +27 volts and an unregulated +50 volts; a type V-15/65-1 rectifier V6 to power the sweep generator with an unregulated voltage of 15, 30 or 65 volts; a type V-15000-10 high voltage rectifier V7 to power the CRT and the V8 rectifier for powering the clamping bridges at +12.6 volts and supplying the CRT with a voltage of +400 volts.

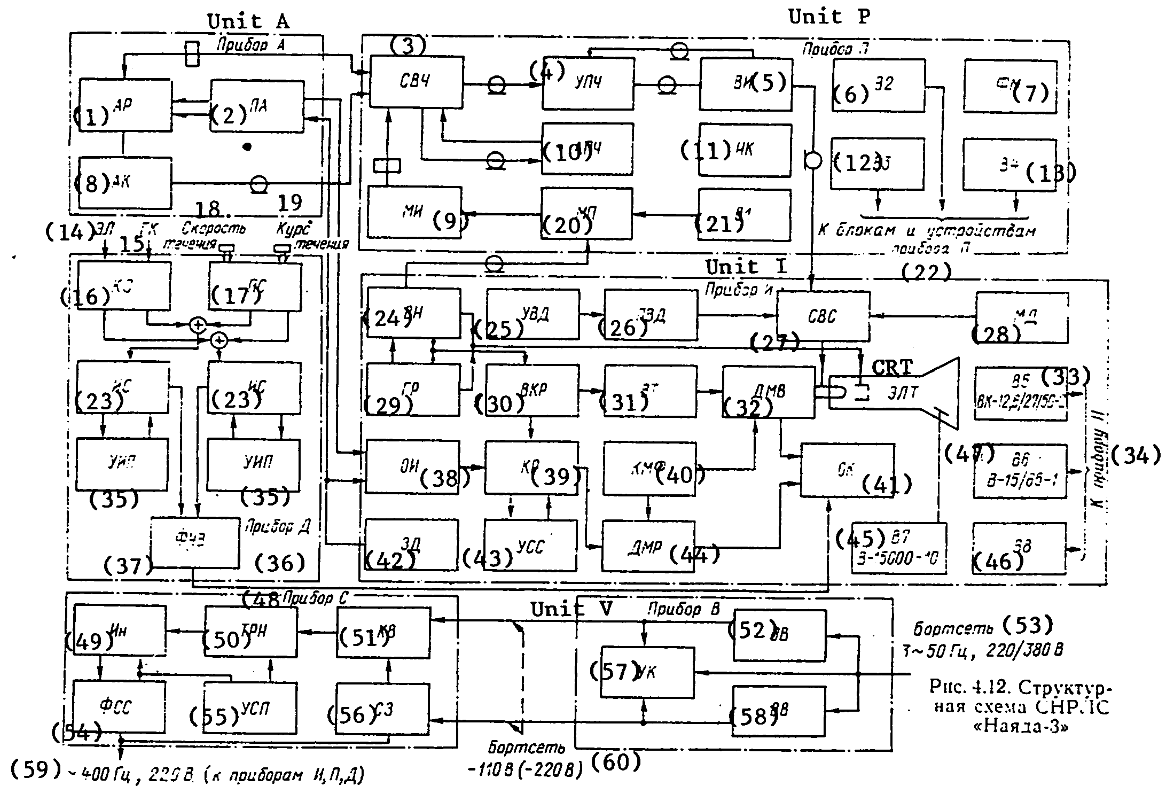

Рис. 4.12. Структурная схема СНРЛС «Наяда-3»

Figure 4.12. Block diagram of the "Nayada-3" marine navigation radar.

Key:
1. Main antenna;
2. Antenna rotation drive;
3. Microwave circuitry;
4. Intermediate frequency amplifier;
5. Video pulse processing circuitry;

[Key to Figure 4.12, continued]:

6. Power supply rectifier 2;
7. Modulator filters;
8. Monitor antenna;
9. Magnetron oscillator;
10. Automatic frequency control;
11. Tuning and metering block;
12. Power supply rectifier 3;
13. Power supply rectifier 4;
14. Electrical log;
15. Gyrocompass;
16. Velocity vector coordinator;
17. Speed correction block;
18. Current speed;
19. Current direction (course);
20. Transmitter modulator;
21. Power supply rectifier 1;
22. To the blocks and devices of unit P [transceiver];
23. Speed integrator block;
24. Azimuth cursor sweep generator;
25. Range cursor control block;
26. Moving range cursor block;
27. Video signal mixer;
28. Stationary range marker block;
29. Sweep generator;
30. Sweep output stage circuitry;
31. Rotating transformer;
32. Cursor sweep diode bridges;
33. Rectifier 5, VK-12.6/27/50-2;
34. To unit I [indicator];
35. Control and tachogenerator feedback difference signals amplifier;
36. Unit D [true motion unit];
37. Phase sensitive rectifier;
38. Image orientation circuit;
39. Sweep coordinator block;
40. Clamping bridge switcher;
41. Defelcting coils;
42. Motor protection circuitry;
43. Tracking system amplifier;
44. Diode bridges for clamping the sweep origin;
45. Rectifier 7, V-15000-10;
46. Power rectifier 8;
47. Power rectifier 6, V-15/65-1;
48. Unit S [static converter];
49. Inverter;
50. Thyristor voltage regulator;
51. Power on-off contactor;
52. Main rectifier;
53. Ship power mains, three-phase, 50 Hz, 220/380 volts;
54. Sine component filter;
55. Static converter control block;
56. Protection circuitry;
57. Monitor circuit;
58. Auxiliary rectifier;
59. 400 Hz AC, 220 volts (to units I, P and D);
60. Ship power mains, -110 volts (or -220 volts).

The synchronizing unit for the radar is a master oscillator, for which a transistorized self-oscillating multivibrator is used which is located in the GR block. This oscillator generates the triggering pulses for the electronic azimuth cursor (EVN) and the transmitter modulator. The synchronization of the circuits for generating the sweep, the moving range cursor markers, the PVD, as well as the stationary range merkers in the "operate" mode is accomplished automatically from the transmitter, while in the "standby" mode, it is accomplished from the master oscillator.

The sweep signal and azimuth cursor sweep are generated using stationary deflecting coils, OK. The indicator circuitry contains two sweep channels, which alternately drive a common output amplifier. The sweep signal pulses are generated in the GR block, while the azimuth cursor sweep pulses are generated in the VN block in the pauses between the signal sweeps.

The sawtooth current pulses of the output stage are split by means of the rotating transformer channels into sine cosine components, which are fed by means of thyristor switches through diode bridges for clamping the sweep origin, DMR, to the deflecting coils. The rotor of the signal sweep rotating transformer is coupled by means of the tracking system to the antenna angular position sensor. The rotor of the rotating transformer channel of the cursor is coupled to the control for the electronic azimuth cursor on the indicator panel, and the angular position of the electronic cursor on the CRT screen is set manually by the operator when determing the direction to a target. The thyristor switches are turned on sequentially for the duration of the forward sweep trace by means of the clamping bridge switcher, the KMF, at the repetition rate of the probe pulses. This provides for the simultaneous and continuous presence of both sweeps on the PPI screen.

The shifting of the sweep center (origin) in the relative motion mode is accomplished by passing a direct current of a particular level and polarity through special stationary deflecting coils for the CRT. The center shift mode is turned on and the direction of the shift is controlled by means of two three-position CENTER SHIFT toggle switches on the indicator. In the true motion mode, the shifting of the image center is continuous to any point on the screen. In the relative motion mode, the image center shifting is accomplished in discrete steps in eight directions on the 1, 2, 4, 8 and 16 mile range scales.

The image is oriented with respect to the course heading or to north on the indicator screen by means of switching the rotating transformer which detects the antenna angular position. In the "North" orientation, the rotating transformer is connected, the rotor of which is turned through an angle equal to the heading of the ship by means of selsyn which is coupled to the gyrocompass.

The true motion unit (unit D) displays a true motion mode (ID) on the indicator. For this purpose, voltages are generated in the unit based on data from the log and gyrocompass which are proportional to the components of the ship's travel in a rectangular system of coordinates with changes in the ship's speed from 0 to 35 knots and the ship's course from 0 to 360°. The current produced by these voltages in the center shift deflecting coils of the CRT moves the origin of the sweep on the indicator screen in the direction of and at a speed proportional to the route vector. The unit provides for moving the sweep origin through two-thirds of the working radius of the screen within a circle having the center in the center of the CRT screen as well as automatically returning the sweep origin to the center of the screen. This operation is accomplished by pressing the RESET button the control panel of unit D. A provision is made in the unit for the capability of manually feeding in the course and speed for making corrections. The true motion mode is automatically cut off when orienting the image with respect to the course or when changing over to the 0.5, 16, 32 or 64 mile range scales. The resolver of unit D is an analog type resolver using electromechanical components.

Unit D contains the following sections: a velocity vector coordinator KS for generating the velocity component of the ship along the N-S and E-W axes and feeding voltages proportional to this velocity; a speed correction block PS, which is needed for making manual corrections for the speed and direction of the current (drift) and feeding out voltages proportional to the components of the corrections for the current velocity along the E-W and N-S axes; a speed integrator block IS, which is intended for generating the component of the ship's route and feeding out voltages proportional to this component; a UIP block, which is the difference amplifier for the difference between the control signals and the tachometric feedback signal in the integrating drive; a phase sensitive rectifier block, FChV, which converts the AC voltages proportional to the components of the ship's route along the N-S and E-W axes to DC voltages of the appropriate polarity.

The ship's speed and course data are entered in the velocity vector coordinator block from the electronic log EL and the gyrocompass GK by means of remote transmission using BS-404NA or SS-150 selsyns. The summing voltages of the velocity vector coordinator and the speed correction blocks are fed to the inputs of the integrating drives in the speed integrator block, which generate the ship's path components along the N-S and E-W axes. These summing voltages are added at the output of each block and compared with the voltage from the tachogenerator which is coupled directly to the shaft of the actuating motor. The difference between these voltages is fed to the control and tachometric feeback difference signal amplifier for amplification up to a power and voltage level necessary for the control of the actuating motor. The rotation angle of the motor's output shaft will be proportional to the time integral of the input voltage. The output shaft of the actuating motor is coupled by a mechanical transmission to the axis of a linear rotating transformer (LVT). Voltages are picked off from the linear voltage transformer rotor winding which are proportional to the components of the ship's travel. After passing through the phase sensitive rectifier blocks, the rectified voltages are fed to the CRT deflecting system true motion windings, which provides for shifting the sweep center (origin) on the PPI screen in the direction corresponding to the ship's heading and at a speed proportional to the ship's own speed.

The static converter (unit S) is intended for converting the DC ship's main voltages to a regulated AC voltage at 220 volts, 400 Hz. The complement of unit S includes: a static converter control block USP; a sine component filter FSS; an inverter, In; a thyristor voltage regulator, TRN; a power switch contactor KV and protective circiutry SZ.

Pulses are generated in the static converter control block which control the operation of the thyristors of the voltage regulator and the inverter. The DC ship's mains voltage, or that from the output of unit V, is fed to the thyristor voltage regulator and to the static converter control block. The regulator operates as a switch. The static converter control block generates three pulse trains which are needed to control the thyristor voltage regulator and the inverter. Two pulse trains, which are shifted relative to each other by one-half of a period of the 400 Hz working frequency, are used to alternately trigger the thyristors of the inverter and control the main thyristor of the regulator. The third sequence of pulses at a frequency of 800 Hz serves to trigger the commutating thyristor. The regulated voltage of the thyristor regulator is converted by the inverter to a sine wave voltage with a large nonlinear distortion factor, where these distortions are attenuated by a filter.

The power mains rectifier (unit V) rectifies the three-phase ship's mains voltage at 220/380 volts, 50 Hz, producing a DC voltage of ±110 volts at the output for a load current of up to 9 amps, and ±110 volts at a current of 50 mA. The alternating component of the rectified voltage does not exceed 0.7 volts. The unit consists of the main rectifier, OV; the auxiliary rectifier, VV; an industrial interference filter; a switching relay; monitor circuitry UK; as well as indicators for the presence of ship's mains voltage and defective fuses.

When the power is turned on, the AC voltage of the ship's mains is fed through the industrial interference filter to the switching relay and to the auxiliary rectifier. The output voltage of the auxiliary rectifier actuates a relay, from which the ship's mains voltage is fed to the main rectifier which powers unit S. Inductive-capacitive filters are used to smooth the pulsations of the rectified voltage in the circuits of the rectifiers.

he voltage of the ship's mains and the output voltages of the main and auxiliary rectifiers are monitored with a meter. Neon lamps are used to indicate the presence of the ship's mains voltage as well as defective fuses.

The superimposed mirror plotting board (unit N) is an optical antiparallax device for making graphical plots when solving navigation problems and simultaneously observing the radar image. It consits of a plane semitransparent mirror and a plotter with a spherical surface made of plexiglass, which is fastened in a metal housing and provided with variable illumination for the plotting surface.

The plotting board has a working diameter of 280 mm, a plotting surface radius curvature of 508 mm and a power consumption of no more than 2.5 watts. A special "Steklograf" pencil is supplied along with unit N for making the graphical plots. The plotting board is applied to the face surface of the indicator. The illumination of the plotting board is supplied through a connector from unit I [the indicator].

The monitor unit (unit K) checks the operability of the functional blocks and assemblies of the radar by means of tolerance monitoring of the levels and amplitudes of the signals fed to the monitor system from the blocks and assemblies being monitored.

Unit K consists of a converter, an analyzer and a generator. The converter, which is designed around two transistors, amplifies the noise signals and converts them to a DC voltage. The analyzer provides for tolerance monitoring of the amplitudes of pulsed signals. The analyzer circuitry is transistorized. The pulse generator takes the form of a blocking oscillator, operating in a self-oscillating mode. The amplitude of the generated pulses can be normalized down to voltage levels of 6, 1 and 0.2 volts.

The supply voltage of 220 volts at 400 Hz is checked by means of unit K, as well as the operability of the converter and analyzer unit K, and the input pulse signals of the blocks and assemblies. The check sequence is set by the positions of the switches on the K unit panel when they are rotated clockwise.

The position of the switches for each radar unit being checked is indicated in the table on the front panel of unit K, while the defective block (or assembly) is indicated in the table found on the inside cover of the bag. The following are located on the front control panel: the meter IP1, the multiposition switch control and toggle switches. Unit K is connected to the sockets of the units being monitored by means of a flexible cable.

The repeater (unit R) feeds out the data and control signals to unit I and to the interfaced units. Unit R incorporates a sublock RS, which is a sync pulse multiplier and a subblock RV which is a video signal multiplier, as well as the V27-1.5-1 rectifier. The complement of the unit also includes circuitry for switching the range scales to the interfaced equipment and elements for checking the operability of the subblocks, the rectifiers and signaling that power is present. To power the automation circuitry and components of the unit itself, the V-27-1.5-1 rectifier produces a voltage of +27 volts. Moreover, the unit supplies the video signals with a transmission gain of 0.9 to 1.2.

The operational status monitoring system (SK) of the radar makes it possible to troubleshoot faults and check the tuning of the klystron, the magnetron current, the setting of the IF amplifier and AFC crystal current, and check the functioning of the AFC system. The parameters of the monitor system have the following values:

--Maximum error of the tolerance checking circuitry for the power characteristics is no more than 5 dB;

--The maximum error of the tolerance monitoring circuitry for the DC signal levels and average values of the AC voltages fed to the testing system is no more than ±4% (with the exception of the DC voltage level of 0.08 volts, the testing error of which does not exceed ±10%);

--Pulse signal amplitudes - no more than ±20%;

--Noise signals - no more than ±20%;

--DC currents - no more than ±15%.

The monitoring system consists of the system for checking the overall operability (KOR) and the troubleshooting system (PN). The overall operational monitoring system contains elements, which are included as individual assemblies in the radar units and modules. The troubleshooting system has built-in monitoring devices in units S, V, P and K. To avoid false information about a fault, the signals which are relayed via the interunit connections, are monitored both in the unit in which they are generated and at the input of the unit to which they are fed.

The operational status of the blocks and assemblies of units S and V is monitored by means of monitor devices built into them, while units I, P and R are checked by means of unit K. Moreover, there is an additional tuning and monitor block (KN) in unit P, which checks the signals of the blocks and assemblies, the testing of which is difficult with unit K.

The overall operational monitoring unit realizes the testing by means of simulating the point equivalent of a target, fixed in both range and direction. The overall monitoring unit consists of a monitor antenna, which is included in unit A, a delay cable and a monitor channel in the microwave block. The monitor antenna is located at a fixed distance from the main radar antenna at a course angle of 180° and serves for picking up the energy of the probe pulses. The received signals, which are delayed by a time which exceeds the width of the probe pulses, are fed to the microwave unit, are amplified by the receiver and then fed to the indicator. A criterion of normal radar operation is the presence of a brightness marker on the CRT screen in the form of an arc with a width of about 120° at a course angle of 180° at a distance of 1 to 3 mm from the probe pulse ring.

Overall operability is checked on the 0.5 mile range scale at maximum receiver gain. The device for checking units S provides for independent monitoring of the power supplies, blocks and assemblies of units S. The monitored signals are fed in a definite sequence to a meter. The criterion of proper operation is the meter needle falling in a specified sector, which is indicated opposite the corresponding switch position.

The device for monitoring unit V provides for independent checking of the power supplies for the unit. In addition to the device, there is also a number of test jacks in unit V for measuring the alternating 220/380 volts at 50 Hz, the 110 volts DC, calibrating the meter IP1 by means of standard meters as well as checking the signal lights for indicating the presence of ship's mains power and indicating that the fuses are good in the auxiliary rectifier.

The operability of unit I and the blocks and assemblies included in it is checked by means of unit K, which is connected during the testing time to a special socket in unit I. The normalization of the signals being monitored from the BK-12.6/27/50-2, V-15/80-1, V-15000-10-1 blocks, as well as the GR [sweep generator] (with the exception of the range marker triggering pulses) and the KMF [clamping bridge switcher] is accomplished by the sensors in these blocks, while the normalization of the +400, -220 and +27 voltages, as well as the automation and pulse signals (sweep, range marker triggering, synchronization and triggering pulses) is accomplished directly in the indicator unit.

The noise signal incoming from unit P is monitored at the input to the SVS [video signal mixer] block. The signal lights for monitoring the condition of the fuses in the input circuits of the unit power supplies are located on the panel of the indicator unit.

The operability of unit P is also monitored by means of portable meter K. Moreover, there is the NK (tuning and metering block) in unit P which monitors the operability of the magnetron, klystron, discharger, as well as the AFC and IF amplifier crystals by means of measuring the current levels in these components, and also monitors the functioning of the entire AFC system and the AFC block directly. The normalization of the signals being monitored from the VK-12.6/27/50-1, V-300/600-1, V-27-3-1 and V-180/240-1 blocks is accomplished by sensors located in these blocks, while the normalization of the pulse signals (modulating pulse, synchronization and triggering pulses) is accomplished directly in unit P. The operability of the IF amplifier and video pulse processing circuitry is monitored based on the generalized noise signal at the output of the video processing block. The operability of unit R is checked by means of meter K.

The layout of the units and the installation of the radar on a ship have their own special features. The operational convenience and specific features of the operation of the units are taken into account in their placement. The P, V, S, KU and ZISh [spare parts and accessories] units are housed in any dry heated room. Units P, V, S and KU are fastened to bulkheads and the set of spare parts, tools and accessories is secured to a deck or a bulkhead.

Units I, D and N are housed in the bridge or navigator's compartment. Unit I is fastened to a deck, and unit D is secured to unit I and the deck. The second I and D units are housed in any dry heated room. Unit N is to be kept in the packing box close to unit I. It is recommended that unit R be located close to the second indicator for convenience in reading the information on the working range scales of the second indicator from the front panel of unit R.

Units I and D in the control panel design are housed in sections of the main control panel of the ship and are located at a distance of no less than 1 m from the magnetic compass. To provide for access to units I and D, the spacing between their side walls and other equipment or bulkheads should be no less than 800 mm. For better heat removal, all of the units must be installed so as to assure an air gap between the units and other ship equipment of no less than 100 mm.

Unit A is placed, where possible, on the middle line of the ship. The "bow" marker should be oriented towards the bow of the ship, while the bracket for the test antenna should be oriented towards the stern. Circular scanning of the space should be provided without any shading or distortion of the antenna beam. The antenna waveguide channel should have no more than two twists, no more than six corner junctions and should be equipped with a cone taper junction (with dimensions of 28.5 x 12.6 mm to 23 x 10 mm) for connection to unit P. To avoid damage to the output flange of unit P during vibration of the ship hull, the waveguide channel should have a flexible section. The overall length of the waveguide channel should be no more than 20 m.

The length of the connecting cable lines between the ship power mains and the KU, V and S units and between units V and S should not exceed 20 m. The permissible length of the cable lines between units KU and I, the electric motor-generator and I, V and I, S and I, I and P, I and R, P and R as well as I and A should be no more than 100 m; the cable length between the electric motor-generator [dynamotor] and the KU unit can run up to 10 m; it can run up to 2 m between units I and D.

The "Nayada" marine navigation radar is controlled by means of controls which are located on units I and D. The following are accomplished on unit I: the turning of the radar on and off; the switching of the range scales; turning the range markers on and off and the short term turning off of the course; adjusting the gain of the signals and image quality; interference suppression control; measurement of ranges and azimuths to targets; switching the image orientation in the relative motion mode; adjusting the scale illumination for the azimuth circle; switching the transmitter operating mode (OPERATE--STANDBY); turning on the antenna rotation and heating; manual fine tuning of the frequency (standby).

Unit D controls the radar in the true motion mode: the true motion mode is switched on; the radar is matched to the log and gyrocompass; corrections are made for the speed and direction of the current (drift); the sweep origin is turned to the center of the CRT screen; and the sweep origin is shifted manually.

During repairs and set-up alignment of the radar, the following are provided in unit P: mechanical and electronic tuning of the klystrons; adjustment of the magnetron current; setting the gating level of the time AGC and its displacement relative to the probe pulse. Unit I in this case provides for the following: adjustment of the image brightness on the PPI screen; adjustment of the brightness of the range markers, the range cursor, the azimuth cursor and the OK [?azimuth marker contactor group?]; zero setting the range cursor; setting the limiting level in the video channel.

Prior to turning the radar on, all of the controls for the units should be in the positions indicated in Table 4.5.

When turning the radar on, the switch for the ship mains voltage is set in the "On" position. The voltage of the ship mains is checked on unit V or S. The RADAR--OFF toggle switch is set in the "Radar" position. In this case, the illumination of the scale mechanism and the labels on the front panel of unit I is turned on. The following should appear on the PPI screen: the PPI sweep of the CRT beam, illuminated by receiver noise; the course marker; the range markers and the line of the electronic azimuth cursor. After four minutes, the transceiver should be turned on, which will be signaled by a light on the control panel of unit I. When the transceiver is operating, the shining blip of the probe pulse and the returns from target will appear on the PPI screen. In the case of clutter from an agitated wave surface, it is necessary to attenuate the clutter using the NEAR FIELD ATTENUATION control.

When the radar is first turned on, one must: adjust the brightness of the range markers (MD) and moving range cursor (PVD); check the maximum error in matching the range markers and the moving range cursor; check the setting of the time AGC strobe delay; turn on unit D, for which the TRUE MOTION--OFF toggle switch is set in the "TRUE MOTION" position; establishe the orientation with respect to the meridian on the indicator unit; sequentially turn on the 1, 2 or 4 mile scales, and in this case, the display with the label OD [relative motion] should go out on unit D; match units I and D to the gyrocompass, and unit D to the log; turn on the illumination for the plotting board N; an overall check is made of the operability of the radar blocks and assemblies; by pressing the CORRECT 0.5 button, the power performance of the radar is checked. A test signal in the form of an arc 90° to 120° long spaced a distance of 1 to 3 mm from the probe pulse ring should appear at a course angle of 180°.

The radar is turned off by means of the RADAR--OFF toggle switch, which must be set in the "Off" position and then the mains cutoff switch, GPV-K, is cut off. When the station is shut down for a short period of time, one is to use the standby mode. For this purpose there is a STANDBY--OPERATE toggle switch in unit I.

Unit K is used to check the operability of the functional modules of the radar units. It is recommended that the check be started with unit I. The proper condition of the unit is determined using the meter K, observing the sequence specified on its front panel. Prior to trouble shooting, one must check the functioning of the radar modules by means of the KOR 0.5 button. Then the K unit is connected to the test socket of the unit being checked. The proper condition of the fuses is checked by means of the signal lights. Trouble shooting is accomplished in the circuits of the rectifier load by means of the Tw-4313 meter by cutting off the individual loads. The 220 volt, 400 Hz voltage is checked, for which the UNIT K--OFF toggle switch with the V1 marking is set in the "Unit K" position, while toggle switch V3 "I-II" is set in position "I". In this case, the meter needle of IP1 should fall within the sector indicated opposite position "4" of the switch with the marking V2.

The power supplies for the unit being tested are checked by setting switch V2 to the position indicated in the table on the front panel of unit K. In all positions, the meter needle of IP1 should fall within the limits of the specified sector.

The operability of unit K is checked, for which the V3 toggle switch "I-II" is set in position "II"; switch V4, "I-II", is set sequentially in positions "I" and "II". The criterion for the operability of unit K is the appearance of the meter needle of IP1 opposite the corresponding positions of switch V4.

Switch V4 is set successively to the positions indicated in the table on the front panel of unit K for each unit of the radar to check the pulse signals of the functional modules. When the functional blocks are in good operating order, the readings of the meter IP1 should correspond to the values indicated opposite the positions of switch V4. If the readings of the meter needle are less than these values, then the number of the defective block is determined from the table found on unit K.

TABLE 4.5

Unit	Unit Controls	Position of the Controls Prior to Turning the Radar On
I [Indicator]	RADAR--OFF toggle switch	"Off"
	STANDBY--OPERATE toggle switch	"Operate"
	OK, MD-OK-OTKL [Deflection coils, Range marker--Deflection coil--Off]	"OK, MD"
	Gyrocompass interface toggle switch OPERATE--MATCH	"Match"
	CENTER SHIFT toggle switch	Middle position
	INTERFERENCE SUPPRESSION--SIGNAL DIFFERENTIATOR--OFF	"Off"
	RANGE AMBIGUITY ELIMINATION	"Off"
	COURSE--MERIDIAN switch	"Course"
	NEAR FIELD ATTENUATION control	"0" on the scale
	GAIN control	"5" on the scale
	ANTENNA ROTATE--OFF--ANTENNA ROTATE, HEAT	When there is a danger of icing, "Antenna rotate, heat". Otherwise, "Antenna rotate".
	SCALE LIGHTING control	Middle positic on the scale
	YaRKOST' ENV [Probably electronic azimuth cursor brightness control; ENV probable typo for EVN]	Middle position
	Sweep brightness (range merker, moving range cursor) control	The position set at the manufacturing plant
D [True Motion Unit]	TRUE MOTION--OFF toggle switch	"Off"
	Gyrocompass and log interfaoe toggle switch:	
	GYROCOMPASS OFF	"Off"
	LOG--OFF	"Off"

TABLE 4.5, continued:

Unit	Unit Controls	Position of the Controls Prior to Turning the Radar On
P [Trans-ceiver]	IF MODES switch	"AFC operate"
	CHECK ASSEMBLIES (currents)--IF MODES toggle switch)	"Check assemblies (currents)"
A [Antenna]	ANTENNA ROTATE--OFF switch	"Antenna rotate"
N [Plotting board]	Illumination control	Middle position

The transmitter is tuned following the replacement of the modulator block (MP) or the magnetron in the following sequence: the STANDBY--OPERATE toggle switch on the panel of unit I is set in the "Operate" position; the check assemblies (CURRENTS)--IF MODES toggle switch and the check assemblies (CURRENTS) multi-position switch, which are located on the front panel of block NK [supplemental tuning and check module] of unit P are set in the "check assemblies (currents)" and "magnetron" positions respectively; the 0.07, 0.25 and 0.7 potetiometers are turned to the extreme left position; the RADAR--OFF toggle switch, located on the front panel of unit I, is set to the "Radar" position, in which the indicator lamp with the label TRANSMITTER lights up on the front panel of unit I; the range scale switch on the panel of unit I is set in one of the following positions: "0.5", "1" or "2 miles"; by rotating the 0.07 potentiometer shaft, the meter needle of the instrument located on the front panel of block NK is set at the 34 microamps division; then the range scale switch is set to position "4" or "8 miles", and by turning the 0.25 potentiometer shaft, the meter needle is set to 34 microamps; finally, by turning the chaft of the 0.7 potentiometer, the meter needle is set to the fixed position of 34 microwamps on the 16, 32 or 64 mile range scales. The runing of the transmitter is completed after the operations enumerated above are performed.

The tuning of the klystron after it is replaced is accomplished in the following manner: the radar is turned on, setting the RADAR--OFF toggle switch on the control panel of unit I to the "Radar" position; the "4" or "8 mile" range scale is selected; the cover of unit P is opened up; the CHECK ASSEMBLIES (CURRENTS)--IF MODES toggle switch is set in the "Check assemblies (Currents)" position; the CHECK ASSEMBLIES switch is turned to the "AFC crystals" position; he IF MODES switch is set in the "Tune klystron" position; the MAXIMUM CRYSTAL CURRENT control is used to achieve the maximum readings of the built-in meter;

if several maxima are observed in the current of the AFC mixer crystals within the adjustment range, then the control is to use to achieve the greatest deflection of the meter needle; the level of the IF amplifier mixer crystal currents is checked, for which the CHECK ASSEMBLIES (CURRENTS) switch is set in the "IF AMPLIFIER CRYSTALS" position; in this case, the readings of the meter shall in the range of 10 to 40 scale divisions of the indicator; the CHECK ASSEMBLIES (CURRENTS)--IF MODES toggle switch is set in the "IF mode" position; the mechanical tuning screw of the klystron is set in the extreme left position by means of rotating it clockwise [sic] using a special wrench, fastened on the inside wall of the cover of unit P.

The mechanical tuning screw for the resonator of the klystron is rotated counter-clockwise until the first maximum deflection of the meter to the left of zero with a transition (during the further turning of the screw) to the right of zero. In conclusion, the klystron rasonator tuning screw is returned to the position in which the meter is set on zero.

In the process of mechanically tuning the klystron using the MAXIMUM CRYSTAL CURRENT control, one must maintain the maximum value of the currents of the AFC mixer crystals. Upon completing the tuning of the klystron, the current levels of the crystals in the IF amplifier and AFC mixers are brought to 27--34 scale divisions on the meter by means of the attenuators of unit P.

The correctness of the klystron tuning is checked by means of the TO THE LEFT--TO THE RIGHT pushbuttons using the meter. By alternately pressing the button in the "To the left" and "To the right" positions, it is checked that when the IF MODES switch is set in the "Klystron tune" position, the deflection of the meter needle to each side falls in a range of 15 to 50 divisions, and when it is set in the "AFC operate" position, the deflection does not exceed 20 scale divisions. If the meter readings are other than the indicated values, then the mechanical tuning screw must be turned to the right position and the klystron tuning repeated. Following the completion of the check, the IF MODES switch must be set in "AFC operate" position, and in this case, the light with the NONOPERATING RADAR MODE label should go out.

The radar is structurally designed in the form of units containining interchangeable blocks and assemblies. Electrical connections are made between the units and the blocks indluced in them through plug connectors. The majority of the blocks are made using printed circuits, semiconductor devices and minature electronic componenets. The controls of the major (Operating) elements for controlling and monitoring the radar are located on the front panels of the units. The set-up tuning controls are located inside the units, at accessible points, in the blocks or individual boards. The structural design of the units provides for access to the internal wiring with the covers opened. The housings of units P, I and R are made in spray proof design. Units S, V, D and KU are made in a protected design, while unit A is a waterproof structure.

The "Al'fa" type unit is intended for estimating the degree of danger in the approach of the ship to objects on the water (from one to five), which are

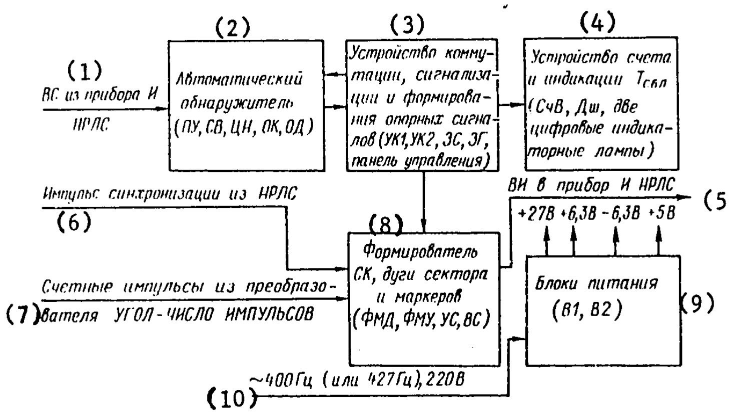

Figure 4.13. Block diagram of the "Al'fa" collision alarm.

Key:
1. Video signals from the indicator unit of the navigation radar;
2. Automatic detector (threshold gate, time gate, digital store, ring scan block and arc scan block);
3. Switching, signaling and reference signal generating unit (control switcher 1, control switcher 2, audio alarm, master oscillator, control panel);
4. Count and indicating unit for T_{sbl} [time to the closest approach point] (time counter, decoder and two digital indicator lamps);
5. Video pulses to the unit and to the navigation radar;
6. Syncrhonization pulse from the navigation radar;
7. Count pulses from the ANGLE--NUMBER OF PULSES converter;
8. Signal ring, sector arc and markers generator (range marker generator, angle marker generator, angular synchronizer and time synchronizer);
9. Power supplies (V1, V2);
10. 400 Hz AC (or 427 Hz), 220 volts.

located within the radar scanning zone at a range of from 3 to 12 miles. The unit is designed for joint operation with the "Nayada" radar and the "Don" radar (when a special interface is used) in the relative and true motion mode. Evaluating the danger of an approach is made by means of special markers which can light up on the PPI screen of the radar, based on two criteria: the closest approach distance D_{kr} and the time to the closest approach point, T_{sbl}.

The "Al'fa" unit consists of a collision warning unit (PS), a set of spare parts, tools and accessories as well as the operational documentation. A block diagram of the "Al'fa" unit is shown in Figure 4.13.

The technical parameters of the collision warning unit are given below:

Working setting range for the signal ring, miles	from 3 to 12
Number of objects (targets) which can be processed simultaneously	5
Operational warm-up time from the completely turned-off state, no more than, seconds	15
Target lock-on probablity for a signal to noise ratio of no more than 4/1, and where the number of false alarms is no more than 3 per hour	0.9
Approach time measurement range, T_{sbl}, minutes	from 0 to 39
Measurement error for P_{sbl} when D_{kr} = 0, in percent of the true value	13
Mean time between failures, hours, no less than	500
Repair time per failure, hours	1
Weight of the collision warning unit, Kg	34
Power consumption, watts	90
Continuous duty time, hours	24
Permissible ambient temperature, °C	from -10 to +50

The automatic detector of the "Al'fa" unit is intended for distinguishing the returns from targets from the output signals of a marine navigation radar receiver (see Figure 4.13). The automatic detector contains the following: threshold gate (block PU), time gate (block SV), digital store (block TsN), ring scanning block OK and arc scanning block OD.

The threshold gate of the detector converts the output signals of the receiver to a train of video pulses, VI, which are amplitude normalized. To reduce the number of false alarms caused by interfering returns from an agitated sea surface, hydrometeors, etc., the working portion of the scan surface is strobed by means of the time gate (block SV), while the digital store (block TsN) segregates only those signals from the sequence of normalized pulses by means of logic processing which periodically repeat no less than three times in five adjacent target scanning periods.

Interscan signal processing is used to combat asynchronous interference. For this purpose, an additional check is made for the presence of a return by means of the ring scanning block OK and the arc scanning block OD in the "NP protection" (asynchronous interference) mode, with the subsequent scanning of space and the automatic detector signal is generated only when such a match occurs.

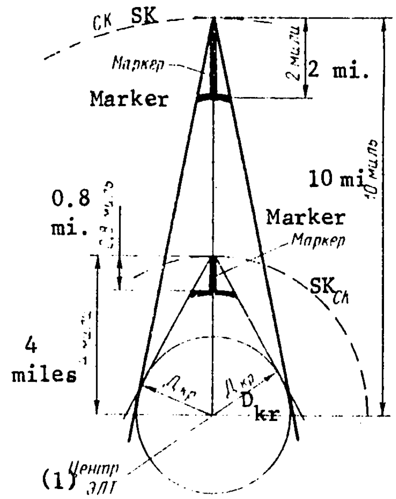

Figure 4.14. Schematic of the "Al'fa" marker unit.

Key: 1. Center of the CRT;
2. SK = signal ring;
3. D_{kr} = closest approach distance.

The next element of the block diagram is the generator for the signal ring SK, the sector arc and the markers. The signal ring and the markers are generated in the FMD blocks (range marker generator blocks), the number of which is determined by the number of working channels. The range marker generator blocks are triggered by the marine navigation radar sync pulses. The signal ring can be continuously set at any range in a range of from 3 to 12 miles by means of a variable delay circuit.

The marker takes the form of a combination of radial line and circular arc segments (Figure 4.14). The length of the radial component of a marker is 0.2 times the range at which the signal ring was set prior to illumination. The angular size of a marker corresponds to the quantity at which the line, run from the far end of the marker through the end of the arc, is tangent to a circle with a radius of two miles. This radius corresponds to the minimum shortest approach distance, which can be taken as safe. Thus, the circle represents the dangerous approach zone.

The marker arc is generated in the angle marker generator block, the SMU (see Figure 4.13) using the signals generated by the angular synchronizer block US, which stores the angular position of the marker relative to the meridian. For this purpose, 1,800 count pulses are fed to the input of the angular synchronizer block per revolution of the antenna from the ANGLE--NUMBER OF PULSES converter.

The approach time display and count unit for Tsb1 consists of a time counter (the SchV block), a decoder block Dsh and two digital indicating lamps. The time counter blocks count the approach time in binary code. The decoder block converts the binary code to decimal code, which is more convenient for controlling two seven-segment indicator lamps. The counting of the approach time begins at the moment of target lock-on by the signal ring or sector arc and is terminated at the moment is locked on by the marker arc.

The unit for switching, signaling and generating the reference signals consists of a first controling switcher (block UK1), a second controling switcher (block

UK2), an audio alarm ZS, a master oscillator ZG and an operational control panel for the unit.

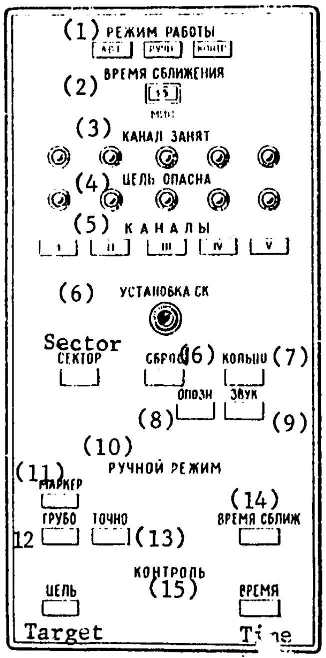

Figure 4.15. Control panel of the collision alarm.

Key:
1. Operating mode: automatic, manual, check;
2. Approach time, minutes;
3. Channel occupied;
4. Target dangerous;
5. Channels: I, II, III, IV, V;
6. Signal ring set;
7. Ring;
8. Identify;
9. Audio;
10. Manual mode;
11. Marker;
12. Coarse;
13. Fine;
14. Approach time;
15. Check;
16. Reset.

The device is powered by 220 volts at 400 Hz from the interfaced marinenavigation radar through the V1 type VP-5-7-1 rectifier and the V2 type VK-27/6.3-1 radar.

Provisions are made in the "Al'fa" unit for two operating modes: automatic and manual, as well as an auxiliary mode which is a check mode. In the first case, a target (object) is automatically locked onto by means of the detector in the zone bounded by the signal ring (or the sector arc) with respect to range with the simultaneous illumination and storage of the position of the marker at the lock-on point. In the manual mode, it is used in the presence of interfence, the detector is switched off and the sighting of the target marker on the TPI screen of the marine navigation radar is accomplished manually by the signal ring and marker using the SET SIGNAL RING control and the pushbutton (keyboard) for MARKER, COARSE and FINE, which are located on the control panel of the collision warning unit (Figure 4.15). The "Check" mode is intended for checking the operability of the unit and trouble shooting the blocks of the unit.

The structural design of the collision warning unit uses modular blocks. It is made in the form of a rack mounted console. The operational controls and information readouts are located on the front panel of the upper cover. The audio alarm units are located on its rear panels. The auxiliary and operating controls of the unit are located on the front panel in a recess under a small cover: the ILLUMINATION button brightness control, the SK [signal ring] brightness and SK BRIGHTNESS--MARKER marker control; the VOLUME audio signal loudness control, as well as the MAINS--OFF power toggle switch for the unit. Also located there are the test jacks and fuses with the signal lights.

All of the operational controls are pushbuttons (keyboard), with the exception of the SIGNAL RING SET control, the knob for which, along with the pushbutton channel switch is made as a separate subblock, consisting of five potentiometers, five lighted pushbuttons, five switching circuits and a blocking device, which precludes the possibility of the set signal ring dropping out in another channel.

The VP-5-7-1 regulated voltage rectifier is located on the rear panel of the chassis, while on the front swing-out cover there are a cassette with the main block and the VK-27/6.3-1 rectifier. All of the blocks of the unit, with the exception of the power supply blocks, are made using double sided printed circuit boards which are standardized with respect to size.

The hookup wiring inside the unit uses plug connectors. A handle for removing the blocks is located in the lower portion of the front cover. An extender circuit board is installed in a free socket of the cassette, where this extended is used when adjusting and checking the unit.

The collision warning unit is installed to the right of the marinenavigation radar indicator at a distance of 150 to 200 mm. The external cables are connected to a terminal board and the radio frequency connectors, located under the cover to the right in the lower portion of the chassis. The external cable lines are brought in through slots in the base of the unit.

The preparation of the "Al'fa" unit for operation begins with a check. For this, one must switch the marinenavigation radar (SNRLS) to the "Prepare" mode on the 16 mile range scale with che range markers turned off. Then the collision warning unit is turned on by setting the POWER MAINS--OFF toggle switch to the "Power mains" position. Then, by turning the ILLUMINATION control clockwise, the presence of lighting of all of the switches is checked which are located on the front panel of the unit (the AUDIO, NP PROTECTION and APPROACH TIME should light up only when switched on).

The OPERATING MODE switch on the control panel of the collision warning unit is set to the "Manual" position; pushbutton "I" of the CHANNELS switch is pressed; the NP PROTECTION button is switched off and the lighting of the zeros on the APPROACH TIME digital display is checked. Then, by rotating the SIGNAL RING BRIGHTNESS control under the swing-out cover of the collision warning unit, the presence of a signal ring on the PPI screen of the marine navigation radar is checked.

To check the functioning of the "Al'fa" unit, the OPERATING MODE switch is set in the "Check" position; the channels switch is set to position "I"; the VOLUME control under the swing-out cover of the unit is set to the center position. Then, by briefly pressing the TARGET button, one confirms the appearance of an intermittent audio alarm signal in the form of seven short beeps, and also confirms that the CHANNEL OCCUPIED green light comes on on the control panel of the collision warning unit and the APPROACH TIME DISPLAY goes out. When the MARKER BRIGHTNESS control is located clockwise, a T-shaped marker should light up on the PPI screen of the marine navigation radar, where the angular position and dimensions of this marker should not change.

After two minutes have elapsed following the first audio signal, the next audio signal should appear in the form of two long beeps.

The number "8" should light up on the APPROACH TIME digital display, the TARGET DANGEROUS red signal light should come on, while the CHANNEL OCCUPIED greeen light should go out. When the RING button is pressed on the collision warning unit, the image of a signal ring should appear in place of the marker image on the PPI screen, the red signal light should go out and zeros should light up on the APPROACH TIME digital display.

Similar checks of the functioning of the "Al'fa" unit must be performed sequentially in the remaining (2-5) channels. After preparing the collision avoidance unit for operation, its controls should be in the positions indicated below:

The POWER MAINS--OFF toggle switch	"Off"
ILLUMINATION, VOLUME, SIGNAL RING AND MARKER BRIGHTNESS controls	Center
NP PROTECTION [asynchronous interference suppression] keyboard	Off
AUDIO keyboard	On
OPERATING MODE switch	"Manual"
CHANNELS SWITCH	"1"

As has already been noted, the "Al'fa" unit is designed for three operating modes: automatic, manual and "check" modes. The first two are the main modes, while the latter is intended for the operational checking of the operability of the unit and troubleshooting.

In the case of automatic operation, one of the following range scales is set with the marinenavigation radar operating: 4, 8 or 16 miles. The collision aviodance unit is turned on by setting the POWER MAINS--OFF toggle switch to the "Power mains" position. The OPERATING MODE switch should be in the "Auto" position. By rotating the SIGNAL RING SET control, the signal ring is brought up to the marker. At the moment the target blip intersects the signal ring (target lock-on), a T-shaped marker appears on the PPI screen of the marinenavigation radar, and the signal ring disappears. During the target lock-on time, a green light in the corresponding channel with the lable CHANNEL OCCUPY comes on and an audio signal is sounded in the form of seven short beeps. The zeros go out on the APPROACH TIME digital display. After target lock-on, the position of the marker on the PPI screen does not change and the return from the moving object (the target) is shifted relative to the marker, passing by the small arc, or after some time, intersects the arc. In the latter case, the target is considered dangerous; the red signal light with the TARGET DANGEROUS label lights up on the control panel and an audio signal is sounded in the form of two long beeps (in both cases, the audio alarm can be turned off by pressing the AUDIO key). The time remaining until reaching the target, T_{kr}, in minutes should light on the APPROACH TIME digital display. The closest approach distance is estimated visually from the distance of the arc segment from its center to the point where it intersects the target. In this case, it is figured that half of the arc marker is proportional to two miles.

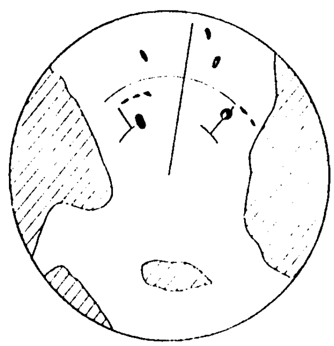

Figure 4.16. Arrangement of targets within a sector of the scan zone.

If during the target observation time within the marker zone, the green signal light begins to flicker, then when the TIME button is pressed, the number "39" (minutes) should appear on the APPROACH TIME digital display. This means that the object or target is going at a slow speed or has passed by the marker arc or is considered safe for passing.

When there are blips from several objects (targets) on the PPI screen of the marinenavigation radar, one must sequentially lock onto them via each free channel. For this, the CHANNELS switch, in step with the locking on to the targets is set to the "II", "III", "IV" and "V" positions. If in the process of observing, several targets are locked on and there arises the necessity of determining to which channel a particular marker corresponds, one must press the IDENTIFIER key (pushbutton), and determine the channel number from the number of markers at the end of the radial component of the marker. In the presence of asynchronous interference, which can be generated by the operating navigation radar of an oncoming ship, it is necessary to use interscan processing, actuating it by pressing the NP PROTECTION pushbutton.

The manual operating mode is used in the presence of interference which cannot be attenuated by the measurers recommended here. After switching the unit to the manual mode, the signal ring should be brought up to the selected target blip and at the moment when the radial sweep line on the PPI screen of the navigation radar coincides with the target blip, one must press the MARKER key. In this case, the marker lights up on the PPI screen and the signal ring will disappear. The CHANNEL OCCUPIED green signal light comes on. The zeros go out on the APPROACH TIME digital display.

If the origin of the marker does not precisely coincide with the target blip, it is necessary to match them, using the COARSE and FINE buttons. When the COARSE button is pressed, the marker is shifted through an angle of 2.4° with each revolution of the antenna in the direction of rotation of the PPI sweep, and when the FINE button is pressed, it is shifted through an angle of 0.8°.

After the far end of the marker is matched to the target blip, the "Al'fa" unit signals with a light that the target is locked on. There is no audio signaling in the manual mode. Just as in the automatic mode, the closest approach distance D_{kr} is determined visually in the manual operating mode, while the approach time T_{sbl} lights on the display when the APPROACH TIME button is pressed at the moment the target blip intersects the marker arc.

Where there are several targets present on the PPI screen, manual operation also provides for sequential lock-on of the targets via each free channel.

A provision is made in the "Al'fa" unit for the capability of operating in the automatic mode in a selected sector of the scan zone. In this case, target lock-on with respect to range is accomplished not with the ring, but rather with an arc having an angular dimension of 50 to 55°. For this purpose, the SECTOR key is pressed during the time the sweep passes through the selected zone sector. After that, the unit operates in the automatic mode only with those objects (targets) which intersect the indicated sector arc (Figure 4.16). The "sector" mode is used when navigating a ship close to shore, in narrow straights or when there is any strongly pronounced interference (thunderstorm clouds, etc.) present within the field of the radar scan.

4.5. Requirements Placed on the Installation, Tuning and Operation of Marine Navigation Radars

Installing and Hooking Up the Transceiver (Unit P). The location for the installation of the transceiver is selected by working from the permissible length of the waveguide channel (line). The following relationship exists in practice between the waveguide line length and the radar detection range of surface targets:

$$D = D_1 K$$

where D is the detection range for a waveguide channel length other than the nominal;

D_1 is the detection range for a waveguide length of 10 m;

K is a coefficient which depends on the waveguide length, the values of which are given in Table 4.6.

TABLE 4.6

(1) Длина волноводного тракта, м	6	8	10	12	14	16	18	20
K	1,02	1,015	1	0,986	0,972	0,959	0,946	0,933

Key: 1. Waveguide channel length, meters.

TABLE 4.7

Частота, МГц Frequency MHz	0,15 0,5	0,5 2,5	2,5 20	20 400
Напряжение радиопомех, мкВ Radio Interference Voltage, microvolts	250	100	50	50

The waveguide channel efficiency is defined by the expression:

$$\eta_{\text{в}} = \frac{1}{1 + \left(K_{\text{б. в}} + \dfrac{1}{K_{\text{б. в}}}\right) 0{,}115 \beta l},$$

where $K_{\text{б.в}}$ is the waveguide traveling wave ratio;

β is the power attenuation in the waveguide, dB/m;

l is the overall length of the waveguide line.

To increase η_{B}, the transceiver is installed as close as possible to the antenna, working from the conditions for reducing the waveguide channel length, having the fewest number of bends as well as turns in the line. When choosing the installation site for the transceiver, one must take into account the assurance of the optimal radar parameters as regards the operational range and blind area.

Where possible, the transceiver should be located in closed heated room having good shielding. When such conditions are absent, it is permissible to install the transceiver in the wheelhouse. In this case, it is necessary to carefully shield the units and filter out interfering voltages. The microwave radiation power flux density with the covers of the transceiver closed, at a distance of 0.5 m from the unit, should not exceed 10 μW/cm [sic].

The interference voltage level at the connection terminals for the external hook up cables should not exceed the values indicated in Table 4.7. The level of the mechanical noise generated during transceiver operation should not be higher than 65 dB. The transceiver is not to be placed any closer than 1 meter to a magnetic compass.

To remove the heat generated by the transmitter block, the spacing between the ship bulkheads, the other equipment and the housing of unit P should be no less than 100 mm. It is essential to provide for free access to the blocks of the unit, as well as take into account the possibility of opening or removing the front doors (or covers) and sliding out the modules, depending on the structure involved; it is also necessary to provide for the appropriate layout of the waveguide lines and the connection of the junction cables.

The technical specifications for the permissible length of the connecting RF cables to the indicator unit should be taken into account in the placement of the transceiver.

The Layout and Installation of the Indicator Unit (Unit I). The type of ship and the requirements placed on the layout of the entire set of navigation instruments are taken into account in the installation of the indicator unit. When one indicator is present, the unit is housed in the wheelhouse, at the bow bulkhead, in such a way that when working with the radar display, the ship's pilot faces in the direction the ship is traveling (towards the bow of the ship).

If the radar has a second indicator or an additional accessory in the form of a situation indicator or other analog device, then the second indicator is installed in the navigator's chartroom or at that point where the plotting is done, i.e., at the navigator's table.

The indicator unit, just as the transceiver, should be located at a spacing of no less than 100 mm from bulkheads, various equipment and other objects which interfer with heat removal from the indicator. In this case, the ability to open or remove the cabinet door should be assured to provide access to the blocks and individual components of the indicator circuitry. If the indicator is installed close to a magnetic compass, the distance between them should be no less than one meter.

When a special electronic radionavigation console is present on a ship, it is also expedient to build the radar indicator into it.

The Installation of Power Supplies and Auxiliary Equipment. Dynamotors and start-up regulating equipment are installed in a special equipment room or other room with metal or metalized bulkheads, in which the deckheads and decks make a reliable electrical contact to the hull of the ship, assuring shielding continuity.

The axis of rotation of the dynamotor plant should be oriented parallel to the midline of the ship. It is necessary in the installation to provide for the capability of servicing the dynamotor and the start-up regulating equipment including the performance of minor repairs, without removing the equipment from the room.

The spacings between the dynamotor plant, bulkheads and other structures of the hull or equipment should be no less than 200 to 250 mm. The start-up regulating equipment (magnetic starter, etc.) is installed in the immediate vicinity of the dynamotor. The remote control of the dynamotor plant should be accomplished from the main indicator by means of the control panel or pushbuttons.

It is recommended that the voltage regulation instruments for the power plant usually be located on the main indicator in the wheelhouse. However, because of the comparatively rate utilization of these instruments, as well as because of the danger of misadjustments, which can take place when the unit is installed with the indicator in the wheelhouse, it is better to locate the indicated units directly at the power plant.

Installing the Radar on a Ship. The rooms intended for the installation of radar equipment should have ventilation, heating (electrical) and lighting (including emergency lighting). Illumination which is too bright and which reduces the visibility of signals on the PPI screen must be avoided at locations where an indicator is installed.

In the power plant room and in the room where the transceiver is installed, the overall illumination at the deck should be no less than 20 lux for incandescent lamps and no less than 75 lux for luminescent lights [15]. Shipboard conditions must be taken into account in the installation and hookup of radar equipment: the rolling and pitching of the ship, hull vibration, elevated humidity, etc.

The large equipment, which is placed on a deck (the indicator, transceiver, power plant) is mounted on steel foundations which are welded or riveted to the metal deck and have a height of no less than 80 to 100 mm from the deck.

The radar equipment which is located on bulkheads or other ship structures is installed on special brackets which are also welded or riveted to the framework.

The equipment containing components which are sensitive to mechanical damge (vacuum tubes, etc.) should be installed on shock absorbers if no shock absorption is provided by the structure of the unit.

The chassis of radar equipment should be carefully grounded (connected to the hull of the ship). If the chassis of the unit has four fastening points or more, then the grounding is accomplished from two points, which are located on the diagonal. When a unit is secured at less than 4four points, one point is grounded.

Units which are mounted on shock absorbers are grounded by means of special metal jumpers.

When running cable lines, the bend radius of low frequency power cables should be no less than five times their outside diameter. The permissible bend radius for RF cables is stipulated in the technical specifications. When selecting a cable path, it is necessary to take the following requirements into account: the cable route should be as staright as possible; the length of a cable line should not exceed that indicated by the manufacturing plant for the equipment; cables are to be run where possible inside ship rooms; the length of line sections which go out onto open places on decks, superstructures, etc. should be minimal; it is not recommended that a cable be run through radio communications rooms or through areas having an elevated temperature.

Special holders or bridging braces are used to secure cable lines, to which a cable is fastened by means of shaped clamps. The spacing between fasteners is chosen in a range of 25 to 45 cm, depending on the section of the path, and the outside diameter and quantity of cable.

When running cable lines through decks and watertight bulkheads, individual or group seals are installed, which are sealed with a special compound. In case it is necessary, when running a cable through a deck, gas tubes are used with sealing galnds. When running a cable through bulkheads and other parts of the hull which do not have to be water tight, steel inserts are used which protect the cable sheething against mechanical damage. The sable lines are run in pipes or covered with protective casings for this same purpose.

The shielding jackets of cables, within the bounds of the cable run, and where they enter into the unit, are grounded by means of connections to the metal hull of the ship. Grounding for the cable run is made at the entrance or exit of the cable from a shielded room, where the transceiver or indicator is installed, as well as at the entrance or exit of a cable from internal rooms to open areas of decks and superstructures.

Cables which are run along bridging brackets are grounded by means of soldering the shielding braid along the length of the cable to a copper bus which is run under the fastening bracket. The shielding braids of cables entering units are grounded in the same way. In this case, a special cuff with a flexible jumper is soldered to a lengthwise soldered tap in the shielding braids, where the end of the jumper is clamped under a grounding bolt of the unit or a grounding screw at the seal gland nut. The grounding of the shielding jacket of a cable can be accomplished in seals by means of special comb terminals, which do not require hot soldering [15].

The Installation of Wabeguide Lines. Waveguide lines (waveguide channels) are composed of individual sections of various configurations: straight line; corner sections bent at various angles; sections twisted through 90°; variable cross-sections; hermetically sealed waveguides, as well as flexible (corrugated, mesh) etc.

Individual sections are joined together by means of choke or smooth flanges. The latter are rarely used, since they produce greater energy losses than choke flanges. To fit the waveguide sections in place, there are usually adjustment sections in the sets of waveguide lines, where these final matching sections have a connecting flange at only one end. The flange is soldered on to the other end in place after the entire waveguide line is assembled.

Hermetically sealed sections are used when running waveguide lines through gas tight bulkheads, decks and other special rooms [15]. Settling basins, dehydrators and moisture absorbers are used to dry waveguide lines. A settling basin takes the form of a tank structure in the form of a cylinder or a rectangular cup, in which the moisture formed in the waveguide drains off. A dehydrator consists of a fan and a heating element. The heated dry air produced by the dehydrator dries the waveguide by means of creating pressure inside the waveguide. A moisture absorber contains a special cartridge, filled with a moisture absorbing compound, for example, silica gel, which takes the form of a chemical composition having a high absorbency.

To reduce noise, waveguide lines should be grounded at the first and last sections when coupling to the units, and at the exit and entrance to rooms. Grounding is accomplished by means of jumpers from the antenna cable or another flexible conductor with terminals soldered on the ends. One end of a jumper is grounded under a bolt of the flange connection, while the other is grounded under a special bolt on the fastening bracket for the waveguide or the hull of the ship. To remove dust and dirt, all waveguide sections are blown out with compressed air at a pressure of 2 to 3 atm prior to installation.

The Installation of Marine Radar Antennas. When choosing the installation site of a radar antenna, one must take into account the influence of the installation height of the antenna: on the radar range, on the size of the blind area (minimum range) of the radar, on the permissible length of the waveguide channel joining the antenna and transceiver, as well as other factors.

Because of this, a radar antenna should, where possible, be located high up, i.e., good circular scanning should be provided. Antennas are not to be located close to smokestacks or in regions where the temperature of the exhaust gases exceeds +50 °C and there is a danger of soot and other combustion products falling on the antenna. Depending on local conditions, radar antennas are mounted on ship masts or on special hollow or truss masts, located on the upper bridge. If conditions permit, then the antenna is to be placed on the midline (DP) of the ship. Where obstacles are present which degrade the circular scanning, the radar antenna installation is shifted relative to the midline of the ship. In accordance with the USSR Registry regulations, an antenna must be shifted to the starboard side.

When two radars are installed on a ship, the antennas are placed on the midline, on stages on the ship's mast or on special masts located to port and starboard [15].

The influence of radar operations on radio communications gear must be taken into account in the placement of the radar antenna. The presence of an electric drive and switching circuits in the radar antenna can create interference to the operation of a marine radio station, especially in the very high frequency band (VHF). For this reason, it is necessary where possible, to separate the radar and VHF radio communications antennas by no less than 3 to 5 meters, prefereably in height.

When installing a radar antenna, one must consider the possibility of the irradiation of persons by the microwave electromagnetic field who are in open spaces on the deck and superstructures. Because of the harmful influence of microwave energy on the human organism, measures must be taken so that the main lobe of the antenna directional pattern passes beyond the bounds of the ship, while the sidelobes (lower lobes) of the directional pattern do not produce a power density greater than that permitted by health safety standards, i.e., 10 $\mu W/cm^2$.

The minimum mounting height for a radar antenna, which precludes the exposure of persons located on deck and on superstructures by the main lobe of the antenna directional pattern can be determined from the approximate formula [15]:

$$h_A = D \tan(\theta/2) + h + h_{man},$$

where D is the distance to the midline between the radar antenna and the most remote point on the deck or superstructure;

θ is the width of the antenna directional pattern in the vertical plane at the half power points;

h is the maximum height of the point of the deck or superstructure under conderation from the water line;

h_{man} is the height of a man, conventionally taken as 2 m.

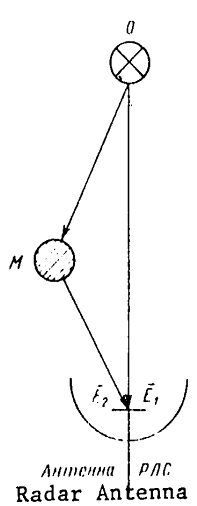

Figure 4.17. On the determination of the total field at the input to a radar antenna.

The influence of sidelobes may also be disregarded if the radar antenna is installed at a height of no less than 6 m from the deck of the compass platform.

For servicing safety, the radar antenna installation site is equipped with a platform having manropes. The antenna rotation should not threaten the safety of the ship's crew. It is necessary to preclude the possibility of running rigging and other objects capable of causing damage to the antenna or failure of the rotation mechanism from coming into the zone of rotation of the antenna (the sweep radius).

The Influence of Shipboard Obstacles on the Precision of the Determination of the Angular Coordinates of Targets. The presence of obstacles on a ship in the path of radar signal propagation (masts, superstructures, pipes, rigging, etc.) produces systematic errors in the determination of angular coordinates, creates false returns and is the cause of the occurrence of shaded sectors on the PPI screen.

The influence of obstables (secondary radiators) is manifest in the occurrence of errors both during the transmission of the probe signals and in the reception of the returns. Since these factors are equivalent, they can be generalized and treated as for the case of radar return reception.

If, for example, a reflecting object is located at point O (Figure 4.17), while an obstacle is located at point M (the secondary radiator), the total field E_0 at the radar antenna input will consist of the field E_1 coming directly from the target, and the field E_2 diffracted from the obstacle: $\bar{E}_0 = \bar{E}_1 + \bar{E}_2$. The field E_2 can differ from the field E_1 in phase and amplitude in the general case, and then:

$$E_0 = E_1 + \rho E_1 e^{-j\alpha} = E_1 (1 + \rho e^{-j\alpha}),$$

where ρ is the E_1 field attenuation coefficient;

α is the phase shift between the fields E_1 and E_2 which is due to the difference in the path of the rays Δd and the phase shift when the field E_2 is reradiated by the obstacle.

As a result, the total field E_0 proves to be nonuniform, and within the limits of the antenna directional pattern in the horizontal plane, has a lobed nature. The number of lobes depends on the radar wavelength and increases with an increasingly shorter wavelength. The lobe nature of the total field shifts the maximum (axis) of the antenna directional pattern in the horizontal plane and leads to systematic errors in the determination of azimuth, i.e., to the occurrence of ship radar deviation or radar deviation (RLD).

The value and sign of the radar deviation (the sign of the correction for the radar deviation), other conditions being equal, depend on the radar wavelength, the antenna directional pattern width in the horizontal plane and are a function of the angle α_0 between the directions to the reflecting target and the obstacle. With an increase in the radar wavelength and the width of the directional pattern of the antenna in the horizontal plane, the radar deviation also increases. An exception is the condition when $\alpha_0 = 0$, i.e., when the reflecting object (target), the obstacle and the radar antenna fall in the same plane. In this case, the lobes of the directional pattern are arranged symmetrically and the error in the determination of the direction to the target will be equal to zero (RLD = 0).

On analogy with the radio deviation of marine direction finders, the radar deviation can be determined experimentally as a function of the course angle (KU) or the compass bearing (KP) to the observation target. In the first case, with the "Course" orientation of the image on the PPI screen, the following readouts are taken simultaneously: the course (KU) is read visually from the azimuth circle of the compass and the radar course angle (RLKU) on the PPI screen of the radar.

Point targets (for example, buoys equipped with a reflector), radar transponder beacons (RMO), etc. are used as the radar bearing target.

In the case of orientation with respect to course, a change in the course angle causes the return blip to move on the PPI screen. For this reason, the determination of the radar deviation should not be made using a turning circle, but rather by using individual course headings at intervals of 5 to 10°.

Prior to doing radio deviation work, it is necessary to carefully center the sweep origin on the PPI screen and to assure good optical visibility and a clear image of the target on the indicator screen for which bearings are taken; the PPI range scale is to be set so that the target blip image on the indicator screen is at the greatest distance from the sweep center (no less than half of a sweep line); all of the rigging on the ship is to be secured as for running.

Based on the results of the observations, the magnitude and sign of the radar deviation (the correction for radar deviation) are determined from the formula:

$$F = p - q$$

where F is the radar deviation angle;

p is the course angle to the target on which the bearing is taken;

q is the radar course angle.

The sign of the radar deviation correction is determined from the rule "from the false to the true". Consequently, when $p > q$, the quantity F will be positive. If $p < q$, then F is negative. The results are entered in an observation and calculation table (Table 4.8). Using the data of the table, a graph of the radar deviation curve is drawn for the given ship. By way of example, graphs of the radar deviation curve for "Don" and "Lotsiya" radars installed on the motorship "Professor Rybaltovskiy", are shown in Figure 4.18. It can be seen from these graphs that the radar error for various radar course angles changes both in magnitude and sign. For the "Don" radar, the value of the radar deviation reaches 5 to 6°, while for the "Lotsiya" radar, it reaches 9 to 10°. Such a large value of the angle F is explained by the comparatively low placement of the "Lotsiya" radar antenna on the ship and the presence of obstacles close to the antenna in the form of the antenna mast of the ship's radio station and whip antenna.

When determining the radar deviation by comparing the radar bearing (RLP) and the compass bearing (KP), which are taken simultaneously on the bearing target, the image of the target blip on the PPI screen should be oriented towards north (the "North" orientation). Since in this case, the position of the blip on the PPI screen does not change, the determination of the radar deviation can be made by traveling in a slow circle (the time for one complete circle should be no less than 30 minutes), simultaneously taking readings of the compass bearing and radar bearing to the bearing target at intervals of 5 to 10°. The results are

TABLE 4.8

(1) № п п	(2) Курсовой угол (p)	(3) Р/Л курсовой угол (q)	(4) Р/Л девиация (F=p—q)	Remarks Примечание
				Название судна (5) . . . Тип НРЛС (6) . . . . Дата Date . . . . Объект пеленгования (7) Шкала дальности (8) . . Расстояние до объекта . . Range to the Target Море . . . Ветер . . Sea Wind

Key: 1. Item No.
2. Course angle (p);
3. Radar course angle (q);
4. Radar deviation (F = p - q);
5. Name of the ship;
6. Type of navigation radar;
7. Bearing target;
8. Range scale.

entered in an observation and calculation table (Table 4.9). A graph of the curve $F = \phi$ (RLP) of the radar deviation is plotted using the data obtained.

Along with the methods enumerated above, the radar deviation can also be determined by other well known techniques in which the course angles to the bearing target are changed.

In addition to systematic errors in the measurement of the angular coordinates, shipboard obstacles can cause the appearance of false returns on the PPI screen. This is due to the fact that the shipboard obstacles have a considerable influence on the sidelobes of the antenna directional pattern.

As is noted in the literature [15], the influence of antenna sidelobes caused by an obstacle can be disregarded if the following condition is met:

$$\alpha_0 \geqslant \frac{\lambda}{d}\sqrt{\frac{\lambda}{L}},$$

where λ is the radar wavelength;
d is the obstacle diameter;
L is the distance between the obstacle and the radar antenna.

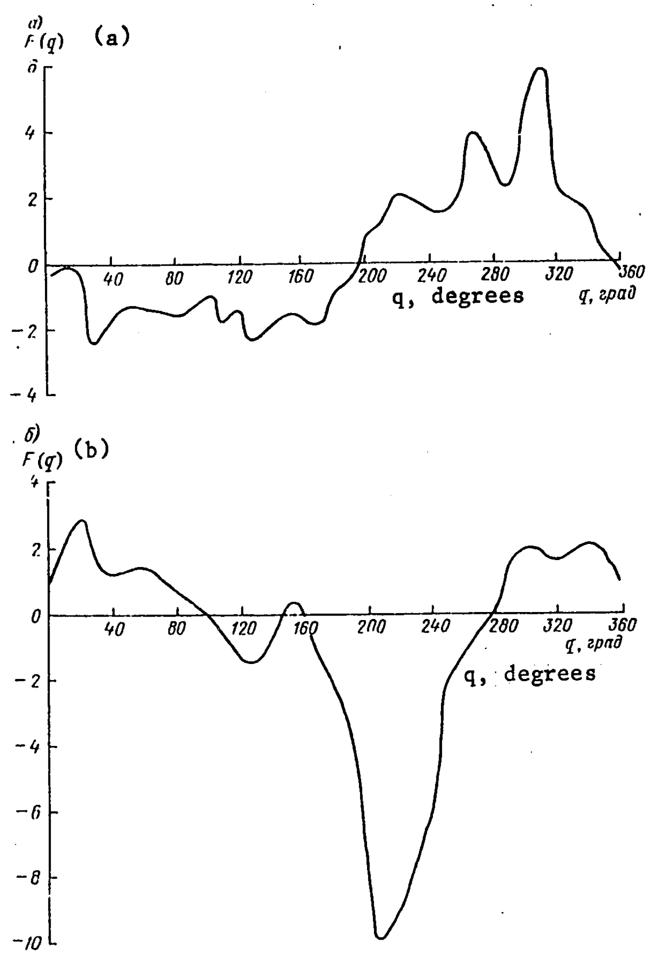

Figure 4.18. Graphs of the radar deviation curves for the ship "Professor Rybaltovskiy":
a. "Don" navigation radar;
b. "Lotsiya" navigation radar.

TABLE 4.9.

(1) № п п	(2) Компасный пеленг (КП)	(3) РЛ пеленг (РЛП)	(4) РЛ девиация (F=КП—РЛП)	(5) Примечание
				Name of the Ship Название судна . . . . Type of Radar Тип РЛС . . . . Дата Date . . . . Объект пеленгования (6) Range Scale Шкала дальности . . . Расстояние до объекта (7) Море Sea . . . Ветер Wind

Key: 1. Item No.;
2. Compass bearing (KP);
3. Radar bearing (RLP);
4. Radar deviation (F = KP - RLP);
5. Remarks;
6. Bearing target;
7. Range to the target.

Moreover, shipboard obstacles cause the appearance of shaded sectors. This is observed in those cases where the size of the obstacle is commensurate with the antenna aperture in the horizontal plane or exceeds it.

Tests of a Marine Navigation Radar Following Insulation on a Ship. Such tests are performed in order to check the conformity of the operational and technical parameters of the radar to the requirements of the technical specifications as well as the radar operating reliability under actual operational conditions. The tests are performed in accordance with a special program, coordinated with the interested organizations and the USSR Registry.

If the navigation radar is being installed on a new ship under construction, then these tests are incorporated in the overall testing program for the vessel. Shipboard tests of navigation radars are broken down in dockside and sea trial tests.

Dockside tests are performed while the ship is at the dock. The following are checked: the equipment complement of the radar and the spare parts, tools and accessories; the placement of the navigation radar equipment on the ship; the condition of the equipment and the action of the controls; the grounding of the chassis of the navigation radar equipment; the quality of the installation; the insulation resistance of the wires and RF cables; the technical parameters of the radar set; the synchronization and in-phase performance of the antenna rotation and PPI sweep of the CRT; the synchronization of the PPI coupling to the gyrocompass; and the precision of the positioning of the fixed range ring markers on the PPI screen.

The completeness of the radar equipment package is checked against the ordering documentation. The presence and condition of the spare parts, as well as the factory and acceptance documentation for the equipment (descriptions, operating instructions, schematics, data sheets and forms) are checked against the acceptance documentation for the project plan and the descriptions of the contents of the boxes of spare parts, tools and accessories.

The placement of radar equipment on a ship is checked against the working drawings of the project plan. The reliability of the equipment fastening and the shock absorbers of the units is checked. The operational conditions of the equipment are checked and evaluated (free opening of the doors and covers, the sliding out of the blocks and units, convenience in the use of the controls and monitor instruments for the navigation radar, the illumination of the scales and other components used for systematic observation).

The condition of the equipment and the action of the controls is checked by means of carefully inspecting the installed equipment. The integrity of the paint and anticorrosion coating, the absence of mechanical damage, the presence and condition of facing screws, glass, labels, frames for meters, the integrity of the equipment mounting (at points accessible for inspection), the reliability of the fastenings of individual components and assemblies of the equipment as well as the cleanliness of the contact surfaces.

The following are checked during the inspection process: the smoothness of the operation of the equipment control, the correctness of the operation of switches, toggle switches and pushbuttons, the smoothness of the travel of moving elements, the condition of contact groups of moving elements; the matching of the positions of the controls with the indicators on scales which have clamps; the correctness and the reliability of the actuation of interlocks; and the good operating condition of the signaling circuits.

The grounding of the equipment chassis should satisfy the design requirements and its resistance should not exceed 20 MOhms. The resistance should be checked by means of a megohmeter, one terminal of which is connected to the GROUND terminal of the unit being tested, while the second is connected to a cleaned area of the ship's hull near the unit.

Quality control of the installation work is accomplished by means of checking the following: the routing of the waveguide and cable lines and their conformity to the working drawings and schematics; the correctness of the fitting of the cables in feedthrough seals and the layout of the cable cores in junction boxes and in the unit; the correctness of the connecting of shielded cores of cables as well as the connection of their braided shields to the chassis of a unit; the correctness of the fitting of cables in RF plug connectors; the absence of mechanical damage to the braided shields of cables; the reliability of the connections in waveguide channels.

TABLE 4.10

Gain Усиление		Attenuation Ослабление		Decibels Децибелы
Отношение напряжений Voltage Ratio	Отношение мощностей Power Ratio	Отношение напряжений Voltage Ratio	Отношение мощностей Power Ratio	
1,000	1,000	1,000	1,000	0
1,059	1,122	0,944	0,891	0,5
1,122	1,259	0,891	0,794	1,0
1,259	1,585	0,794	0,631	2,0
1,413	1,995	0,708	0,501	3,0
1,585	2,512	0,631	0,398	4,0
1,778	3,162	0,562	0,316	5,0
1,995	3,981	0,501	0,251	6,0
2,239	5,012	0,447	0,200	7,0
2,512	6,310	0,398	0,158	8,0
2,818	7,943	0,355	0,126	9,0
3,162	10,000	0,316	0,100	10
3,548	12,590	0,282	0,0794	11
3,981	15,850	0,251	0,0631	12
4,467	19,950	0,224	0,0501	13
5,012	25,120	0,199	0,0398	14
5,623	31,620	0,178	0,0316	15
6,310	39,810	0,158	0,0251	16
7,079	50,120	0,141	0,0200	17
7,943	63,100	0,126	0,0158	18
8,913	79,430	0,112	0,0126	19
10,000	100,000	0,100	10^{-2}	20
17,780	316,200	0,0562	$3,16 \cdot 10^{-3}$	25
31,620	1000,000	0,0316	10^{-3}	30
56,23	$3,162 \cdot 10^{3}$	0,0178	$0,316 \cdot 10^{-3}$	35
100,00	10^{4}	10^{-2}	10^{-4}	40
177,80	$3,162 \cdot 10^{4}$	$5,62 \cdot 10^{-3}$	$0,316 \cdot 10^{-4}$	45
316,2	10^{5}	$3,16 \cdot 10^{-3}$	10^{-5}	50
562,0	$3,162 \cdot 10^{5}$	$1,78 \cdot 10^{-3}$	$0,316 \cdot 10^{-6}$	55
1 000,0	10^{6}	10^{-3}	10^{-6}	60
1 770,0	$3,162 \cdot 10^{6}$	$0,562 \cdot 10^{-3}$	$0,316 \cdot 10^{-6}$	65
3 162,0	10^{7}	$0,316 \cdot 10^{-3}$	10^{-7}	70
5 620,0	$3,162 \cdot 10^{7}$	$0,178 \cdot 10^{-3}$	$0,316 \cdot 10^{-7}$	75
10 000,0	10^{8}	10^{-4}	10^{-8}	80
17 800,0	$3,162 \cdot 10^{8}$	$0,562 \cdot 10^{-4}$	$0,316 \cdot 10^{-8}$	85
31 620,0	10^{9}	$0,316 \cdot 10^{-4}$	10^{-9}	90
56 200,0	$3,162 \cdot 10^{9}$	$0,178 \cdot 10^{-4}$	$0,316 \cdot 10^{-9}$	95
10^{5}	10^{10}	10^{-5}	10^{-10}	100

After turning the radar on, it is essential to make sure that there are no power leaks or sparking in the flange waveguide joints. A neon lamp may be used to check for power leakage.

The absence of sparking can be checked visually or it can be heard [15]. Where sparking is present, the repetition rate of the pulses is heard.

The insulation resistance is checked between individual cores, as well as between the cores and the cable braid. Megaohmeters at 500 and 1,000 volts are used for the insulation measurement. The insulation resistance of any cable should be no less than MOhm regardless of its length.

The technical parameters of the radar are checked by means of testing the following: the actual sensitivity of the receiver; the average transmitter power; the standing wave ratio of the antenna-waveguide channel of the radar; the spectrum of the probe pulse.

Radar testers (RLS testers) corresponding to the band of frequencies used in the CW mode are employed to measure receiver sensitivity.

The output power of the transmitter is estimated based on the average or pulse power. The average power is measured by means of a special instrument: a power meter or a radar tester used for this purpose, which is connected to the output of a directional coupler in the radar waveguide line.

The standing wave ratio (KSV) [SWR] of the antenna-waveguide channel characterizes the matching to the line and the radar antenna. The SWR is determined with the antenna stopped and the radar turned on. The incident and reflected wave power is measured by means of the radar tester at the flanges of a directional coupler. The SWR can be determined from the following expression [15]:

$$\text{SWR} = \quad \text{KCB} = \frac{1 + \sqrt{\alpha}}{1 - \sqrt{\alpha}},$$

where α is the power reflection factor, which is equal to:

$$\alpha = (P_{ref}/P_{for})\Delta$$

P_{ref} is the reflected power;

P_{for} is the forward power, measured through the coupler;

Δ is a correction factor, in relative units.

When determining Δ, first the value of the coefficient in found in decibels:

$$\Delta' = K_2 - K_1$$

where K_1 is the forward coupling attenuation, dB;

K_2 is the reflected coupling attenuation, dB.

Both quantities K_1 and K_2 are indicated by a special mark on each lead of the coupler. Based on the value obtained for Δ' in decibels, the power ratio for the attenuation is found by means of Table 4.10. The permissible value of the SWR should fall in a range of 1.2 to 1.5.

The frequency spectrum of the magnetron probe pulse is determined by means of a spectrum analyzer or an echo chamber with a narrow bandwidth. In the case where an analyzer is used, its input is connected to any flange of a directional coupler in the radar waveguide channel.

The image of the pulse spectrum should be stable, without doubling of the main lobe, and have brightly pronounced minima and first sidelobe maxima which do not exceed 0.25 of the main lobe. In the case of a distorted modulating pulse waveform and an insufficiently matched load, the spectrum of the magnetron pulse can prove to be distorted.

A check of the operational characteristics of a navigation radar is made during the sea trials.

The minimum navigation radar range is checked by means of measuring the minimum distance to a reflecting target, at which the return from it can be observed separately from the probe signal and the target coordinates can be determined.

The measurements are to be made in the absence of sea clutter, with optimal receiver gain (time AGC) and normal brightness of the return on the PPI screen. An average sea buoy, launch or boat, which slowly approaches the ship or moves away from it is used as the reflected target. At the moment the probe and return signals and the PPI screen touch, the target is stopped, and the distance between the ship on which the radar being tested is installed and the target is measured with a measuring line.

The check of the maximum navigation radar range is made when the ship is standing in a road or when putting out to sea. An approaching target which falls in sectors free of shading is used for the measurements. The desired range is measured by means of the moving range ring (PKD) or the range cursor (VD). The measurement is made using a reliably distinguished return with a probability of 0.5, when no more than one miss follows after a blip from the approaching target; and after two or more blips, which follow one after the other, there are no more than two misses in a row. Since the radar detection range depends on many factors such as the type of target, the power potential of the navigation radar, the condition of the atmosphere, the mounting height of the antenna and the length of the waveguide line. The value of the maximum range is indicated in the technical specifications for the given type of radar for the particular type of target with a definite installation height of the antenna and waveguide length. As an example, average values of the radar detection range are given below for various sea targets:

Type of Observation Target	Detection Range, Miles
Skerries, rocks and rock faces at a level of 0.5 to 1 m	Up to 2
Flat sandy shore	1 - 5
Steep rock faces, cliffs	Up to 20
Hills, mountains	15 - 40
Isolated beacons	5 - 10
Bridges across rivers, channels	Up to 5
Buoys:	
Small	0.5 - 1
Class 2	2 - 4
Class 1	4 - 6
With corner reflectors	6 - 8
Floating beacons	6 - 10
Fishing trawlers	6 - 9
Ships with a displacement of, meters:	
1,000 [tons]	6 - 10
3,000	10 - 13
10,000	10 - 16
50,000	16 - 20
Individual ice floes, low icebergs	Up to 3
High, large icebergs	3 - 15
Small boats	Up to 2

The check of navigation radar range resolution is made when the ship is standing still by means of measuring the minimum distance between two point targets, located on the same heading angle, for which it is possible to observe them separately and determine their coordinates.

Two boats or two cutters equipped with corner reflectors are used as the reflecting targets, which should be placed at distances which assure a clear image of the return blips on the PPI screen. Upon a command from the ship where the navigation radar being tested is installed, both targets, which lie on the same course angle relative to the ship, slowly come together until the moment when their blips make contact on the PPI screen. At the moment the blips make contact, the targets are stopped and the distance between them is measured with the precise range finder of the navigation radar or a water resistant (kapron) filament line.

The navigation radar resolution in azimuth is checked by means of measuring the minimum angle between two point targets located at the same distance from the navigation radar, for which separate observation and determination of the coordinates of these targets is assured on the PPI screen. During the measurements, two cutters or boats initially come together at a range at which the returns from them are seen to clearly merge on the PPI screen, i.e., they are not resolved. Then, upon an instruction from the ship, the cutters or boats begin to slowly move, moving apart from each other in the transverse direction relative to the direction of the ship. At the moment separate blips from the targets appear on the indicator screen, the cutters or boats are stopped on a command from the ship and the course angles or bearings to each return blip are measured. The difference between the measured angles characterizes the navigation radar resolution with respect to direction (azimuth).

The determination of the maximum range measurement error is made when the ship is docked or at a mooring. The range measurements are made using a point target. The range to the target should be determined beforehand by geodesic means with an accuracy of 0.3%. The range to the target blip on the PPI screen is measured repeatedly by different observers by means of matching the leading edge of the moving range ring to the blip from the target (the object). The maximum error for 95% of the observations should not exceed the values provided in the technical specifications for the navigation radar.

The determination of the maximum azimuth measurement error is made sequentially for six headings of the ship, at intervals of 60°. When measuring the direction towards a selected point target, several readings of the course angle or bearing are made simultaneously using the scale of the PPI indicator and an optical direction finder. The comparison of the resulting readings represents the error, the maximum value of which should not go beyond the limits of the technical specifications for the radar in 95% of the measurements.

The shaded sectors are determined with the ship traveling in a slow circle having the minimal radius where the sea waves are rated at no more than one to two balls [1 to 2 points on a 12 point scale]. A low tonnage (tug, cutter, etc.) at a range of 4 to 5 miles from the radar, the returns from which are clearly seen on the PPI screen, is chosen as the bearing target. The course angles or bearings between which the return blip image disappears on the PPI screen are the boundaries of the shaded sectors.

The results of the observations are entered in the navigation radar form for the station operation accounting.

CHAPTER 5 AUTOMATED MARINE NAVIGATION RADARS

5.1. The "Okean" Marine Navigation Radar

The "Okean" marine navigation radar is designed for installation on large tonnage ships as the main radar [11].

TABLE 5.1

Unit Designation Code	Unit Name	Overall Dimensions, mm			Weight, kg	Power Consumption, KVA
		Width	Depth	Height		
A3	Antenna (3.2 cm band)	3300	588	570	245	0.18
A10	Antenna (10 cm band)	3300	1265	570	345	0.18
A	Two-band antenna	3300	1400	1550	375	0.30
P3	Transceiver (3.2 cm)	365	372	1370	131	1.20
P10	Transceiver (10 cm)	365	572	1370	155	1.20
I1	Indicator with the true motion system and auto-tracking	950	593	1360	330	1.50
I2	Simplified indicator	760	593	1250	215	1.00
V	Computer	340	620	970	120	0.70
PK	A3 and A10 antenna switcher	170	530	270	18	2
AT04	Power plant	667	490	432	250	10
AT02	Power plant	595	430	360	152	5
PMM	Single power mains starter	174	400	360	16	--
BRN	Control block	185	425	400	22	--
	Cabinet of spare parts, tools and accessories	415	460	1295	127	--
	Box of spare parts, tools and accessories	542	572	845	64	--

The "Okean" radar operates in one of two bands (3 and 10 cm) and solves the following problems:

1. Observes the radar situation in true and relative motion modes, and also measures the coordinates of targets;

2. Automatically tracks a selected target while feeding out its coordinates in a PPI mode;

3. Automatically solves the problem of passing a target being tracked and makes recommendations for course or speed maneuvering either separately or simultaneously for safe passing.

TABLE 5.2

Таблица 5.2

(1) № комплекта	Units Приборы	Power Supply Агрегат питания 220 В volts	380 В volts	(2) Потребляемая мощность кВ·А KVA	кВт KW	Weight Масса, кг kg
01	А, П3, П10, И1, И2, В	АТО-4-400-Б1, ПММ-1112-113, БРН-141-3	АТО-4-400-В1, ПММ-1112-131, БРН-141-3	9,5	8,8	2100
11	А3, А10, П3, П10, И1, И2, В, ПК	АТО-4-400-Б1, ПММ-1112-133, БРН-141-3	АТО-4-400-В1, ПММ-1112-131, БРН-141-3	8,6	8,0	2150
13	А3, А10, П3, П10, И2, И1, ПК	АТО-4-400-Б1, ПММ-1112-133, БРН-141-3	АТО-4-400-В1, ПММ-1112-131, БРН-141-3	8,0	6,6	1900
15	А, П3, П10, И1, И2	АТО-4-400-Б1, ПММ-1112-133, БРН-141-3	АТО-4-400-В1, ПММ-1112-131, БРН-141-3	9,0	7,5	1800
21	А3, П3, И2	АТО-2-400-Б1, ПММ-1112-131, БРН-241	АТО-4-400-В1, ПММ-1112-115, БРН-241	4,3	3,5	1000
23	А10, П10, И2	АТО-2-400-Б1, ПММ-1112-131, БРН-241	АТО-2-400-В1, ПММ-1112-115, БРН-241	4,3	3,5	1150

Key: 1. No. of the set;
2. Power consumption.

The listing of the units incorporated in the "Okean" navigation radar is given in Table 5.1.

Besides the units and power supplies with the start-up control equipment indicated in the table, the radar complement also includes:

--Installation kit for assembling the 3-cm waveguide channel and the microwave cable sections for connecting the 10-cm transceiver to the antenna;

--The set of spare parts and accessories for the radar;

--The set of spare parts and accessories for the power supply;

--The set of plug connectors for the cables running between the units;

--The set of operational documentation which contains the technical description and operating instructions, the electrical schematics and kinematich circuits, the inventory and documentaticn for the spare parts, tools and accessories, the installation kit, as well as the operational documentation and packing.

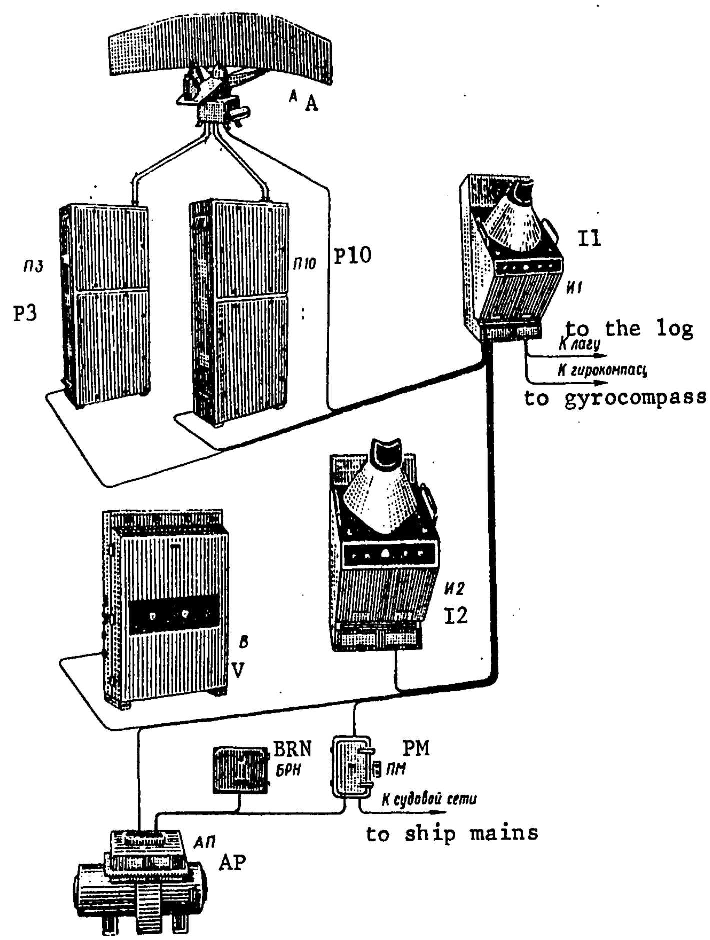

Figure 5.1. The equipment complement of the complete "Okean" radar set.

Key: A. 3.2 and 10 cm antenna;
P3. 3 cm band transceiver;
P10. 10 cm band transceiver;
I1. Indicator with autotracking and true motion systems;

Key [cont.]: I2. Simplified indicator;
V. Computer;
BRN. Power plant voltage control block;
PM. Single power main magnetic starter;
AP. Power plant.

Depending on the customer's requirements, the "Okean" radar is supplied with various equipment complements.

The composition of the complete sets which are manufactured is given in Table 5.2. For any equipment complement, the "Okean" radar is supplied with a power supply and start-up regulating equipment using the ship power mains at 220/380 volts AC, 50 Hz.

The technical parameters and operational characteristics of the "Okean" navigation radar are given below:

The 0.5 probability detection range for an antenna mounting height of 20 m above sea level, in miles:	
A shore 60 m high	20
A ship with a displacement of 5,000 tons	12
Average sea buoy	5
Minimum detection range for a probability of 0.5, m	60
Maximum range determination error, in % of the full scale reading of the indicator scale from the moving range ring, on the following scales:	
1, 2 miles	1.5
4 miles	1.0
8, 16, 32 and 64 miles	0.6
Maximum azimuth determination error in the case of measurements with the electronic cursor, in degrees at wavelengths of:	
3.2 cm	1
10 cm	1.5
The 0.5 probability range resolution on the 1 and 2 mile scales, in m	15
The 0.5 probability angular resolution, in degrees, in the following bands:	
3.2 cm	0.7
10 cm	2.1
The maximum error in the true motion of the marker for the ship itself on the screen, no more than:	
With respect to course, in degrees	3
With respect to speed, knots	1.5
Maximum error of the autotracking system with a quiet sea:	
With respect to angle, in degrees:	
In band I	0.5

In band II	0.7
With respect to range, m:	
In band I	40
In band II	30
Maximum errors in the calculation of the parameters for passing a ship being tracked in the case where the ships travel at constant speeds and with constant course headings, no more than:	
Closest approach error, miles	± 0.2
Error in the time remaining until the closest approach, %	5
Target course error, degrees	8
Target speed error, knots	2
Carrier frequency, MHz:	
In band I	9,400--9,460
In band II	3,030--3,090
Probe pulse width, in microseconds, on the following scales:	
1, 2 and 4 miles	0.1
8, 16, 32 and 64 miles	50
Pulse power of the transmitter, in KW, no less than	50
Pulse sensitivity of the display receiver channels, in dB, on the following scales:	
1, 2, and 4 miles	115
8, 16, 32 and 64 miles	120
Intermediate frequency of the receiver, MHz	60
Receiver bandwidth, MHz:	
In the "0.5" mode	$4^{+0.5}_{-1.0}$
In the "0.1" mode	$12^{+3.0}_{-1.0}$
The antenna directional pattern width at the 0.5 level relative to the maximum power, in degrees, no more than:	
In the horizontal plane:	
In band I	0.7
In band II	2.3
In the vertical plane	15--25
Sidelobe attenuation, in dB, no less than	23
Scan rate (rotational speed) of the antenna, r.p.m.	16--17
Antenna gain, in dB, no less than:	
In band I	31
In band II	27
Working diameter of the screen of the indicators, mm	400

Range scales, miles	1, 2, 4, 8, 16, 32 and 64
Interval between the fixed range rings on all scales, amounting to one-fourth of the set scale, in miles	0.2, 0.5, 1, 2, 4 8 and 16
Continuous duty time, hours	24
Warm-up time for the radar after being turned on, minutes	4
Permissible temperature variation, degrees C:	
For units A, A3, A10 and the waveguides	from -40 to +50
For the other radar units	from -10 to +50
Permissible variations in the parameters of the ship power mains, volts:	
From ship power mains at a frequency of 50 ± 2.5 Hz	220/380 ±5%
From DC ship power mains	110/220 ±10%

An external view of the most complex equipment complement, set No. 01, is depicted in Figure 5.1.

Specific Features of the "Okean" Navigation Radar

The "Okean" navigation radar is a two-band radar set, which operates at wavelengths of 3.2 and 10 cm. This permits the maximum utilization of the advantages of each of the bands.

The 3 cm band equipment complement provides for good resolution and precision in determining coordinates. The 10 cm equipment makes it possible to improve the noise immunity of the radar against the influence of precipitation and wave agitation as well as increase its operational range.

Backups are provided for the units of the "Okean" radar through the standardization of the assemblies and blocks as well as the capability of connecting them in the following four configurations:

1) I1--P3; I2--P10;
2) I1--P3; I2--P3;
3) I1--P10; I2--P3;
4) I1--P10; I2--P10.

This significantly increases the reliability of the radar equipment.

The "true motion" mode improves the orientation of pilots and the decoding of the radar information when sailing close to shores and in narrow straits. In this mode, the actual navigation picture is reproduced on the I1 indicator screen (see Figure 5.1), i.e., the target pips from stationary objects remain stationary, while the pips of moving targets move on the screen at a speed proportional to the true speed. This is accomplished by excluding the velocity vector of the ship, the radar vehicle, from the relative velocities of the observed targets, by means of moving the origin of the plan position indicator in the direction of ship travel and at a rate proportional to its speed.

It is possible in the "Okean" radar to automatically solve the problem of passing an oncoming ship. Following manual "lock-on" to the echo return from the target of interest, the range and azimuth automatic tracking system generates the current coordinates for the target range and bearing, while the computer V continuously calculates the relative path of the oncoming ship, the closest approach distance to it, its speed and heading, as well as the time to the moment of closest approach.

A provision is made in the radar for the capability of "playing through" the maneuvers of one's own ship in accordance with the situation and the SHIP COLLISION AVOIDANCE REGULATIONS (PPSS) by means of simulating the changes in speed and heading. After finding the safe maneuver, one can give the command for the change in the heading or speed of the ship.

A simplified block diagram of the "Okean" navigation radar is shown in Figure 5.2.

The Antennas [A, A3, A10]

The antenna consists of the radiofrequency section, the AOM32-4 antenna drive (1.5 KW, 220/380 volts, 50 Hz), a two-stage reducer for rotating the antenna, four type I.0.671.300 TU sine-cosine rotating transformers as well as the contact device and the heating elements.

The radiofrequency section of each of the A, A3 and A10 units includes the following major assemblies:

a) The radiator, which is a horn in the dual band and 10-centimeter antennas and a slot antenna in the 3-centimeter band;

b) The antenna used in unit A3 is a slotted waveguide;

c) The reflector in the dual band antenna is a continuous truncated parabolic cylinder and a grid reflector in the 10 cm antenna;

d) The rotating junction is a dual channel junction in unit A and a single channel one in units A3 and A10;

e) The antenna channel which joins the radiators to the rotating junction.

Decoupling is accomplished between the channels in the two band antenna by having different polarization for the corresponding horns: horizontal in the 3.2 cm band and vertical in the 10 cm band.

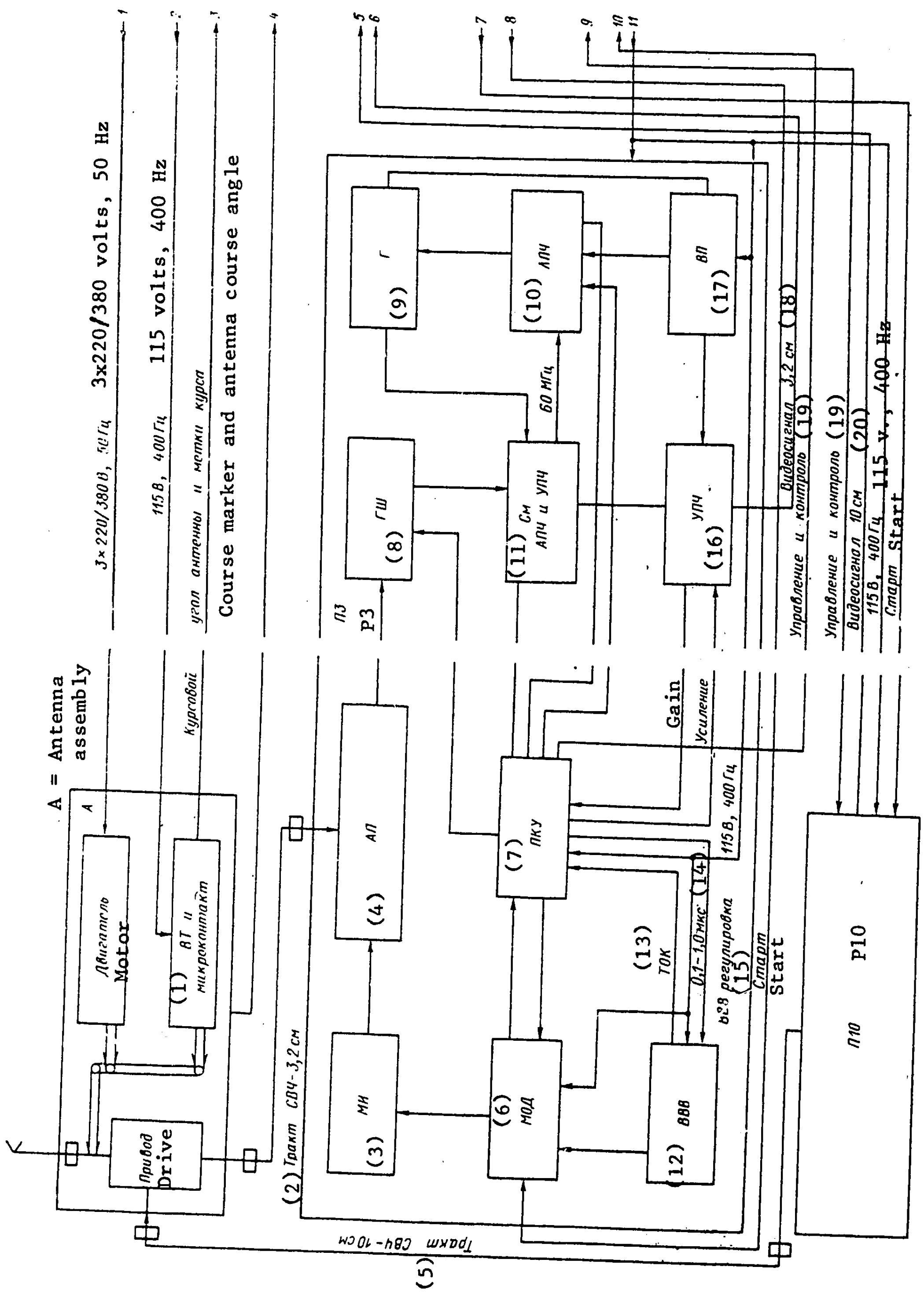

Figure 5.2. Block Diagram of the "Okean" Navigation Radar

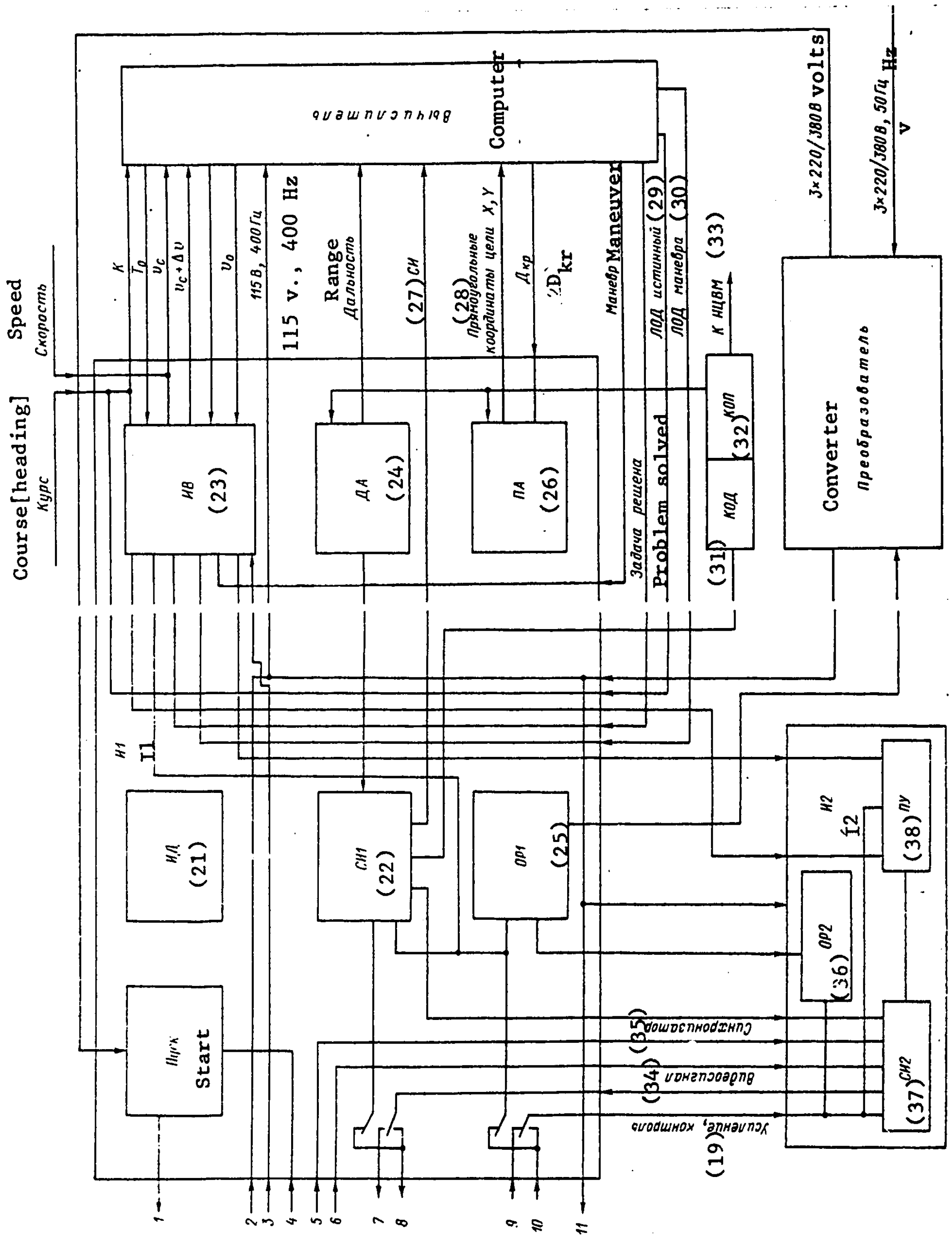

Figure 5.2, continued. Block diagram of the "Okean" navigation radar.

Key to Figure 5.2:

1. Rotating transformer and microswitch;
2. 3.2 cm microwave channel;
3. Magnetron oscilator;
4. Antenna switch;
5. 10 cm band microwave channel;
6. Modulator;
7. Control and monitor panel;
8. Noise generator;
9. Oscillator;
10. Automatic frequency control circuitry;
11. IF amplifier and AFC mixers;
12. High voltage power supply for the magnetron and modulator;
13. Current;
14. 0.1 to 1.0 microseconds;
15. Control for the high voltage power supply for the magnetron and modulator;
16. Intermediate frequency amplifier;
17. Receiver rectifier;
18. 3.2 cm video signal;
19. Monitor and control;
20. 10 cm video signal;
21. True motion block;
22. Synchronizer 1;
23. Computer indicator;
24. Automatic range tracking block;
25. Orientation block 1;
26. Azimuth automatic tracking block;
27. Sync pulses;
28. X and Y target cartesian coordinates;
29. True relative motion line;
30. Maneuver relative motion line;
31. Azimuth error circuitry of the automatic tracking system;
32. Azimuth error channel;
33. To the digital navigation computer;
34. Video signal;
35. Synchronizer;
36. Orientation block 2;
37. Synchronizer block 2;
38. Indicator control panel.

The rotating junction consists of a waveguide to coaxial transition and a contactless choke connection. In the two band junction, the outer conductor of the coaxial portion for band I is the inner conductor of the coaxial portion for band II.

Power is fed to the antenna rotation motor through a starter.

The instantaneous position of the antenna A is transmitted to the plan position indicator by means of coarse and precise readout sine-cosine rotating transformers. Each pair provides for the rotation of one PPI. The coarse readout rotating transformer (VT) is driven by the phase sensitive rectifiers of the PPI sweep generating channels, while the precise readout rotating transformer is driven by the azimuth angle strobe and course marker generator circuitry.

Only one coarse readout rotating transformer and one precise readout rotating transformer are mounted in single band antennas, since in this case, the antenna is coupled to only one plan position indicator.

The contactor actuates at the moment the antenna is positioned along the midline of the ship, once per antenna revolution and controls the course marker generator circuit.

The heating elements are intended for heating the drive during the cold season, as well as in the case of elevated humidity.

The switch makes it possible to disconnect the power to the motor when working near the antenna, something which prevents turning on the rotation from the plan position indicator.

The overall dimensions and weights of the antennas are given in Table 5.1.

The Transceivers

Each of the transceivers (P3, P10) consists of the transmitting and receiving sections (Figure 5.3). The transmitting section incorporates the following: the magnetron oscillator MI, the magnetron oscillator modulator MOD and the high voltage power supply for the magnetron and the modulator (VVV). The receive section contains: the microwave SVCh block, the intermediate frequency amplifier block UPCh, the automatic frequency control block AFC, the receiver power supplies block VPR and the control and monitoring panel PKU. Type MI-189B magnetrons are used as the microwave pulse generators in the 3 cm band and MI-12 magnetrons are used in the 10 cm band.

The modulator consists of a blocking oscillator with a trigger pulse amplifier (a 6N1P vacuum tube), a submodulator (two TGI1-35/3 thyratrons) and a final keying stage using a GMI-7 vacuum tube.

The first stage of the modulator is designed around a 6N1P twin triode. The left half is the trigger pulse amplifier and the right half is the blocking oscillator.

The submodulator is designed around two TGI1-35/3 thyratrons with storage lines. The first thyratron operates on the 1, 2 and 4 mile range scales. In this case, its stage generates a pulse with a width of τ = 0.1 microseconds. The second thyratron operates on the 8 to 64 mile scales. Its pulse width is τ = 0.5 microseconds.

The switching of the thyratrons is accomplished through the low voltage circuits by a switcher, controlled from the PPI indicator when the range scales are switched.

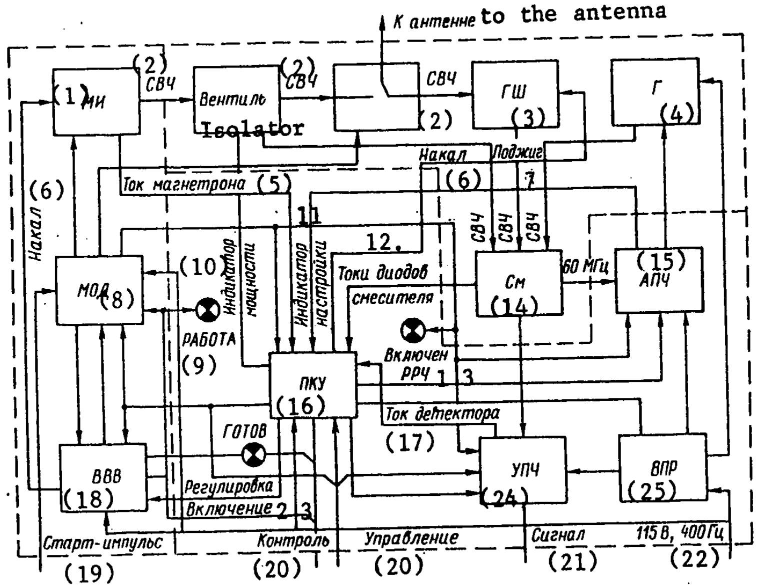

Figure 5.3. Block diagram of the P3 (or P10) transceiver.

Key:
1. Magnetron oscillator;
2. Microwave output;
3. Noise generator;
4. Oscillator;
5. Magnetron current;
6. Filament
7. Ignition;
8. Modulator;
9. Operate;
10. Power indicator;
11. Tuning indicator;
12. Currents of the mixer diodes;
13. Manual frequency tuning on;
14. Mixer;
15. Automatic frequency control;
16. Control and monitor panel;
17. Detector current;
18. High voltage power supply for the magnetron and modulator;
19. Start pulse;
20. Monitor and control;
21. Signal;
22. 115 volts, 400 Hz;
23. Control on;
24. Intermediate frequency amplifier;
25. Receiver power supplies.

The τ = 0.1 or 0.5 microsecond pulses having an amplitude of about 1,000 volts are fed to the control grid of the GMI-7 tube. The latter turns on, and a voltage of 15 KV DC is applied to the magnetron from the storage capacitor. A pulse is generated.

The probe pulse from the magnetron in unit P3 is propagated in the antenna and waveguide system through the following channels:

--A section with a metering sensor for the average probe pulse power;

--A section with a coupler for coupling the microwave power to the AFC channel;

--A ferrite--waveguide TRANSMIT-RECEIVE switch;

--A section for metering the transceiver voltage and measuring the traveling wave ratio of the antenna-waveguide channel, etc.

The power meter consists of small, series connected thermocouples, built into the narrow wall of the waveguide. The average power level is indicated by a meter in the PKU [control and monitor panel]. It is calibrated at the factory.

A unidirectional power coupler branches 1/1,000-th of the probe pulse power into the AFC channel.

The TRANSMIT-RECEIVER switch consists of a tee, a ferrite section and a slotted bridge. It connects the antenna-waveguide channel to the transmitter at the moment of transmission and to the receiver following the transmission of the probe pulse.

The channel for the 10 cm band probe pulse differs from that for the 3 cm band primarily in its structural design.

A ferrite isolator is inserted between the power measurement sections and the TRANSMIT-RECEIVE switch. It improves the oscillation stability of the 10 cm magnetron by means of attenuating the reflected wave by 20 dB. The isolator losses when passing the forward wave are 0.5 dB.

A series circuit with a gas type RR-54 discharger on the receiver side and an RR-56 on the transmitter side is used as the TRANSMIT-RECEIVE switch. Power is split off to the AFC channel in this same section through a limiting attenuator.

The modulator is powered by means of rectifiers which are built into it.

The -27 volt at -2.5 amps rectifier, which is intended for powering all of the transceiver relays, is designed in a bridge circuit using D-214 silicon diodes.

The +250 volt at 0.1 amp rectifier serves for powering the plate circuits of the preamplifier and blocking oscillator stages, as well as the bias magnetization windings of the saturable reactor of the high voltage rectifier. The rectifier is designed in a bridge circuit using D-211 silicon diodes with a capacitive filter.

The +1,250 volt at 0.03 amp rectifer is intended for powering the screen grid of the GMI-7 modulator tube. It is designed as a voltage doubler using D-1005A silicon diodes.

The +2.5 KV at 0.013 amp rectifier serves for powering the anode circuits of the thyratron and is designed as a voltage doubler using D-1005A silicon diodes.

The -800 volt rectifier, which is used to produce the bias voltage at the output stage control grid, is designed as a voltage doubler using D-1005A silicon diodes.

The high voltage rectifier consists of high voltage and filament transformers, type V2-0.06/25 vacuum tube rectifiers, a type K-41-1G-16-0.1 + 10% twin capacitor, a block of discharge resistors as well as relays for protection and turning systems on.

A doubler circuit is used in the rectifier with regulation of the output voltage by a saturable reactor. The relays for turning on the various rectifiers as well as the relays for protecting the VVV [high voltage power supply for the magnetron and modulator] are housed in the VVV block (see Figure 5.3). In the case of rectifier overload, the power is cut off to the contactor which breaks the power supply circuit for the primary winding of the high voltage transformer.

Reclosure of the circuit can be accomplished by the OPERATE toggle switch in the PKU [control and monitor panel] block or the OPERATE toggle switch in the indicator.

The receiving section of the band I microwave block consists of the TRANSMIT-RECEIVE switch, a gas discharger, a noise generator, mixers and K-27 klystron local oscillator.

A voltage of -800 volts is fed to a special electrode of the RR-21 broadband discharger to maintain a glow discharge, which facilitates the ignition of the discharger during the operation of the magnetron.

The GSh-2 noise generator consists of a waveguide section and a tube running through its wide wall, inside which there is a gas discharge tube.

In the working position, the received signals pass through the noise generator section without losses. When power is applied, the noise generator generates noise at a constant level. This makes it possible to determine the receiver sensitivity.

The power of the K-27 klystron local oscillator is distributed by means of a coaxial to waveguide junction between two channels: the signal channel and the AFC channel. The level of the energy tapped off is regulated by means of attenuators. The klystron can be fine tuned mechanically (when the klystron or magnetron is replaced) as well as by means of changing the voltage at the reflector either manually (RRCh) or automatically (APCh) [AFC].

The AFC and signal mixers are designed in a balanced circuit configuration using D405A and D405AP silicon diodes.

The operation of the mixer is monitored by means of measuring the DC components of the rectified diode currents. The currents are tapped off to a meter of the control and monitor panel through filters.

The microwave block for the band II receive channel includes the TRANSMIT-RECEIVE switch, a type GSh-2 noise generator, the mixers for the AFC and signal channels as well as the type K-12 klystron local oscillator.

The noise generator is inserted in the coaxial line between the antenna switch and the signal mixer. A portion of the line has the form of a helical inner conductor, wound on a capsule in which a gas tube is inserted.

The frequency of the K-12 klystron oscillator is controlled by changing the volume of the external resonator by means of a travel screw as well as by electronic means.

A coaxial tee branches the klystron power to the signal and AFC mixer channels. The power level is regulated by variable coaxial attenuators.

The 10 cm band mixers are designed in a balanced circuit configuration using D-405A and D405AP [sic] diodes. The decoupling and phasing of the signals and the local oscillator are accomplished by means of ring distributors.

The eight stage intermediate frequency amplifier, UPCh, is tuned to the intermediate frequency of 60 MHz and designed around 6Zh9P vacuum tubes.

A low noise circuit using two pentodes connected as triodes is used in the first two stages of the IF amplifier. The first stage is designed in a common cathode configuration while the second is a grounded grid circuit.

The gain is 40,000. The bandwidth in the "0.5" mode amounts to 4 MHz and 12 MHz in the "0.1" mode.

A bandwidth of 12 MHz is assured for the IF amplifier through the use of bandpass filters having two resonant circuits shunted with resistors in the second, third, fourth, fifth and eighth stages.

The switching of the bandwidth from 12 MHz to 4 MHz is accomplished by blocking the tube of the seventh stage, depending on the position of the BAND-D switch. Following amplification, the signal is detected by an AM detector, designed around a D3MA diode, the video pulses are amplified in a two stage amplifier designed around 6Zh9P vacuum tubes and the left half of a 6N6P tube, and fed through a cathode follower (the right half of the 6N6P tube) to the plan position indicator. Distinguishing the returns from a target against a background of interference from precipitation is improved when the short time constant network is switched in between the video amplifier stages.

The differentiating network is switched in by means of a relay from the PPI using the RAIN--NO CLUTTER switch.

The voltage for manual and time AGC is fed to the third and fourth IF amplifier stages.

The automatic frequency control block, APCh [AFC], provides for the following operating modes:

a) Automatic search and lock-on to the magnetron frequency;

b) Tracking the magnetron frequency;

c) Manual adjustment of the klystron frequency from the indicator or from the control and monitor panel.

The AFC block consists of a three stage intermediate frequency amplifier designed around 6Zh9P vacuum tubes, a frequency discriminator, using a 6Kh2P tube, an actuating section and a tuning indicator.

The actuating portion of the circuit consists of an amplifier (6N3P vacuum tube) and a diode transitron circuit configuration (the right half of the 6N3P and the 6Zh5P vacuum tube).

In the search mode, when there is no signal at the input to the AFC circuit, the voltage at the output of the actuating circuitry changes in accordance with a sawtooth waveform and is fed to the klystron reflector, changing its frequency in the corresponding fashion.

When a signal is present at the input to the circuit, the output stage operates as a DC amplifier.

The VPR3 (or VPR10) block of rectifiers, which is intended for powering the receivers of units P3 and P10, includes four rectifiers, two filament transformers and fuses.

All of the rectifiers are designed in a bridge circuit using diodes.

The VS-150-0.25 rectifier (150 volt, 0.25 amp regulated rectifier) is used to supply the plates and screen grids of the IF amplifier and AFC tubes.

The V-200-0.135 rectifier supplies the plate of the noise generator tube.

The VS-300-0.05 and VS-250-0.05 rectifiers supply negative voltage to the cathodes of the klystron and transitron of the AFC channel.

The VS-300(350)-0.0025 rectifiers are connected in series with the VS-300-0.05 rectifier (in the VPR10) or the VS-250-0.05 rectifier (in the VPR3) and provide a negative voltage of -550 volts (in the VPR3) or -650 volts (in the VPR10) to the resistors in the control and monitor panel and AFC blocks which in conjunction with the transitron regulate the voltage at the klystron reflector.

The control and monitor panel incorporates a meter with a switch for the circuits to be checked and an OPERATE--MONITOR switch, which connects the circuits being checked either to the controls of the console or to the controls and meters of the indicator.

The control and monitor panel makes it possible to measure the following:

--The currents of the IF amplifier mixer diodes;

--The currents of the AFC mixer diodes;

--The average power at the transmitter output;

--The plate current of the noise generator;

--The plate current of the IF amplifier detector for metering and checking the sensitivity of the receiver;

--The -27 volt, -600 volt, -300 volt and +150 volt rectifier voltages;

--The currents of the AFC tuning indicator;

--The magnetron current.

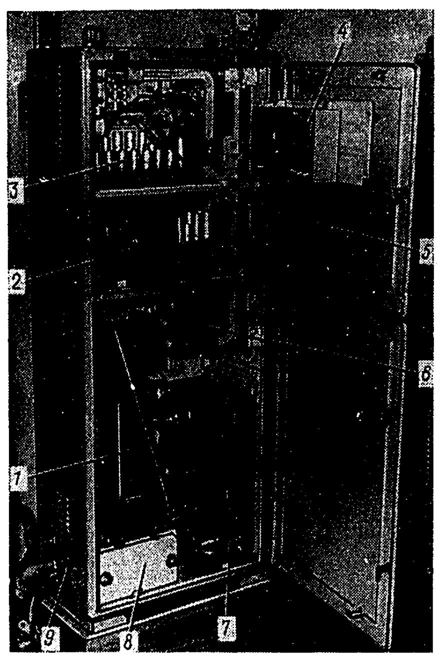

Figure 5.4. General view of unit P3 [3-cm band transceiver].

Key: 1. High voltage rectifier block;
2. Block of receiver rectifiers;
3. Microwave compartment;
4. Control and monitor panel;

Key [cont.]:
5. Interlock;
6. Magnetron;
7. Modulator block;
8. Compartment of plug connectors;
9. Sockets for the connection of a light, headset and soldering iron.

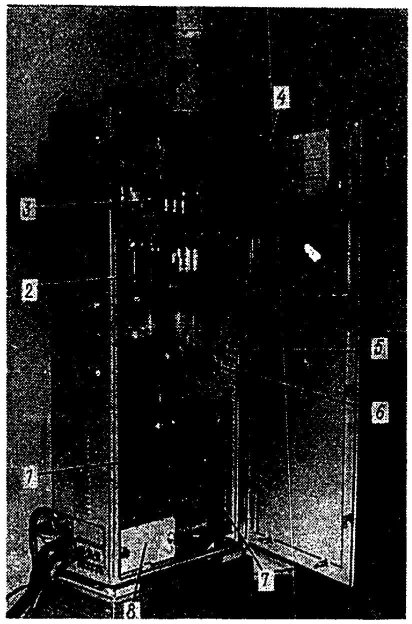

Figure 5.5. General view of unit P10 [10-cm band transceiver].

[Key the same as for Figure 5.4]

The OPERATE--CHECK switch switches such controls in the indicator and transceiver as:

--The network for switching the local oscillator tuning from manual to automatic and vice-versa using the AFC--MANUAL FREQUENCY CONTROL toggle switch;

--The circuit for turning on the high voltage using the OPERATE--TURNED OFF toggle switch;

--The circuit for blocking the actuating of the transceiver from the indicator. It cannot be turned on in the "Check" mode if the READY--TURNED OFF toggle switch is switched off;

--The RRU [?manual gain control?] circuit using the RRCh [manual frequency control] potentiometer;

--The gain control circuit of the IF amplifier from the GAIN potentiometer.

The TUNE potentiometer for setting the initial voltage level at the klystron reflector as well as the magnetron current control potentiometers are located in the control and monitor panel.

The transceivers P3 and P10 (Figures 5.4 and 5.5) are structurally designed in the form of racks. Each rack is broken down into compartments by horizontal partitions. The receivers and their power supplies are housed in the top compartments, while the transmitters are housed in the lower ones.

Plugs for external cable connections are located in a compartment in the lower section. The compartment is connected by a pipe to the upper compartment. The lines to the transmitter pass through the wall of the compartment by means of feed-through capacitors. This provides for the requisite decoupling between the receiver and transmitter units.

The racks are equipped with exhaust ventilation. The external air in the room is sucked in through louvers, cut in the side walls and rear wall of the cabinet where the major heat liberating blocks and components are located: the magnetron, modulator tubes, as well as the high voltage power supply for the magnetron and modulator, the AFC and IF amplifier blocks. The air flow is routed through branch pipes from the louvers to the heat radiating surfaces and radiators of these surfaces; the same branch pipes remove the heated air to an air duct on the rear wall of the chassis. An exhaust fan with an output of 50 l/sec is mounted at the distribution pipe of the air duct or the ship's exhaust system is used. In this case, the excess heating of the air in the region of the transceivers does not exceed 5° C. In the case of failure of the ventilation system, a protection circuit cuts off the transceivers if the temperature of the magnetron block exceeds the ultimate permissible level (+140° C).

The upper and lower compartments of the racks are closed with swingout covers, which have electrical and spray protection seals about the perimeter.

The transmitter assemblies which are subject to high voltage are insulated by potting them in epoxy resin, while the connections between them are made with shielded high voltage wire.

Access to the components of the blocks in the units is possible after the blocks are removed, which are connected to the rack by means of special cables.

When the cover of the lower compartment is opened, an interlock contact breaks the power supply circuit for the unit, while a mechanical discharger automatically shorts the high voltage circuits to chassis ground. Plug sockets are provided in the transceiver racks for the connection of a light, headphones and soldering iron.

Indicators.

The I1 and I2 indicators are the major units for the control, monitoring, display and reading of information.

The following is accomplished in units I1 and I2:

--Generates the signals which synchronize radar operation;

--Generates the radar plan position indication of the situation based on information received from the transceiver, antenna, gyrocompass and log;

--Automatically determines the current coordinates of the target selected by the operator and transmits them to the computer;

--Operationally controls and monitors the entire radar station;

--Relays the power voltages incoming from the power plant to all of the radar units;

--Relays signals between units of the radar.

The following assemblies and blocks are included in the complement of indicator I1 (Figure 5.6):

a) Indicator tube block TR1;

b) Orientation block OR1;

c) Computer indicator block IV;

d) True motion block ID;

e) Block of tracking systems for automatic azimuth tracking, PA;

f) Block of tracking systems for automatic range tracking DA;

g) Azimuth autotracking error channel assembly KOP;

h) Range autotracking error channel assembly KOD.

The functional links between the blocks and assemblies, the output signals and voltages as well as the interconnections to other units of the radar are also shown in Figure 5.6.

The following are incorporated in unit I2 (Figure 5.7):

--The indicator tube block TR2;

--The orientation block OR2;

--The indicator control console PU.

Also shown in this same figure are the ties between the blocks of unit I2 and those to other units of the radar set. Besides the indicated assemblies and blocks, each indicator includes switching, connecting, metering and protective components.

The TR1 tube assembly of the plan position indicator (Figure 5.6) is intended for displaying the radar image and consists of three functional groups:

1) A type 45LM1V CRT with sweep generating elements;

2) The synchronizer;

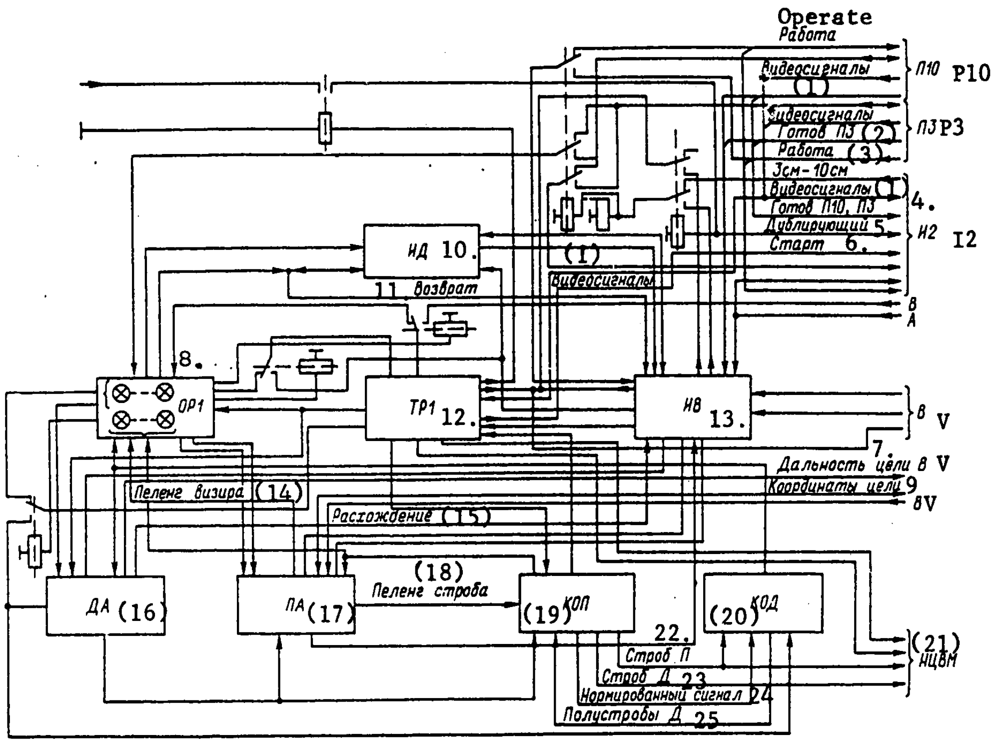

Figure 5.6. Block diagram of indicator I1.

Key:
1. Video signals;
2. P3 [P3 = 3.2 cm transceiver];
3. Operate;
4. P10, P3 ready;
5. Duplicating;
6. Start;
7. Target range;
8. Orientation block 1;
9. Target coordinates;
10. True motion block;
11. Return;
12. Indicator tube block 1;
13. Computer indicator block;
14. Cursor bearing;
15. Passing;
16. Block of automatic range tracking systems;
17. Automatic azimuth tracking block;
18. Strobe bearing;
19. Automatic azimuth tracking error block;
20. Automatic range tracking error block;
21. Navigation computer;
22. Bearing strobe;
23. Range strobe;
24. Normalized signal [return];
25. Range gates.

3) Rectifiers and connecting elements.

The orientation block OR1 includes the major controls for the indicator with the elements which generate the corresponding control currents and voltages.

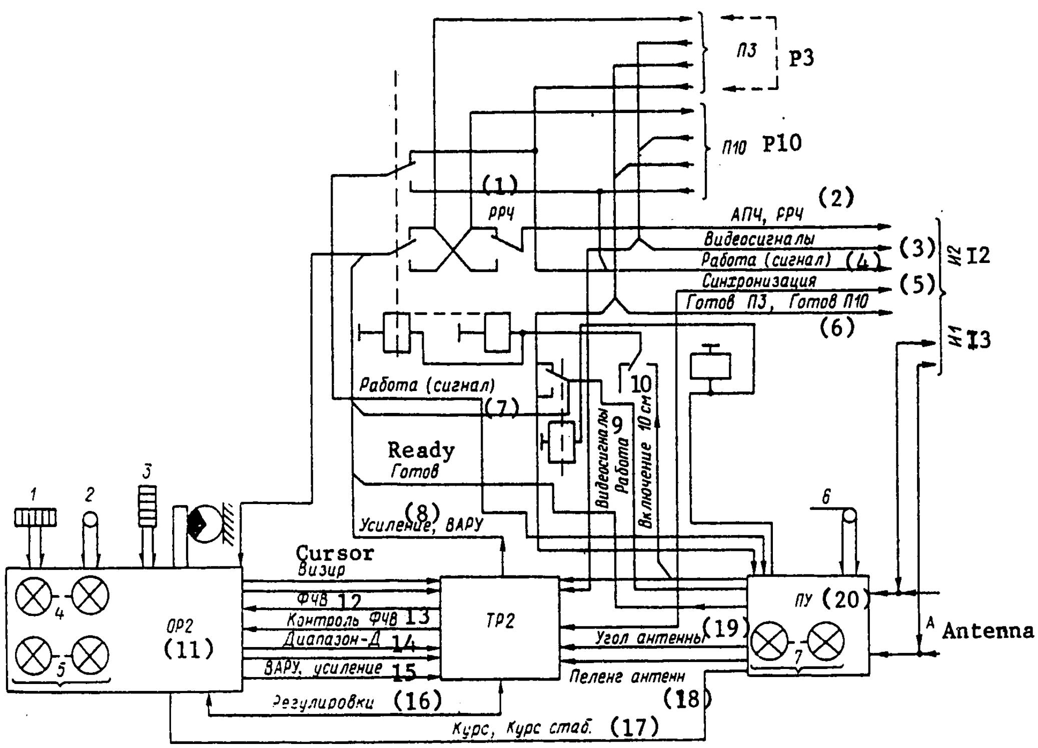

Figure 5.7. Block diagram of indicator unit I2.

Key:
1. Manual frequency control;
2. AFC, manual frequency control;
3. Video signals;
4. Operate (signal);
5. Synchronization;
6. P3 [3.2 cm transceiver] ready, P10 [10 cm transceiver] ready;
7. Operate (signal);
8. Gain, time AGC;
9. Video signals; operate;
10. 10 cm on;
11. Orientation block 2;
12. Phase sensitive rectifier;
13. Phase sensitive rectifier metering;
14. Band - D [?range?];
15. Time AGC, gain;
16. Controls;
17. Course, course stabilized;
18. Antenna bearing;
19. Antenna angle;
20. Indicator control panel;

1. Adjusting controls;
2, 6. Switch;
3. Controls for the range and bearing cursors;
4, 5. Readout display;
7. Readout display for the transmitters and antenna.

The true motion block serves to derive control signals, which shift the origin of the sweep of the indicator CRT in the direction and at the speed of travel of the ship, represented with the same scale as the image.

The target range tracking (DA and KOD circuits) and azimuth tracking channels (the PA and KOP circuits) operate in the "tracking" mode when resolving the problem of passing and determining the parameters of an oncoming ship.

All of the controls for the computer, the display and readout scales, on which the computation results are displayed, are located on the computer indicator block. Additionally, some controls for the radar and the indicator are located on the front panel of the unit.

Indicator I2 does not provide for radar operation in "true motion", "tracking" or "computer" modes.

The TR2 tube block (see Figure 5.7) contains the following:

--A type 45LM1V cathode ray tube with sweep elements;

--Synchronization units;

--Rectifiers and sweep elements.

Orientation block OR2 incorporates the main controls for the indicator. This unit does not have any relay or diode logic circuitry for mode switching or universal joint links to other blocks.

The indicator control panel block incorporates the controls for the indicator, rotating transformers for image orientation, relays with elements for turning on the power plant, the antenna, the transceiver and the indicator.

It is expedient to treat the indicator units in terms of the functional structural configuration, which consists of the stages for generating, amplifying and converting the signal as well as feeding it out to the final stage.

The synchronizer channel consists of the channel of peakers and the crystal controlled master oscillator (KOK), the scale frequency channel (KMCh), as well as the channel of voltage amplifiers which drive the phase shifters (KUS).

The pulsed voltage of the master crystal oscillator is generated in the KOK, as a result of the division of which by means of the flip-flop divider of the scale frequencies channel, a grid of scale frequencies is obtained, from which the various synchronization signals are generated in the plan position indicator blocks.

The voltage amplifier channel is used only to segregate the sinusoidal voltages at frequencies of 5 KHz and 81 KHz from the "meander" type voltages at the same frequencies, and then subsequently amplify them.

The channel for generating the transmitter start pulses. the cursor and signal sweep brightening and width pulses generates the following signals:

a) The reference cursor and signal start pulses;

b) The transmitter start pulses;

c) The electronic cursor and signal sweep width pulses;

d) The pulses for brightening the cursor and signal sweeps.

The channel incorporates the stages of the scale frequency channel and crystal controlled master oscillator and peaking channel blocks.

The channel for generating the time AGC voltage generates a negative voltage which blocks the receiver. Clutter from an agitated sea surface is suppressed by changing the time constant and voltage level.

The generation of the stationary range ring markers is based on the use of scale frequencies generated by a flip-flop divider of the synchronizer. The channel for generating the stationary range ring markers consists of elements of the scale frequencies channel and the crystal controlled master oscillator and peaking channel.

The phase metering technique of obtaining moving range rings is used in the "Okean" radar. The generating channel includes stages of the scale frequencies channel, voltage amplifier channel, automatic range tracking system and crystal controlled master oscillator and peaking channel blocks.

The plan position indication sweep is generated in the PPI by means of two mutually perpendicular stationary deflecting coils by means of passing sawtooth waveform pulses through them, the envelope of which is modulated by the antenna rotation with a phase shift of 90°. The channel for generating the signal sweep, the cursor sweep and the LOD [relative motion line] consists of elements and stages of unit A [the antenna], the computer indicator block, as well as the indicator tube assemblies for units 1 and 2. Changing the "north--stabilized course" orientation is accomplished by switching in the corresponding sine-cosine rotating transformers in the computer indicator block.

The true motion block generates the voltage for shifting the sweep origin in the same direction and at a speed proportional to the motion of the ship itself. This makes it possible to eliminate the vector of the ship's speed, the radar vehicle, from the relative velocities of the targets, i.e., to create a true motion mode.

Based on the log and course data, a speed vector is constructed in the computer indicator block in "North--South" and "West--East" coordinates. The components of the travel route are obtained by integrating the scaled components of the speed vectors by means of integrating drives in the true motion block.

The resulting voltage is applied to the displacement coils of the indicator tube block 1. In this case, the sweep origin is displaced at a speed proportional to and in the direction of motion of the ship itself.

A provision is also made for automatic reorientation of the image if the center of the sweep is shifted beyond one-third of the radius of the CRT screen or if the course of the ship deviates by $\pm 30°$ from the initial heading.

A true motion mode is provided only on the 1, 2, 4 and 8 mile scales with the "North" orientation.

The automatic range tracking channel turns on the DA [block of automatic range tracking systems] and the KOD [automatic range tracking error circuitry] blocks, and provides for automatic range tracking of a selected target in a plan position indication mode.

A tracking circuit using two integrators is employed in the radar. In the automatic range tracking block, the target is "locked on", and a time delay is generated by the phase metering method. Range gates are generated in the automatic range tracking error block, and a time comparison of the gates with the normalized return from the target is also accomplished in this block. Using a "number to voltage" converter, the autotracking error is converted from a number to a voltage and fed to the automatic range tracking block. Following amplification and modulation, the error signal controls the drives of the main and supplemental integrators so that the autotracking error tends to zero.

The azimuth automatic tracking channel provides for automatic target tracking with respect to angle in a plan position mode and incorporates the PA [automatic azimuth tracking] and KOP [automatic azimuth tracking error] blocks.

The target is "locked on" manually in the automatic azimuth tracking block, and a time delay is generated in the form of the envelopes of the rotating transformers. In the automatic azimuth tracking error block, a gate pulse, strobe center and strobe pulses are generated from the envelopes. The timewise mismatch of the strobe and envelope of the target return is converted from a number to a voltage and fed to the automatic azimuth tracking block, where the rotors of the sine-cosine rotating transformers are rotated by means of the main and auxiliary integrators to that position in which the autotracking error in azimuth tends to zero.

The Computer Indicator

All of the remote controls for the computer are concentrated in the computer indicator block (IV), as well as the scales and display for the computer results. Moreover, some controls for the radar and the plan position indicator are located on the computer indicator block.

The major electrical components of the unit are combined in four functional assemblies: for the course K, speed v_c, time remaining to the closest approach T_0 and the time delay (see Figure 5.2).

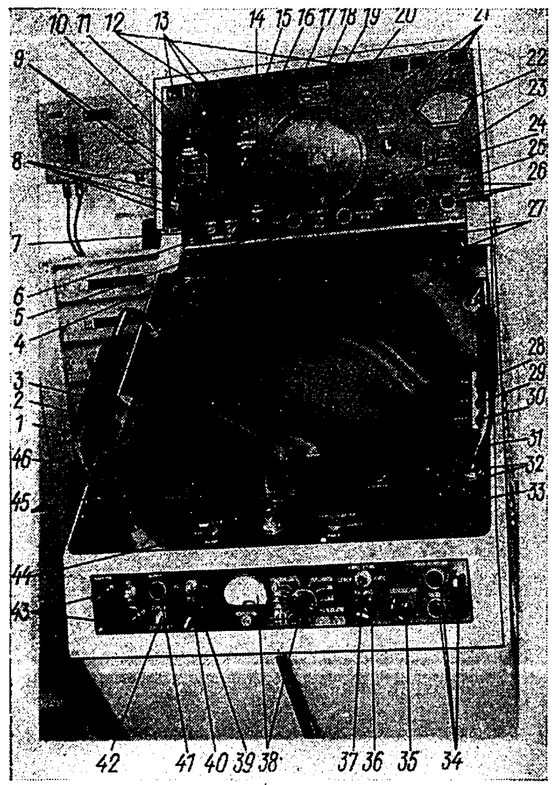

Figure 5.8. General view of the orientation block and the computer indicator of indicator unit I1.

[See text for key]

The speed circuitry contains the elements for converting the information on the speed derived from the ship log.

The course assembly is composed of elements for converting the information incoming from the gyrocompass, as well as the rotating transformer plotters for the speed vector.

The closest approach time circuitry incorporates the components for solving for T_0 using the relative course and speed data of an oncoming ship, as well as the range and azimuth to it.

The COURSE CORRECTION and SPEED CORRECTION controls are used to play through a maneuver when solving the passing problem. The function of the remaining controls and displays are described in detail on pages 173-174.

The rectifiers supply the voltages to power the transistors of the assemblies and blocks, as well as those for the switching and control circuits.

Each regulated rectifier consists of the main and auxiliary rectifiers, as well as the regulator.

The main rectifiers are designed in a bridge circuit configuration, while the auxiliary rectifiers use a doubler circuit. The rectifiers produce voltages of 27, 400, 600 volts as well as 6 and 15 KV.

The orientation block (Figure 5.8) incorporates the controls for the indicator, which generate the corresponding control voltages and currents.

In terms of the functional designation, all of the controls can be broken down into several groups.

The following are included among the controls and readouts for the indicator operating mode:

--The PPI BRIGHTNESS control (1) and PPI FOCUS control (2) by means of which the optimal brightness and focusing of the image on the screen is set;

--The COURSE MARKER control (3), by means of which the requisite brightness of the course trace is set;

--The NKD [STATIONARY RANGE RING] control (28), PKD [MOVING RANGE RING] control (29) and CURSOR control (30), which are intended for setting the requisite brightness of the stationary range rings, the moving range ring and the electronic cursor line on the PPI screen;

--The INDICATOR--OFF toggle switch (25), which serves for turning the indicator on and off;

--The BAND--D [RANGE] control (27), by means of which the range scales on the indicators are switched (the signaling that a scale is switched on is accomplished on a display);

--The RANGE control (32), intended for controlling the position of the moving range ring on the image sweep and the cursor sweep (the range is indicated on a display panel in the form of a numerical value with a precision of down to hundredths of a mile);

--The BEARING control (45), which serves to control the angular position of the mechanical and electronic cursors (the bearing is read on the circular scale only in the "north" mode);

--The RADIUS control (36), which in the "relative motion" mode moves the sweep center of the image radially outward from the center of the screen;

--The ANGLE control (40), which in the "relative motion" mode moves the center of the image sweep in a circle with a radius set by the RADIUS control;

--The ILLUMINATION control (35), by means of which the brightness of the circular scale and display framing the indicator screen is set.

The following number among the controls and readouts for the transceivers and the entire radar:

--The POWER PLANT ON--OFF buttons (34), by means of which the power plant is started and stopped by remote control;

--Toggle switch 3-10 (8), by means of which the working frequency is chosen in the two-band radars (when both transceivers are connected to one PPI, the control can be realized only from the main indicator, a fact which is signalled by the MAIN and DUPLICATE display);

--The READY--OFF (7) and OPERATE--OFF (6) toggle switches, which are intended for turning on the transceivers and applying the high voltage to the magnetron. The READY display signals the readiness of the high voltage to be turned on, while this turning on is accompanied by the lighting of the OPERATE display;

--The NORTH--COURSE--COURSE STABILIZE (37) switch, by means of which the orientation of the image is changed on the indicator screen. Displays are mounted above the screen which show the orientation which is turned on. In the "course stabilized" mode, the COURSE and COURSE STABILIZED displays are turned on. If the ship deviates from the course matching that when the unit was turned on, the COURSE display goes out;

--The ID--OD [TRUE MOTION--RELATIVE MOTION] toggle switch (39), which is intended for turning on the "true motion" mode (in this case, the TRUE MOTION display lights up);

--The RAIN--NO INTERFERENCE toggle switch (42), which in the "rain" position switches in the MPV [small time constant] circuit in the video signal channel, which promotes a reduction of clutter from precipitation;

--The ANTENNA ON--OFF toggle switch (26), which serves for switching the antenna rotation on and off (in this case, the ANTENNA display lights up);

--The AFC--MANUAL FREQUENCY CONTROL toggle switch (43), by means of which one switches from AFC to manual control by means of the RRCh control [manual frequency control];

--The SEA CLUTTER control (46), by means of which the time automatic gain control system is adjusted;

--The CURSOR--RELATIVE MOTION LINE toggle switch (44), which in the "relative motion line" position provides for a mode such that the direction of the electronic cursor indicates the relative heading of the ship itself with respect to the target, which is automatically calculated by the computer;

--The GAIN control (31), which is intended for adjusting the radar receiver sensitivity;

--The UNIT V--OFF toggle switch (4), by means of which one switches to the mode for the solution of the passing problem;

--The TEST (5) button, which serves to switch the I1 indicator computer to a check mode in which the output data of the indicator computer should correspond to the values given in the tables attached to the panels of the units;

--The OFF--LOCK-ON--TRACK toggle switch (33), which is intended for turning on the target tracking and lock-on modes;

--The TARGET SPEED button (23), which when pressed, the meter needle indicates the speed of the target; when the button is released, the unit indicates the closest approach range;

--The COURSE CORRECTION (13) and SPEED CORRECTION (21) controls in indicator I1, by means of which one plays through the maneuver for passing in the passing problem solution mode, while in the "true motion" mode, corrections are made for the drift and current. The course and speed, taking the corrections into account, are read out from the scales which are placed above the controls. The MATCH COURSE and MATCH SPEED displays indicate the necessity of setting the controls to the initial positions;

--The RETURN button (41), which is intended for re-orienting the image in the "true motion" mode.

The following are included among the metering and readouts for the radar:

--The CHECK switch (38), which makes it possible to check the values of the voltages and currents of the units (the nominal value of the parameters being checked corresponds to the setting of the meter needle within the range of the red or green sectors, as well as to the zero mark in the center of the scale);

--The BEARING (14) and RANGE (24) scales which serve for the precise readout of the coordinates of a target being tracked;

--The CLOSEST APPROACH TIME scale (22);

--The T MIN scale (11);

--The APPROACH TIME GREATER THAN AN HOUR display (16), which displays the time remaining until the closest approach to the target being tracked;

--The PASSING display (15) which indicates the fact that the target being tracked is going away;

--The PROBLEM SOLVED display (17), which in the turned on state, guarantees the accuracy of the output data;

--The MANEUVER display (18), which signals a change in course or speed of one's own ship or a ship being tracked, which is signified by a rotation of the relative motion line through 5° or a change in the relative speed of the ships by ± 2.5 knots;

--The APPROACH DANGEROUS display (12), which lights up in the case where the calculated distance of the closest approach is less than 2 miles;

--The TIME CIRCUITRY FAILURE display (19), which lights up when the most important part of the computer fails;

--The scale (20) with two "small ship" pointers, which make it possible to read out the course of one's own ship (the small white ship) and the ship being tracked (the red one).

The BAND--D [RANGE] switch and the NORTH--COURSE--COURSE STABILIZE toggle switch are independent switching controls for the indicator modes.

The modes can be changed by means of other controls following the definite setting of the controls indicated above. To change over to the "true motion" mode, one must beforehand set the "north" orientation and switch to one of the range scales: 1, 2, 4 or 8 miles. The "lock-on" and "track" modes can be switched on only on the 8 and 16 mile range scales in the "relative motion" mode.

The Computer

The computer, in conjunction with the range and azimuth autotracking blocks, and the computer indicator of indicator I1, automatically solves the problem of the ship which is the vehicle for the "Okean" radar passing a ship, the blip of which is being tracked automatically.

The indicators of the major parameters calculated by the unit are given on pages 155-156 and below:

Path along the true motion line which assures the solution of the problem with the precision indicated on [one to two words obscured or missing in original], in miles, no more than	1
Range of parameters which can be computed:	
K_0, degrees	0--360
D_0, miles	0--12
T_0, minutes	0--60
V_0, knots	0--60
K_{target}, degrees	0--360
V_{target}, knots	0--30
Δv, knots	0--30
ΔK, degrees	0--360
Parameters of the course sensing selsyn:	
Type	BS-404ATV
Revolution scale division, degrees	1
Maximum load moment, g · cm	20
Parameters of the speed sensing selsyn:	
Type	NS-404ATV
Revolution scale division, knots	0.2
Maximum load moment, g · cm	30
Power consumed from the 115 volt, 400 Hz mains, in KVA:	
In the "lock-on" mode	0.13
In the "solution" mode	0.53

The computer incorporates the following individual electromechanical structural assemblies:

a) The unit for the increments in the relative path components ΔS_0;

b) The plotter for the vector of the relative path K_0;

c) The relative velocity V_0 unit;

d) The converter for the course data K incoming from the gyrocompass;

e) The converter for the velocity data v incoming from the log;

f) The converter for the time data T incoming from the autorecorder, the clock unit or the BTV unit itself;

g) The plotter for the relative velocity vector K_0 = var., when playing through a maneuver;

h) The power supply and generator for the PROBLEM SOLVED signal and the raw data for the "test" mode (P);

i) BTV is the current time unit (not present in the first batch of radars).

The basic circuit of the unit takes the form of a schematic showing the electrical connections between the external sockets of the units enumerated here, as well as their connections to the external plug connectors of the unit.

The Control of the "Okean" Radar

The controls and the initial positions corresponding to them before turning the unit on are indicated below:

Toggle switch 25, INDICATOR--OFF	"Off"
Toggle switch 7, READY--OFF	"Off"
Toggle switch 6, OPERATE--OFF	"Off"
Image orientation switch 37, NORTH--COURSE--COURSE STABILIZED	"North"
Toggle switch 42, RAIN--NO CLUTTER	"No clutter"
Toggle switch 43, AFC--MANUAL FREQUENCY CONTROL	"AFC"
Toggle switch 39, ID--OD [TRUE MOTION--RELATIVE MOTION]	"OD"
Toggle switch 44, CURSOR--RELATIVE MOTION LINE	"Cursor"
Toggle switch 33, OFF--LOCK-ON--TRACK	"Off"
Toggle switch 4, UNIT V [computer]--OFF	"Off"

The positions of the remaining controls are set after the unit is turned on.

The radar is turned on in the following order: the power plant is turned on by means of the black pushbutton 34; the indicator is turned on with toggle switch 25; the frequency is selected by means of toggle switch 8; by setting toggle switch 7 in the "ready" position, the transceiver is switched on; the brightness and focusing of the stationary and moving range ring markers is adjusted, as well as the course marker, using the appropriate controls; the antenna is turned on, by pressing black button 26. After four minutes, display 7 lights up: READY 3 CM (or READY 10 CM). Toggle switch 6 is used to turn on the high voltage, and in this case the OPERATE display lights up.

The radar is turned off in the opposite order.

Depending on the specific conditions, the selection of the orientation mode is accomplished by means of toggle switch 37: NORTH--COURSE--COURSE STABILIZED.

It is possible to shift the center of the sweep in a range of two-thirds of the radius in the case of true motion indication on the 1, 2, 4 and 8 mile scales by means of controls 36 (RADIUS) and 40 (ANGLE).

The "relative motion" mode is the main one for both indicators. The "true motion" mode is possible in the indicator I1 when the following controls are turned on beforehand: range scale switch 27 is set to one of the "1--8 mile" positions; switch 37, NORTH--COURSE STABILIZED--COURSE, is set in the "north" position; toggle switch 39, TRUE MOTION--RELATIVE MOTION, set in the "true motion" position.

A provision is made in the radar for the possibility of manually returning the sweep origin to the initial position by means of pressing pushbutton 41, RETURN.

Operation of indicator I1 is possible in the "autotracking" mode with the "North" orientation and the relative motion indication set on the 8 and 16 mile range scales. In this case, it is necessaiy to perform the following operations:

a) Toggle switch 33, OFF--LOCK-ON--TRACK, is set in the "lock-on" position. The cross at the end of the electronic cursor indicates the position of the autotracking strobe;

b) By rotating controls 10 (BEARING) and 9 (RANGE), the cross is matched up with the selected target;

c) Toggle switch 33 is thrown to the "track" position.

The scales of units 14 and 24 will show the current values of the bearing and range of the target being tracked.

The computer is turned on by pushing button 4, COMPUTER.

After the blip of the ship being tracked passes the one mile point on the relative motion line, display 17, PROBLEM SOLVED, comes on. The results with the specified precision are shown on the scales of the computer indicator. If the approach time exceeds an hour (for a ship traveling with the radar ship), display 16, APPROACH TIME GREATER THAN AN HOUR, lights up. In the case where a departing target is tracked, the PASSING display 15 comes on.

A provision is made in the "Okean" radar for playing through a maneuver, i.e., simulating the course or speed changes (or both simultaneously), so as to pass the ship being tracked at the distance desired. The correctness of computer operation is checked by means of the "test" mode.

5.2. The "Okean-M" Marine Navigation Radar

The "Okean-M" marine navigation radar is intended for installation on large tonnage ships of the merchant marine and fishing fleets, for the purpose of improving navigation safety in the open sea, as well as close to shore and in narrow straits.

TABLE 5.3

Unit Code Desig- nation	Unit Decimal Number, Type	Unit Name	Overall Dimensions, mm			Weight, kg	Power Consump- tion, KVA
			Width	Depth	Height		
A	LYe2.092.014.SP	Parabolic, com- bined, two-band antenna	3490	965	1197	500	1.8
A3	LYe2.901.011.SP	Slotted waveguide 3-cm band antenna	3295	810	809	300	1130
A10	LYe2.091.012.SP	Slotted waveguide 10-cm band antenna	3441	1015	1140	400	1130
P3	LYe2.000.047.SP	3-cm band trans- ceiver	590	470	1560	158	0.9
P10	LYe2.000.048.SP	10-cm band trans- ceiver	590	470	1560	180	0.9
I	LYe2.048.064.SP	Indicator	600	880	1390	280	0.6
V	LYe2.300.020.SP	Computer	700	347	1350	280	0.5
ID	LYe2.316.005.SP	True motion unit	494	270	680	50	0.33
K1	LYe3.622.052.SP	Switching unit for the single band version	352	226	475	30	0.12
K2	LYe3.622.051.SP	Switching unit for the two band version	500	250	620	60	0.24
K3	LYe3.622.053.SP	Radar switching unit, equipped with units V or ID	534	126	295	15	--

TABLE 5.3 [cont.]

Unit Code Designation	Unit Decimal Number, Type	Unit Name	Overall Dimensions, mm			Weight, kg	Power Consumption, KVA
			Width	Depth	Height		
KI	LYe2.334.000.SP	Transmission metering unit	230	128	182	3	--
KP3	LYe2.735.000.SP	Voltage metering unit for P3	475	275	282	25	--
KP10	LYe2.735.001.SP	Voltage metering unit for P10	360	280	302	25	--
	ATO-2-400	Converter	365	710	450	170	4.1
	ATO-4-400	Converter	518	716	587	280	7.4
	PMM-1112	Single mains starter	248	174	394	10.5	--
	BRN-143/3	Voltage regulator block	354	146	302	13	--
	--	S1-49 oscilloscope	170	430	223	8.5	0.038
	--	Ts-431 volt-ohm-milliammeter	110	205	80	1.5	--

The "Okean-M" radar operates in one or two bands (3 and 10 cm) and provides for the following:

--Observation of the radar situation in a true or relative display mode on a PPI screen, as well as the measurement of the polar coordinates of targets;

--Automatic target tracking in a circular scan mode at ranges of from 1 to 15 miles for a relative speed of from 0 to 60 knots with continuous feedout of the current coordinates of the target (range and azimuth). The automatic tracking is accomplished with preliminary manual lock-on to the selected target;

--Automatic solution of the problem of passing a target being tracked with the feedout of data on the range to the target, its speed and the time to closest approach. Playing through the course or speed maneuvering or both of these simultaneously makes it possible to come up with recommendations for safe passing.

The "Okean-M" navigation radar is a modernized version of the "Okean" navigation radar. It is manufactured and supplied in different equipment packages: one and two band radars; with autotracking, true motion and computer systems, as well as without them.

TABLE 5.4

(1) Наименование шкафа или ящика ЗИПа	Overall Габаритные размеры, мм Dimensions, mm			(2) Масса, кг	(3) Количество, шт.	№ комплекта Set No.
	Ширина Width	Глубина Depth	Высота Height			
Шкаф-стойка (4)	460	465	1345	140	2	00—31
Укладочный ящик (5)	582	550	705	31	1	00—31
» »	410	370	265	20	1	00—31
» »	410	370	175	18	1	00—31
» »	410	370	265	20	1	04, 05, 10, 11, 16, 17, 22
» »	410	370	265	20	1	22, 23, 26, 27, 30, 31
» »	410	370	265	20	1	06—31
» »	580	362	304	25	1	12—31
» »	410	370	265	20	1	00—05

Key: 1. Designation of the cabinet or box of spare parts, tools and accessories;
2. Weight, kg;
3. Number, pieces;
4. Rack cabinet;
5. Packing box.

The listing of the units incorporated in the "Okean-M" navigation radar complement is given in Table 5.3.

Besides the indicated units, the radar complement also includes:

--Installation set for assembling the 3 cm band antenna-waveguide channel and the microwave cable for the 10 cm band radar;

--Sets of spare parts, tools and accessories for the radar (Table 5.4) and the power plant;

--The set of plug connectors for the interunit connecting cables;

--The set of operational documentation.

The "Okean-M" navigation radar equipment complement, which is manufactured in complete sets, is listed in Table 5.5.

Any radar package is supplied with the power plant using the ship power mains at 220/380 volts AC and 50 Hz. A block diagram of the "Okean-M" navigation radar is shown in Figure 5.9.

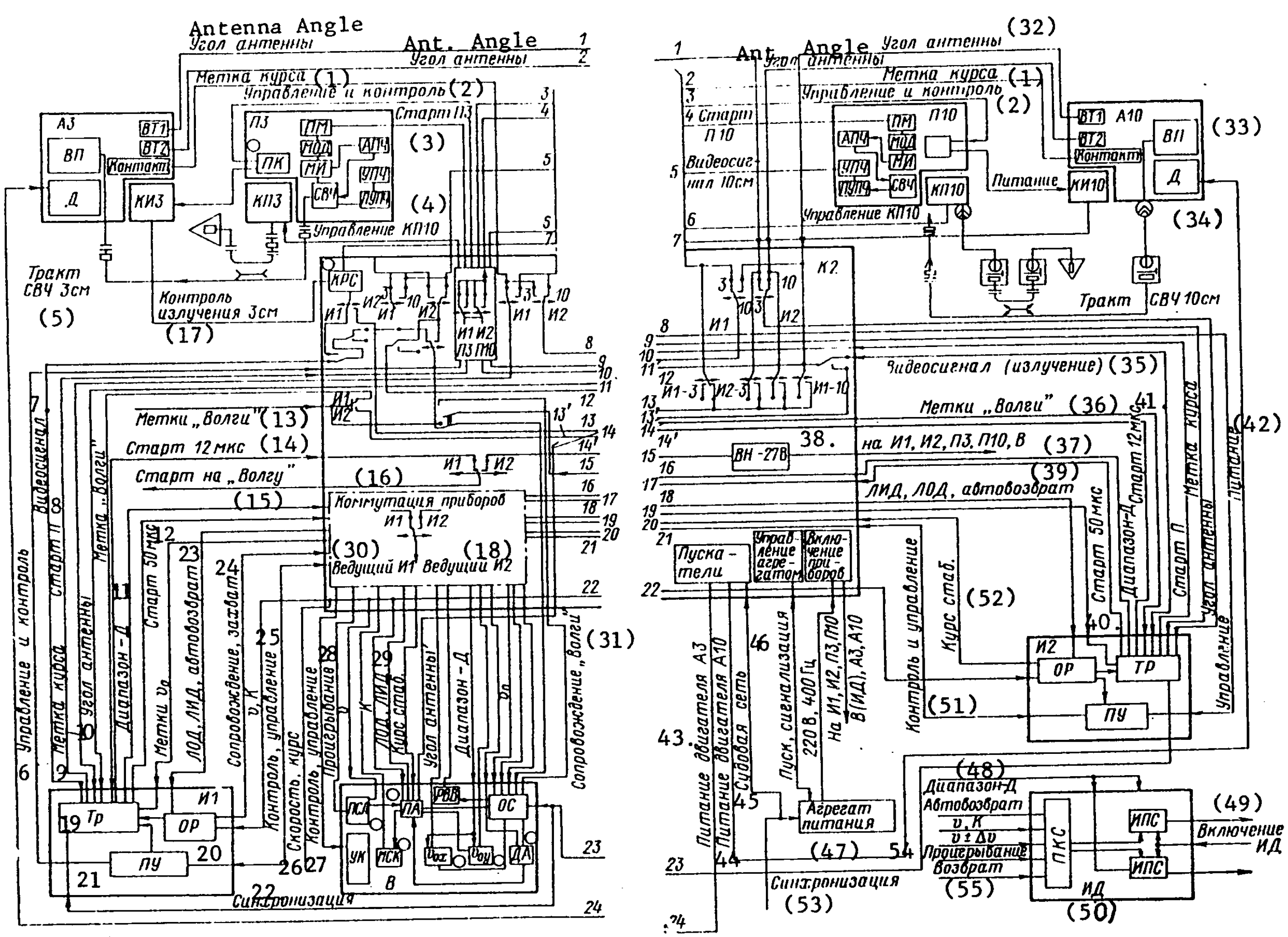

Figure 5.9. Block diagram of the "Okean-M" navigation radar

Key:
1. Course marker;
2. Control and metering;
3. Start P3 [3 cm transceiver];
4. KP10 control [10 cm band test unit consisting of an echo chamber and mechanical tuning assembly];

Key [cont.]:

5. 3-cm microwave channel;
6. Control and metering;
7. Video signal;
8. Start P [transceiver];
9. Course marker;
10. Antenna angle;
11. Band--D;
12. Start 50 microseconds;
13. "Volga" markers;
14. Start 12 microseconds;
15. Start 2 "Volga";
16. Switching between indicator units I1 and I2;
17. 3-cm transmission monitoring;
18. Indicator I2 master;
19. CRT circuitry;
20. OR = orientation block;
21. Control console;
22. Synchronization;
23. Relative motion line, true motion line, autoreturn;
24. Track, lock-on;
25. Metering, control;
26. Speed, course;
27. Metering, control;
28. Play-through [maneuver simulation];
29. Relative motion line, true motion line;
30. Indicator I1 is master;
31. Track "Volga";
32. Antenna angle;
33. Rotating joint;
34. Motor;
35. Video signal (transmit);
36. "Volga" markers;
37. To indicator I1, indicator I2, transceiver P3, transceiver P10 and the computer V;
38. -27 volt rectifier;
39. True motion line, relative motion line, autoreturn;
40. Start 50 microseconds;
41. Start 12 microseconds;
42. Power;
43. Power for the motor of the 3-cm antenna;
44. Power for the motor of the 10-cm antenna;
45. Ship power main;
46. Start, signaling;
47. Power plant;
48. Band-D;
49. Turn on true motion;
50. ID = true motion block;
51. Metering and control;
52. Course stabilized;
53. Synchronization;
54. Play-through [maneuver simulation];
55. Return.

Key for Antenna Unit A3 [3-cm band antenna]:

VP = Rotating joint;
VT1 = Rotating transformer 1;
VT2 = Rotating transformer 2;
Kontakt = Switch contact;
D = Motor;
KI3 = 3 cm band transmit monitor;

P3 [3-cm transceiver]:

PM = Submodulator;
MOD = Modulator;
PK = Power supply and metering block;
MI = Pulsed magnetron;
APCh = Automatic frequency control;
UPCh = Intermediate frequency amplifier;
PUPCh = IF preamplifier;
SVCh = Microwave circuitry;

Key [cont.]: KP3 = 3-cm band voltage metering unit;

[Unit V, the computer]:
- PSL = Log speed converter;
- PA = Automatic bearing (assembly);
- RVV = Time delay relay;
- OS = Signal processor
- DA = Automatic range unit;
- UK = Metering unit;
- MSK = Course and speed maneuver assembly;

[Unit ID = True motion circuitry]:
- PKS = Speed and course converter;
- IPS = Speed projection integrator.

The major technical and operational parameters of the "Okean-M" navigation radar are given below:

The 0.7 probability detection range for the case of an antenna mounted at a height of 15 m above sea level, miles:	
A shore line with a height of 6 to 60 m	10-22
A ship with a displacement of from 20 to 5,000 registered tons	6-13
Intermediate sea buoy at a wavelength of 3.2 cm	5.9
The same, for 10 cm	3.3
Minimum 0.7 probability detection range for an antenna mounted at a height of 5 m above sea level at a wavelength of 3 cm, no more than, in meters	50
The same, at a wavelength of 10 cm, no more than, in meters	70
The range measurement precision, in percent of the maximum range scale:	
Using the moving range ring	±1.0
Using the electronic cursor	±2
The same, using the autotracking system on a straight line section, in m	±25
The azimuth measurement precision in degrees:	
At a wavelength of 3.2 cm	±1.0
At a wavelength of 10 cm	±1.0
With autotracking on a straight line segment	±0.25
The range resolution for the case of a separate observation probability of 0.7 using the 1 mile scale, in m	15
The azimuth resolution, measured by the electronic cursor, with a probability of 0.7 degrees, at a wavelength of:	

3.2 cm	0.7
10 cm	2.3
The course reading precision, in degrees:	
Using the "K ± ΔK" scale of unit I [the indicator]	±0.3
Using the course marker	±1.0
Precision of the true motion indication (for equipment sets with the computer or true motion unit):	
With respect to course, degrees	1.5
With respect to speed, percent	±3.0
Precision of the speed transmission from the log on the "v ± Δv" scale of the unit, in knots	±0.2
Pulse modulation frequency, MHz:	
In the 3.2 cm band	9400-9460
In the 10 cm band	3030-3090
The pulse power of the transmitter at the flange of unit P [transceiver], in KW, more than	50
Receiver sensitivity, in dB, on the following scales:	
1, 2, 4 miles	115
8 - 64 miles	120
Pulse repetition rate, in Hz, on the following scales:	
1, 2 miles	3400±300
4 miles	1700±150
8, 16, 32 miles	850±80
64 miles	425±40
Pulse width, in microseconds, no more than, on the following scales:	
1, 2 miles	0.11
4 miles	0.2
8, 16, 32 miles	0.4
64 miles	0.8
Intermediate frequency, in MHz	60
Width of the directional pattern at the half power level, for unit A, in degrees:	
In the horizontal plane in the 3 cm band	0.75±0.05
The same, in the 10 cm band	2.25±0.25
In the vertical plane in the 3 and 10 cm bands	20±3
The same, for unit A3, in degrees:	
In the horizontal plane	0.75±0.05
In the vertical plane	20±3
The same, for unit A10, in degrees:	
In the horizontal plane	2.25±0.25
In the vertical plane	20±3

The working diameter of the indicator screen, mm	400
Range scales (numerator) and the graduation interval between the fixed range rings (denominator), in miles	1/0.25, 2/0.5, 4/1, 8/2, 16/4, 32/8, 64/16
Image scales on the screen of the indicator unit, on the following scales:	
1 mile	1:3,200
64 miles	1:598,000
Antenna rotational speed, r.p.m.	16

The "Okean-M" navigation radar has the following specific features:

a) The "Okean-M" navigation radar is a two band radar (3.2 and 10 cm) with separate slot antennas and standardized drives;

b) A standardized indicator (I) is used;

c) A true motion unit has been developed (ID);

d) Redundancy is provided for units A, P, and I;

e) The autotracking system with the true motion unit is placed in the computer unit V and provides for radar operation in a true motion mode. The relative and true motion lines (LOD and LID [respectively]) are reproduced on the CRT screen. The problem of passing ships can be solved for the case of any stabilization. The relative or absolute speeds are read out as well as the range and closest approach time by means of moving range rings and time markers on the relative and true motion lines;

f) The range readout precision using the moving range ring has been improved and its circuitry has been simplified;

g) The operational stability of the transmitter has been improved through the use of four probe pulse widths, as a function of the range scale;

h) The offset mode for the cursor sweep origin makes it possible to determine the bearing from one target to another target and measure the distance between them;

i) The phase sensitive rectifiers of the indicator have been standardized;

j) An exhaust system has been developed for the transceiver units using a single fan;

k) The ferrite isolaters of the switches for transceiver units P3 and P10 have been standardized;

l) The image brightness of the PPI sweep has been stabilized when switching range scales;

m) The reparability has been facilitated and the possibility of manufacturing radar units has been improved through changes in their structural design;

TABLE 5.5

Equipment Set Number (1) Номер комплекта	Decimal Number of the Radar Station (2) Децимальный номер станции	Three-Phase Ship Mains Voltage, 50 Hz, Volts (3) Напряжение трехфазной судовой сети 50 Гц, В	Equipment Complement [Units] (4) Приборный состав	Installation Set (5) Монтажный комплект	Spare Parts, Tools and Accessories (6) ЗИП	Operational Documentation (7) Эксплуатационная документация	Power Plant With Start and Regulating Equipment, and Spare Parts, Tools and Accessories (8) Агрегат питания с пускорегулирующей аппаратурой и ЗИПом	Power Consumption From Ship Mains, KVA (9) Мощность, потребляемая от судовой сети, кВ·А	Radar Station Weight, in kg (10) Масса станции, кг
00 01	ЛЕ1.000.050 ЛЕ1.000.050.01 LYe.....	380 220	А3, П3, КП3, И, К1	ЛЕ4.075.150	ЛЕ1.000.050.ЗИ	ЛЕ1.000.050.ЭД	(11) Для судовой сети 380 В, 50 Гц: АТО-2-400, ПММ-1112	6,2	906
02 03	ЛЕ1.000.050.02 ЛЕ1.000.050.03	380 220	А3, П3, КП3, П, К1, ИД	ЛЕ4.075.150.01	ЛЕ1.000.050.ЗИ	ЛЕ1.000.050.ЭД		6,2	956
04 05	ЛЕ1.000.050.04 ЛЕ1.000.050.05	380 220	А3, П3, КП3, Н, К1, В	ЛЕ4.075.150.02	ЛЕ1.000.050.ЗИ ЛГ2.300.020.ЗИ	ЛЕ1.000.050.02ЭД ЛЕ1.000.050.02ЭД	БРН-143/3 BRN-143/3	6,2	1186
06 07	ЛЕ1.000.050.06 ЛЕ1.000.050.07	380 220	А10, П10, КП10, П, К1	ЛЕ4.075.150.03	ЛЕ1.000.050.01ЗИ	ЛЕ1.000.050.03ЭД	(11) Для судовой сети 380 В, 50 Гц: АТО-2-400, ПММ-1112, БРН-143/3	6,2	1036
08 09	ЛЕ1.000.050.08 ЛЕ1.000.050.09	380 220	А10, П10, КП10, Н, К1, НД	ЛЕ4.075.150.04	ЛЕ1.000.050.01ЗИ	ЛЕ1.000.050.04ЭД		6,2	1086
10 11	ЛЕ1.000.050.10 ЛЕ1.000.050.11	380 220	А10, П10, КП10, Н, К1, В	ЛЕ4.075.150.05	ЛЕ1.000.050.01ЗИ ЛЕ1.300.020.ЗИ	ЛЕ1.000.050.05ЭД		6,2	1286

(1) Номер комплекта	(2) Децимальный номер станции	(3) Напряжение трехфазной судовой сети 50 Гц, В	(4) Приборный состав	(5) Монтажный комплект	(6) ЗИП	(7) Эксплуатационная документация	(8) Агрегат питания с пускорегулирующей аппаратурой и ЗИПом	(9) Мощность, потребляемая от судовой сети, кВ·А	(10) Масса станции, кг
12 13	ЛЕ1.000.050.12 ЛЕ1.000.050.13	380 220	А3, А10, П3, П10, КП3, К10, И, П, К2	ЛЕ4.075.150.06	ЛЕ1.000.050.023И	ЛЕ1.000.050.06ЭД	(11) Для судовой сети 380 В, 50 Гц: АТО-4-400, ПММ-1112, БРН-143/3	11,0	1856
14 15	ЛЕ1.000.050.14 ЛЕ1.000.050.15	380 220	А3, А10, П3, П10, КП3, КП10, П, И, К2, ИД	ЛЕ4.075.150.07	ЛЕ1.000.020.023И	ЛЕ1.000.050.07ЭД		11,0	1906
16 17	ЛЕ1.000.050.16 ЛЕ1.000.050.17	380 220	А3, А10, П3, П10, КП3, КП10, И, И, К2, В	ЛЕ4.075.150 08	ЛЕ1.000.050.023И ЛЕ2.300.020.3И	ЛЕ1.000.050.08ЭД		11,0	2106
18 19	ЛЕ1.000.050.18 ЛЕ1.000.050.19	380 220	А, П3, П10, КП3, КП10, П, И, К2	ЛЕ4.075.150.09	ЛЕ1.000.050.023И	ЛЕ1.000.050.09ЭД	(12) Для судовой сети 220 В, 50 Гц: АТО-4-400.1 ПММ-1112, БРН-143/3	10,0	1516
20 21	ЛЕ1.000.050.20 ЛЕ1.000.050.21	380 220	А, П3, П10, КП3, КП10, И, П, К2, ИД	ЛЕ4.075.150.10	ЛЕ1.000.050.023И	ЛЕ1.000.050.10ЭД		10,0	1536
22 23	ЛЕ1.000.050.22 ЛЕ1.000.050.23	380 220	А, П3, П10, КП3, КП10, И, И, К2, В	ЛЕ4.075.150.11	ЛЕ1.000.050.023И ЛЕ2.300.020.3И	ЛЕ1.000.050.11ЭД		10,0	1766
24 25	ЛЕ1.000.050.24 ЛЕ1.000.050.25	380 220	А3, А10, П3, П10, КП3, КП10, И, П, К2, К3, ПД	ЛЕ4.075.150.12	ЛЕ1.000.050.023И	ЛЕ1.000.050.12ЭД		11,0	1921
26 27	ЛЕ1.000.050.26 ЛЕ1.000.050.27	380 220	А3, А10, П3, П10, КП3, И, П, КП10, К2, К3, В	ЛЕ4.075.150.13	ЛЕ1.000.050.023И ЛЕ2.300.020.3И	ЛЕ1.000.050.13ЭД		11,0	2121
28 29	ЛЕ1.000.050.28 ЛЕ1.000.050.29	380 220	А, П3, П10, КП3, КП10, П, И, К2, К3, ПД	ЛЕ4.075.150.14	ЛЕ1.000.050.023И	ЛЕ1.000.050.14ЭД		10,0	1551
30	ЛЕ1.000.050.30	380	А, П3, П10, КП3, КП10, П, П, К2, К3, В	ЛЕ4.075.150.15	ЛЕ1.000.050.023И ЛЕ2.300.020.3И	ЛЕ1.000.050.15ЭД		10,0	1781

Key to Table 5.5:
1. Equipment set number;
2. Decimal number of the radar station
3. Three-phase ship mains voltage, 50 Hz, volts
4. Equipment complement [units];
5. Installation set;
6. Spare parts, tools and accessories
7. Operational documentation
8. Power plant with start and regulating equipment, and spare parts, tools and accessories
9. Power consumption from ship mains, KVA
10. Radar station weight, in kg
11. For ship power mains at 380 volts and 50 Hz:;
12. For ship power mains at 220 volts, 50 Hz:.

n) The radar has built in manual tolerance metering of the operability of the assemblies, blocks and voltages of the transceivers;

o) The service life of the radar is 10 years; the operating life (operating time until the ultimate status is reached) is 25,000 hours; the service life between repairs is 5,000 hours.

Antennas

The antennas are intended for the directional transmission and reception of microwave energy pulses with circular scanning.

Single band (unit A3, the 3 cm band antenna and unit A10, the 10 cm band antenna) as well as two band [unit A - two band antenna (3 and 10 cm)] antennas are used in various radar equipment complements. The major technical parameters of the A3, A10 and A units are given below:

The sidelobe radiation level in the horizontal plane relative to the main lobe on both sides of the main lobe, in dB, no less than:	
In a range of 5° in the 3 cm band for units A3 and A	24
In a range of 5° in the 10 cm band for units A10 and A	24
In a range of 15° in the 3 and 10 cm bands for units A3, A10 and A	28
The voltage traveling wave ratio, no less than	0.5
Power mains for the motors of the antenna drives, three-phase, 50 Hz, volts	220 or 380
Power consumption by the drive motors, in KV [sic], no more than:	
Unit A for a wind speed of up to 50 m/sec	1.5
Units A3 and A10	0.9
Power consumption from the ship mains by the heating elements, in watts, no more than	80

Each of the units A3, A10 and A consists of three major assemblies:

1. A slot radiator (two radiators in unit A);
2. A rotating microwave junction: a single channel type in units A3 and A10, and a dual channel type in unit A;
3. The antenna rotation drive.

Units A3 and A10 take the form of slotted waveguide radiators. The directional pattern in the horizontal plane is shaped by a system of slots in waveguide sections, while it is shaped in the vertical plane by a horn. There are adjustment bolts and inductive stubs on the back side of the horn of unit A3; the position of the bolts and stubs is set when the antenna is set up at the manufacturing plant and should not be disrupted during operation. There are only adjustment bolts on the back side of unit A10. The polarization is horizontal.

The rotating microwave junction is mounted on a bracket in the lower portion of the drive housing and takes the form of a waveguide to coaxial junction of a button or probe type.

The rotation drive for units A3, A10 and A consists of an electrical motor, a reducer, a rotating microwave junction, transducers for the remote transmission of the antenna rotation angle to the indicator and computer units as well as a start sensor for the course marker generation channel in the indicator units.

The antenna is rotated clockwise by an asynchronous three-phase motor through a two stage reducer.

Power is delivered to the electric motor, depending on the equipment complement, either through the starters of unit K2 (the two band equipment sets), or through the starter of unit K1 (the one band equipment set).

There are two sine-cosine rotating transformers in the drives of units A3 and A10 to produce the plan position indication sweep in indicator unit I as well as the azimuth gates in unit V [the computer].

The magnetically controlled electrical contact actuates once every antenna revolution, when the main transmission lobe matches the midline of the ship.

The heating elements and the ANTENNA DRIVE AND TRANSMIT switch are also installed in the drive.

The heating elements are intended for heating the internal spaces of the drive for the purpose of reducing humidity following long term downtimes of the unit during the cold season of the year and under conditions of frequent dewfall on the external surfaces of the ship.

The ANTENNA DRIVE AND TRANSMIT switch serves to break the power circuit for the electric motor of the drive and the heating elements, as well as the interlocking in the power circuits for the high voltage rectifiers of units P3 and P10 to prevent the possibility of transmitting microwave probe pulses when performing repair and preventive maintenance work in the area of the A3 and A10 antennas.

Unit A contains two 3 and 10 cm band radiators similar to the radiators of units A3 and A10. The microwave power is fed to the radiators through a dual channel rotating junction. The rotational drive for antenna A is structurally similar to the drives for units A3 and A10. Four sine-cosine rotating transformers are located inside the drive for unit A to transmit the antenna rotation angle to indicator units I1 and I2 as well as the computer V. The function and structure of the electromagnetic contact is the same as in units A3 and A10.

The radio frequency channels are intended for transmitting the microwave power pulses from the transmitter to the antenna and the target return pulses received by the antenna to the receiver.

Transceivers

The transceivers, units P3 and P10, are intended for generating and shaping the microwave sounding pulses, as well as for the conversion and amplification of the target returns and the transmission of the latter to the indicator and to obtain target blips on the CRT screen, as well as to the computer unit V to provide for the operation of the automatic target tracking channels.

The major technical characteristics of units P3 and P10 are given on page 179 and below:

The receiver intermediate frequency, MHz	60 ± 2
Maximum amplitude of the receiver output pulse, in volts, no more than	2.8 ± 0.5
Pulse width at the receiver output on the 1 and 2 mile range scales, in microseconds, no more than	0.35
Manual control range for the receiver gain, in dB, no less than	40
Maximum time constant of the time AGC in microseconds, no less than	100
Parameters of the negative triggering pulse incoming from the indicator unit I:	
Amplitude, volts	5 - 7
Width, microseconds, no more than	1.5 ± 0.5
Rise time, microseconds, no more than	0.2
Receiver bandwidth, in MHz, no less than, on the following range scales:	

1, 2, 3 and 4 miles	12
8, 16 32 and 64 miles	4.5 ± 1.5
Power consumption from the 220 volt, 400 Hz mains, in VA, no more than	900

Each of the P3 and P10 units consists of the transmitter (Figure 5.10), the complement of which includes the magnetron oscillator MI, the modulator block MOD, the submodulator block PM, the high voltage rectifier for the transmitter VVP, the power supply and metering block PK, and the receiver, which contains the microwave assembly SVCh, the intermediate frequency preamplifier PUPCh, the intermediate frequency amplifier UPCh, the automatic frequency control block AFC, the metering and control block KU as well as the blocks of power supply rectifiers.

Units P3 and P10 include a number of components which are installed in racks and which are not included in the complement of the blocks enumerated above: a storage capacitor and charging resistor for the transmitter, a receiver protection discharger RZP, a ferrite isolator and switch, a block of emitter followers EPS, etc.

The interconnections between the individual blocks is shown in Figure 5.10.

The "start transmitter" pulse is fed from the transmitter start generator channel through the delay line of a block of emitter followers to trigger the submodulator. A pulse with an amplitude of 1,000 volts and a width corresponding to the range scale set in the indicator is generated in the submodulator block.

The circuit of the block contains two channels:

1. The channel for generating the leading edge of the pulse;
2. The channel for generating the trailing edge.

The second channel is triggered through a delay line as a function of the range scale. Each of the channels consists of a blocking oscillator (the right half of a 6N1P-YeV vacuum tube) with a trigger amplifier (the left half of the indicated tube). The output pulses of the blocking oscillators are fed through cathode followers (a 6N1P-YeV vacuum tube) to the trigger amplifier (the right half of a 6GMI-6 tube) and a TGI1-35/3 thyratron respectively. The leading edge of the output blocking oscillator pulse (the left half of the GMI-6 vacuum tube) coincides with the start of the first channel pulse, while the trailing edge coincides with the start of the second channel blocking oscillator pulse, and the width of the output pulse is governed by the delay of the second channel start in the second delay line. The relays which are controlled from the indicator switch this delay.

The pulse generated by the submodulator block is fed to the modulator block MOD, which uses a GMI-7 tube. The cutoff modulator is first turned on and the storage capacitor of the high voltage rectifier, the VVP, is connected to

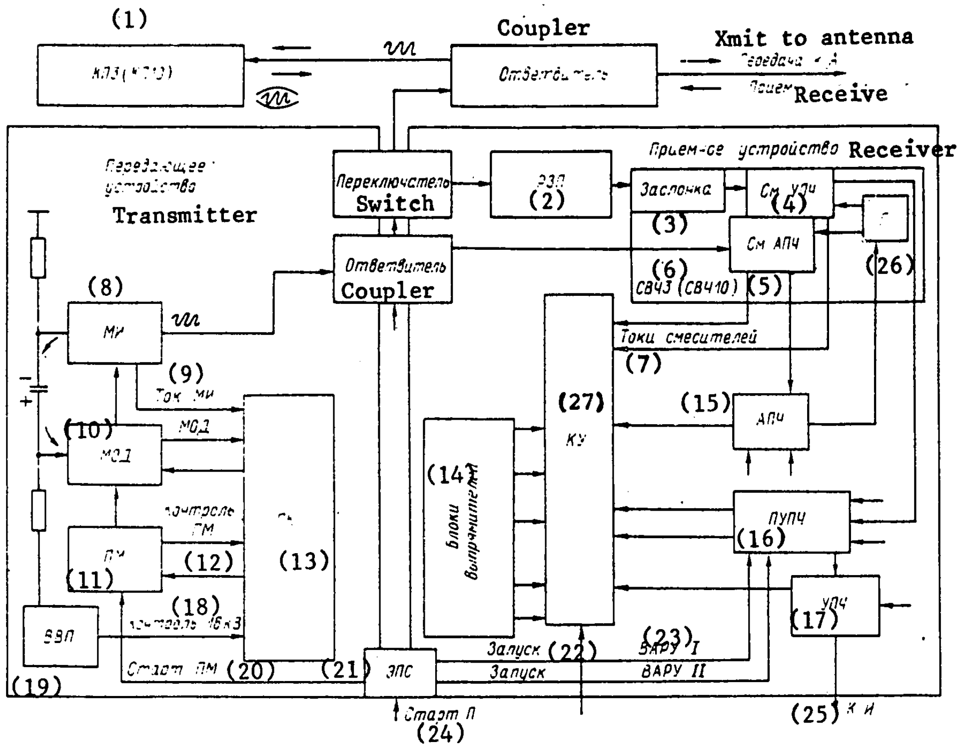

Figure 5.10. Block diagram of transceiver units P3 and P10.

Key:
1. KP3 (KP10) = units for monitoring the 3 cm (or 10 cm) band voltage;
2. Protective discharger for the receiver;
3. Shutter;
4. IF amplifier mixer;
5. AFC mixer;
6. SVCh3 (or SVCh10) [3 cm (or 10 cm) microwave circuitry];
7. Mixer currents;
8. Magnetron oscillator;
9. Magnetron oscillator current;
10. Modulator;
11. Submodulator;
12. Submodulator metering;
13. Power supplies;
14. Rectifier blocks;
15. AFC;
16. IF preamplifier;
17. IF amplifier;
18. 16 KV metering;
19. High voltage power supply;
20. Submodulator start;

Key [cont.]: 21. Emitter followers;
22. Triggering;
23. Time AGC 1;
24. Start transceiver;
25. To the indicator;
26. Oscillator;
27. Metering and control unit.

the magnetron. The width of the microwave pulse generated by the magnetron is governed by the width of the subjodulator pulse.

In the intervals between pulses, the storage capacitor is charged by the VVP block (16 KV).

The microwave pulses from the magnetron are fed through a directional coupler to a ferrite TRANSMIT-RECEIVE isolator, which routes them through the radio-frequency channel to the antenna.

The directional coupler is intended for transmitting part of the transmitter power to the automatic frequency control system, the AFC, of the receiver.

The ferrite isolator-switch provides for the operation of the receiver and transmitter using one antenna, and also protects the magnetron against high power pulses reflected from ship structures and inhomogeneities in the radiofrequency channel. The switch consists of a ferrite section with a slotted bridge and a twin tee with a load.

The magnetron power incoming to unit P3 (or P10) is estimated based on the width of the return signals from a tunable echo chamber of unit KP3 (or KP10), which are observed in the form of a flare spot on the indicator screen.

The radial line of the flare characterizes the power potential of the transceiver. It increases with an increase in the transmitter power or receiver sensitivity. The signal received by the antenna is fed through the microwave channel, the ferrite isolator, and the receiver protection discharger to the microwave block (SVCh3, SVCh10) of the receiver.

The gas discharger (RR-83N-T for SVCh3 and RR-OP-7 for SVCh10) serves for additional attenuation of the probe pulse power which leaks through the slotted bridge of the ferrite switch into the receiver. This pulse can cause the receiver mixer diode to fail.

The transmitter is powered from a high voltage rectifier, the VVP, and the three power supplies of block PK.

The high voltage power supply, in addition to the high voltage rectifier, contains protective and voltage switching and adjustment components.

The VN-1500-0.025 rectifier block is designed as a doubler. It supplies the plates of the output blocking oscillator tube in the PM [submodulator] block and the screen grid of the GMI-7 tube in the modulator block.

The block of VN-800-0.01 and VN+250(110)-0.01 rectifiers power the tubes of the submodulator stage and supply bias to the control grid of the modulator.

There are test jacks for checking the pulse parameters and measuring the voltages in the transmitter blocks, and provisions are also made for metering the operation of the transmitter using meters in the KU [metering and control block] and PK [power supplies] blocks.

The SVCh3 (SVCh10) block serves for converting the received SVCh [microwave] pulses to the intermediate frequency, as well as for protecting the mixer diodes Sm against the high power signals incoming to the receiver input from other radars when the station is turned off.

Block SVCh3 consists of the following major assemblies: the electromagnetic shutter, the K-714 klystron, the intermediate frequency amplifier mixer using D405B diodes, the AFC mixer using D405V diodes, a slotted bridge, and an attenuator with a splitter and a block of slotted bridges.

The electromagnetic shutter covers the waveguide channel of the receiver when the radar is shut down, and when the radar is turned on, it opens the channel up and passes all of the received signals without attenuation. The shutter takes the form of a waveguide section with a cross section of 23 x 10 [mm], in the wide wall of which there is an electromagnet with a core. When the radar is turned on, a voltage of 27 volts is applied to the electromagnet, the core pulls in and opens the waveguide. At the moment the radar is cut off, the electromagnet is de-energized and releases the core, which is pushed into the waveguide by a spring and covers it.

A klystron with an internal resonator and a waveguide output with a cross section of 23 x 10 [mm] is used as the local oscillator. The frequency of the klystron is tuned after it is replaced or the magnetron is replaced by means of mechanically tuning the klystron resonator.

Tuning the frequency in a range of 20 to 30 MHz during operation is accomplished by changing the voltage applied to the reflector. The operability of the local oscillator is checked based on the mixer diodes and resonator currents at the control and metering panel.

Three variable attenuators are used in block SVCh3, one of which is inserted in the channel for splitting off the probe pulse power to the AFC mixer, while the two others are inserted in the channels for splitting off the local oscillator power to the AFC and IF amplifier mixers. The attenuators provide for the attenuation of the power in a range of 1 to 25 dB.

There are two mixers in block SVCh3, one of which converts the microwave signals received by the antenna to the intermediate frequency, which is fed to the IF preamplifier, while the other converts the transmitter signals which are split off to the intermediate frequency for the operation of the AFC block.

Block SVCh10 consists of the following major assemblies: the klystron local oscillator, the blocks of attenuators, and the mixers of the AFC and IF amplifier channels. There is no magnetic shutter in the SVCh10 block. Its function is performed by a diode limiter in the protective device for the receiver, which is located after the discharger and which considerably attenuates the influence of external signals.

The mixers of block SVCh10 which are designed around D408 and D408P diodes perform the same functions as those in the SVCh3 block. A klystron with an external toroidal resonator is used as the local oscillator. The local oscillator frequency is changed by means of changing a contact stub in the resonator cavity, while the frequency is tuned during operation by changing the voltage applied to the reflector.

The variable IF AMPLIFIER MIXER CURRENT, AFC MIXER CURRENT and AFC SIGNAL LEVEL attenuators regulate the power level fed from the local oscillator to the AFC and IF amplifier mixers respectively as well as the level of the probe pulse power split off to the AFC channel.

The intermediate frequency amplifiers (PUPCh [IF preamplifier] and UPCh [IF amplifier]) amplify the received signal. The most important characteristics of the IF amplifier and preamplifier channels are given below:

The Intermediate Frequency Preamplifier, PUPCh	
Bandwidth at the 3 dB level, in MHz, for the following range scales:	
8 to 64 miles	4 ± 1
1, 2, and 4 miles	18 ± 3.0
Center frequency of the passband, in MHz, on the following range scales:	
1 to 4 miles	60 ± 2
8 to 64 miles	60 ± 0.7
Gain, in dB, no less than	17
Time constant of the time AGC, in microseconds	0.3 to 70
Current consumption, in mA, no more than, for the following circuits:	
+50 volts	40
-12.6 volts	30
Intermediate Frequency Amplifier, UPCh	
Bandwidth at the 3 dB level, in MHz	14 ± 2
Center frequency of the passband, MHz	60 ± 1.5
Gain, in dB, no less than	10
Input signal range, in dB	40

Maximum amplitude of the output signal, in volts, no more than	2
Maximum level of the echo chamber signal, volts	0.6 ± 0.1
Current consumption, in mA, no more than	70

The intermediate frequency channel as a whole is characterized by the following main electrical specifications:

Center frequency, MHz	60
Bandwidth, in MHz, on the following range scales:	
1 to 4 miles, no less than	12
8 to 64 miles, no more than	6
The gain when receiving weak signals, in dB, no less than	80
Output signal polarity	Negative
Maximum amplitude, in volts, no less than:	
Of the signal	2.0
Of the noise	0.3
Gain control	Manual, and Time AGC

The signals from the output of the mixer are fed to the input of the intermediate frequency preamplifier, which is designed for time AGC.

The first stage is designed around a low noise 6S51N-V triode. The remaining three stages are designed around radiofrequency 6Zh45B-V pentodes. A provision is made for changing the bandwidth when switching range scales.

The gain of the IF preamplifier is adjusted by means of a time automatic gain control circuit (VARU) [time AGC]. The time AGC voltage (negative) blocks the receive channel during the time of probe pulse transmission (leak-through) as well as during reflections from inhomogeneities in the waveguide-antenna channel. In the subsequent time period, the amplitude and waveform of the time AGC voltage is changed so that the level of sea clutter at the output of the receive channel is compared to the internal noise level. The time AGC generator circuit consists of amplifiers for triggering the time AGC, designed around 1T308V transistors, two blocking oscillators designed around 1T308V transistors and an OR gate also using 1T308V transistors.

The time AGC voltage is obtained as a result of mixing the time AGC I and time AGC II pulses in the OR gate. The time AGC I pulse reduces the receiver gain during the time the probe pulse acts as well as the primary reflection from the inhomogeneities of the antenna and the radiofrequency channel.

The time AGC II pulse varies the receiver gain with time in accordance with an exponential law from a minimum value up to the nominal value in the zone of exposure to reflections from sea waves.

The eight stage main intermediate frequency amplifier, which is designed around 6Zh45B-V vacuum tubes is intended for manual gain control of the signals at the intermediate frequency as well as the detection and transmission of these signals to the indicator.

Dual and single resonant circuit section bandpass filters are used in the amplifier between the stages.

The amplified signal is detected by means of a D18 diode, amplified by a video detector designed around a 2T602B transistor and fed through the emitter followers of unit K2 (or K1) to the indicator.

In the two band radar set, the video signals are switched from units P3 and P10 between indicators I1 and I2 in unit K2.

Manual gain control is provided by feeding a voltage of -12.6 volts to the control grids of the first three stages of the main intermediate frequency amplifier in the IF amplifier block either from the GAIN potentiometer in the intermediate frequency block of unit I [the indicator] in the "operate" mode, or from the GAIN potentiometer in the KU block of unit P3 (or P10) in the "check" mode.

In the two band radar sets, the switching of the gain control circuits of units P3 and P10 between units I1 and I2 is accomplished in unit K2.

The automatic and manual frequency tuning channel, the APCh--RPCh (see Figure 5.8), is intended for maintaining the difference between the frequency generated by the klystron and the magnetron equal to the intermediate frequency of the receiver. This is accomplished by tuning the klystron frequency through changing the voltage applied to its reflector by either the manual frequency control, RPCh ("RPCh" mode) or automatically (the "APCh" [AFC] mode).

The AFC--manual frequency control channel contains the AFC block, the AFC mixer of block SVCh3 (or SVCh10) and the control and metering elements in block P3 (or P10) as well as the elements in block PU [indicator control panel] of indicator unit I.

The AFC block consists of a four stage intermediate frequency amplifier using 6Zh45B-V vacuum tubes, a discriminator designed around a 6Kh7B-V vacuum tube, a video amplifier using a 6Zh9G-V tube, a peak detector, a DC amplifier and search oscillator using a 6Zh10B-V tube and an output cathode follower.

The major technical specifications of the AFC block are given below:

Discriminator frequency response:	
Spacing between maxima, MHz	10 ± 2
Zero, MHz	0.5 ± 0.7
Slope, volt/MHz, no less than	70

Sawtooth search voltage:	
Peak-to-peak, in volts, no less than	20
Range, microseconds	0.6 ± 0.4

The AFC block provides for the following operating modes:

a) Automatic search for the magnetron frequency;

b) Tracking the magnetron frequency;

c) Manual frequency control for the klystron, accomplished from the indicator control panel of the indicator unit I or block KU [metering and control unit].

TABLE 5.6

Rectifier Designation	Deviation of the Voltage from the Nominal Value when the Mains Voltage Changes by ±5% or when the Load Current Drops to Zero, Volts	Amplitude of the Alternating Component of the Output Voltage, Volts, No More Than	Remarks
VS ± 300-0.05	± 0.6	0.06	--
VS-300(-255)-0.05	± 0.6	0.06	300 volts for P3
VS-12.5-0.025	± 0.6	0.05	255 volts for P10
VS-50-0.25	± 0.25	0.01	--
VN-12.6-0.08	--	0.01	--

The switching of the AFC--MANUAL FREQUENCY CONTROL modes is accomplished in the AFC block, which is controlled in the "Check" mode by the TUNE AFC--MANUAL FREQUENCY CONTROL toggle switch, which is located in the metering and control unit of unit P3 (or P10), or in the "Operate" mode by the AFC--MANUAL FREQUENCY CONTROL toggle switch, which is located in the indicator control panel of indicator I.

In the two-band radar sets, the switching of the control circuits for the AFC--MANUAL FREQUENCY CONTROL channels of units P3 and P10 between indicators I1 and I2 is accomplished in unit K2 using the "3-I1-10", "3-I2-10" and "I1-master-I2" signals.

The receiver is powered by the following blocks: VS±300-0.05, VS-300(255)-0.05; VS-12.5-0.025; VS-50-0.25; VN-12.6-0.08.

The main technical specifications for the power supplies are given in Table 5.6.

The rectifiers of the VS±300-0.05, VS-300(255)-0.05 and VS-12.5-0.025 blocks power the klystron, the manual frequency control circuits and the output stages of the AFC block.

The VS-50-0.25 and VN-12.6-0.08 blocks supply the plate circuits and screen grid circuits of the IF amplifier and preamplifier blocks as well as the intermediate frequency amplifier of the AFC block, the time AGC circuitry and the video amplifier of the IF amplifier block. This same block supplies the 6.3 volts at 400 Hz for the filament circuits of the IF preamplifier, IF amplifier and AFC block vacuum tubes.

The receiver can be metered in its blocks through sockets and contacts intended for checking the pulse and voltage parameters.

A provision in made for built-in metering of the operational mode using a meter in the monitor and control block, KU. The monitor and control block of P3 (and P10) includes a meter, switches for the circuits being checked, and controls for the unit. The monitor and control block is intended for measuring the voltages of the rectifiers, the receiver detector in the IF amplifier block, the amplitude of the time AGC pulse, the currents of the AFC and IF amplifier mixer diodes, as well as the current consumption of the IF amplifier and AFC blocks.

The power potential of the transceiver is monitored based on the pulse width of the signals from the tunable echo chamber of unit KP3 (or KP10), which are observed as a flare trace on the screen of the indicator unit I. The power potential metering channel includes the KP3 (or KP10) unit and the ECHO--CHAMBER toggle switch which is located on the indicator control panel of the indicator unit I.

TABLE 5.7

Parameter Designation	Values of the Parameter	
	Unit KP3	Unit KP10
Echo chamber sensitivity, dB/μsec	7.5	4.8
Working band of frequencies, MHz	9,400-9,460	3,030-3,090
Electromechanical tuning range, MHz	35-40	35-40
Electromechanical tuning period, seconds	16	16
Frequency readout error, MHz, no more than	5	5

Note: The indicated parameters of the units apply to any frequency in the working band.

Unit KP3 (or KP10) consists of an echo chamber and a mechanical tuning assembly (MPK). The major technical specifications of the KP3 and KP10 units are given in Table 5.7.

The echo chamber of the unit consists of a volumetric resonator with a tuning piston, a detector section with a microammeter and a plotting board with a graduated frequency graph.

The mechanical tuning assembly of unit KP3 (or KP10) provides for the following:

--Automatically tuning the resonator off of the transmitter frequency following the completion of operation;

--Continuous manual tuning of the resonator by means of reading the tuning frequency;

--Continuous automatic tuning of the resonator in a range of 30 to 40 MHz.

The mechanical tuning assembly consists of an electric motor, a reducer with two graduated scales and the TUNING control, the OPERATE--OFF--MATCHING toggle switch for echo chamber control and the MATCHED signal display. Power is fed to the mechanical tuning assembly after the ECHO-CHAMBER toggle switch is thrown on the indicator control panel of indicator unit I.

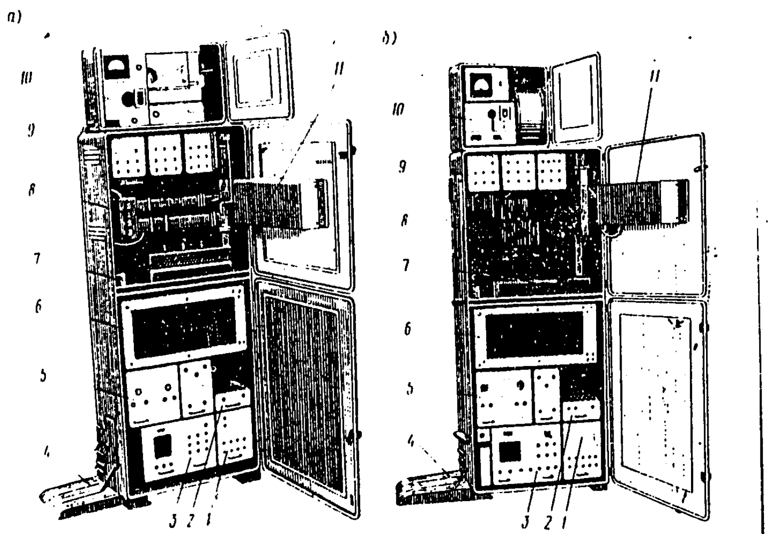

Figure 5.11. External view of units P3 and KP3 (a), and P10 and KP10 (b).

Key:
1. Submodulator block;
2. Modulator block;
3. Power supply and metering block;
4. Block of emitter followers;
5. High voltage rectifier;
6. Magnetron compartment;
7. IF preamplifier, IF amplifier and AFC blocks;
8. Mixers;
9. Receiver power supplies;
10. KP unit [test unit consisting of echo chamber and mechanical tuning assembly];
11. Metering and control block.

The resonator of the echo chamber is tuned manually by the TUNING control in the mechanical tuning assembly of unit KP3 (or KP10) to the transmitter frequency, based on the maximum deflection of the microammeter needle of the tuning indicator.

In the case of remote tuning from indicator unit I, the chamber is tuned automatically in a range of 30 to 40 MHz around the carrier frequency of the transmitter. The power potential is estimated based on the maximum flare spot on the PPI screen.

The transmitter frequency is measured from readings on the echo chamber scale, which is tuned to this frequency by means of the graphs.

The echo chamber can be used to tune the klystron.

The power potential of the radar is monitored based on the length of the flare (in miles) on the CRT of indicator unit I in the AFC mode. The nominal flare length for each radar set is written in the data sheet. The duration of the echo signal usually falls in a range of 11 to 17 μsec for P3 and 17 to 25 μsec for P10.

The structural features of units P3 (or P10) and KP3 (or KP10) are shown in Figure 5.11. The blocks of the units are housed in a welded cabinet, which is divided by a horizontal partition. The receiver units are housed in the upper compartments of the cabinet, while the transmitter is housed in the lower ones.

The major electronic blocks of unit P3 (and P10) are made in the form of box chassis, within which the electrical circuitry is concentrated.

The Indicator (Unit I)

The indicator performs the following functions:

a) Generation of the signals which synchronize radar operation;

b) Generation of the image of the radar situation based on the information received from the transceivers, antennas, gyrocompass and log;

c) Display of the results of solving a collision avoidance problem, performed by the computer;

d) Operational control and metering of the station.

The major technical specifications of the indicator unit are given on page 179 and below:

Range sweep and PPI cursor nonlinearity, in percent, of the greatest range of a band, no more than	5
Angular error in the PPI cursor and range sweep, in degrees, no more than	1.0

Mutual angular error in the cursor and range sweeps within limits of three-fourths of the PPI radius, in degrees, no more than	0.7
Error in the moving range ring, percent of the greatest range of a band, no more than	1.0
Parameters of the transmitter triggering pulse:	
Amplitude, in volts, no less than	5
Polarity	Negative
Width, microseconds	1.5 ± 0.5
Repetition rate, in Hz, on the following range scales:	
1 and 2 miles	3,400
4 miles	1,700
8, 16 and 32 miles	850
64 miles	425
Video signal:	
Bandwidth, MHz, no less than	14
Amplitude, in volts, no more than	2
Effective noise voltage, in volts, no less than	0.3
Polarity	Negative
Power consumption from the 220 volt, 400 Hz mains, in VA, no more than	570

The indicator unit I2 consists of the tube block TR, the orientation block OR and the control panel PU (see Figure 5.9).

The tube block contains the following: the synchronizer which generates the signals which provide for the operational modes of the radars (13 assemblies); the scale chokes assembly (MDR), which incorporates a discharge network and scale chokes for the cursor and range sweep; four phase sensitive rectifiers of the generator channels and two rectifiers for the shifting of the cursor sweep and main sweep; two switched amplifier assemblies (UKR) of the cursor and range sweep tracking and generating channels; range (D) and bearing angles (P) for manual control of the electronic cursor; two blocks of VN±12.6-1.5, VN±20-2.5, VN±125-0.4 and VVI-15 KV rectifiers for powering the CRT of the indicator unit.

The orientation block OR incorporates the electromechanical cursor and range sweep stabilization and orientation elements, as well as the controls for units P3 (or P10), the computer and the true motion unit.

The control panel PU contains the radar operating controls and the built-in metering elements.

The sync signals control the transmitter and indicator operating modes and are generated in the crystal controlled oscillator assembly (GKCh), in three pulse frequency divider assemblies (DChI), two sweep pulse generator assemblies (FIR); a phasing pulse generating assembly (FIS), an advanced start generating assembly (FUS), a cursor shift and advance assembly (USV), a brightening amplifier assembly (USP), a video amplifier assembly (VUS), a coarse range readout assembly (GOD) and a precise readout assembly (TOD).

The layout of the indicator I1 controls is shown in Figure 5.12.

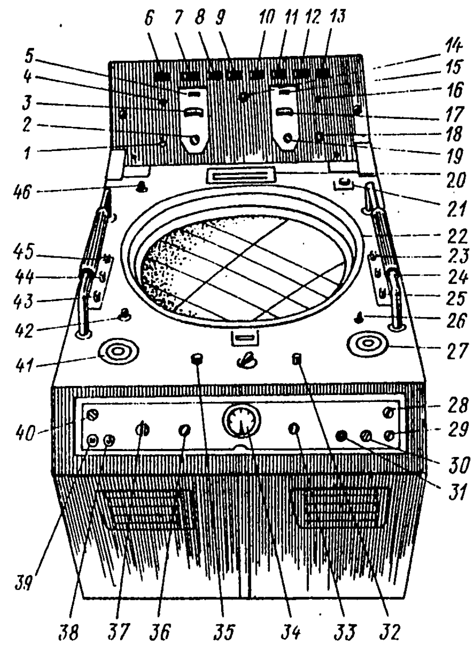

Figure 5.12. The layout of the controls of indicator I1.

Key:
1. CROSS LINES control;
2. ΔK control;
3. K + ΔK scale;
4. OPERATE--OFF toggle switch;
5. ΔK ENTERED display light;
6. OPERATE display light;
7. LOCK-ON display light;
8. TRACK display light;
9. PROBLEM SOLVED display light;
10. RELATIVE MOTION LINE display light;
11. TRUE MOTION LINE display light;
12. SIMULATION display light;
13. TRUE MOTION display light;
14. TRUE MOTION--V [computer] switch;
15. Δv ENTERED display light;
16. TRUE MOTION RETURN toggle switch;
17. v + Δv scale;
18. VOLGA control;
19. Δv control;
20. 1/0.25, 2/0.5, 4/1, 8/2, 16/4, 32/8 and 64/16 display lights, which signal that the range scale is turned on, and the NORTH--COURSE STABILIZED display light for the kind of orientation;
21. BAND--D switch;

Key [cont.]: 22. MILE scale; 23, 24, 25. FIXED RANGE RING, MOVING RANGE RING, CURSOR controls; 26. CURSOR SHIFT--CURSOR--CENTER SHIFT toggle switch; 27. RANGE control; 28. ILLUMINATION 2 control; 29. PRECIPITATION control; 30. PRECIPITATION--OFF control; 31. "4" check switch; 32. GAIN control; 33. "3" check switch; 34. Test meter; 35. SEA CLUTTER control; 36. "2" check switch; 37. "1" check switch; 38. MANUAL FREQUENCY CONTROL--AFC toggle switch; 39. MANUAL FREQUENCY CONTROL control; 40. "1" illumination control; 41. BEARING control; 42. NORTH--COURSE--COURSE STABILIZED toggle switch; 43, 44, 45. BRIGHTNESS, FOCUS, COURSE MARKER controls; 46. ECHO CHAMBER toggle switch.

The elements for generating the visible image in the indicator unit can be functionally combined in several channels:

The channel for generating the reference voltages provides for the timewise tying together of all of the processes in the radar. Included in it are the following blocks: the crystal oscillator, DChI1 [pulse frequency divider 1], DChI2, DChI3, FIS [phasing pulse generator], FIR-D [sweep pulse generator for the range] and the FIR-V [sweep pulse generator for the cursor]. The channel for generating the range sweep brightening and width pulses generates the range sweep width pulses for controlling the switches of the UKR-D assembly [switched amplifier for the range circuitry] to generate the forward range sweep trace pulse and the course marker in the brightness amplifier assembly. The channel is designed around the components of the range sweep pulse generator circuitry.

The channel for generating the cursor sweep brightening and width pulses feeds out the pulses for controlling the switches of the cursor and the generation of the cursor forward trace brightening pulse. The channel is designed around the components of the range sweep pulse generator and brightness amplifier circuits. The channel for generating the range sweep, RD, provides for the generation of the main plan position sweep. It incorporates components of units A (A3 and A10), the CRT blocks and the orientation block of indicator unit I.

The cursor sweep generating channel generates the cursor sweep after the completion of the main sweep at the pulse repetition rate on the 1 to 16 mile range scales and incorporates the components of the tube, orientation and control panel blocks of indicator unit I. The principle for the generation of the cursor and range sweeps in the "Okean-M" radar is similar to that in the "Okean" radar.

In equipment sets with unit V [the computer], the cursor sweep generator channel is used to reproduce the relative or true motion lines on the CRT screen. The channel for shifting the range sweep center and the cursor sweep center provides for the simultaneous manual shifting of the centers of the range and cursor sweeps. The channel is also used for the simultaneous automatic shifting of the sweep centers in the "True Motion" mode and for the automatic shifting of the cursor sweep center with a stationary range sweep in the "Relative Motion Line", "True Motion Line" and "Simulation" modes. The channel for shifting the range and cursor sweep centers incorporates components of the control panel, orientation and CRT blocks of indicator unit I.

The channel for generating the cursor sweep shift pulses and advanced starts produces the pulses for controlling the displacement of the cursor sweep in the case of an unshifted range sweep, for the generation of the phasing pulse in the SIU [?phasing pulse generator?] of the orientation block of the computer unit, for the control of an interfaced "Ladoga" electronic indicator (EIS) and "Volga" fishing fleet radio coordinator, as well as for the control of the precision delay of the moving range ring generator channel. The channel includes USV [cursor shift and advance] and FUS [advanced start generator] assemblies.

The channel for generating the pulses to trigger the transmitter and the time AGC circuitry produces the time AGC and "Start P" transmitter triggering pulses at a zero start pulse repetition rate and incorporates the components of the FIS [phasing pulse generator] assembly.

The course marker generator channel generates the "Course Marker Brightening" pulse train once every revolution of the antenna when the direction of radiation of the antenna coincides with the midline of the ship. The channel is composed of elements located in the antenna units (A3 and A10) and in the brightening amplifier assembly.

The brightening pulse amplifier channel (USP assembly) is intended for mixing and amplifying the pulses incoming to the cathode of the CRT to brighten the range sweep, the cursor sweep or the T_0 markers of the computer unit and the course marker.

The moving range ring generation channel produces a pulse, which following amplification and inversion in the video amplifier, is fed to the CRT modulator and is observed on the cursor and range sweep.

The moving range ring pulses are generated by a dual readout device, which incorporates components of the indicator control panel as well as the D [range], TOD [precise range readout], GOD [coarse range readout] and VUS [video amplifier] assemblies, an electromechanical contactless phase shifter with phasing elements, as well as a potentiometer with scaling resistors of the range assembly of the CRT block.

The dual readout device consists of the precise range readout circuitry using the phase shifter of the range assembly and the coarse range readout circuitry with the potentiometer delay of the GOD assembly. The fixed range ring generator channel produces range calibrated pulses for the approximate measurement of distances on the CRT screen. The channel incorporates elements of the intermediate frequency block as well as the FChI [expansion unknown] and video amplifier assembly.

The video amplifier (the VUS assembly) is intended for amplifying the video signals from the receiver of unit P3 (or P10), the fixed and moving range ring marker pulses, the cross-lines where a computer unit is present as well as the markers for a "Volga" radio coordinator which is interfaced to the radar. The amplifier output is connected to the CRT modulator.

The power supply and control channel for the cathode ray tube includes the controls and power supplies for the tube assembly block and the indicator control panel.

Five blocks with unregulated rectifiers located in the CRT block are used to power the blocks of the indicator unit: two VN±12.6-1.5 power blocks, a VN+20-2.5 block, a VI+125-0.4 block and a VVI-15 KV block. Their technical specifications are given in Table 5.8.

TABLE 5.8

Обозначение выпрямителя Rectifier Designation	Voltage, volts Напряжение, В	(1) Амплитуда переменной составляющей выходного напряжения, В, не более
ВН±12,6-1,5	12,6±1,3	0,05
ВН±20-2,5	20±2	0,01
ВН±125-0,4	125±12,5	1,7
	125±12,5	0,1
ВВН-15 кВ	15 000±1000	15
	400±40	4
15 KY		—
	-150^{+10}_{-20}	1,5

Key: 1. Amplitude of the alternating component of the output voltage, in volts, no more than.

The operation of the indicator unit I and its assemblies is monitored by means of jacks for checking the parameters of the supply voltages and pulses. A provision is also made for monitoring the operating modes of the indicator and transceiver units using a meter in the indicator control panel block by means of four monitor switches in this block. The operability of the transceiver is checked by means of the "I" monitor switch.

The values of the supply voltages for the indicator unit are checked in position "2" of the monitor switch; in position "3", the operability of the major assemblies of the indicator is checked by measuring the DC component of the pulses and voltages; in position "4", the switched amplifier and FChV [expansion unknown] assemblies of the channels for generating and shifting the center of the range and cursor sweeps.

The blocks and assemblies of indicator unit I are structurally located on three major support components of the chassis: the rack, which swings out below the CRT block and which opens above the indicator control panel. The electromechanical block of the orientation unit is mounted on the upper platform of the rack.

All of the electrical connections between the blocks and assemblies are made by means of plug connectors.

The true motion unit is intended for realizing the "True Motion" and "True Motion Simulation" modes in radar equipment sets without the computer unit, on the 1 to 8 mile range scales and where the "North" and "Course Stabilized" image orientation is set.

The true motion unit performs the following functions:

a) It generates the voltages for moving the center of the range and cursor sweeps on the CRT screen of the indicator unit in the direction of the heading and at a speed proportional to the ship's speed based on the data from the log and gyrocompass;

b) It generates the return signal for the reorientation of the image on the CRT screen;

c) Generates the voltage for the initial shift of the sweep center vertically downward based on the return signal when the "Course Stabilized" orientation is set, or shifts it in a direction opposite to the course, when the "North" orientation is set;

d) Provides for working out the maneuver for safe passage of oncoming ships using the simulation method.

The basic technical specifications of the true motion unit are:

--The error in generating the speed components does not exceed 1% of the maximum value;

--The error in generating the course components does not exceed 1°;

--The radius of the circle delineating the reorientation boundaries amounts to 0.5 + 0.05 of the radius of the CRT screen.

The true motion unit takes the form of an electromechanical computer, composed of assemblies and components of the computer unit V, which realize the "True Motion" mode. The following assemblies are incorporated in it: PKS - the speed and course conversion unit; the IPS - two speed projection integrators; the ASI - the unit for automatically resetting the integrators. Also included in the unit are two UI-16A amplifiers and a number of other components.

In the single band equipment sets, the true motion unit is connected directly to the indicator. In the two band equipment sets without the K3 unit, the true motion unit is connected directly to indicator I1. Where unit K3 is present, it is possible to switch the true motion unit between indicator units I1 and I2.

The speed and course converter converts the data from the log and gyrocompass concerning the speed vector from polar coordinates to cartesian coordinates (the axis of the initial course K, i.e., the vertical axis of the CRT screen, and the axis perpendicular to it), by means of a sine-cosine rotating transformer coordinator and scales the result by means of MVT [?scaling rotating transformers?].

The integrator assembly converts the speed projection on the indicated axes to voltages proportional to the route components. These voltages shift the sweep origin in the direction and at a rate proportional to the speed of the ship itself by means of shifting coils.

The automatic integrator reset unit generates the RETURN signal for the automatic reorientation of the image when the center of the sweep intersects the boundaries of a circle having a radius equal to half of the CRT screen radius in a direction opposite to the course (the "North" mode) or vertically downward (the "Course Stabilized" mode).

The image reorientation can also be accomplished manually.

The simulation of a maneuver is accomplished with a relative motion of the target blips using the components which effect the "True Motion" mode, and for this reason, the mode is called "True Motion Simulation".

Because of the persistence of the phosphor, traces of the relative motion of targets can be seen on the screen, which make it possible to determine the relative motion line. In the case of a dangerous relative motion line, the navigator using the entry controls for ΔK and Δv changes the relative motion line so as to determine a safe maneuver.

The true motion unit is constructed in a spray proof variant in a cast silumin housing.

Unit K1 is incorporated in the complement of single band radar sets and is intended for the following: turning the power plant on and off as well as the drive motor for the antenna A3 (A10), unit P3 (or P10) and the computer indicator; feeding a voltage of -27 volts to the radar units, which powers the connecting elements, as well as a voltage of 24 volts at 50 Hz for a soldering iron and a lamp, for heating the drive of antenna A3 (or A10); supplying a voltage of -10 volts which supplies the antenna microcontactor; relaying the branching interunit connecting lines (telephone, video signal, etc.); signaling normal functioning of the power actuation circuits which actuate the ANTENNA, TRANSCEIVER READY, PREHEAT display lights; coupling to the "Volga" and "Ladoga" electronic indicator interfaces; and for metering the station operating time.

The technical specifications of the K1 unit are given below:

The output voltage, in volts, for the following load current, no more than:	
5 A	27 ± 10%
0.7 A	24 ± 10%

Test video signals:	
Amplitude, volts	2 ± 0.5
Repetition period, microseconds	1 - 1.5
Width, microseconds	300 - 2,200
Polarity	Negative
Duration of the delay relative to the transmitted pulse, microseconds	10 ± 0.1

The equipment complement of unit K1 includes: the VN±27V-25A block; the EP2 assembly - emitter followers; and the radar set operational metering assembly.

Unit K2 is incorporated in two band radar sets and performs the following functions: turning the radar units on and off and switching between them, supplying voltages, and the other functions indicated for unit K1.

The technical specifications of unit K2 are similar to the characteristics of unit K1.

The complement of the unit K2 includes two VN±27V-5A blocks, a EP1 assembly of emitter followers, and a KRS assembly: a unit for monitoring the radar set operation.

The K3 unit is included in two band radar sets in which a provision is made for the capability of switching the true motion unit (or computer) from indicator unit I1 to indicator I2, i.e., to any unit which performs the functions of the master unit.

The Computer

The computer (unit V) is intended for the following:

--Solving problems of passing ships which come near and feeding out the solution results and recommendations for maneuvering on the PPI screen in the form of LOD relative motion lines or LID true motion lines with time markers on them from which the relative speed v_0 or true speed v_I is estimated, as well as the time to the closest approach point T_0;

--Assuring a true motion mode when the orientation of the image is set on "North" or "Course Stabilized" on the 1 to 8 mile range scales.

The major technical specifications of the unit are given below:

Mean square error in calculating coordinates in the "Track" mode, no more than:	
With respect to azimuth, minutes	± 18
With respect to range, m	± 25
The computational error in the "Track" mode:	
Of the relative course K_0, in degrees, no more than	± 3
Of the target course K_t, in degrees, no more than	± 6
Of the course K or ΔK maneuver, in degrees, no more than	± 7
Of the v speed maneuver, in knots, no more than	± 1.4

The minimum solution time for the passing problem (for the actuation of the PROBLEM SOLVED display light) from the moment the "Track" mode is switched on, in minutes	2.5 ± 0.25
The processing time for the maximum of the range and azimuth mismatch in the "Lock-on" mode, seconds	10
Processing the coordinates of strobe centers in the "Lock-on" mode, no more than:	
With respect to azimuth, minutes	± 18
With respect to range, m	± 50
The MARKER T_0 negative polarity signal in the "Track" mode:	
Amplitude, volts	6 ± 2
Relative width, microseconds	1.25 ± 0.12
Initial shift voltage in the "True Motion" mode, volts	79 ± 0.5
RETURN signal voltage in the "True Motion" mode, volts	82 ± 2
Shift voltage in the "True Motion" mode, with precisions of:	
With respect to speed, knots	± 0.3
With respect to course, degrees	± 1

The characteristics of the MARKER signal are given in Table 5.9.

TABLE 5.9

MARKER Signal	Amplitude, Volts	Pulse Width, µsec	Repetition Period in a Pulse Train, µsec
Normalized	5 ± 2	1.8 ± 0.2	1,200 ± 100
Cross-lines:			
Angular component	5 ± 2	0.5 ± 0.1	1,200 ± 100
Radial component	5 ± 2	7 ± 2	1,200 ± 100
Radial component (target in the gate)	5 ± 2	13 ± 3	1,200 ± 100

The Equipment Complement of the Unit. Computer unit V contains electronic and electromechanical sections.

The assemblies of the electronic section of the computer unit V perform the following functions.

The video signal normalizer (NVS) is intended for segregating the target video pulse train from the noise background and normalizing these pulses with respect to amplitude and width.

The synchronization and control circuitry (SNU) is intended for generating such signals as the 81 KHz meander, the 50 µsec pulse, the 81 KHz count pulse, the reset for generating T_0, the 200 μsec pulse, the T_0 GATE and TARGET IN THE GATE .

The range error expander (ROD) is intended for generating the TARGET GATED and ROD PULSES signals.

The coarse range readout circuitry (GOD) is intended for generating the approximate value of the current range to the target (the rough reading) and tying the range gates to the PPI sweep.

The precision range readout circuitry (TOD) generates the pulse corresponding to the current range to the target (the precise reading).

The cross-lines and range gates unit (PDP) generates the 1ST GATE RANGE, 2nd GATE RANGE and CROSS-LINE R (radial component) and CROSS-LINE A (angular component) signals.

The azimuth strobe generator (FSP) is intended for generating the STROBE AZIMUTH and RESET AZIMUTH signals.

The time marker generator (GMV) generates the pulses for brightening the relative or true motion lines on the CRT screen.

The bidirectional pulse counters (RSI's) are intended for counting a number equal to the difference in the GATED VIDEO pulses located in the first and second azimuth gates, as well as in the first and second range gates (RSI-1D and RSI-2D).

The circuit for controlling the pulse counters (USI) generates the AZIMUTH GATE CENTER, RANGE GATING and AZIMUTH gate signals.

The KOD assemblies are intended for converting the numerical azimuth error (KPN-P) or the numerical range error (KPN-D) to an error in the form of a 400 Hz voltage corresponding to the bearing and range.

The tracking error amplifier (UOS) is intended for amplifying and scaling the ΔP [Δ Azimuth] and ΔD [Δ Range] errors.

The metering assembly and timing relays are intended for turning on the PROBLEM SOLVED display light after the solution of the passing problem and the completion of the transient processes in the automatic target tracking systems.

Two VN± 12.6-1.5 unregulated rectifiers generate a voltage of +12.6 V to power the circuits of computer unit V.

The assemblies of the electromechanical section of computer unit V perform a number of functions.

The log speed converter (PSL) converts the log speed data.

The automatic azimuth tracking assembly (PA) is intended for generating signals which determine the angular position of the gate in the "Lock-on" and "Track" modes, as well as entering the course maneuver being simulated when playing through safe passing situations.

The automatic range tracking assembly (DA) generates signals for the tracking error block which determine the time position of the range gate of the auto-tracking system.

The course and speed maneuver assembly (MSK) generates signals which define the rotation angle of the relative or true motion lines on the CRT of indicator unit I when selecting a maneuver for safe passing during the simulation of situations.

Two speed projection integrators (IPS) produce components of the speed vector v_{ox} and v_{oy} in cartesian coordinates.

The automatic reset assembly for the integrators is intended for generating the AUTORETURN signal.

The solution of a passing problem consists of several steps which are performed sequentially.

In the "Lock-on" mode (step I), the operator sets the azimuth and range controls so that the target which is being locked on to is located at the end of the electronic cursor. With correct lock-on, the length of the radial line of the cross-line is doubled, which indicates that one can change over to the "Track" mode.

In the "Track" mode (step II), the integrators process the current position of the range and azimuth gates. Simultaneously, the speed vector components v_{ox} and v_{oy} are calculated in cartesian coordinates.

Step III begins at the moment the transient process is finished in the azimuth and range autotracking units, and the PROBLEM SOLVED display light comes on. In this case, the course and speed maneuver unit, using the projections of the v_{ox} and v_{oy} vectors, generates voltages in the "LOD" [relative motion line] mode which are proportional to the value of the argument (the course K_0) and the scalar value (the speed v_0), while in the LID [true motion line] mode, it generates the parameters for the true motion of the target K_t and v_t. The time markers T_0 are generated at the same time. Thus, the following display is reproduced on the CRT screen:

--The course of the relative motion of the targets K_0 (in the form of a relative motion line in the "LOD" mode);

--The true motion course of the target K_t (in the form of a true motion line in the "LID" mode);

--The target tracking time T_0 to the point of closest approach D_0 in the form of dashed lines of a brightened true or relative motion line, the number of which is proportional to T_0.

The closest approach distance D_0 is determined by means of the moving range ring at the moment of touching the relative motion line. If the closest approach distance is small (D_0 = 2 miles) and the bearing to the target is constant or changes extremely little, and T_0 = 15 to 20 minutes, then the navigator is obligated to carry out step IV in solving the collision avoidance problem: determine the recommended maneuver for his own ship for safe passing.

The simulation of the maneuver is accomplished as follows. Using the ΔK and/or Δv controls on the indicator unit I, new values of the course and/or the speed are set using the "K $\pm$ ΔK" and "v + Δv" scales so that the relative motion line is tangent to or turns away from the previously established two mile moving range ring. As a result of entering the simulated ΔK and/or Δv, the computer unit V supplies the recommended increments of the values ΔK and Δv to realize a safe passage.

Structural Features of the Computer Unit V. Unit V is made in a spray-proof cast silumin housing, which is closed with a swing-out cover. Inspection windows are provided in the cover to observe the scales for the bearing, course, range and speed.

The electromechanical assemblies are secured on the inside on the cast frame, while the assemblies of the OS block are secured to the lower rotating frame. The electrical connections are made between the assemblies in the unit by means of screw-down terminals. The external cable entrance is realized through windows existing in the bottom. The spray protection for the unit is accomplished using a rubber washer between the cover and the housing.

Recommendations for the Layout and Operation of the "Okean-M" Radar Units

The radar units and the power plant (with the exception of the antenna units A, A3 and A10) are to be installed in closed rooms.

It is recommended that units A, A3 and A10 be positioned so that there are no shaded sectors. The units should be oriented in line with the STERN--BOW indicator, located on the housing of the antenna drive.

The installation platform for the antenna should be parallel to the plane of the true horizon with a precision of $\pm 1°$.

In sets with two antennas (A3, A10), they are arranged one above the other on the midline of the ship. A stepped placement of the units on the midline of the ship or symmetrical with respect to it is permitted. The spacing between the vertical axes should not exceed 3 m. The slotted radiator should be spaced in height at a distance of no less than 1 m.

Units P3 and P10 should be placed in separate rooms in such a way that the length of the waveguide channel does not exceed 20 m.

Units KP3 and KP10 are installed on top of units P3 and P10, where holes are provided for the fastening bolts.

TABLE 5.10

Номер кабеля Cable No.	Марка, сечение, мм² Type, Cross-Section mm²	Прокладка Cable Route	
		от прибора from unit:	к прибору to unit:
1	КНРЭ 3×6	Щит судовой сети (1)	ПММ-2112
2	КНРЭ 4×2,5	ПММ-2112	АТО-4-400
3	КНРЭ 3×1,0	БРП-143/3	К2
4	КНРЭ 2×6,0	АТО-4-400	К2
5	КНРЭ 7×1,0	АТО-4-400	БРП-143/3
6	КНРЭ 7×1,0	ПММ-2112 (1)	К2
7	КНРЭ 3×6,0	Щит судовой сети	К2
8	КНРЭ 4×2,5	ПММ-2112	Вентилятор приемопередатчика (2)
9	КНРЭ 3×1,0	КП10	П10
10	КНРЭ 3×1,0	КП3	П3
11, 12	РК-75-4-11	П10	К2
13	КНРЭ 2×6,0	П10	К2
14	МЭРШН-100 2×1,0	П10	К2
15	МЭРШН-100 12×1,0	П10	К2
16	КНРЭ 12×1,5	П10	К2
17, 18, 19	КНРЭ 12×1,5	А	В
20	КНРЭ 4×2,5	Привод А (3)	К2
21, 22	МЭРШН-100 12×1,0	П3	К2
23	КНРЭ 12×1,5	П3	К2
24	КНРЭ 2×6,0	П3	К2
25, 26	РК-75-4-11	П3	К2
27	МЭРШН-100 12×1,0	К2	И1
28	МЭРШН-100 12×1,0	К2	И1
29	КНРЭ 2×6,0	К2	И1
30	КНРЭ 2×6,0	К2	И1
31, 32, 33, 34, 35, 36	РК-75-4-11	К2	И1
37	КНРЭ 2×6,0	К2	И2
38	МЭРШН-100 12×1,0	К2	И2
39	МЭРШН-100 12×1,0	К2	И2
40	КНРЭ 12×1,5	К2	И2
41	РК-75-4-11	И1	И2
42	КНРЭ 7×1,0	Гирокомпас (4)	И1
43	КНРЭ 7×1,0	»	И2
44	КНРЭ 7×1,0	Лаг Log	И1
45	КНРЭ 7×1,0	»	И2
46	КНРЭ 7×1,0	Гирокомпас (4)	В
47	КНРЭ 7×1,0	Лаг Log	В
48	КНРЭ 12×1,5	К2	В
49	КНРЭ 3×1,0	К2	К3
50	КНРЭ 12×1,5	К3	И1
51	КНРЭ 12×1,5	К3	И1
52	МЭРШН-100 12×1,0	К3	И1
53	КНРЭ 12×1,5	К3	И2
54	КНРЭ 12×1,5	К3	И2
55	МЭРШН 100 12×1,5	К3	И2
56, 57	КНРЭ 12×1,5	К3	В
58	МЭРШН-100 12×1,0	К3	В
59, 60	РК-75-4-11	К2	В
61	КНРЭ 12×1,5	А	В
62, 63, 64	КНРЭ 12×1,5	К3	И1
65, 66, 67	РК-75-4-11	К3	И1
68, 69, 70	МЭРШН-100 12×1,0	К3	И2
71, 72, 73	РК-75-4-11	К3	И2
74	КНРЭ 12×1,5	К3	В
75, 76	МЭРШН-100 12×1,0	К3	В
77, 78, 79	РК-75-4-11	К3	В

Key to Table 5.10: 1. Ship power mains panel;
2. Fan of the transceiver;
3. Antenna drive;
4. Gyrocompass.

Indicator I is placed in the wheelhouse and secured to the deck. The height of the seat above the deck level should be about 120 mm. The rear wall of the indicator should be separated from the bulkhead by a spacing of no less than 300 mm. The distance from a magnetic compass to the indicator unit should be no less than 700 mm, otherwise these units should be separated by a steel shield.

It is recommended that the computer unit be installed in the wheelhouse or navigator's compartment and secured to a deck or bulkhead. The height of the deck cushion should be 120 ± 10 mm. The cable entrances are on the rear wall.

It is recommended that the true motion unit be located in the wheelhouse or the navigator's compartment and secured to the deck or to a bulkhead. The height of the base of the unit above the level of the decking should be 800 to 1,200 mm. The cable entrances are brought into the rear wall.

It is recommended that units K1 and K2 be installed in the wheelhouse and secured to bulkheads. The height of the bases of the units above the decking level should be 700 to 1,200 mm. The cable entrances are on the rear walls.

Unit K3 is located in any accessible room.

The power plant with the start and regulating equipment should be housed in the equipment room in accordance with MRTU 615-6853-63.

The interconnections between the "Okean-M" radar units are made using cables of the following types: KNRE, MERShN-100 and RK-75-4-11.

The length of the cables between the units should not exceed the following values:

100 m between units P3, P10 and the indicator unit I;

20 m between units located in the wheelhouse and navigator's compartment;

120 m between units A, A3, A10 and the indicator unit, as well as the computer unit.

The length of the radiofrequency cables should be the same in the two band version.

The cable documentation is given in Table 5.10.

Technical Operating Rules

The Power On and Off Control for the Units and Blocks. When the black button is pressed for turning on the POWER PLANT power, the "Power Plant" light comes on (see Figure 5.12).

All of the radar units are turned on (with the exception of the computer and true motion units) using the following switches on unit K2 (or K1): INDICATOR 1--OFF, INDICATOR 2--OFF, P3--OFF, P10--OFF, as well as the pairs of A10 and A3 pushbuttons with the indication shown by the corresponding display lights of the units I1 and I2: P3 READY, P10 READY, ANTENNA--3, ANTENNA--10. The READY--3 and READY--10 display lights come on three to four minutes after turning the transceivers on. When the OPERATE--OFF toggle switch is turned on, the OPERATE display light comes on.

The computer and true motion units are turned on automatically when the appropriate mode is set on the master indicator. When only one indicator is turned on, it must be set in the "Master" mode.

Operating Mode Controls for Indicator Unit I. The BRIGHTNESS potentiometer regulates the brightness of the CRT display.

The NKD [fixed range ring], PKD [moving range ring], CURSOR and COURSE MARKER potentiometers adjust the brightness of the fixed and moving range ring markers, the cursor and the course marker respectively.

The beam of the indicator CRT is focused by means of the FOCUS control.

The ILLUMINATION-1 potentiometer regulates the brightness of the display lights and scales located outside the viewing hood, as well as the MILES counter.

The ILLUMINATION-2 potentiometer adjusts the brightness of the display lights and scales found inside the viewing hood.

The ranges to the target of interest and the azimuth to it are measured by means of the RANGE and AZIMUTH controls.

The Operating Mode Controls for the Radar. These include the NORTH--COURSE--COURSE STABILIZED, TRUE MOTION--RELATIVE MOTION--SIMULATION, COMPUTER, CURSOR and SHIFT CENTER switches.

The BAND--RANGE switch sets the requisite range scale with the appropriate signaling on display 20 (see Figure 5.12).

The scale display light indicates the RANGE SCALE in the numerator and in the denominator, the distance between the FIXED RANGE RING markers for the given range scale.

The distribution of the frequency bands between the indicators, and the setting of one of them in the "Master" mode is accomplished by the following pushbuttons: 3--INDICATOR I1--10, 3--INDICATOR I2--10 and I1--MASTER--I2, which are located on the subpanel of unit K2 under the lower door.

The SEA CLUTTER, GAIN, MANUAL FREQUENCY CONTROL--AFC and MANUAL FREQUENCY CONTROL potentiometers adjust the operation of the receiver in unit P3 (P10). The PRECIPITATION--OFF toggle switch turns on the short time constant circuit for the differentiation of the video signals in the video signal amplifier of the transceiver unit P.

The PRECIPITATION potentiometer continuously varies the time constant of the differentiating network.

Switches for Monitoring the Parameters and Operability of the Units and Blocks. The CHECK-1 switch monitors the magnetron current, the mixer current in units P3 (or P10) as well as the operation of the rectifiers and assemblies of indicator unit I in the first three positions. In the fourth position, the microammeter is disconnected, while in the fifth position, it is switched over to switch CHECK-2, which by means of the microammeter makes it possible to check the power supply of the unit and connect the microammeter to the CHECK-3 switch. Using the latter, one can check the operability of the CRT sweep assemblies and the test outputs for the low current circuits of the synchronizer.

The ECHO CHAMBER--TRANSMIT toggle switch turns on the echo chamber to check the power potential of the transceivers.

The switches, toggle switches and microammeter of the KU block [metering and control block] serve for monitoring the supply voltages and the major parameters of the transmitter blocks.

Turning the Radar On and Off, Orienting and Adjusting It

The positions of the controls for the units prior to turning the radar on (initial positions) are given in Table 5.11.

The radar in equipment sets having the K2 unit is turned on using the controls located on it in the following order:

a) Press and release the 220 volt, 400 Hz pushbutton to turn on the power plant; in this case, the 220 volt, 400 Hz light comes on;

b) Using pushbuttons 3--INDICATOR 1--10, 3--INDICATOR 2--10 and INDICATOR 1--MASTER--INDICATOR 2 located on the subpanel of the unit K2, distribute the frequency bands between units I1 and I2; set one of them in the "Master" mode. The circuit configuration chosen is reflected in the display light in the upper part of the unit;

c) Set the I1 and I2 switches in the vertical position; in this case, the I1 and I2 display lights respectively should come on, and power is fed from the power plant to units I1 and I2;

TABLE 5.11

Units	Controls of the Units	Initial Position
K2 (K1)	INDICATOR I1--OFF; INDICATOR I2--OFF switches	"Off"
K2 (K1)	P3--OFF; P10--OFF switches	"Off"
K2 (K1)	TRACK toggle switch	"Okean"
I	OPERATE--OFF toggle switch	"Off"
I	PRECIPITATION--OFF toggle switch	"Off"
I	SHIFT CURSOR--CURSOR--SHIFT CENTER toggle switch	"Cursor"
I	MANUAL FREQUENCY CONTROL--AFC toggle switch	"AFC"
I	COMPUTER switch	"Off"
I	NORTH--COURSE--COURSE STABILIZED toggle switch	"Course"
I	TRUE MOTION--RELATIVE MOTION toggle switch	"Relative Motion"
A3, A10	TRANSMIT AND ANTENNA DRIVE switch	"On"
I	TRUE MOTION--COMPUTER switch	"Off"
KU	TEST--OPERATE switch	"Operate"

d) Set switches P3 and P10 in the vertical position. After three to four minutes, the READY P3 and READY P10 display lights are turned on, which means that units P3 and P10 are ready for the "Operate" mode to be turned on;

e) Push buttons A3 and A10; in this case, the ANTENNA 3 and ANTENNA 10 display lights respectively are turned on (in radar sets having antenna unit A, the start-up is accomplished with any pair), which means that units A3 and A10 (or A) are started.

The radar in sets having unit K1 is turned on using the controls located on it in the following order:

a) Press and release the black 220 volt, 400 Hz button; in this case, the 220 volt, 400 Hz light comes on;

b) Press and release the black A button; in this case, the ANTENNA display light should come on, which means that units A3 and A10 are started;

c) Open the cover of the front panel of unit K1 and set switches I and P in the vertical position; in this case, the I and (after three to four minutes) the READY P display light should come on;

d) Using the operating mode controls of the indicator, set the requisite brightness of the display lights and scales, brightness of the screen display and all markers and check for their presence on the screen;

e) Check to see that the readings of the K ± ΔK course and v + Δv speed scales match the readings of the gyrocompass and log repeaters with a precision of ± 0.3° and + 0.2 knots; in the case of a difference in the readings, match them up by pressing and rotating the MATCH COURSE and MATCH SPEED controls which are located under the cover of block OR. This operation is also performed in unit V [the computer] or ID [true motion];

f) Switch off the ΔK ENTERED and Δv ENTERED display lights by rotating the ΔK and Δv controls, if they were turned on;

g) Set the OPERATE--OFF toggle switch in the "Operate" position, making sure beforehand that the READY P3 (or P10) display light is on in unit K2, and the READY P is on in unit K1; in this case, the OPERATE display light comes on;

h) Check the nominal readings of the meter in the PU [indicator control panel] block in the following positions of the check "I" switch: "Magnetron" (green sector), "IF amplifier mixer" (black sector) and "AFC mixer" (black sector);

i) Set the SEA CLUTTER and GAIN controls in a position such that there is no additional brightening of the screen by sea returns and the targets are clearly observed.

To check the power potential of the radar on the "8" range scale, it is necessary to throw the ECHO-CHAMBER toggle switch of indicator unit I. A flare trace from the echo chamber should be periodically observed on the screen in the form of a lobe, the length of which must be measured by means of the moving range ring and compared with the value indicated in the radar data sheet.

Check the readings of the MILES counter by means of matching the moving range ring to the second stationary range ring. In this case, the counter should read 0.5 + 0.01; 1 ± 0.02; 2 ± 0.04; 4 ± 0.08; 8 + 0.16; 16 ± 0.32 and 32 ± 0.64 on the 1, 2, 4, 8, 16, 32 and 64 mile scales.

Normal operation of the transmitter is monitored based on the magnetron current if the "I" monitor switch of the indicator control panel of indicator unit I is set in the "Magnetron" position.

During the operation of transceivers P3 and P10, individual breakdowns in the magnetron and modulator tube are possible, which cause the transmitter overload protection to actuate. In this case, the OPERATE display light goes out, while the meter needle goes to zero.

To restore normal operation of unit P3 (or P10), it is necessary to throw the OPERATE--OFF toggle switch to the "Off" position, and after four to five seconds, again set it in the "Operate" position. If after turning the unit on three or four times the OPERATE display light does not come on, one is to troubleshoot and eliminate the defect in accordance with the instructions for radar set operation.

The major frequency tuning mode is AFC. Manual frequency control (RPCh) is recommended in the case of failure of the AFC.

Manual frequency control is realized only in the case of returns from a target, sea clutter or an echo chamber signal in the following order:

a) Set the AFC--MANUAL FREQUENCY CONTROL toggle switch in the "Manual Frequency Control" position;

b) Rotate the GAIN and SEA CLUTTER controls clockwise to the stop;

c) Set the check "I" switch of the indicator control panel in the "IF Amplifier Mixer";

d) By smoothly rotating the manual frequency controls, establish the maximum brightness of the target returns.

The radar is turned off in the following order:

a) Set the OPERATE toggle switch on the indicator unit I in the "Off" position; in this case, the OPERATE display is turned off;

b) Set the P3, P10 (or P), I1, and I2 (or I) switches on unit K2 (or K1) in the horizontal position; in this case, the READY P3, READY P10 (or READY P), I1 and I2 (or I) display lights respectively are turned off;

c) Press and release the red A3, A10 (or A), 220 volts, 400 Hz buttons on unit K2 (K1); in this case, the ANTENNA 3, ANTENNA 10 (or ANTENNA) display lights and the 220 volt, 400 Hz light respectively are turned off.

The choice of the image scale and orientation on the PPI screen is realized by the BAND--D [RANGE] switch. The range scale which is turned on and the distance between the fixed range rings are indicated by lighted numbers on a display located above the screen (under the viewing hood).

When navigating in straits, skerries, along shorelines, in channels and when coming into port and leaving port, it is recommended that the "1", "2", "4" and "8" range scales be used [14].

As the ship's speed increases, the scales must be increased. A "ID" ["True Motion"] mode is provided on these scales, as well as the possibility of shifting the image center by one-half of the screen radius with relative motion by means of the ΔK and Δv controls.

It is recommended that the center shift be used in the case where it is desirable to have maximum information from one side of the ship while preserving the scale being employed.

The "8" and "16" scales are recommended for navigation safety in the open sea, since in this case, large and intermediate vessels are detected reliably at the maximum range. At the same time, these scales have a sufficiently large scale for the detection of small ships and objects close to the ship. Operation in the "Computer" and "Cursor Shift" modes is provided only on these scales.

It is recommended that the "32" and "64" scales be used only to determine the ship's position where correctly identified reference markers are present at ranges of up to 64 miles.

With normal refraction, the radar detects targets 200 to 1,000 meters above sea level at ranges of up to 32 miles.

With super-refraction, low lying shores, islands and other targets can also be detected at the indicated range.

The choice of the image orientation on the PPI screen is accomplished by the NORTH--COURSE--COURSE STABILIZED toggle switch. The set orientation mode is reflected on the corresponding NORTH, COURSE and COURSE STABILIZED display lights, which are located under the screen.

The "North" mode is recommended as the main one in the open sea and when navigating near shore, where the radar is used to determine the ship's position and determine the danger of approaching oncoming ships.

In the "Course Stabilized" mode, the image is oriented along the midline of the ship and stabilized in a range of $\pm$ 3° from the gyrocompass. This mode is used when sailing in straits, skerries and channels, since the image is not blurred with the yawing and turning of the ship.

In the "Course" mode, the image is oriented along the midline of the ship. This mode is most convenient when visually piloting the ship using large scale range scales. A drawback to the mode is the smearing of the image when the ship rotates and yaws.

The relative motion (OD) is switched on when the OD--V [RELATIVE MOTION--COMPUTER] switch on unit I is set in the "Off" position.

The azimuth is measured by the electronic cursor (EV) on the 1 to 16 mile scales for all orientations, as well as in the case of a shifted center on the 1 to 8 mile scales.

Azimuth measurement on the 32 and 64 mile scales is accomplished with the "North" orientation only by the mechanical cursor (MV).

In the "Course" orientation mode, the course angle on the 1 to 64 mile scales is to be measured only by means of the mechanical cursor.

The range in all modes can be measured by means of the electronic cursor and the moving range ring. On the 32 and 64 mile scales, the range is measured only by means of the moving range ring. An approximate reading of the range can be made by means of the stationary range ring.

The measurement of the directions between targets on the 1 to 64 mile scales can be made by means of the mechanical cursor.

The precise measurement of the azimuths between targets, as well as the range between them on the 8 and 16 mile scales can be made using the offset electronic cursor.

The relative motion line (LOD) on the 8 and 16 mile scales can also be precisely determined by means of the offset electronic cursor.

The true motion (ID) mode is possible in radars which have the computer and true motion units incorporated in the indicator unit, on the 1 to 8 mile scales in the case of the "North" or "Course Stabilized" orientation. The true motion mode is recommended for navigation in straits, channels, along shorelines, between islands and when entering and leaving port. The smearing of the image is prevented in the true motion mode and the identification of moving targets is assured. In this case, the estimation of true speeds and courses of all moving targets based on the trails their blips leave by persistence on the PPI screen are relatively easily estimated.

The true motion mode can be switched on by preliminarily setting the following controls on indicator unit I: the BAND--D [RANGE] is set to the "1", "2", "4" or "8" position; the NORTH--COURSE--COURSE STABILIZED switch is set to the "North" or "Course Stabilized" position; the CURSOR SHIFT--CURSOR--CENTER SHIFT switch is set the "Cursor" position.

The moment the true motion mode is turned on, the center of the sweep is shifted along the opposite course heading by a distance of half of the screen radius and then begins to move along the course at the speed of ship travel for the scale of the set range scale.

The limits of sweep origin motion are chosen from the condition of reliable viewing and are determined by the moment of actuation of the autoreturn system. The latter actuates if the sweep center is shifted by half of the radius from the CRT center and if there is a change in the ship's course by $\pm$ (175 + 5)°.

The sweep center can be shifted manually to the origin by means of turning on the CHECK V [COMPUTER]--RETURN ID [TRUE MOTION] toggle switch to the "Return ID" position. It is recommended that the manual return be matched to the point in time which follows directly after the completion of the ship's maneuver.

The motion of blips from known stationary targets indicates the drift of the ship with the action of wind or current or the presence of an error in the readings of the log or gyrocompass.

The ΔK and Δv controls are used to enter course and speed corrections until the blip becomes stationary. In this case, the true course and speed of the ship relative to ground can be read out from the $K \pm \Delta K$ and $v \pm \Delta v$ scales.

Solving the problem of passing an oncoming ship is accomplished by means of the computer unit. For this, the controls are set in the following positions on indicator unit I, which is switched to the "Master" mode: BAND--RANGE to position "16"; NORTH--COURSE--COURSE STABILIZED to the "North" position; TRUE

MOTION--COMPUTER to the "Off" position; and SHIFT CURSOR--CURSOR--SHIFT CENTER to the "Cursor" position.

The target lock-on and switch to the autotracking mode are accomplished in the following manner:

a) The COMPUTER switch of the indicator unit is set in the "Lock-on" position;

b) The CURSOR and CROSS-LINES controls are used to set good brightness of the cross-lines at the end of the electronic cursor with each revolution of the antenna;

c) By turning the AZIMUTH and RANGE controls, the end of the electronic cursor is matched up with the center of the near boundary of the blip of the target being locked-on.

With proper lock-on, the length of the radial line of the cross-lines will double.

The "Track" position is turned on at the point in time when the sweep approaches the position of the cursor line at an angle of 20 to 50°. In the case of target loss during autotracking, the length of the radial line of the cross-lines is cut in half; in this case, it is necessary to repeat the lock-on.

During the automatic tracking process, one can use the electronic cursor to determine the coordinates of other targets.

The moment the transient process is completed in the target autotracking system is registered by the actuation of the PROBLEM SOLVED display light on the OR block of indicator unit I.

After this, the COMPUTER switch is to be set in the "LOD" [relative motion line] position; in this case, the relative motion line of the oncoming ship lights up on the screen and the LOD display light is turned on.

The distance D_0 is determined by means of setting the moving range ring tangential to the relative motion line. The time T_0 in minutes is determined by means of counting the number of markers on the relative motion line segment from the blip of the ship being tracked to the tangent point on the periphery of the moving range ring and multiplying the resulting number of markers times 6 minutes.

The true motion line (LID) of the ship lights up when the COMPUTER switch is set in the "LID" position; the LID display light is turned on in this case.

The relative or true speed of an oncoming ship is determined using the T_0 markers for the relative or true motion lines respectively in the following sequence: by rotating the RANGE control, the moving range ring marker on the true motion or relative motion line is matched to the start of the second marker (counting from the origin of the true or relative motion lines); the readings of the MILES counter, multiplied by 10, correspond to the relative or true speed of the oncoming ship in knots.

If t_0 = 15 to 20 minutes, and D_0 = 2 miles, then in accordance with the Regulations for Preventing Collisions at Sea and in line with the specific conditions, it is necessary to determine the maneuver for the ship by means of simulation. A maneuver is simulated with the COMPUTER switch thrown to the "Simulate" position; in this case the SIMULATE display light comes on, and the relative motion line will be indicated on the PPI screen.

Taking the particular navigation situation into account and using the ΔK and Δv controls, those values of the course and speed are chosen for which a safe closest approach distance is assured. After this, the decision is made to execute the maneuver.

By rotating the ΔK and Δv controls, the ΔK ENTERED and Δv ENTERED display lights are turned off and the COMPUTER switch is set in the "Relative Motion Line" position.

The observation of the new passing situation continues in this position after the execution of the maneuver.

5.3. Specific Features of Marine Radionavigation and Radar Complexes

The major reason for the increase in the danger of collision is the increased complexity of ship navigation conditions, which is due to technical progress in the construction and development of the world-wide fleet. The increase in the displacement of seagoing vessels leads to a degradation of their maneuvering qualities and a limiting of the maneuvering area because of the increased draft, which transforms the open sea into confined water routes.

The construction of new types of seagoing vessels, as well as the use of progressive methods for loading and unloading ships in port and the substantially elevated specific share of the running time in the operating period have all, along with the increased demand for sea shipments, led to a significant increase in ship traffic.

The rise of the accident rate in the merchant marine, which is due to collisions of ships at sea, leads to increasing losses of transport facilities and the cargo being shipped, to the loss of crew and passengers and to ever increasing contamination of the water environment.

Under the conditions which had come about by the beginning of the 1960's, there arose the clear necessity for the creation of effective ship collision warning systems (PSS).

The volume of necessary information which should be made available to the pilot by any ship collision warning system during the process of passing one or more ships was ascertained on the basis of a study of the visual manner of solving this problem under conditions of good visibility.

Any ship collision warning system should provide the ship's pilot with four kinds of information (four phases):

1) Information on detected objects which threaten a collision or a dangerous approach;

2) Information on the established headings of targets, since this governs the use of the ship collision avoidance regulations;

3) Information on the evaluation of the safety of a course or speed maneuver being undertaken by the ship itself relative to a dangerous target, as well as relative to other ships, initially of no danger as regards a collision;

4) Information on the estimate of the passing dynamics to avoid a new danger of collision as a result of maneuvering a threatening or other ship.

Under the conditions of the continuing growth in the traffic density on the major maritime routes, the role of radar as a means of early detection of targets representing a collision danger has increased significantly. Because of this, specialists have set about a detailed study of the questions of collision warning, specifically by means of radar.

The difference in the approach to the principles of processing radar returns, the degree of automation and the form of the information presented to the ship's pilot has led, despite the unity of the requirements placed on it, to the appearance of various systems, the number of which now exceeds 25.

All of these systems, which reflect the effort to automate to a greater or lesser extent the process of ship passing, can be broken down into two main groups:

1) Systems with data storage which use various memories and which produce on the indicator screen the trajectories of the passed motion of the targets; either an endless loop of magnetic tape (the Marconi Predictor radar of the "Marconi" Company) or a screen coated with a long persistence phosphor (the unit of the "Kelvin Hughes" Company) or a digital computer (the "Scan-100" system of the "F8M Systems" Company [10]) can be used as the data store;

2) Systems which predict the position of targets at a certain point in time, where digital computer processing and evaluation of the radar data is used for these purposes; both a specialized digital computer (the "Digiplot" system of the "Lotron Corp.") and a general purpose computer (the "Compact" system of the "GEC-AEJ" Company) can be used as the computer.

The complement of the majority of systems includes the following functional blocks:

1. The radar - the main information sensor which provides for visual observation of the target.

2. The situation indicator - usually a plan position indicator on the screen of which the following can be shown: the alphanumeric data generated by the digital computer as well as circles and vector lines.

The induced information usually takes the form of:

--The ordinal number of the target;

--The data of the autotracking system;

--The moving marker used for indicating the position and locking-on to a target for autotracking.

The trajectories of targets, the relative velocity vectors and other forms of data display are displayed where necessary.

3. The control panel - a unit which provides for the control of the system and is directly tied to the indicator.

The operating mode of the system is set from a special panel of switches, which is additionally used for entering and retrieving data, locking-on for autotracking, manual tracking and simulating a maneuver.

4. The digital computer - a general purpose digital computer for the execution of the computing operations needed for system functioning.

5. An interface block - a unit needed to match the digital computer to the remaining system units. It includes such functional components as an alphanumeric data generator, a vector line generator, a data entry module, a system synchronizer, an autotracking module and an indicator synchronizer.

6. The log and the gyrocompass are course and speed information sensors for the ship itself, needed for system operation.

The following are incorporated in the system for the purpose of rendering the maximum aid to the ship's pilot when solving a problem of passing:

--An autotracking unit which makes it possible to automatically track a target;

--A manual tracking unit which makes it possible to track a target "Manually" under conditions of strong interference from an agitated sea surface;

--A trajectory generator, which serves to generate the markers for the past position of the targets;

--A unit for computing the position of the closest approach point, which makes it possible to generate information on the distance and the time of closest approach to the target;

--A safety ring generator, which generates so-called safety rings on the indicator screen at a definite radius around the ship itself, which when these rings intersect target blips, actuate audio and visual alarms, which alert the ship's pilot to the presence of an oncoming ship in the zone being monitored;

--A maneuver simulator, which makes it possible to evaluate the situation for a certain in time ahead when changing the ship's own speed and heading, but with the assumption that the course and speed of oncoming ships are constant;

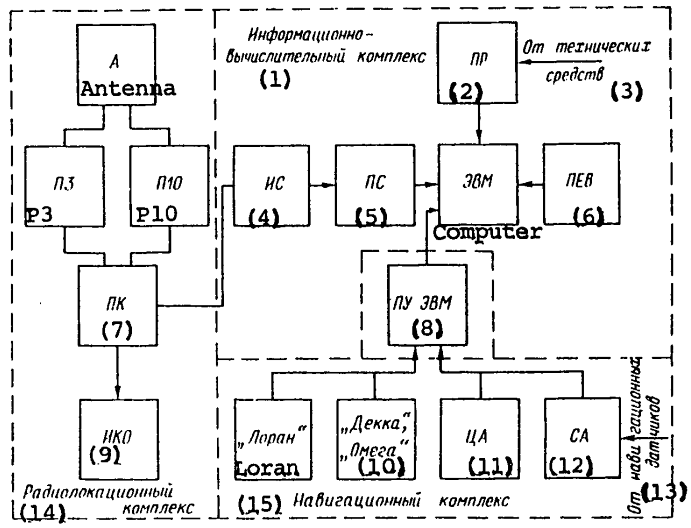

Figure 5.13. Block diagram of the "Briz-1" system [collision warning].

Key:
1. Data computer complex;
2. Recording unit;
3. From the technical facilities;
4. Situation indicator;
5. Synchronizer;
6. Standard time generator;
7. Switching unit;
8. Computer control console;
9. Plan position indicator;
10. "Decca" and "Omega";
11. Digital autocomputer;
12. Automatic plotter section;
13. From the navigation sensors;
14. Radar complex;
15. Navigation complex.

--A true motion unit which makes it possible to obtain a true motion display on the indicator.

Comprehensive navigation systems have been developed in recent years, an integral part of which is the ship collision warning subsystem.

The "Briz-1" system is intended for solving the following problems [10]:

a) Automatic computation and plotting of the ship's route;

b) Determine the ship's position in geographic and route coordinate systems;

c) Ship collision avoidance;

d) Solve applied problems in accordance with preset programs.

The "Briz-1" system is broken down into three sets in accordance with the structural configuration and the problems being solved (Figure 5.13): the radar, the data computer and automated navigation systems.

Functionally speaking, the "Briz-1" system is broken down into navigation and ship collision warning subsystems.

The main data sensor for the ship collision warning subsystem is the radar complex, consisting of a two-band radar (3 and 10 cm), a PPI display and a situation indicator, the IS. The primary radar and secondary graphic information are displayed on the latter.

The radar complex provides independently for the following:

--The display of the surface radar situation on plan position indicators;

--The measurement of the ranges and azimuth to surface targets on the PPI display;

--The automatic detection of surface targets when they intersect signal rings at ranges of 12.9 and 5 miles.

In conjunction with the data computer complex, the radar complex provides for the following:

--Automatic tracking of 12 surface targets where they are initially entered manually and automatically in the case of autodetection;

--Semi-automatic tracking of up to 3 targets where the overall number of targets which can be tracked runs up to 15;

--Generating the coordinates of the motion parameters, components of the approach to and the tracking of targets as well as their display in vector and digital form;

--The automatic identification of dangerous targets when they are tracked;

--Manually playing through a maneuver for passing by means of simulating the course or speed of the ship itself with the display of the extrapolated secondary information at the time the maneuver is completed;

--Automatically generating the recommended maneuver for the ship itself to pass all of the targets being automatically tracked;

--Digital display of the coordinates, parameters of motion and components of the approach to any of the targets being tracked at the selection of the ship's pilot;

--Predicting the development of a situation with a lead time of up to 30 minutes.

The navigation subsystem incorporates independent navigation data sensors (the dual mode "Vega-K" correcting gyrocompass, the "Sektor-K" remote data transmission magnetic compass, timers, the "Ugra-K" induction log and the "Onega" Doppler log) as well as nonautonomous units (the "Decca", "Loran" and "Omega" radionavigation display receivers in a rack mount design as well as the "Rumb" RDF).

The problem of automatically determining the ship's coordinates is solved by means of the general-purpose computer and the navigation data transducers, including the data from radar reference points. The entering of the raw data into the computer is accomplished automatically from all of the transducers.

An autoplotter can be used in conventional and observational computation modes. In the latter case, the position of the ship is continuously corrected automatically based on radionavigation and radar data.

A provision is made for the possibility of determining the ship's position via teletype. In this case, the attribute of the problem being solved and the requisite initial data are entered in the data computer complex (IVK). The results of the computations, along with the estimate of their precision, are displayed on a digital display, printed on a paper strip and after pushing a button, are transmitted to the route plotter.

By employing manual entry, one can solve astronomical problems more precisely than by conventional techniques, as well as calculate the azimuth and determine the range to a specified point via a rhumb line or a great circle route, compass corrections, drift, etc.

The switching unit (PK) makes it possible to switch the 3 or 10 centimeter band radar PPI display to the plan position indicator and the status indicator at the discretion of the navigator.

The synchronization unit PS provides for timewise synchronization of the system channels.

CHAPTER 6. DOPPLER NAVIGATION RADARS

6.1. Specific Features of Doppler Navigation Radar Operation

The operational principle of the Doppler-Belopol'skiy radar system, as is well known, consists in the fact that with the relative motion of a radar and a target, the frequency of the received reflected signals does not remain constant, but changes in accordance with a definite law. This property was discovered in 1842 by the Austrian physicist C. Doppler, and was confirmed experimentally for the first time under laboratory conditions for light waves by the Russian physicist A.A. Belopol'skiy in 1900 [17].

The amount of the frequency change indicated above depends on the velocity and direction of the relative motion of the radar and the target, as well as the wavelength (frequency) of the radar. A block diagram of the simplest doppler radar (DRLS) is shown in Figure 6.1. The transmitter transmits probe signals in the form of CW unmodulated oscillations at a frequency of f_1. The frequency f_2 of the returns from the target which arive at the receiving antenna of the radar will differ from the frequency f_1 of the probe signals by the amount of the so-called doppler frequency F_D: $f_2 = f_1 \pm F_D$. The plus sign corresponds to the case where the radar and the target are coming together, while the minus sign corresponds to separation.

The attenuated probe signals and the received returns are fed to the receiver input, a beat frequency at the difference frequency of $f_1 - f_2$ is produced, and following detection, we obtain the doppler frequency at the receiver output, which is equal to:

$$F_D = f_1 - f_2 = 2v_p/\lambda$$

where v_p is the radial component of the target velocity;

λ is the wavelength of the radar probe signals.

If the wavelength is expressed in centimeters, and the radial velocity of the target is expressed in kilometers, then the formula for calculating the doppler frequency in Hertz will assume the form:

$$F_D = 55.6(v_p/\lambda).$$

The doppler frequency expressed as a function of the direction of travel of an object (target), located at point 0, can be characterized by the pattern in polar coordinates which is shown in Figure 6.2 [17]. In this diagram, the radius vector characterizes the direction of target motion, while the length of the vector characterizes the value of the doppler frequency, taking the sign into account. An increase in the doppler frequency is noted in the diagram with a plus sign, while a decrease is noted with a minus sign.

The Doppler-Belopol'skiy effect causes the frequency spectrum of the reflected signal to shift, something which can be illustrated graphically (Figure 6.3). If one assumes that the probe and return signals take the form of a sinusoidal oscillation of infinite duration, then the frequency spectrum is characterized by a single spectral line.

A target approaching and going away from the radar causes a corresponding frequency shift in the returns of from $f_{min} = f_1 - f_D$ to $f_{max} = f_1 + F_D$. Consequently, the spectral lines will move along the frequency axis f as shown in the figure. Because of the fact that the reflected signal practically is an infinitely long sine wave, as well as because of fluctuations in the effective back-scatter cross-section (EPO) of the targets, and in the beam scanning of the antenna and the acceleration of the targets, the spectrum of the return will be somewhat wider than shown in Figure 6.3.

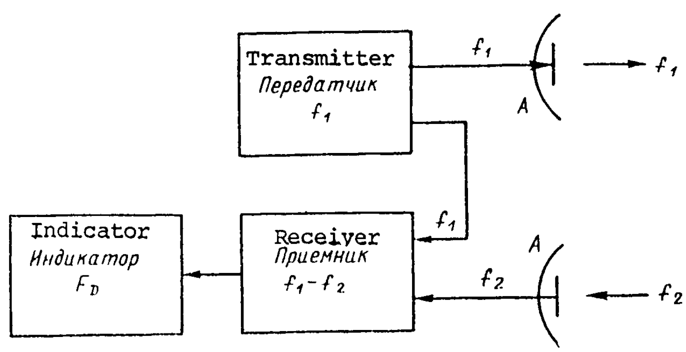

Figure 6.1. Schematic of a doppler radar.

CW doppler radars are widely used to measure the velocity being made good by aircraft, wind speed, the speed of motor vehicles, etc.

Doppler radars have recently begun to be widely used in ship navigation for measuring the docking speed of ships. This is explained by the fact that the appearance of large tonnage vessels, in particular, tankers with displacements of 150,000 to 200,000 tons and more have made it necessary to take steps to take steps to prevent damge when mooring such ships to a dock.

Equipping ships with transverse thrusters, the use of docking tugs and similar measures do not completely solve the problems. During mooring, the ship pilot should have exhaustive information on the position of the ship relative to the dock and the ship's speed. The visual methods of determining the ship's speed and the distance to the wharf using objects on shore when docking large tonnage ships which have been used up to the present time are becoming unsuitable. Many of the existing docks cannot sustain a collision of 150,000 to 200,000 ton displacement ship with it if the ship's speed exceeds 3 to 5 m/min. Consequently, it becomes necessary to precisely measure the speed of the ship, which goes down to 0.5 to 1 m/min [12].

A block diagram of a doppler radar (DRLS) is shown in Figure 6.4. It contains the following: an unmodulated CW microwave oscillator at a frequency of f_0, GSVCh; an isolator, RU; a directional antenna A; a mixer, Sm; a doppler frequency amplifier, UDCh and an indicator. The sounding microwave pulses at f_0 pass through the isolator to the antenna, and at the same time, following attenuation in the isolator, are fed to the input of the receiver mixer.

The reflected signals at a frequency of $f_0 \pm F_D$ are fed to the mixer input and are mixed with the probe signal frequency f_0. The difference frequency beats produce a doppler frequency F_D at the mixer output which is amplified by the doppler frequency amplifier stages.

A device which measures the doppler frequency serves as the indicator. Since the radial velocity of the target v_p and the doppler frequency are related by the linear function $v_p = F_D(\lambda/2)$, the indicated indicator, a frequency meter, can be graduated in velocity units (for example, meters per minute). In practice, when using a doppler radar as a speed meter for the motion of targets, it proves to be necessary to ascertain in which direction the target is moving relative to the doppler radar, i.e., whether it is approaching or going away.

This task can be carried out in several ways. For example, using individual filters which are tuned to frequencies of $f_0 - F_D$ and $f_0 + F_D$, which fall on both sides of the probe signal frequency f_0 [sic]. In the first case, the reflected signal frequency proves to lower than the frequency f_0, and consequently, the target is moving away from the doppler radar. On the other hand, in the second case the frequency of the returns proves to above the frequency f_0 and consequently, the target is approaching the doppler radar.

The sign of the doppler frequency can also be determined by the phase method, by means of processing the received returns in a dual channel receiver, as shown in Figure 6.5 [17]. If the target is approaching, then the output voltages of channels I and II will be expressed by the following functions:

$$E_{\rm I} = E_m \cos(2\pi F_D t + \varphi);$$
$$E_{\rm II} = E_m \cos\left(2\pi F_D t + \varphi + \frac{\pi}{2}\right),$$

where: E_m is the signal voltage amplitude;

ϕ is a constant phase angle, which depends, for example, on the initial detection range of the object (target).

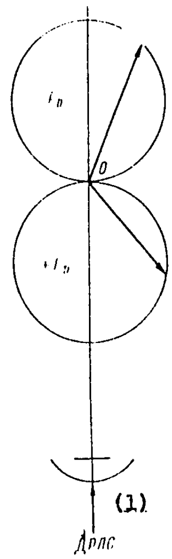

Figure 6.2. Pattern in polar coordinates.

Key: 1. Doppler radar.

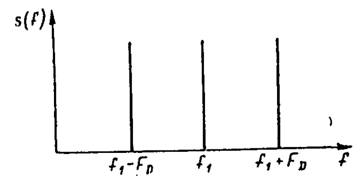

Figure 6.3. Graph of the return signal spectrum.

Key: s. The signal amplitude; f. Frequency.

When the target is moving away from the doppler radar, the output signal voltages of both receiver channels will be determined by the following equations:

$$E_I = E_m \cos(2\pi F_D t - \varphi);$$
$$E_{II} = E_m \cos\left(2\pi F_D t - \varphi - \frac{\pi}{2}\right).$$

Thus, the direction of target motion is determined by the lead or lag of the output signal phase of channel II of the receiver relative to channel I. The indication of target direction can be made, for example, by using a two-phase synchronous electric motor. When measuring the output signal phase, the direction of rotation of the electric motor indicates the direction of travel of the object (the target).

6.2. The "Istra" Radar for Measuring the Docking Speed of Ships

The "Istra" unit is a doppler radar for the measurement of the docking speed of a ship. The following units are incorporated in the "Istra" doppler radar set: the radar (RL), the indicator (IP), the pedestal (T), the distribution panel (RShch), the junction box (SYa) and the ATO-1-400 type power plant (AP) [12].

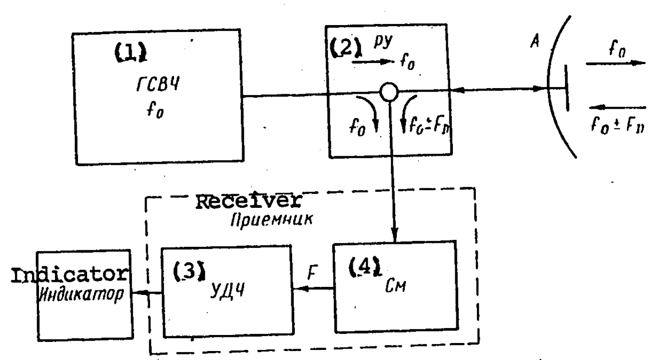

Figure 6.4. Block diagram of a doppler radar.

Key: 1. CW microwave generator;
2. Isolator;
3. Doppler frequency amplifier;
4. Mixer.

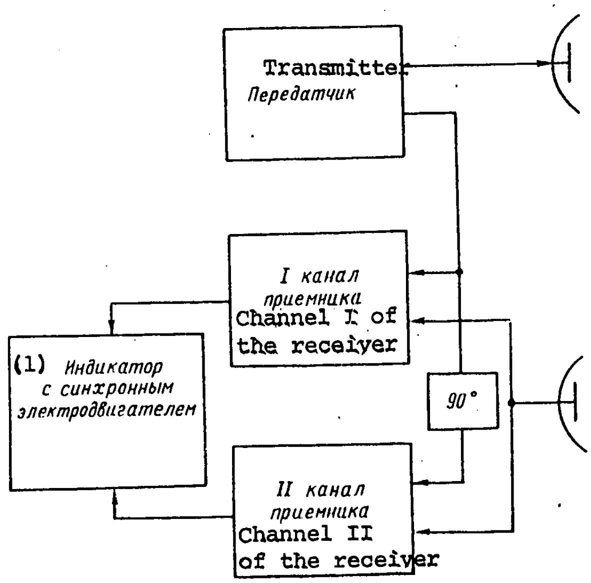

Figure 6.5. Block diagram of a dual channel doppler radar receiver.

Key: 1. Indicator with a synchronous electric motor.

The radar unit is a speed frequency sensor and takes the form of a portable doppler radar. The radar unit is structurall designed to be water proof and is stored in the interior rooms of a ship in the packing box.

The indicator unit is intended for feed out information on the measured speed. It is of a waterproof design and is permanently mounted on the flying bridge.

The pedestal is intended for the installation and mounting of the portable radar on it. The pedestal unit T is mounted permanently on deck close to both sides, at the bow, in the middle and at the stern of the ship. To connect the radar set, the pedestal has a cable with a plug connector. The pedestal is equipped with a rotating device having a clamp to aim the radar in azimuth and elevation at the target. When the ship is underway the upper part of the pedestal (rotating mechanism and the power cable) are covered with a protective cap.

The distribution panel (unit RFhch) is intended for connecting the units, monitoring the power mains voltage and for the installation of the fuses. The units of the radar are interconnected by cables run in the ship.

TABLE 6.1

Complement of Doppler Radar Units	Number of Units in a Set		
	No. 1	No. 2	No. 3
Radar	2	2	1
Mounting pedestal	6	4	2
Distribution panel	1	1	1
Indicator	2	2	0
Junction box	2	1	0
Power plant	1	1	1

The complement of units in the "Istra" doppler radar and the equipment set variants are shown in Table 6.1. A block diagram of the connections of the units for all of the equipment set variants is shown in Figure 6.6. As can be seen from the Table and the block diagram of the connections of the units, there are no indicator units in set No. 3. In this case, the speed is read out by means of the indicator unit located directly in the radar set.

The radar set is a portable doppler radar, a block diagram of which is shown in Figure 6.7, and contains the following elements: the radio frequency CW3-cm band oscillator with a power of 10 mW using a Gunn diode; an isolator, which consists of a directional coupler and a circulator, which provide for the operation of the Doppler radar transceiver into a common antenna having a directional pattern width of 6°, with a beavertail pattern; a dual channel receiver which consists of mixers, Doppler frequency amplifiers and a test signal generator.

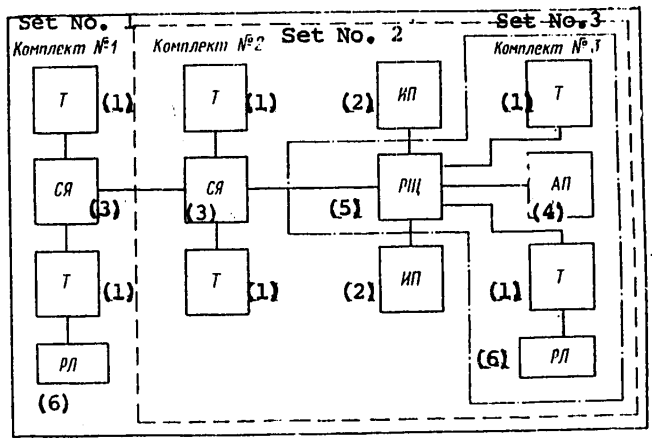

Figure 6.6. Circuit configurations of the "Istra" Doppler radar units.

Key: 1. Mounting pedestal;
2. Indicator;
3. Junction box;
4. Power plant;
5. Distribution panel;
6. Radar.

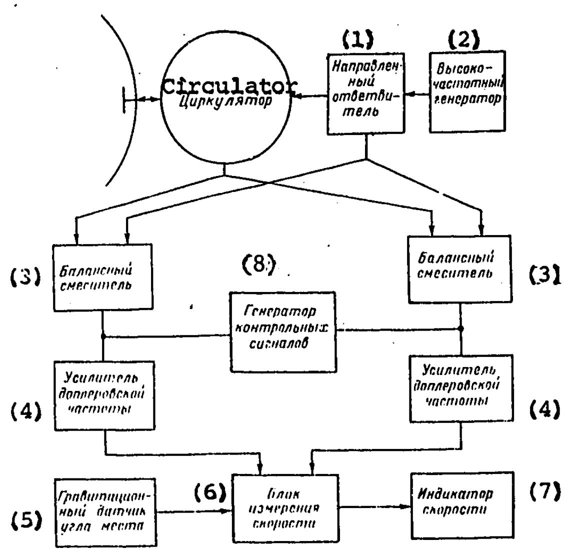

Figure 6.7. Block diagram of the radar set.

Key: 1. Directional coupler;
2. RF generator;

[Key to Figure 6.7, continued]:

3. Balanced mixer;
4. Doppler frequency amplifier;
5. Gravitational elevation angle sensor;
6. Speed measurement block;
7. Speed indicator;
8. Test signal generator.

Additionally, the doppler radar circuitry includes the following: a speed measuring block, speed indicators and a gravitational elevation angle sensor. The receive channels have a quadrature characteristic, i.e., when receiving returns from approaching or departing targets, two identical doppler frequencies are produced at the output of the receiver mixers having phase differences of +90° or -90°.

Following amplification, the doppler frequency is fed to the speed metering unit, which contains a meter at the output which is graduated in meters per minute with zero in the center. The deflection of the meter needle to the right corresponds to the doppler radar approaching the reflecting target and the deflection of the needle to the left corresponds to moving away from the reflecting target.

When measuring the speed at which a ship approaches the dock using signals reflected from dockside structures, the signal power level fluctuates greatly, and as measurements have shown, can reach 30 dB and more [12]. For this reason, the indicator unit in the lattest models of the "Istra" doppler radar contains a logic circuit for the analysis of the received signals. This makes it possible to improve the operating reliability of the indicator and eliminate dropouts in the measurement of the docking speed of a ship.

To prevent errors in measuring speed which are caused by aiming the radar unit during docking at a large elevation angle relative to the horizontal, a gravitation elevation angle sensor is provided in the doppler radar circuitry having a potentiometer which is inserted in the speed indicator circuit. When the radar unit is aimed at an angle to the horizontal, the value of the sensor resistance changes, correcting the meter readings.

The technical characteristics of the "Istra" doppler radar are shown in Table 6.2, and for comparison, the technical characteristics of the similar TD1/1 doppler radar produced by the English "James Scott" company [12].

Prior to docking, the radar units are installed on the bow and stern mounting pedestals on that side where the ship will be moored to the dock. If the dimensions of the dock do not allow for measuring the docking speed from two points, then the radar unit is installed on the mounting pedestal located in the center part of the ship.

TABLE 6.2

Technical Characteristics	The "Istra" Doppler Radar	The TD1/1 Doppler Radar
Transmitter carrier frequency, GHz	9.48	14.1
Transmitted power, mW	10	10
Width of the antenna directional pattern, degrees	6	6
Range of speeds which can be measured, m/min	0-150, 0-30 and 0-15	0-30, 0-15
Speed measurement precision, %	10	-
Circuit for improving the speed measurement reliability	YES	NO
Operational range, mm:		
Maximum	800	150-200
Minimum		
Aiming angle of the speed sensor, degrees:		
In the vertical plane	10-45	45
In the horizontal plane	90	360
Error correction for speed measurement when the radar unit is inclined in the vertical plane	YES	NO
Information on the direction of radar aiming on the indicator unit	YES	NO
Operational monitoring of the radar unit using a doppler signal simulator	YES	YES
Electrical power supply	From the ship mains through a converter	Independent, from storage batteries

After turning the radar on and checking its operability, the operator aims the radar unit at any object on the dock, which gives a good return signal in the given direction, and reads the docking speed from the meter of the radar indicator unit. Then, the data obtained on the course angle to the reflecting target, the speed and its sign are relayed to the indicators of the indicator unit from the two radar units, which provide for separate measurement of the speed of the bow and stern of the ship.

CHAPTER 7 MARINE INFRARED AND TELEVISION EQUIPMENT

The use of infrared and television equipment on ships significantly improves the resolution of a number of navigation problems, provides for remote control of machines, mechanisms and power plants and facilitates the monitoring of their operation and the performance of loading and unloading operations.

Infrared and television equipment makes it possible to obtain additional information for navigational purposes under conditions where the use of radar is limited (observation in the blind area of the radar, during docking, or going through locks).

Infrared night vision equipment makes it possible to observe the surrounding situation on the water surface and on shore at night when there is no visibility in optical instruments. This is especially important for ships navigating rivers, through skerries, and narrow channels in a complex navigational situation.

The inadequate range and considerable dependence on meteorological conditions are holding back the application of infrared equipment on fishing and merchant marine vessels.

7.1. The "Mgla" Infrared Night Vision Equipment

The "Mgla" equipment is intended for observing the surrounding situation on the water surface and on shore at night in the absence of naked eye visibility or visibility in optical instruments.

The equipment is installed on ships of the river fleet and provides for high quality readings and failure free service in a temperature range of from -10° to +30° C.

The "Mgla" infrared night vision equipment (Figure 7.1) consists of the PNV-1 infrared telescope 6, the M-45 infrared projector 2, the power supply 5 and the synchronous control mechanism which provides for tracking the projector in azimuth and elevation with the night vision unit.

The synchronous control unit incorporates drive 4 of the PNV-1 night vision unit, as well as drive 1 of the M-45 projector and the remote coupling cable 3 between the unit and the projector.

The overall dimensions of the units and the locations for their installation on a ship are shown in Figure 7.1.

The major technical data for the infrared night vision equipment are given below:

Optical characteristics:	
Magnification	from 2.3 to 2.7
Field of view, degrees	14 $\pm$ 5%

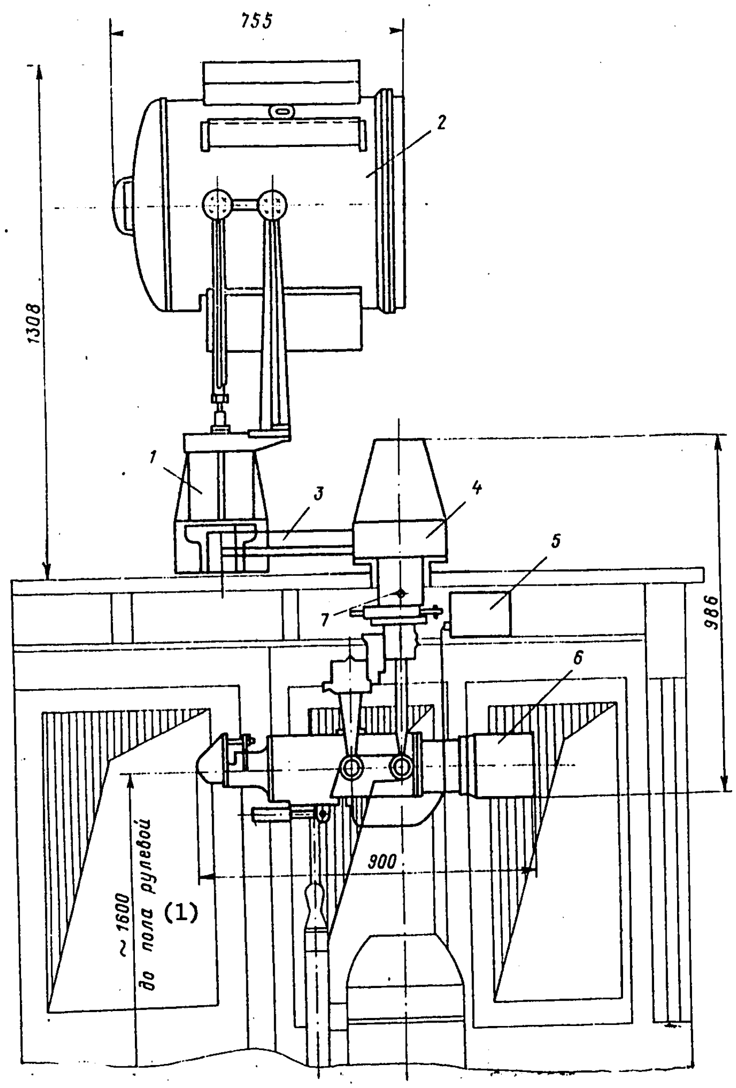

Figure 7.1. The "Mgla" equipment and its mounting position on a ship.

Key: 1. Approximately 1,600 [mm] to the floor of the wheelhouse.

Objective focal length, mm	200
Relative aperture [F number]	1:1.65
Eyepiece lens magnification, degrees [sic]	5
Exit pupil diameter, mm	80

Electronic-optical characteristics:	
Photocathode	Oxygen-cesium
Resolution in the center, m/mm	24
Magnification	from 0.57 to 0.67
Diameter of the working field of the photocathode, mm	50
Working voltage, KV	18
Electrical characteristics:	
Supply voltage, volts	220
Power mains frequency, Hz	50
DC voltage, volts	24
Overall dimensions of the power supplies, mm	210x206x161
Telescope length, mm	836
Sweep radius, mm	125
Weight, kg:	
Telescope	16.5
Power supply	4.5
Set in the packing	65
Delivery equipment complement:	
Infrared telescope	1
Power supply	1
2RM22KPEChGZV1 insert	1
SShR20P2EG6 insert	1
Cover	1
Packing box	1
Stowage box (spare parts, tools and accessories)	1
Technical description and operational instructions	1
Service log	1

Operational Principle

The night vision unit is an infrared radiation receiver, where the IR radiation is either radiated by the target or reflected from it.

The infrared telescope (Figure 7.2) is a monocular electronic-optical sighting unit, based on the principle of converting invisible (infrared) rays to visible ones by means of an electronic-optical converter (EOP).

The infrared rays are projected by the six-lens objective 3 onto the photocathode of converter 5, which converts the light image to an electronic one. This image is then transferred to the screen and converted to an optical one which is viewed by means of eyepiece lens 7.

The light filters 1 and 2 suppress the visible portion of the spectrum and pass only the infrared rays into the instrument.

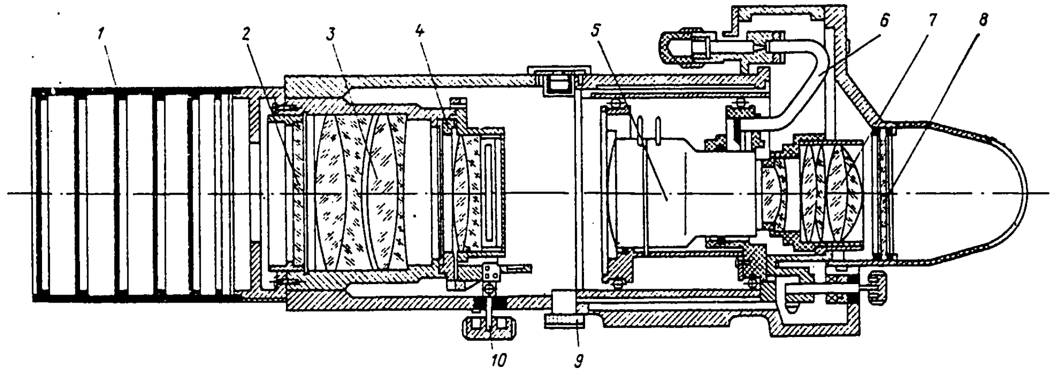

Figure 7.2. The infrared telescope.

Protective glass 8 protects the parts and assemblies located inside the instrument housing against moisture and dust.

An iris stop 4 is placed between the fourth and fifth lenses of the objective to limit the entrance aperture of the objective in the case of excess illumination. The stop drive is coupled with a hinge to hand-wheel 10, by means of which the aperture is stopped down.

The moving section of the instrument is the converter 5 and the eyepiece 7. The high voltage is fed to the converter by means of cable 6, while the negative charges are tapped off through contact 9.

The power supply consists of the following functional assemblies: the rectifier, the voltage regulator, the self-excited oscillator and the high voltage rectifier.

When powered from the ship power mains at 220 volts, 50 Hz by means of the low voltage rectifier, which is designed around a transformer and a bridge circuit using diodes, a DC voltage of 24 volts is obtained. This voltage or the same voltage of the mains is stabilized by means of regulators and a transistor and is fed to the oscillator, where the DC is converted to AC. The alternating pulsed voltage is stepped up to 10 to 12 volts [sic] by means of a transformer and rectified using a selenium stack rectifier. A rectified voltage of 17 to 20 KV is obtained at the output of the power supply, which is fed to the electronic-optical converter.

Brief Instructions for the Installation, Mounting, Alignment and Operation of the Unit

The night vision unit is secured to hanger 7 of the drive (Figure 7.1). The drive provides for the rotation and inclination of the unit when aiming it at a target, the fastening of the unit in the wheelhouse, as well as the synchronous transmission of the position taken by the unit to the projector. The housing of the drive 4 is installed on the roof of the wheelhouse and fastened to the base with bolts.

The synchronous orientation of the PNV-1 night vision unit and the M-45 projector is provided by a drive using coupling cable 3.

The structural design of the drive makes it possible where necessary to take the night vision unit down (slip down) from under the ceiling of the wheelhouse.

In the operating position, the PNV-1 night vision unit is lowered under its own weight by means of a hydraulic shock absorber.

The M-45 projector with the infrared filter is installed on the housing of drive 1, the base of which is secured to the mounting on the roof of the wheelhouse. The drive is controlled by the coupling cable.

The remote coupling cable 3 couples the horizontal rotation pulleys and the vertical travel rods of the PNV-1 night vision unit and M-45 projector drives. The coupling cable assembly includes the following: steel cables, thimble eyes, intermediate inserts for the coarse setting of the projector and unit positions, as well as rigging screws for the precise setting of the optical axes of the night vision unit and the projector.

The guidance of the telescope is accomplished in the horizontal and vertical planes by the synchronous control mechanism.

The brightness of the image is adjusted by stop 4 depending on the visibility. When a bright light source falls within the field of view, one is to work with the light filter and stop the objective down to normal brightness.

It is necessary to keep the night vision unit clean and in good working order. The external optical components may be cleaned only using the materials supplied with the unit.

One must protect the PNV-1 night vision unit against shocks during operation and transportation. The condition of the drying agent in the cartridges must be checked no less than once a month. During the operational period, care of the synchronous control mechanism reduces to the timely tensioning of the cables, checking the operation of the shock absorber and breaks, and lubricating the vertical rods of the projector and night vision unit drive.

7.2. The "Gorizont" Marine Television Installation

The "Gorizont" marine television installation is intended for the following:

--A navigation aid for ship piloting (docking, checking and observing the course when following a ship, going through locks, etc.);

--Observing loading and unloading operations in holds and on the deck;

--Remote observation of the operation of machinery, power plants and mechanisms;

--Remote monitoring and control of production processes in the port area.

Depending on the quantitative complement of equipment units, distinctions are drawn between the following: the "Gorizont" and "Gorizont-1-1" single camera installations; the five-camera "Gorizont-2", "Gorizont-2-1" and "Gorizont-2-2" installations [2].

The complement of the various equipment sets is shown in Table 7.1. Supplied along with the units is a set of spare parts, tools and accessories, an installation set as well as cables and operational documentation.

The major technical parameters of the units are given below:

The interlace sweep standard:	
Frame frequency	25
Number of lines per frame	625
Frame aspect ratio	4:3
Horizontal resolution, lines:	
In the center, no less than	550
At the corners	450
Number of brightness gradations which can be distinguished, no less than	7
Image size on the video monitor screen, mm	300x226
The automatic gain control attack time for a brightness change of from 200 to 100,000 lux, in seconds, no more than	5
Maximum coupling line length, mm [sic]	500
Continuous duty time in the operating mode, hours	24
Supply voltage, volts	220 ± 22
Supply voltage frequency, Hz	50 ± 2.5
Power consumption, KW:	
"Gorizont-1", "Gorizont-1-1"	0.6
"Gorizont-2", "Gorizont-2-1", "Gorizont-2-2"	1.1

A block diagram of the "Gorizont-2" television installation is shown in Figure 7.3.

The KTP--KTP5 transmitting cameras convert the light image to an electrical signal.

The KTP-54 camera has a single objective optical attachment lens with remote control of the stop and focusing, with interchangeable OKS1-22-1, "Gelios-33", "Yupiter-3" and "Yupiter-9" objectives.

The KTP-54-1 camera has a dual objective optical attachment with "Gelios-33" and "Yupiter-9" objectives, which are included in the set of attachments with remote control of the focusing, the stop and can interchange objectives with a scale change by a factor of 2.4 times.

TABLE 7.1

Таблица 7.1

Unit Прибор	(1) Комплектация, единиц приборов Gorizont-1 «Горизонт-1»	«Горизонт-1-1»	«Горизонт-2»	«Горизонт-2-1»	«Горизонт-2-2»	(2) Габаритные размеры, мм Height Высота	Width Ширина	Depth Глубина	Weight, KG Масса, кг
KTP-54 КТП-54	1	—	3	—	—	685	300	254	20,0
КТП-54-1	—	1	2	—	2	741	300	245	23,0
КТП-55	—	—	—	5	3	300	226	525	22,0
БС-25	1	1	5-	5	5	350	188	283	13,0
УН-6 UN-6	1	1	3	—	1	570	295	535	60,0
УН-9	—	—	2	—	1	⌀	240×175		7,5
БК-38	—	—	1	1	1	425	437	214	20,0
БУФ-6	1	1	1	1	1	425	437	214	22,0
ПУ-43	1	1	—	—	—	460	126	290	8,5
ПУ-44	—	—	2	2	2	460	126	290	8,0
ИВК-40	1	1	2	2	2	450	580	435	48,0
БС-26	—	—	1	1	1	255	190	135	3,0
Стойка Stand	1	1	1	1	1	411	460	1052	53,0

Key: 1. Equipment complement, number of units;
2. Overall dimensions, mm.

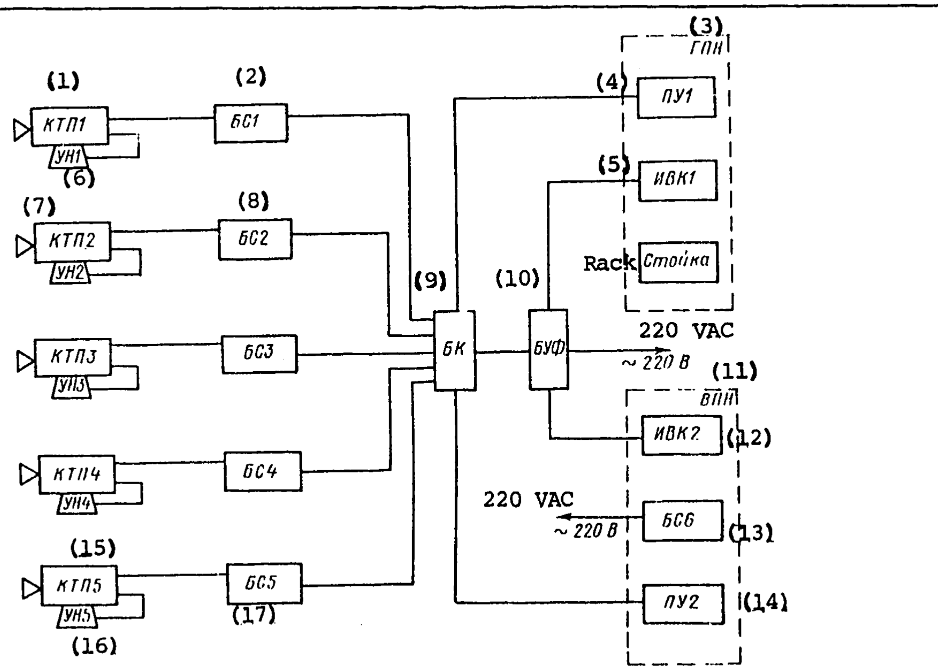

Figure 7.3. Block diagram of the "Gorizont-2" marine television installation.

[Key to Figure 7.3]:

1. Transmitting TV camera 1;
2. Interconnection block 1;
3. Main observation post;
4. Control console 1;
5. Video monitor 1;
6. Control and guidance 1;
7. Transmitting TV camera 2;
8. Interconnecting block 2;
9. Switcher;
10. Driver and amplifier unit;
11. Remote observation post;
12. Video monitor 2;
13. Connecting block 6;
14. Control console 2;
15. Transmitting TV camera 5;
16. Control and guidance unit 5;
17. Connecting block 5.

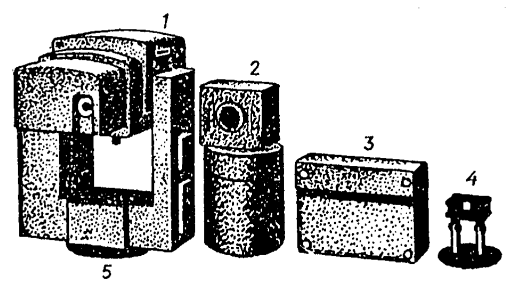

Figure 7.4. General view of the transmitting units.

Key: 1. KTP-54 or KTP-54-1 TV camera;
2. KTP-55 TV camera;
3. BS-25 connecting block;
4. UN-9 Guidance unit;
5. UN-6 Guidance unit.

The KTP-55 camera has a single objective optical attachment with remote control of the stop and focusing with interchangeable "Gelios-33", "Yupiter-3" and "Yupiter-9" objectives.

The camera can be cited on the object being observed either remotely by means of the UN-6 control and guidance blocks or directly by means of the UN-9 [control and guidance unit 9].

The BS-25 and BS-28 connection blocks generate the supply voltages for the transmitting camera and provide for the connection of a supplemental lighting source.

The video signal from the KTP1--KTP5 [TV cameras 1-5] is fed through the BS1--BS5 connecting blocks and the BK switching block to the amplification and driver circuitry, the BUF. The composite television signal is fed via a cable to the IVK1 and IVK2 video monitors for the playback of the image.

The PU-43 control console is used in the single camera installation and provides for the following: remotely turning the standby and operating modes on and off, aiming the cameras at a target and focusing, stopping the objective down and changing the objective (scale), as well as feeding out instructions for additional lighting and turning the back-up sync generator on and off.

The PU-44 control console is used in a multiple camera installation and provides for switching the camers and performs the functions indicated above.

In a multiple camera installation with PU1 and PU2 [control consoles 1 and 2], the main control is conducted from the main observation post, the GPN. The same picture is present on video monitor unit 2 of the remote observation post, the VPN. In the on-duty mode, the main observation post, or when it is shut down, the control of the installation can be realized from the remote observation post.

The transmitting end units are (Figure 7.4): the KTP-54 (or KTP-54-1) television camera, the BS-25 connection block, and the UN-9 and UN-6 guidance units can be placed on decks, superstructures on and on masts.

The receiving end units are (Figure 7.5): the PU-44 and PU-43 control consoles, the IVK-40 video monitor, the BK-38 switching block, the BUF-6 driver and amplifier, the BS-26 connecting block as well as the KTP-55 transmitting TV camera should be housed in inside rooms.

The "Gorizont" installation is designed for applications under conditions of haor-frost, sea fog, severe mechanical loads as well as magnetic and electrical fields. All of the units can operate in a relative humidity of up to 98% at a temperature of +40 °C.

The following types of cables are used for the connections between the units: KMPVE-500 (7 x 1.5) between transmitting TV cameras 1 - 5 and guidance and control units 1 - 5; TKOSV-37 between transmitting TV cameras 1 - 5 and connecting blocks 1 - 5 and the switcher; KMPVE-50 (30 x 1.5) between the switcher and control consoles 1 and 2; RK-75-7-12 between the driver and amplifier unit and video

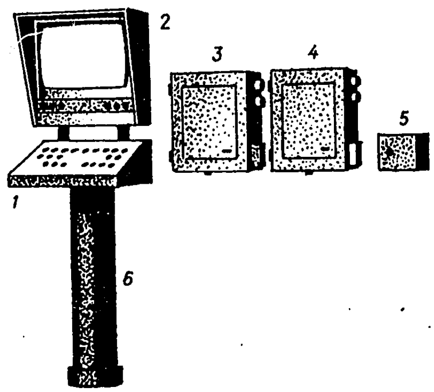

Figure 7.5. General view of the receiving units.

Key: 1. PU-44 control console;
2. 1VK-40 video monitor;
3. BK-38 switcher;
4. BUF-6 driver and amplifier unit;
5. BS-26 connecting block;
6. Stand.

monitors 1 and 2; KMPVE-500 (4 x 1.0) between connecting blocks 1 - 5 and video monitors 1 and 2.

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