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Translation

Multiprogram Wire Broadcasting

By

V. Ya. Dzyadchik, S. A. Zaslavskiy
B. N. Filatov, A. V. Shershakova

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MULTIPROGRAM WIRE BROADCASTING

Moscow MNOGOPROGRAMMOYE PROVODNOYE VESHCHANIYE in Russian 1974
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CONTENTS PAGE

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MULTIPROGRAM WIRE BROADCASTING

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[Text] A study is made of various multiprogram broadcasting systems combined with other forms of communications; the advantages and disadvantages of the various methods of creating triple-program broadcast channels based on the existing overhead wire broadcasting networks are analyzed; a study is made of the problems of interference and standardization of the quality indexes of the channels and individual devices; a description is presented of the station and subscriber equipment, monitoring and measuring instruments and high-frequency devices.

The book is designed for engineering and technical workers involved with the design, introduction, operation and maintenance of the triple-program broadcast system.

FOREWORD

In the Soviet Union, the triple-program wire broadcast system (TPB) has been introduced in all large cities. In spite of the rapid development of radio and television broadcasting, multiprogram wire broadcasting will in the future be one of the prospective broadcast media.

The TPB system was developed by the Scientific Research Radio Institute in in 1960. The system has recently received further development. Considering the operating experience and the results of the investigations, new improved transmitting and receiving devices have been developed, a set of monitoring and measuring instruments has been built, and new high-frequency devices for the wire broadcast networks have been developed.

However, the future development of the wire broadcasting network (WB) will be greatly influenced by modern civil construction distinguished by the fact that instead of the continuous construction of buildings of equal height, local microdistricts with high-rise complexes of varying heights are being organized. This is changing the structure of the WB network.

The overhead lines running on supports on the roofs of the variable-height buildings present problems in construction and maintenance. Difficulties will also be encountered in taking the line from one local microdistrict to another as a result of the wide outside thoroughfares and streets.

A way out of the situation which is already realizable in practice is partial or complete conversion of the distribution network to cable construction using the city telephone exchange lines, the basements of buildings, service corridors and the introduction of cable inserts in the overhead lines.

Accordingly, the question arises of rebuilding the WB networks and creating new layouts for the city broadcast networks. It is possible to propose that the development of a city wire broadcast system will proceed along the path of combining the system with other communication networks.

In this book a study is made of the problems of building multiprogram broadcast systems combined with other forms of communications. The advantages and disadvantages of various methods of building the TPB channels based on the existing overhead WB networks are analyzed, the problems of interference and standardization of quality indexes of the channels and individual devices are investigated, descriptions are given of the station and subscriber equipment, the measuring instruments and high-frequency devices, and a study is made of the measurement techniques and methods of tuning the devices.

The chapters and divisions of this book were written by the following: Chapter 1, §§2.1, 2.2, 2.14, 4.6 by V. Ya. Dzyadchik; §§2.4, 2.5, 2.10-2.13, 4.1-4.5, 4.7 by S. A. Zaslavskiy; Chapter 3, §§2.3, 2.6-2.9, and Appendices 1-4 by V. Ya. Dzyadchik and S. A. Zaslavskiy jointly; and Chapters 5, 6, 7 and 8 jointly by B. N. Filatov and A. V. Shershakova. The book is designed for engineering and technical workers of the maintenance enterprises, the workers of the design organizations engaged in the introduction of the TPB system and it can be used as a text for students in the middle and higher communications schools.

The authors express their deep appreciation to the reviewer of the book L. Ya. Kantor and the responsible editor V. I. Shanurenko for valuable recommendations and suggestions.

Comments on the book should be sent to Izdatel'stvo Svyaz' (101000, Moskva-Tsentr, Chistoprudnyy Bul'var, 2).

CHAPTER 1. MULTIPROGRAM WIRE BROADCAST SYSTEMS

1.1. Basic Characteristics of the MPB [Multiprogram Wire Broadcast] Systems

The wire broadcast system is the set of devices designed to shape and amplify broadcast program signals and distribute them by means of a wire distribution network to the subscriber receivers with subsequent conversion of the electric signals to acoustic. A necessary element determining the technical essence of such a system is the lines and line equipment, the purpose of which determines the name of the given wire broadcast system.

Accordingly, the MPB systems can be based on the following wire distribution networks: telephone communications, collective television reception systems, the domestic broadcast network, and on the basis of an autonomous low-frequency signal-program broadcast system.

Depending on the method of transmitting the broadcast program signals, two versions of the MPB systems are distinguished: low-frequency and high-frequency.

In the low-frequency version the signals of all programs are transmitted in the initial low-frequency spectrum.

In the high-frequency version, the program signals are transmitted in the form of modulated high-frequency signals.

With respect to methods of construction and use of the distribution network the MPB are separated into the following: uncommuted systems using one physical network to transmit the broadcast signals and other types of information, the commutation type systems using one physical network to transmit the signals of all programs and the commutation type systems using several physical circuits for transmitting the broadcast systems and other types of information.

Each system is characterized by another quality class and number of channels, the frequency band used by the modulation method, the type of receiver and the technical-economic indexes.

1.2. MPB Systems Using Physical and Artificial Large-Capacity Cable Networks

The structural diagram of the system using a multiprogram cable is illustrated in Fig 1.1. On the transmitting side the broadcast signals are fed to the line at comparatively high voltage (60 or 30 volts). On the subscriber side, the simplest receiver is used. This type of system is reliable, convenient in operation and maintenance, but it requires a large number of physical circuits in the cable equal to the number of transmitted programs.

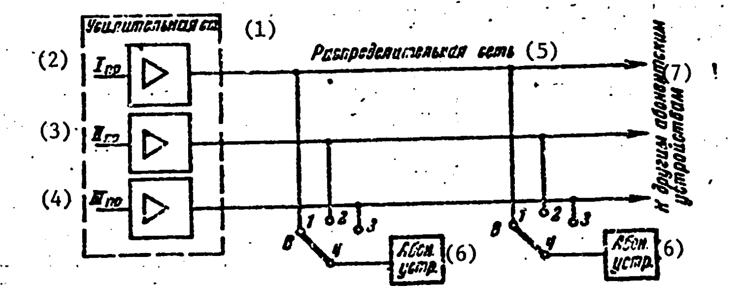


Figure 1.1. Structural diagram of the low-frequency MPB system

Key:

1. Repeater station
2. I program
3. II program
4. III program
5. Distribution network
6. Subscriber sets
7. To other subscriber sets

In practice the version of this system is used where along with the physical networks artificial, so-called phantom networks are used (see Fig 1.2). The operating principle of this type of system consists in the following: the signals of four programs are transmitted from the repeater station to the distribution network. Three programs are fed to the subscriber network over three physical circuits. Program IV uses the physical networks of programs II and III, and it is connected to the midpoints of the secondary windings of the transformers Tp_1. On the subscriber side the signals of program IV are picked up from the midpoints of the primary winding of the TP_2 transformers. In order to create the phantom circuit chokes are more frequently used. With a complete equivalent circuit from the point of view of symmetry and equality of the halfwindings of the transformers Tp_2 and Tp_1 the magnetic fluxes created by the signals of program IV and the voltage as a result of asymmetry are equal to zero in the circuits of programs II and III.

The subscriber network is made up of a four-pair cable. In each subscriber set a program switch I is provided by means of which the corresponding program is selected. However, considering the high signal voltages in such a system, careful symmetry is required. Asymmetry of the circuits caused by deterioration of the state of the cable (for example, as a result

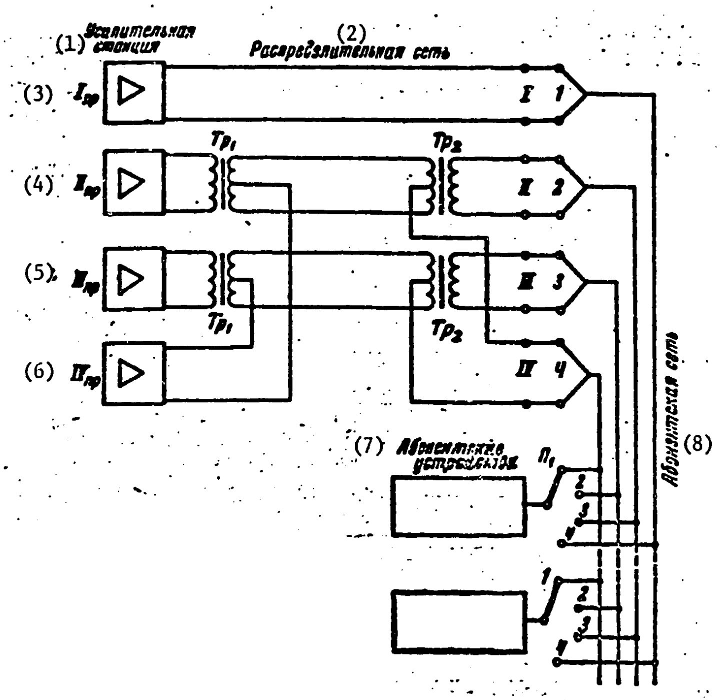


Figure 1.2. MPB system using physical and artificial large-capacity cable networks

Key:

1. Repeater station
2. Distribution network
3. $\mathrm{I}_{\text{program}}$
4. $\mathrm{II}_{\text{program}}$
5. $\mathrm{III}_{\text{program}}$
6. $\mathrm{IV}_{\text{program}}$
7. Subscriber sets
8. Subscriber network

of a change in insulation resistance) and also failure of the transformers will lead to a decrease in the crosstalk attenuation between them. An important difference between the phantom circuit and the physical circuit is that they have different primary equivalent parameters. By comparison with the physical circuit, the resistance of the phantom circuits is approximately half; the inductance is approximately a third, and the capacitance of the line is approximately threefold. This leads to the fact that the frequency characteristic of the phantom circuit is worse than that of the physical circuit. In addition, as a result of increased capacitance, overloading of the terminal stages of the program repeaters is possible.

Fig 1.3 shows a version of a phantom circuit which eliminates the indicated deficiency.

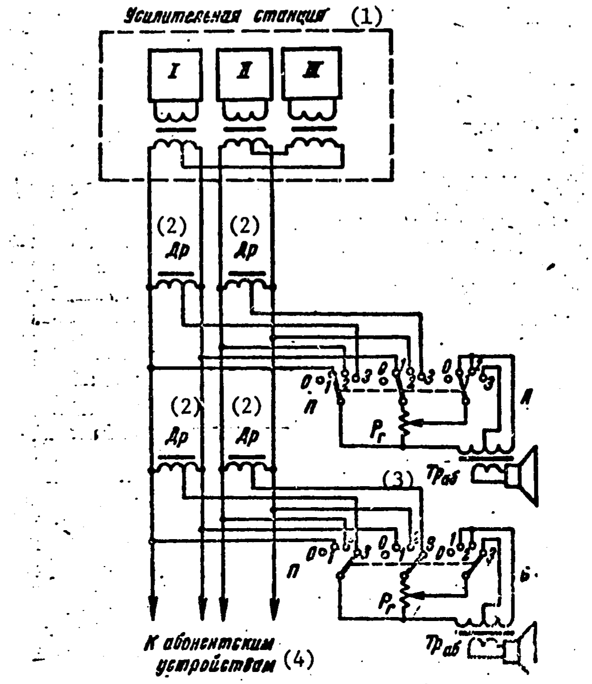


Figure 1.3. Version of the MPB system using the phantom circuit

Key:

1. Repeater station
2. Choke
3. Transformer
4. To the subscriber sets

The signal voltage at the beginning of the phantom circuit is cut in half by comparison with the ordinary circuit, and on the receiving side at the subscriber their level is equalized. This is achieved by selecting the corresponding coefficients of the output and subscriber transformers. As a result, favorable operating conditions are created for the repeater, the frequency characteristic of the phantom circuit improves, which now is loaded on both ends by a corresponding lower load resistance. In the given system the phantom circuit is created by using four chokes with midpoints, and the signals of program III are transmitted through it.

As illustrated in Fig 1.3, programs I and II are fed to two subscriber sets A and B. When selecting programs I and II, the voltage is fed from the volume control P_Γ to the entire winding of the subscriber transformer Tp_{ab}

(positions 1, 2 of the switch П). In the case of selecting a third program (position 3 of the switch П) only part of the primary winding of the transformer is connected to the volume control. As a result, the subscriber does not notice the difference in the voltages, independently of which circuit is used, although only half the signal level is fed through the phantom circuit.

The practice of creating phantom circuits indicates that the stable crosstalk attenuation does not exceed 50 decibels (with a requirement of to 70 decibels). It must be noted that the indicated version of the system can be used for the single-element networks in the repeater-subscriber section. Its application also on the existing distribution network is possible when it is necessary to increase the number of programs transmitted to the subscriber distribution network. In this case only the subscriber network will be changed, and the distribution lines will be kept the same.

1.3. Multiprogram Wire Broadcast System over the City Telephone Exchanges

General Information

Inasmuch as the MPB system is based on the city telephone exchange, measures must be adopted to see that they are completely compatible technically and organizationally. When building the MPB system, the following requirements are imposed on it:

1) Introduction of it must not interfere with the telephone circuitry or have any noticeable effect on the quality of the telephone conversations;

2) The MPB system equipment must not interfere with privacy of the telephone conversation;

3) The MPB system must be designed so as not to introduce significant changes into the telephone and office equipment.

Commutation Type MPB System

Inasmuch as each subscriber line is used little in time, the idea has come up to use the telephone system to transmit broadcast programs. In order to create such a system, low-frequency repeating equipment has been installed at the automatic telephone offices [12] for each WB channel, and station switchboard equipment has also been installed. A receiver made up of a program selection unit, low-frequency repeater and loudspeaker is installed at the location of the telephone network subscriber. The program is dialed similarly to how this is done in telephone communications, as a result of which the subscriber telephone line is disconnected from the telephone distributing frame and it is connected to one of the broadcast repeaters. By using this technique, the telephone network is used both for telephone conversations and for broadcast jointly, but not simultaneously. In order to eliminate the interference of the broadcast program signals on other telephone circuits the voltage of the broadcast signals is kept small, and their amplification occurs in the subscriber receiver. However, the gain of the receiver must be so small that it does not interfere with privacy of the telephone conversations. The danger of hearing telephone conversations increases with a decrease in the crosstalk attenuation between the cable circuits. A significant disadvantage of this system is the fact that the subscriber is offered the possibility of using the network to obtain only one type of information in each time interval: when a telephone call comes in the subscriber must interrupt the broadcast transmission.

Fig 1.4 shows a system which implements the indicated MPB system. This version of the system was proposed in the USSR in the 1930's by A. V. Vinogradov, but it was not implemented at that time as a result of a number of technical deficiencies.

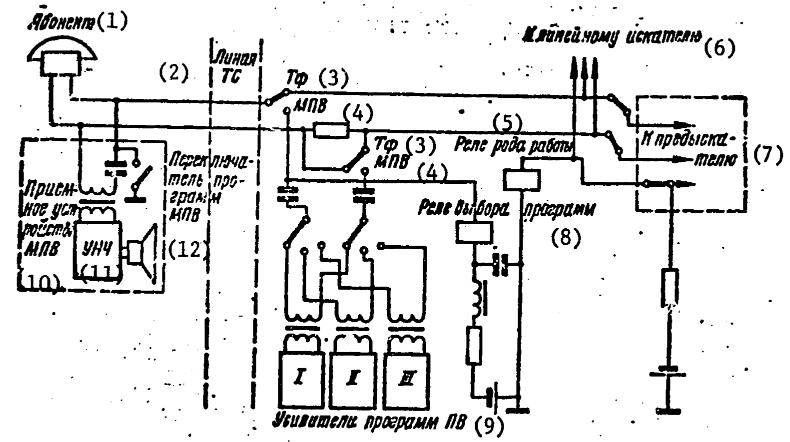


Figure 1.4. Schematic diagram of low-frequency WB over a telephone line with program selection

Key:

1. Subscriber
2. Telephone line
3. Telephone
4. MPB
5. Mode of operation relay
6. To the connector
7. To the preselector
8. Program selection relay
9. WB program repeater
10. MPB receiver
11. Low-frequency repeater
12. MPB program switch

High-Frequency MPB System

The procedure for using the telephone network for each system consists in transmitting the broadcast programs on the high-frequency band.

Let us consider the factors which must be considered in creating such an MPB system. First, it is necessary to consider the possibility of broadcast interference from the telephone systems as a result of the station switching equipment and the subscriber dials. Low-frequency filters connected on both ends must attenuate the effect of this interference in the occupied broadcast band.

Second, interference is possible from the radio broadcast stations, the level of which determines the minimum signal voltage at the subscriber.

Thirdly, it is necessary to consider the different attenuation of the side frequencies causing noticeable nonlinear distortions. For efficient use of the AM repeater power, all of the lines connected to the telephone office are grouped depending on the length of the line, and each group has the required level of high frequency signals at the input to maintain a sufficient signal level at the end of the line [12].

The schematic illustrating the principle of the construction of a high-frequency wire broadcast system is presented in Fig 1.5. Transmitters each with its own program, are installed at the telephone office. The broadcast programs can reach these transmitters from the information sources by various paths.

The high-frequency signals from the transmitters are fed to common buses and by means of the station connection filters (SCF), to the subscriber telephone lines. The station connection filter contains high and low-frequency filters connected in parallel. The low frequency filter does not pass the MPB signals, and it also eliminates the effect of the interference caused by the commutation devices of the station. The high-frequency filter prevents penetration of the low-frequency signals into the high-frequency equipment. The subscriber filter (SF) is installed at the end of the subscriber telephone line. It is also made up of high-frequency and low-frequency filters having analogous purpose. The terminal receivers are connected to the corresponding output. In order to simplify the station connection filters and the subscriber filters, inasmuch as they are an important element of the system, the frequency band occupied by the MPB signals must be selected as far as possible from the frequency band occupied by the telephone channel. Considering the admissible damping on the city telephone exchange lines and the possible use of radio broadcast receivers, the frequency of the long-wave band is selected from 150 to 350 kilohertz.

Fig 1.6 shows the structural diagram of a six-channel MPB system. The six-carrier frequencies are modulated in the transmitters by the corresponding signals of different programs, and they are transmitted through the filters C_1-C_6 to the wide-band high-frequency repeater or channel repeaters KY if greater power is required. The carrier voltage of each broadcast channel is about 5 volts. When using signal-channel repeaters, it is

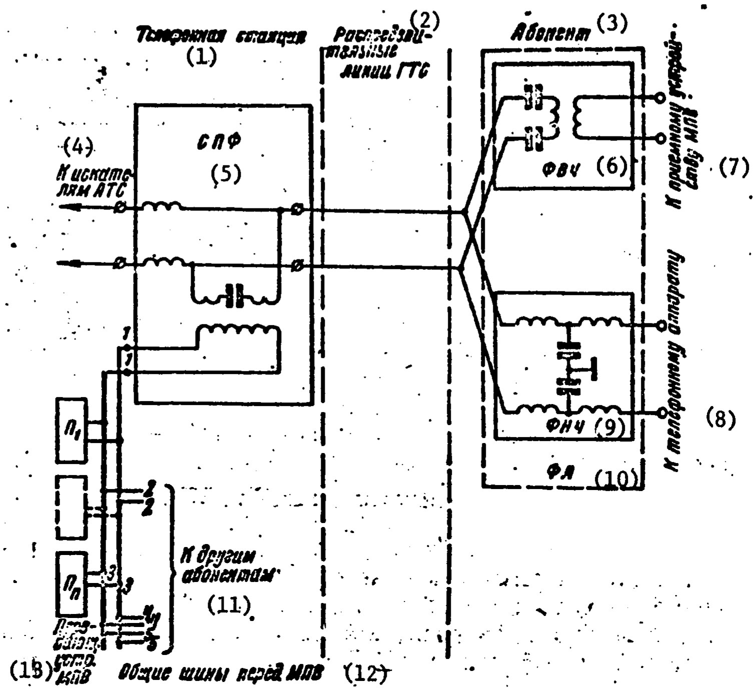


Figure 1.5. Structural diagram of the high-frequency MPB system based on the telephone network

Key:
1. Telephone office
2. City telephone exchange distribution lines
3. Subscriber
4. To the automatic telephone office selectors
5. Station connection filter
6. High-frequency filter
7. To the MPB receiver
8. To the telephone set
9. Low-frequency filter
10. Subscriber filter
11. To the other subscribers
12. Common buses in front of the MPB
13. MPB transmitters

possible to obtain a voltage of about 25 volts at the output of each channel.

Depending on the length of the line, one wide-band repeater can feed up to several hundreds of subscriber lines.

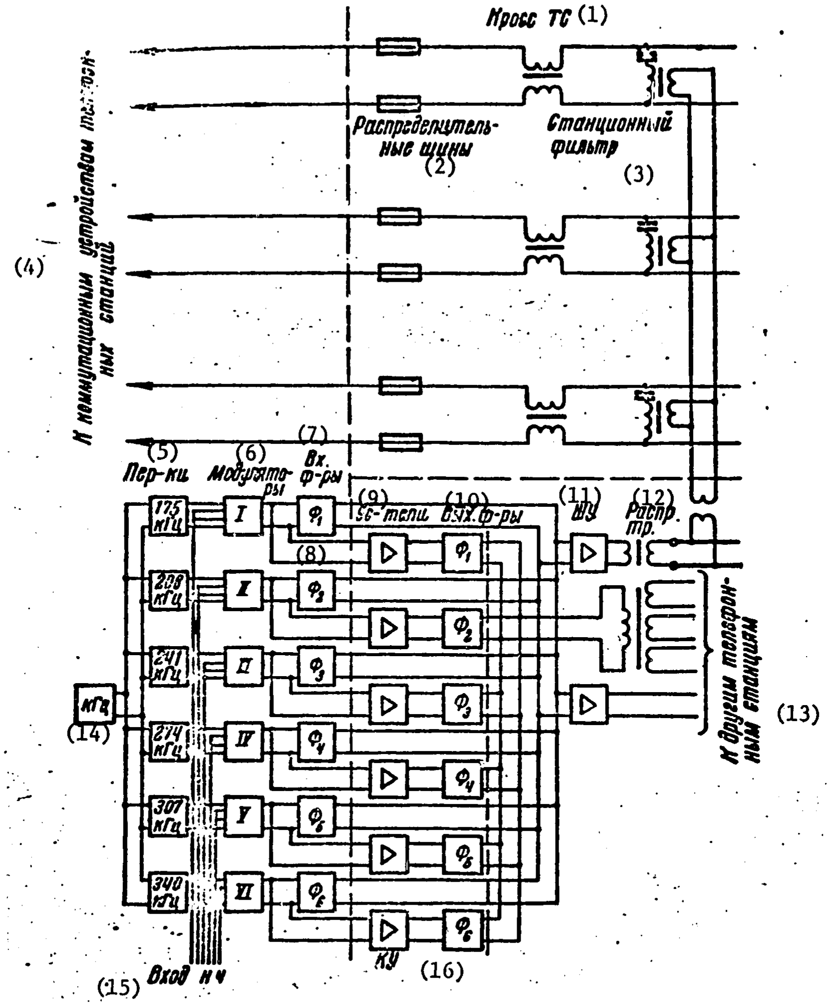
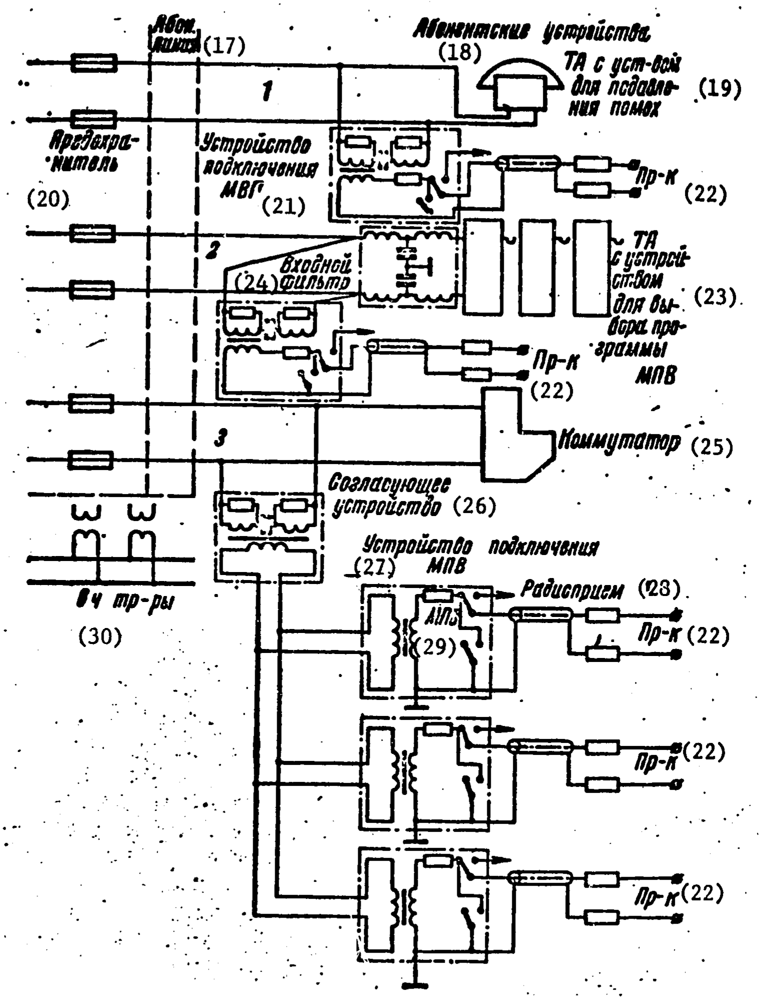


Figure 1.6. Schematic of low-frequency MPB

Key:

1.	Telephone network distributing frame	9.	Repeaters
2.	Distribution buses	10.	Filter outputs
3.	Station filter	11.	Wide-band repeaters
4.	To the switchboard equipment of the telephone offices	12.	Distributing transformer
5.	Transmitters	13.	To the other telephone offices
6.	Modulators	14.	kilohertz
7.	Filter inputs	15.	Low-frequency input
8.	$\Phi_{...}$ = filters	16.	Channel repeaters



of the city telephone exchanges

Key:

17. Subscriber line
18. Subscriber sets
19. Telephone with interference suppressor
20. Fuse
21. Device for connecting the MPB
22. Receiver
23. Telephone with MPB program selection device
24. Input filter
25. Switchboard
26. Matching device
27. MPB connection circuit
28. Radio receiver
29. MPB
30. High-frequency transformers

The complex made up of six single-channel repeaters can be serviced by several thousands of subscriber lines.

On the receiving side the MPB signals can be picked up on a special receiver or a long-wave band ratio broadcast receiver.

Fig 1.6 shows versions of the use of an ordinary radio broadcast receiver as the receiver. It is connected to the MPB network by a device made up of a symmetric transformer and switch permitting conversion from reception over the MPB network to radio reception by coaxial cable (the subscriber line 1). It is possible to connect several receivers to one subscriber line through the matching device (line 3). If part of the subscribers use the services of the MPB system of the switchboard type, and it is necessary to send high-frequency MPB signals over the same subscriber line, then in addition to the matching device it is necessary to connect the low-frequency input filter in front of the telephone sets of the subscribers using the switchboard type system (line 2).

A special MPB receiver having high acoustic indexes can also be used. It is constructed by the direct repeating scheme and is made up of filters tuned to fixed frequencies, a detector and repeater.

Considering the organizational principles of the MPB system over the telephone network it is possible to note that the filters introduced on both ends of the line are important elements providing for the absence of influence of the systems on each other (the telephone and broadcast systems). The introduction of the filters increases the ohmic resistance of the lines for the telephone systems with centralized feed, it increases the damping of the low-frequency telephone conversation signal. The attenuation in the low-frequency filters must not be more than 0.2-0.25 decibels. In this case the quality of the telephone conversation transmission will not be negatively affected. On the other hand, as was pointed out earlier, privacy of the telephone conversations must not be disturbed. In Fig 1.6 it is obvious that the voltages of the high-frequency signals are fed to a common bus to which the high-frequency station filters are connected. Thus, the subscriber lines connected to this bus are connected to each other through the low-frequency station filters, and there is a danger of intelligible crosstalk.

In order to avoid mutual influence between the subscriber lines, the equivalent resistance of the distribution transformers on these frequencies is made small. The attenuation on the low-frequency station filters on the order of 90 decibels is entirely sufficient to guarantee impossibility of hearing intelligible telephone conversations even with the help of repeating equipment. It is possible to hear conversations only in an emergency when all of the low-frequency filter coils are short-circuited.

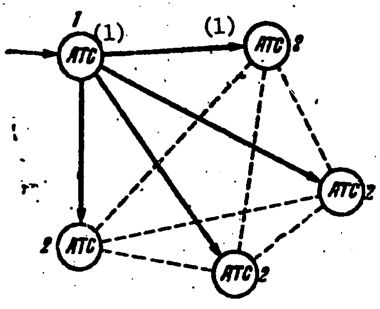


Figure 1.7. Structural diagram of the construction of the MPB system over the city telephone exchange lines (without junction formation):
1 -- central wire broadcast station; 2 -- terminal wire broadcast station; ——— connecting lines of the city telephone exchange used for MPB; - - - connecting lines of the city telephone exchange used only for telephone communications

Key:

1. automatic telephone office

Depending on the structure of the city telephone exchange, two versions of constructing the high-frequency MPB system are possible. The first version is for division of the city telephone exchanges into districts constructed by simple junction formation by the principle of "each-to-each" couplings between the automatic telephone offices. The second version is with complex junction formation of the city telephone exchanges of large cities with several simple networks of district city telephone exchanges. The structural diagrams of such MPB systems are presented in Figures 1.7 and 1.8 respectively. The MPB system uses frequency multiplexing of the connecting lines between the automatic telephone offices and the subscriber telephone lines in both versions. The multiplexing of the connecting lines is provided for over a separate pair in the interoffice communications cable isolated specially for this purpose. The subscriber lines are used simultaneously for MPB and telephone conversations. In the first version a central wire broadcast station is set up at one of the automatic telephone offices, for example, 1. The broadcast program signals are fed to this automatic telephone office from various sources: the radio broadcast equipment room; from local studios and isolated receiving stations. In the second version the central wire broadcast station is equipped either at an automatic telephone office or at the incoming communications junction (3,4). The terminal wire broadcast stations which service the subscriber network of the given automatic telephone office are set up at the remaining automatic telephone offices (2).

The structural diagram of the equipment for the central wire broadcast station is presented in Fig 1.9. It includes the following: program sources 1, a transmitter complex 2 made up of modulators for each program;

band filters 3; multichannel repeaters 4 and high-frequency matching transformers 5. The multichannel repeaters can be installed to feed several connecting lines or one having high attenuation. In addition, terminal wire broadcast station equipment with single-channel repeaters 7, with band filters 3, station subscriber filters 6, the number of which is equal to the number of multiplex subscriber lines, is set up to feed the subscriber lines of the given station.

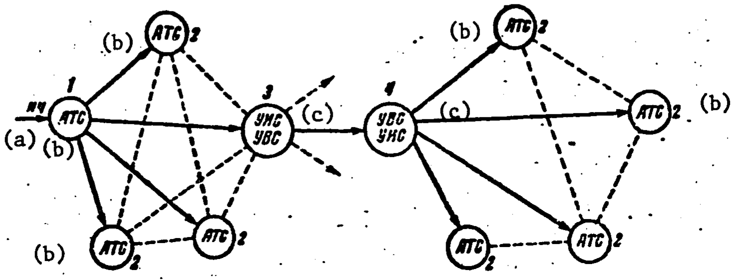


Figure 1.8. Skeletal diagram of the MPB network over the city telephone exchange lines (with junction formation):

1 -- central wire broadcast station; 2 -- terminal wire broadcast station; 3,4 -- intermediate wire broadcast stations; —— connecting lines of the city telephone exchange used for MPB; - - - connecting lines of the city telephone exchange only for telephone communications

Key:

- a. low frequency
- b. automatic telephone office
- c. UIS -- outgoing communications junction; UVS -- incoming communications junction

With respect to the isolated physical circuits (the connecting lines) between the automatic telephone office from the repeaters 4 to all other ATS-2 [automatic telephone offices] high frequency broadcast program signals are fed. In order to equalize the broadcast signal attenuation in the different channels, equalizing circuits are installed at the end of the line. The structural diagram of the terminal wire broadcast stations is presented in Fig 1.10. After correction (the equalizing circuit 1) the high-frequency signals go through the band input filters 2 to the single-channel repeaters 3 where they are repeated to the required level and are added by means of the signals in a common load in the form of high-frequency transformers 4. Then after grouping, the signals are fed to the station subscriber filters 5 for distribution over the subscriber lines running to the automatic telephone office distributing frame.

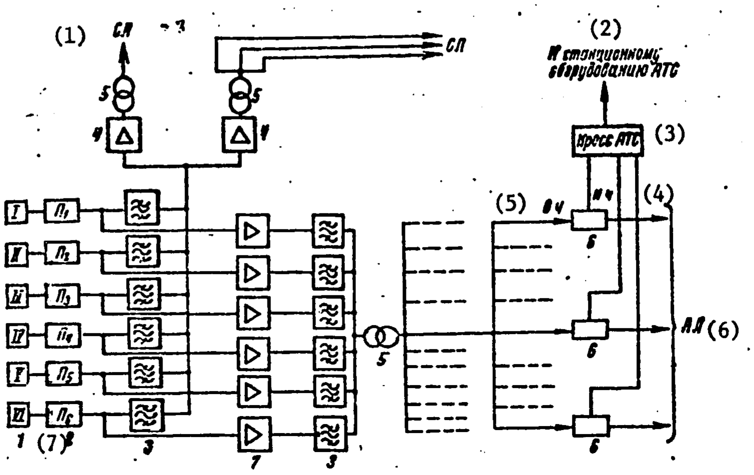


Figure 1.9. Structural diagram of the equipment for the central wire broadcast station for MPB over the city telephone exchange located at the automatic telephone office

Key:
1. connecting line
2. to the station equipment of the automatic telephone office
3. automatic telephone office distributing frame
4. low frequency
5. high frequency
6. subscriber line
7. program

For the city telephone exchange with complex junction formation (Fig 1.8) where the junctions for the incoming and outgoing communications exist by means of which communications are realized between the groups of district automatic telephone offices located in various junction districts another station object is introduced -- the intermediate wire broadcast station -- which is organized in the incoming or outgoing communications junctions. The structural diagram of the intermediate wire broadcast station equipment is presented in Fig 1.11. The high-frequency amplitude-modulated signals are fed over one of the interstation communication lines in tandem through the intermediate wire broadcast station to the frequency equalizer, and after repeating they go over the connecting lines to the automatic telephone office or to the communication junctions.

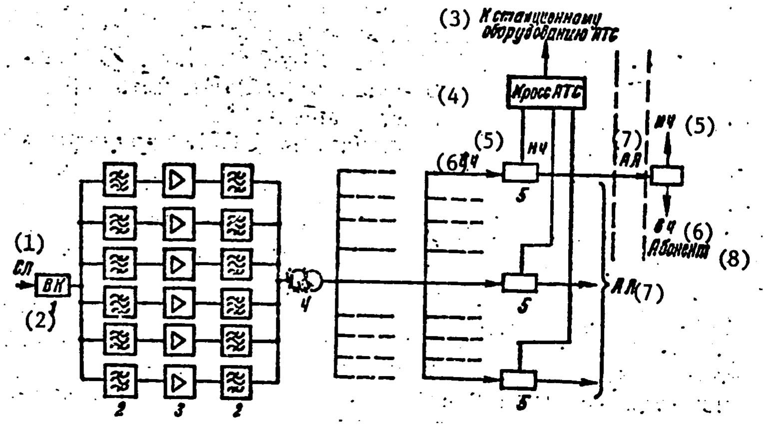


Figure 1.10. Structural diagram of the equipment of the terminal WB station for MPB over the city telephone exchange located at the automatic telephone office

Key:
1. connecting line
2. switch
3. to the station equipment of the automatic telephone office
4. automatic telephone office distributing frame
5. low frequency
6. high frequency
7. subscriber line
8. subscriber

When the equipment of the central wire broadcast station is located at one of the communications junctions, the structural diagram varies, and only the terminal wire broadcast station is set up at all of the automatic telephone offices.

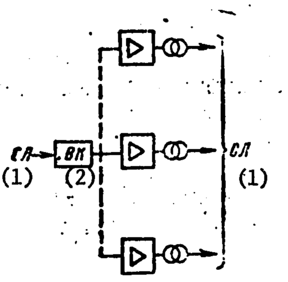


Figure 1.11. Structural diagram of the intermediate wire broadcast station equipment placed at the outgoing communications junction (incoming communications junction)

Key: 1 -- connecting line
2 -- switch

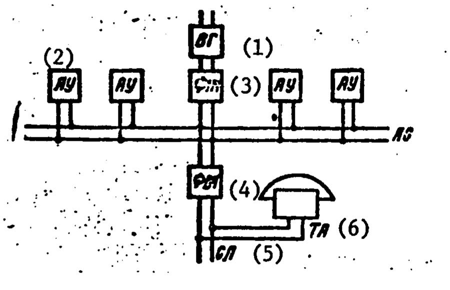


Figure 1.12. Circuit diagram of the receivers

Key: 1 -- group rectifier; 2 -- subscriber set; 3 -- low-frequency filter; 4 -- high-frequency filter; 5-- connecting line; 6 -- telephone

From the investigation of the indicated diagrams of the MPB system it follows that it turns out to be rigidly connected to the telephone communications system. Common station and line equipment are used. However, in order to receive the MPB broadcast program signals it is necessary to be a telephone network subscriber.

As was demonstrated in Fig 1.6 there is a method of feeding the broadcast signals to several subscribers over one telephone pair. The subscriber uses an individual receiver with autonomous feed as the receiving set.

The system using the subscriber line for simultaneous feed of the high-frequency programs and feeding the subscriber sets from a common rectifier is also of interest. This type of system is presented in Fig 1.12.

For simplification of the subscriber set under new conditions when semiconductors are being widely introduced, it can be expedient to use the group rectifier and the autonomous network for simultaneous feed and supply of the MPB signals.

As is obvious from Fig 1.12, the MPB signals are fed from the automatic telephone office over the connecting line to the telephone. Simultaneously, this line is also used for telephone communications; here the telephone is connected by the usual method. Through the special device -- the high-frequency filter shown in Fig 1.13 — the MPB signals are fed to a common autonomous network into which the feed by direct current is also input. Requirements are imposed on the high-frequency filter -- to connect the two networks electrically and not pass low-frequency speaking signals and call signals to the autonomous network. The direct current feed goes to the autonomous network from the group rectifier through the low-frequency filter (Fig 1.14). The rectifier is fed from the household electric network.

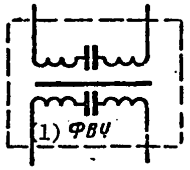


Figure 1.13. Filter circuit diagram

Key:
1. high-frequency filter

For reception of high-frequency MPB signals, the subscriber set is used, the simplified schematic diagram of which appears in Fig 1.15. The high-frequency signals are fed through the high-frequency input filter to the detector and the low-frequency repeater. The constant feed voltage is fed to the repeater of the subscriber set through the low-frequency filter which does not transmit the MPB signals inasmuch as it has greater attenuation with respect to high frequency. The attenuation is insignificant for direct current. The expediency of creating the investigated autonomous network is especially obvious if the repeater in the subscriber set is made from transistors. It is necessary to have only one voltage rating -- for operation a DC voltage to 50 volts is sufficient. The networks with this voltage simplify the satisfaction of the safety engineering conditions, and therefore they can be made of cheaper materials. On the other hand the receiver is also simplified. It does not contain circuits under dangerous voltage, and the feed unit is absent in general. As a result, the structural design is simplified, and the subscriber set becomes cheaper. In the subscriber set designed to receive several programs, a switch is used. A deficiency of the investigated system is dependence of the operation of the MPB receiving network on the state of repair of the autonomous feed network.

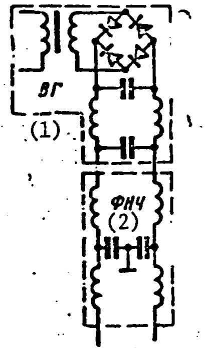


Figure 1.14. Diagram of a group rectifier
Key:
1. group rectifier
2. low-frequency filter

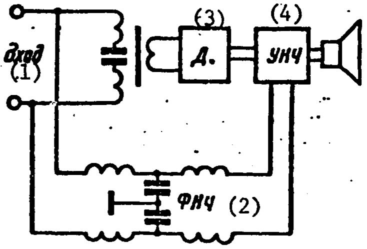


Figure 1.15. Structural diagram of the receiver
Key:
1. input
2. low-frequency filter
3. detector
4. low-frequency repeater

1.4. Switchboard Type Multiprogram Broadcast Systems Based on the Television Distribution Network

At the present time in the Soviet Union and abroad there is a great deal of interest in cable television systems. This is connected with the fact that the problem of improving the quality of television broadcast and increasing the number of programs is difficult to realize as a result of "crowding of the airwaves." In addition, microwave television finds it difficult to get along with the new civil construction with its multistory complexes of different heights constructed from reinforced concrete, as a result of which the so-called "television shadow zones" and multiple repeated reflections of the high-frequency television signals appear.

In addition, the movement away from individual antennas is connected with the esthetic requirements of architecture. Collective cable television systems are appearing on the scale of the individual buildings, the individual block and microdistrict of the city.

Fig 1.16 shows the structural diagram of a WB system constructed on the basis of the television distribution network made of a large-capacity symmetric cable for transmitting low-frequency broadcast signals. It is designed for simultaneous transmission of the broadcast signals and the television signals to a large number of subscribers over one physical network.

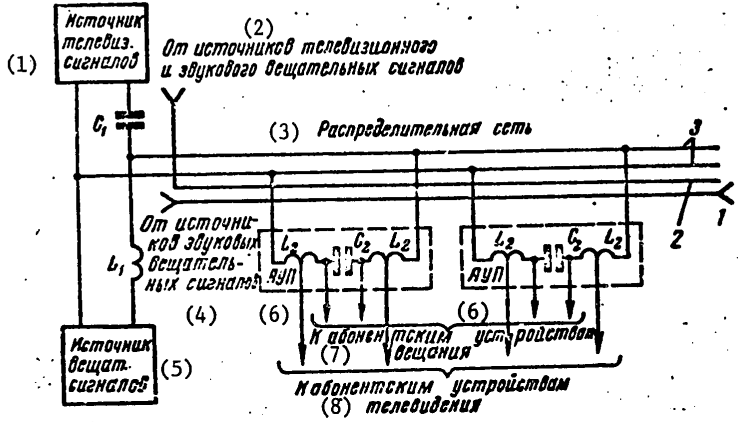


Figure 1.16. Structural diagram of the low-frequency MPB over the television distribution network

Key:

1. Source of television signals
2. From the television and sound broadcast signal sources
3. Distribution network
4. From the sound broadcast signal sources
5. Source of broadcast signals
6. Subscriber connection circuits
7. To the subscriber broadcast equipment
8. To the subscriber television equipment

The investigated MPB system must provide for transmission of television and broadcast signals along the distribution line without noticeable attenuation and absence of their mutual effect. In addition, the great difference in frequency simplifies its realization. At the beginning of the line only the sound broadcast signals are fed to one pair in the distribution network made up of a large-capacity cable, and the television and wire broadcast signals are fed to the others by means of the connection circuit which in the simplest case can be made up of an induction L_1 and a capacitance C_1.

The subscriber connection circuits which can service one or several subscribers are used for connection to the distribution line. The inclusion of the subscriber connections increases the attenuation of the line; therefore the requirement of decreasing the effect of the low-frequency devices on the television signals and vice versa is imposed on it.

The diagram of the subscriber connection circuit is depicted in Fig 1.16. It contains the inductance L_2 and the capacitor C_2. For low-frequency signals the resistance of the inductance of the subscriber connection circuit is of significance. For high-frequency signals the device is a high-frequency transformer. This type of device provides for connecting one or several subscriber sets without a significant increase in losses to the high-frequency lines. Each individual pair of the large-capacity cable has its own sound broadcast and television program transmitted over it. For selectionof the program a multiposition switch is used on the subscriber end.

The use of individual circuits for transmitting each program offers the possibility of transmitting television signals of different programs on one carrier frequency, getting along without selective circuits -- it makes it possible to simplify the receiver and to use an ordinary nonspeaker for the sound broadcast programs. Thus, the advantage of the switchboard system is the possibility of using relatively low-frequency symmetric cables and simpler subscriber sets. This type of MPB system has found application in England.

The investigated MPB system makes it possible to use the simplest broadcast receivers without amplifying (active) elements in the channels, and it offers the possibility of using coaxial cable as the distribution line, for example, to create a matched television and WB network in an apartment building.

There are MPB systems which provide for the possibility of all-around use not only of the distribution network, but also other elements and junctions of the system, for example, transmitting station equipment and receiving subscriber sets, as a result of which the system elements, and in particular, the receiver, are simplified. A version of such a system is depicted in Fig 1.17.

The distribution network is made up of the 1,2 large-capacity cable. Two different television programs are fed to two physical circuits shielded from each other, on the same frequency; the sources of the sound programs which can be sound accompaniment of television programs and simply broadcast programs, are connected to the circuit simultaneously.

The station equipment of the system includes the carrier frequency generator Γ on 6 megahertz. The output of the generator is fed directly through the buffer stages to two modulators to which the signals come from the video program sources in the range from 0 to 3 megahertz. The modulated signal

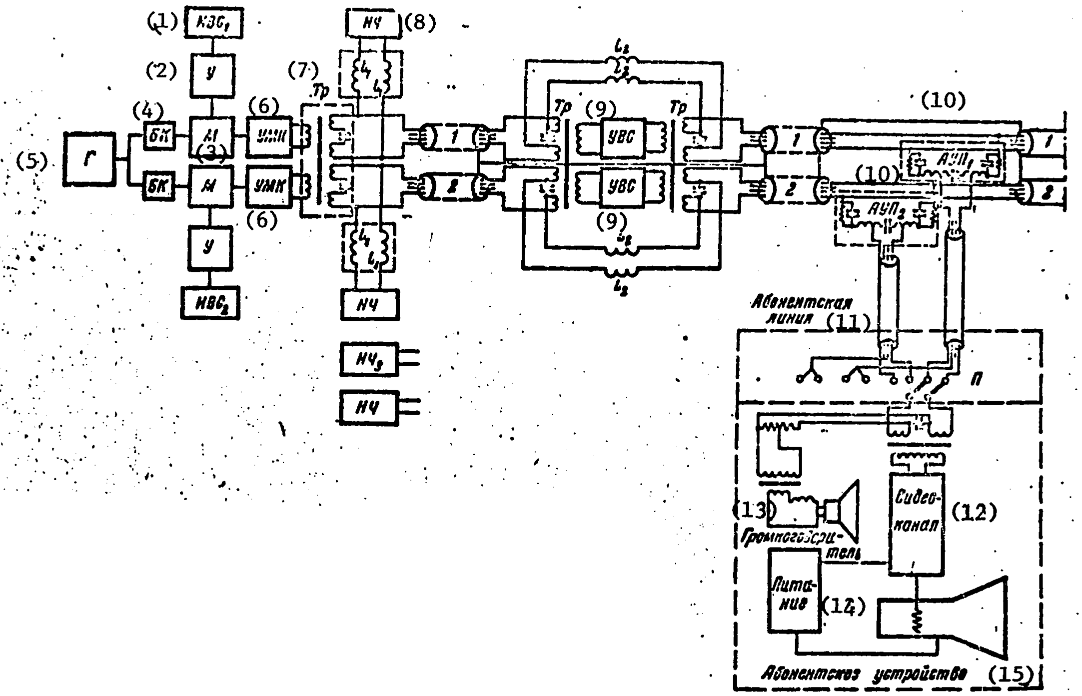


Figure 1.17. Version of the low-frequency MPB system over the television distribution network

Key:

1 -- video program source$_1$; 2 -- repeater; 3 -- modulator; 4 -- buffer stage; 5 -- generator; 6 -- UMK*; 7 -- Tp -- transformer; 8 -- low frequency; 9 -- UVS; 10 -- subscriber connection circuit; 11 -- subscriber line; 12 --video channel; 13 -- loudspeaker; 14 -- feed; 15 -- subscriber set

*modulated oscillation repeaters

in the 3-9 megahertz band is repeated and is connected through transformers to the first and second cable pairs respectively. The sound frequency signals or sound accompaniment of television programs goes through the connection circuit to the secondary windings of the transformers and is transmitted over the same pairs. The other cable pairs are only used for broadcasting. In order to decrease the attenuation of the high-frequency signals along a long distribution line, repeaters are installed. In this case a bypass consisting of an inductance L_2 is provided for the low-frequency signals.

The subscriber connection circuit can be connected before and after the repeaters, and it has a circuit analogous to the previously investigated one. The subscriber equipment contains a high-frequency repeater, a video signal detector and other television receiver elements. The loudspeaker for receiving the sound broadcast signals is connected through a transformer to the primary winding of the high-frequency input transformer. By using the switch П it is possible to select the first or second television program or the sound broadcast program.

The investigated version of the system with the simplest subscriber equipment is used abroad.

1.5. Multiprogram Wire Broadcasting in Foreign Countries

Wire broadcasting means are used by the residents of Austria, England, Holland, Sweden, Switzerland and Spain. In spite of the presence in these countries of a widely developed radio broadcast network, the interest in wire broadcasting has not slackened and is explained by a number of factors. Thus, in some countries it has become possible to use wire broadcasting means to organize high-frequency multiprogram broadcasting in different languages which is superior to radio broadcasting with respect to quality.

The MPB systems of England and Holland constitute an exception. Low-frequency MPB systems are used there in which a special large-capacity cable is used. In Holland, for example, two types of cables are used: shielded four-pair cables with paper insulation and lead sheathing; shielded four-pair cables with polyethylene insulation and sheathing. Four programs are transmitted over these cables.

The combined broadcast and television program distribution networks have found application which use symmetric large capacity cables covering the frequency band to 13 megahertz. In England the number of subscribers to such systems has reached 1.1 million. There is a similar network also in Zürich, Switzerland. Up to six broadcast programs are transmitted over these networks.

In the rest of the above-enumerated countries, the high-frequency MPB system over the telephone networks based on high-frequency symmetric large-capacity cables has found broad application.

The wire broadcast system which arose in Switzerland before World War II at the present time encompasses about 900 telephone offices and services more than 450,000 subscribers. Since 1958 this type of system has begun to be introduced in many cities of Italy and Spain (Madrid, Barcelona and a number of other countries) where it encompasses 63 automatic telephone offices and services about 750,000 subscribers.

The MPB system provides for program transmission of the first and highest quality classes with a 20-15,000 hertz band. For reproduction of programs with such quality a special receiver must be installed.

Both radio broadcast programs and special programs are transmitted over the MPB network. The exchange of programs is practiced between cities along with transmission of high-quality musical recordings.

However, the high-frequency WB systems over the telephone networks, being distinguished by high quality and operating stability, still have not found mass application.

Recently interest has arisen in the creation of complex cable television and WB broadcast networks. Systems of this type are being developed at the fastest possible rate at the present time, for they provide the largest number of channels and will permit reception on ordinary radio receivers. The broadcast and television signals take up a band of 40-300 megahertz. Coaxial cables are used to create the distribution networks. Such systems have begun to be introduced in many countries of Europe and the United States.

In the United States, complex wide-band networks have been built on the basis of the cable television networks since 1963. Telephone, television signals, broadcast programs and data transmission signals are transmitted over these networks.

The broad development of cable television systems in various cities over which various types of information will be transmitted is proposed. However, their realization requires the solution of many special organizational and engineering problems and no specific results have as yet been achieved in this respect.

CHAPTER 2. TRIPLE-PROGRAM WIRE BROADCAST SYSTEM (TPB)

2.1. Structural Diagrams of the City WB Networks

The functional diagram of the WB system is presented in Fig 2.1. The signals repeated by preamplifiers are fed from the program sources over program transmission channels or connecting lines to powerful repeaters or transmitters where basic repeating of them takes place. Then the signals go to the WB distribution network for transmission with given quality indexes to the subscriber receivers.

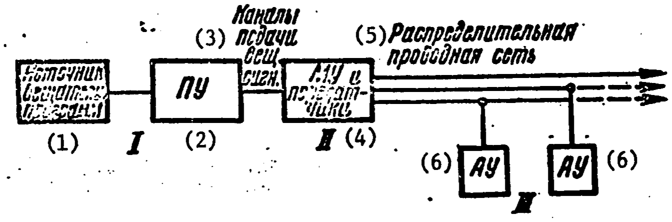


Figure 2.1. Functional diagram of a wire broadcast system

Key:

1. Source of broadcast programs
2. Preamplifiers
3. Broadcast feed channels
4. Powerful repeaters and transmitters
5. Wire distribution network
6. Subscriber receivers

Thus, the wire broadcast system has three distinct sections (Fig 2.1). The first section I is characterized by low broadcast signal levels. The formation of the program and the transmission of the signal to the second section II takes place in this section with given quality indexes.

Basic repeating (obtaining of the defined power) of the broadcast signal takes place in section II with minimum distortions for the low-frequency outgoing signal and commutation of it to the distribution network.

The third section is the fastest section III. This is the wire distribution network which realizes distribution of the broadcast signal power over the cable or overhead line networks to the subscriber receivers, without introducing noticeable distortions into the quality indexes of the broadcast signal.

The receivers are passive subscriber units -- loudspeakers, which convert the electric signals to acoustic signals, or special receivers with active elements. The subscriber **sets** are designed for the use of a defined power of broadcast signal and reproduction of it with given quality (acoustic) indexes.

There are several versions of constructing the city WB networks. They all have the above-enumerated functional sections, but they are distinguished by the volumetric indexes: the number of service subscribers, the number of program feed channels, the extent of the connecting lines for the first section, the number of stations, the power of the repeaters and transmitters and their number, the presence of passive power distribution elements and the number of transformer substations, the different types of distribution lines and their volumetric indexes for the third section and also types of subscriber sets used.

The investigation of the development of the WB [wire broadcasting] in the cities indicates that the first and third sections have changed little. Great changes have occurred in section II. The basic purpose of these changes has been most advantageous distribution of the active elements of the network over the territory and insurance of mutual redundancy of the active and passive station equipment [3, 4, 5, 7].

Depending on the structure of the station and line installations of the WB network, they are divided into several types distinguished by their structure. It is necessary to point out two types of indexes which determine each WB network. The first type characterizes the electrical data of all the elements and assemblies in the final analysis influencing the quality of the electroacoustic parameters. The second has no influence on the quality, but characterizes the structure -- complexity of the network.

Let us assume that the electroacoustic data must not depend on the type or complexity of the network and must be insured in equal measure for the subscriber. This is insured by calculating the elements according to the recommended procedure and the electrical design standards. Let us consider only the volumetric indexes characterizing the structure.

The simplest diagram of the city network is presented in Fig 2.2. The following are indicated in the diagram:

YC -- WB repeater station. The complex of repeating, transmitting and commutation equipment (the transmitters of programs II and III of the TPB networks) is characterized by the type of repeating equipment and the complexity of the commutation equipment;

PΦ -- the distribution feeder line. The number of distribution feeder lines depends on the number of service points and density;

AT -- subscriber transformer. The number of subscriber transformers depends on the number of service subscribers and the density of the load;

ДС -- intrabuilding distribution network characterized by the wire length and number of subscriber sets;

AY -- subscriber set;

ЦСПВ -- central wire broadcast station realizing preamplification of the broadcast program signals, feed of them to the repeater station and providing for the functions of monitoring the entire WB network. It is combined with the WB repeater station.

Thus, the structure of the network is characterized by the following data: the number of connecting lines of the central wire broadcasting station to the repeater station; the number of repeaters (transmitters); the operating power P required to service all of the subscribers; the number of distribution feeder lines; the number and power of the subscriber transformers; the number of service subscribers N.

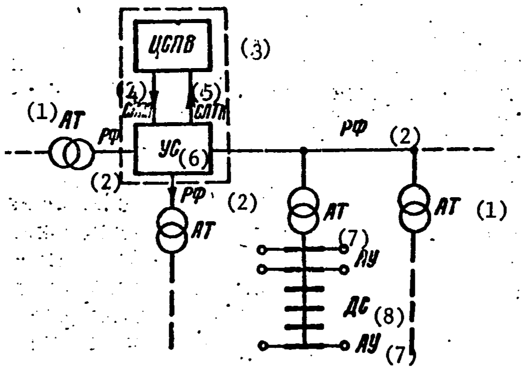


Figure 2.2. Diagram of the centralized WB network

Key:

1.	Subscriber transformer	6.	Repeater station
2.	Distribution feeder line	7.	Subscriber set
3.	Central wire broadcast station	8.	Intrabuilding networks
4.	Program feed connecting line		
5.	Remote control and remote monitoring connecting line		

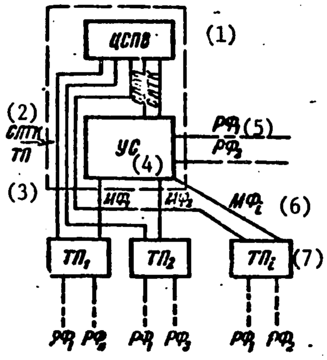


Figure 2.3. Diagram of the centralized WB network with two-step power distribution

Key:

1. Central wire broadcast station
2. Remote control and remote monitoring connecting line
3. Transformer substation
4. Repeater station
5. Distribution feeder line
6. Main feeder
7. Transformer substation

This type of wire broadcast network is called a centralized wire broadcast network. It is characterized by the fact that the equipment performing the function of the central wire broadcast station, as a rule, is in the same facility with the repeater equipment and the switchboard equipment of the repeater station. The network has only one active broadcast signal power distribution junction.

Fig 2.3 shows a more complicated structure of the network in which the following are indicated:

СЛПП - program feed connecting line; number of them depends on the number of programs and the number of repeaters and transmitters of the auxiliary high-frequency programs installed at the repeater station;

СЛТК - remote control and remote monitoring connection line; the number of lines is determined by the number of controlled objects. In the given case with invariant active station part of the system, the form of the power distribution varies.

The power of the broadcast signals from the repeaters and transmitters of the repeater station goes to several local distribution networks via the passive distribution junctions of the transformer substations.

The line connecting the active distribution junction of the repeater station to the passive junction of the transformer substation is the main feeder line.

The transformer substation is the station passive equipment complex which is used to transmit the power to the distribution feeder lines.

The power of the transformer substation is determined by the number of distribution lines, their structural specifications and magnitude of the load. In order to control the remote monitoring of the operation of the transformer substation, connecting lines are used.

The distribution network remains unchanged and is similar to the distribution network of the system in Fig 2.2. Inasmuch as all of the notation adopted previously is kept for all layouts of the network and the distribution network is identical in structure, hereafter it will be designated simplified.

The wire broadcast network is called centralized with two-step power distribution when it has one active power distribution junction and several passive distribution junctions. The central wire broadcast station is territorially combined with the repeater station, which is illustrated in the diagrams by the dotted line.

Since the main feeder line operates with increased transmission voltage, the range of the system is expanded. The voltage is stepped down at the transformer substation using special transformers. Additional indexes appear in this network: the number of transformer substations, the main feeder lines, the remote control and remote monitoring connecting lines.

Fig 2.4 gives the diagram of the WB network in which its station part is altered by comparison with the previously investigated one (Fig 2.2). In the given case the power P_{op} required for normal operation of the entire network is distributed among several objects of the repeater station with different value of it. In this system the network structure is characterized by two additional indexes: the repeater station power and the number of repeater stations, and it is called the decentralized network.

The powerful repeaters are installed separately in several territorially separated repeater stations which receive the broadcast program signals over connecting lines from a single centralized repeater station (the centralized wire broadcast station) which can be combined with one of the repeater stations. Here the WB network has several active station power distribution junctions in its makeup.

Fig 2.5 shows the layout of the network with further complication of the structure. The broadcast program signals from the central wire broadcast station (as a rule, isolated) are fed to several reference repeater stations at which they are repeated to defined powe and are distributed by means of the transformer substations throughout the serviced territory.

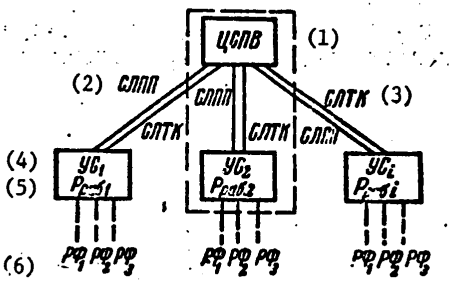


Figure 2.4. Schematic of a decentralized WB network

Key:

1. Central wire broadcast station
2. Program feed connecting line
3. Remote control and remote monitoring connecting line
4. Repeater station
5. P_{op}
6. Distribution feeder line

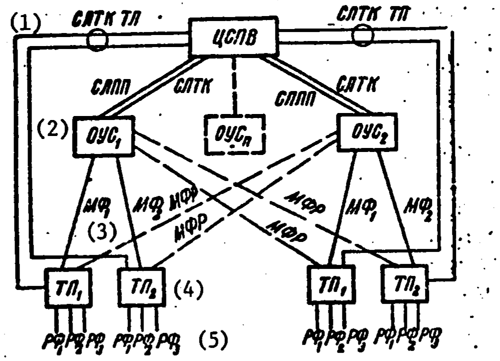


Figure 2.5. Schematic of the decentralized WB network with two-step power distribution

Key:

1. Remote control and remote monitoring connecting line of the transformer substation
2. Reference repeater station
3. Main feeder
4. Transformer substation
5. Distribution feeder line

In this network layout there are main feeder lines which connect the transformer substations to the adjacent repeater stations of the reference repeater stations. This method of transmitting the signals to the transformers substation is called two-way feed of the transformer substations.

On failure of the main feeder which is feeding the transformer substation at the given time, the distribution network of the given transformer substations switches to another feeder which has been in reserve up to this time.

On failure of the reference repeater station, the transformer substation switches to other reference repeater stations. At the repeater stations provision has been made for additional power $P_{reserve}$ both in the form of a separate powerful repeater or transmitter and in the form of a reserve of installed power of the repeaters or transmitters of the reference repeater stations. Continuous operation of the network is insured in this complex structure.

The city network constructed by this principle is called a decentralized network with two-step power distribution of the broadcast signal; in practice it is frequently called the improved three-element system. The network has several active and passive power distribution junctions. The WB distribution network for this structural layout remains unchanged in theory.

In the investigated WB network, several other indexes are being added: the number of repeater stations of the reference repeater station; the number of reserve main feeder lines; the powers of the repeaters of the reference repeater station -- operating and auxiliary (used for reserve for the repeaters in the given station or the repeaters of adjacent reference repeater stations).

Each investigated layout of the network has its own advantages and disadvantages. The advantages of the centralized networks can include the following: the construction of the station in one location (where it is easier to insure an uninterrupted power supply), simplification of the redundancy of the active station transmitters, monitoring devices, powerful repeaters and their maintenance.

Deficiencies include the following: complexity of the distribution network, longer lines and less efficiency correspondingly, less operating stability of the WB network as a whole.

The advantages of decentralized system include the following: high operating stability under emergency situations with high efficiency of the distribution network, simultaneous simplification and shortening of the distribution lines and improvement of their operating reliability. The deficiencies include the following: greater complexity of the operation and maintenance of the station devices and difficulty in insuring autonomous power supply sources. However, the last deficiency is felt less and less in practice, for the reliability of the city power supply has increased.

The modern city WB networks are similar to those described, and, as a rule, they are in the form of a set of the described systems and vary in accordance with the development of the given city.

It must be noted that unfortunately there are no strict calculated bases for the selection of one version or another, and the remaining, it would appear to be obvious, principles frequently turn out to be contradictory. Thus, centralization of the active station objects is convenient for operation and maintenance, but it implies the application of long distribution lines having increased attenuation and frequency distortions. The application of one powerful, high-power repeater is more advantageous with respect to expenditures of equipment and maintenance than several low-power repeaters. However, in a number of cases, considering redundancy, this leads to an unsubstantiated increase in the installed power of the repeater stations. Therefore, the choice of the optimal WB system must be preceded by technical-economic calculation of several versions of the station and line structures.

2.2. Basic Principles of Constructing the Low-Frequency WB City Networks

The modern WB network in the cities is built considering optimal economic and operating indexes in accordance with the specific conditions, dimensions, configuration of the city, the number of population, and the prospects for civil construction.

In the majority of cities in the USSR with a population up to 50,000 (with a number of points to 10 to 15,000) predominantly centralized wire broadcast networks are being built with two-element distribution network. In this case all of the repeater, reception and switching equipment is concentrated at one station. The first element of the network is the subscriber lines which feed the subscriber sets, and the second element is the distribution feeder lines to which the building networks and subscriber lines are connected through the step-down subscriber transformers. The rated low-frequency voltage for the city feeder lines is 120 and 240 volts.

In larger cities (population to 150,000), centralized wire broadcast networks are being constructed with mixed construction. In such networks, as a rule, there is one WB station in which the basic power of the low-frequency repeaters is concentrated. Several distribution feeder lines (from 5 to 20) go out from the station to supply the subscribers of the main residential area of the city and one to two main feeder lines with simplified type transformer substation to feed the network located in remote parts of the city. Sometimes high-voltage rural type feeder lines with a voltage of 480 to 960 volts are built to supply the network of adjacent populated areas or the suburbs.

In cases where the construction of the main feeder line is connected with large expenditures or technical disadvantages, to feed the network of the remote part of the city a repeater substation is constructed with remote control and monitoring and program feed from the basic station, that is, a decentralized network is created with two-element distribution network. In the republic and the majority of oblast centers decentralized WB networks are being built.

The station powers are distributed with respect to several reference repeater stations. Each reference repeater station feeds several transformer substations with a sound frequency power of 5 or 7.5 kilowatts each through the 960 volt main feeder lines. At the transformer substation the voltage is stepped down from 960 to 240 or 120 volts and goes to the distributing feeder lines which feed the subscriber network of the part of the city serviced by the given transformer substation.

Redundancy in which each sound frequency transformer substation receives two-way feed from two reference repeater stations over two main feeder lines is characteristic of the system. Each of these lines can be operating or reserve. When there is damage to one of these lines the automation response, deenergizing the damaged line and the feed of the transformer substation is automatically switched to the main line from the other reference repeater station which is in a state of repair. In case of any emergency with the reference repeater station (deenergizing, damage to the connecting line or equipment), its load (transformer substation) is remotely switched from the central wire broadcast station to the adjacent reference repeater station by remote control equipment.

When it is impossible or economically inexpedient to build a reserve main line, the reserve feed of the transformer substation located in a remote part of the city is provided from the substation block in which the existing repeater equipment is most frequently used.

The program feed to all the reference repeater stations, repeater stations and substation blocks, the remote control of them and monitoring of their operation and the operation of the transformer substation are centralized from the central wire broadcast station over the so-called connecting lines, for which the telephone pairs of the city telephone exchange especially corrected and selected in the large capacity cables are used.

In Table 2.1 values are presented from the basic volumetric indexes of the city WB networks, excluding Moscow and Leningrad.

The analysis of the volumetric indexes of the city WB networks indicates that for the majority of the city the average number of reference repeater stations and repeater stations does not exceed 5. The average number of main feeder lines (operating) emerging from one repeater station is equal to three, and only in an emergency, on total failure of all of the repeaters of the adjacent reference repeater station or the electric power supply

Table 2.1

Name of index	Values of index Minimum	 Medium	 Maximum	Units of measure
Power of the repeater station	5	14.2	35	kilowatt
Operating power of the transformer substation	2.4	4.4	5.2	kilowatt
Number of transformer substations connected to one repeater station in the operating mode	1	3	6	pieces
Length of the main operating feeders	1.7	4.4	7.6	km
Length of the main reserve feeder	-	-	13.0	km
Length of the distributing feeder	1.5	-	6.0	km
Number of subscriber transformers per km of line	5	-	40	pieces
Load of the subscriber transformers	22	43	97	radio points[1]

[[1] Translator's note: the Soviet name for a loudspeaker connected to a local wire broadcast network.]

network feeding it, the number of simultaneously included main feeder lines can reach 6. The cases of a larger number are extremely rare.

In the cities with decentralized WB network and a three-element schematic for constructing its linear part, the required installed power of the reference repeater stations does not exceed 35 kilowatts, and in the minimum, 5 kilowatts, and the most frequently encountered, 15 kilowatts. The reference repeater stations are made up of standard high-frequency repeaters with an output of 15 and 5 kilowatts, the commutation and auxiliary industrial output equipment.

In Moscow and Leningrad, the reference repeater stations with a power of 60 and 30 kilowatts are widespread. They are equipped with repeater modules with an output capacity of 30 kilowatts of specialized manufacture.

In the WB networks, light elements are used in large quantity; a standard subscriber line armature has been built, all of the basic assemblies of the structures have been standardized, the rated voltages in the various elements of the channel have been established.

The main distribution feeder lines, the subscriber lines and the household circuits are constructed on the basis of the specific planning and design.

For construction there are clear technical recommendations. In Table 2.2 values are presented for the attenuations and the transmission coefficients with respect to the power of sections of the WB channel and with respect to the low frequency channel.

However, the optimal solutions for the single-program WB networks obtained as a result of many years of generalization of experience, do not always coincide with the requirements for the MPB system.

Table 2.2.

Segment of the channel	Attenuation of the channel	Transfer coefficient with respect to power
Output of the active circuit — input of the distributing circuit	1.5 decibels	0.9
Beginning-end of the distributing line	3 "	0.45
Primary winding of the subscriber transformer -- output of the subscriber network (household network)	1/8	0.95
Beginning-end of the subscriber line (household line) of the network (at the end of the line)	1 decibel	0.98
Total attenuation	4 decibels	-
Total power transmission coefficient	-	0.38

2.3. Basic Principles with Respect to Creation of the MPB System

The necessity for creating the MPB system in the USSR was caused first of all by the multinational structure of the population of the country, the requirement of providing the WB listeners of the union, autonomous republics, autonomous oblasts with full-value national programs without loss of the union programs. In those parts of the country where broadcasting is in one language, the introduction of MPB permits noticeable variation of the transmission considering the interests of the individual population groups.

The creation of the MPB has required the consideration of the state of the technical level of the communication means and a number of social and economic conditions arising at the beginning of the 1960's. These basic principles are reduced to the following. A widely developed WB system has come about in the country with a multimillion fleet of simple, cheap single program receivers (by the end of 1962, there were 32 million of them). The system has recommended itself as sufficiently reliable for information transmission, and it was for many subscribers the only source of operative information and high-quality broadcasting. At the same time the city telephone exchanges at that period were inadequately developed. Under these conditions it would be most correct to solve the problem of MPB in the USSR only by creating it on the basis of the single-program broadcast network using a low-frequency channel.

The next argument determining the mass nature and popularity of the MPB system is the cost of the subscriber receiver. It must not significantly exceed the cost of the single-program loudspeaker and must be less than the cost of the cheap radio broadcast receivers themselves. Only under such conditions is it possible to count on the mass production of the MPB system.

According to the economic requirements the MPB system must be introduced with minimum capital expenditures and not cause significant additional operating expenditures.

The end of the 1960's is characterized by broad application of electrovacuum devices in all the technical means of air and wire broadcasting and the beginning of use of transistors in the individual equipment developments with low output power, relatively narrow band of reproducible frequencies and low quality indexes.

Use of the single-program broadcast networks as the base for creating the MPB system required mutually matched decision making between the existing low-frequency channel and the auxiliary program channels of minimum possible mutual loss for each of them.

The WB networks developed in the cities are different, and the MPB system must be inscribed with minimum deviations in these versions of building the networks. Requirements of insuring higher quality indexes than the indexes achieved during radio broadcasting in the long and medium wave bands, guarantees of given auxiliary program signal levels at all of the subscriber WB points for various types of wires (bimetallic and steel), in the presence of cable entries, for the distributing network of different configuration (with different number of feeders, different extent of the distributing feeder lines and different density of the subscriber transformers) are imposed on the MPB system.

In addition, it is necessary to insure sufficient mutual protection between the air broadcast and the WB systems. The introduction of the MPB system based on the single-program WB network requires the development of the remote control and remote monitoring systems.

It is necessary to provide the MPB system with additional high-quality, reliable sources and channels for transmitting the broadcast programs. The discussed basic principles were adopted as the initial prerequisites when creating the Soviet MPB system.

When creating the MPB system it is necessary to determine the following: number of transmitted programs, the carrier frequencies, the type of modulation, the levels of the high-frequency signals in the WB channel considering electromagnetic compatibility with the radio broadcast and communications systems, the versions of constructing the MPB system for the various structural layouts of the WB network; the quality class of the high-frequency channels of the MPB system and standardization of them.

2.4. Number of Programs, Carrier Frequencies and Type of Modulation

The indicated characteristics are completely determined by the possibilities of the single-program wire broadcasting system and obtaining the minimum cost of the subscriber receiver. The transmission of the low-frequency signal at high levels over the overhead wire network determines the possible range of frequencies for creating additional channels. This frequency range is bounded below by the frequency spectrum of the low-frequency program with upper normalized frequency with respect to quality class I of 10 kilohertz, and it is bounded at the top by the beginning of the long-wave band -- a frequency of 150 kilohertz. Considering the high signal levels of the low-frequency program and, consequently, the significant levels of the harmonics of the low-frequency signal, it is necessary to separate the spectra of the high-frequency signals from the low-frequency signals.

Theoretically, considering the possible filtration of the harmonics of the low-frequency signal at the output of the low-frequency repeater of channel I, it is possible to use the frequency range beginning with 30 kilohertz. In adopting the frequency range to the beginning of the long-wave band of 10 kilohertz, it is possible to consider that for frequency multiplexing of the WB system there is a frequency band of 30-140 kilohertz. When transmitting programs with two-band amplitude modulation in this frequency band with a reproducible frequency band of $\Delta F=6$ kilohertz corresponding to quality class II of All-Union State Standard 11515-65 and with frequency clearance between the channels of 3 kilohertz, the number of possible transmitted programs n determined from the condition

$$140-30=2\Delta Fn+3(n-1), \qquad (2.1)$$

is potentially seven.

The obtained number of MPB channels is potentially possible on their reception on the superheterodyne type receiver which is similar with respect to cost to the radio broadcast receivers. Actually, the number of possible transmitted programs with the WB network decreases significantly in connection with a reduction in the actually admissible frequency band for the MPB purposes.

This reduction on the part of the lower part of the frequency band is caused by the presence of significant additive interference from the low-frequency channel sufficiently noticeable in the frequency band to 100 kilohertz although this interference could be appreciably reduced by installing the corresponding low-frequency filters at the input of the main and distributing feeder lines connected to the low-frequency repeater. The most significant obstacle to the use of low-frequency part of the free frequency band is significant increase in the multiplicative interference from the low-frequency channel increasing with a decrease in the carrier frequency. The cause of the appearance of this interference is the presence of distributed and concentrated nonlinearities in the WB channel which the steel wire and poor contacts have.

The solution to the problem of modulation and demodulation with the simplest two-band amplitude modulation presents known difficulties with a low ratio of the carrier and the modulating frequencies. In addition, a further difficulty in the use of this part of the frequency band is the more noticeable difference with respect to the conditions of transmitting the upper f_B and the lower f_H side frequencies. The difference increases with an increase in the ratio

$$f_B/f_H = (f_0 + F_B)/(f_0 - F_B), \qquad (2.2)$$

where F_B is the higher modulating frequency; f_0 is the carrier frequency.

With an increase in the carrier frequency the indicated ratio approaches one, which indicates the equal conditions of the transmission of the side frequencies of the AM signal spectrum. It must be noted, for example, that the transmission of the 15 kilohertz modulating frequency band with the least carrier frequency of 178 kilohertz over a uniform matched telephone pair in the Italian MPB system is simpler than the transmission of the 6 kilohertz modulating frequency band with a carrier frequency of 78 kilohertz over a nonuniform, branched wire broadcast network in the Soviet TPB system, in spite of the closeness of the ratios f_B/f_H for the given cases.

As is known, increasing the difference in the transmission conditions of the upper and lower side frequencies corresponding to one modulating frequency leads to an increase in the nonlinear distortions of this modulating frequency on reception.

The limitation of the actual frequency band for the MPB in the upper part is caused by the greater damping of the WB lines in this frequency band and the nature of the appearance of mutual inferference with the radio broadcast long-wave bands.

On the whole, the use of the possible frequency band with a frequency of f_{max}=140 kilohertz and f_{min}=30 kilohertz for the ratio of $f_{max}/f_{min}=4.7$ presents significant difficulties from the point of view of insuring the optimal transition conditions for all the MPB programs. As an example it is necessary to note that the ratio f_{max}/f_{min} in the Italian MPB system on transmission of six programs is $f_{max}/f_{min}=358/163=2.2$; in the Swiss system with this number of programs, with the reproducible frequency band of 10 kilohertz, $f_{max}/f_{min}=350/165=2.12$ respectively, at the same time as in the adopted Soviet TPB system for two programs transmitted on the high-frequency spectrum and the reproducible band of 6 kilohertz, this ratio is 126/72=1.75.

Thus, the presented arguments indicate the necessity for constricting the frequency band for transmission of MPB programs and conversion of it to the upper part (to 120-130 kilohertz.

On the other hand the requirements following from the necessity of creating a simple, inexpensive subscriber receiver lead to somewhat different conclusions. The complexity, cost (C) of the receiver are related in a defined way to its input parameters:

$$C = \varphi\left(\frac{\overset{(1)}{Z_{\text{вх}}}}{\underset{(2)}{U_{0\text{вх}}}}, \frac{f_{01}}{f_{02}}, \frac{U_{01}}{U_{02}}\right), \qquad (2.3)$$

Key: 1. input; 2. 0 input

where Z_{input} is the modulus of the input impedance of the receiver; $U_{0\ inp}$ is the sensitivity of the receiver; f_{01}, f_{02} are the carrier frequencies of two adjacent programs (here $f_{01}<f_{02}$); U_{01}, U_{02} are the input voltages of the carrier frequencies.

The ratio $Z_{inp}/U_{0\ inp}$ characterizes the required input power and determines the required number of repeating stages; the ratio f_{01}/f_{02} characterizes the carrier frequency difference and determines the complexity of the frequency-selective devices of the receiver; the ratio U_{01}/U_{02} characterizes the inequality of the input voltages of the carrier frequencies and also defines the requirements on the selective devices.

Thus, beginning with the frequency ratios for simplicity of the receiver it is necessary to have as large a separation of the received carrier frequencies as possible, which naturally simplifies the selective system of the receiver and leads to the possibility of the application of the direct repeating receiver with simple filters.

The separation of the carrier frequencies is to a great extent, if not basically, the defining factor when designing various frequency devices installed on the WB network when building the high-frequency channels. When solving the problem of the separation of high-frequency channels, the greatest separation of the carrier frequencies is desirable.

It is also necessary to consider that the individual sections in the 30-150 kilohertz frequency band are used for special services. Beginning with the indicated arguments, the placement of two programs in the high-frequency band is in practice possible. Here versions with carrier frequencies of 80 and 130 kilohertz were tested; then, 46 and 78 kilohertz and, finally, for the existing TPB system, carrier frequencies of 78 and 120 kilohertz were adopted.

When selecting the form of modulation for transmission of additional programs, the complexity of the subscriber receiver, the width of the frequency band occupied by each program, the noiseproofness of the high-frequency channels and also the possibility of the simplest reception of the TPB programs on the existing radio broadcast receivers are considered.

The use of frequency modulation, as the performed research demonstrated, turned out to be unrealistic in view of the significant complexity of the receiver, the requirement of a wide transmitted frequency band (60 kilohertz) when it is necessary to obtain sufficient noiseproofness from the low-frequency channel.

The application of the single-band modulation without the carrier frequency makes it possible to cut the band of transmitted frequencies of each channel approximately in half, which insures the possibility of increasing the number of transmitted programs, it increases the noiseproofness with respect to the low-frequency channel, but in this case a quite complex receiver is required.

The use of the radio broadcast receivers for receiving TPB programs in the case of the transmission of FM signals or single-band modulation requires the creation of additional complex receiving attachments.

Therefore, the most acceptable which is indicated also by foreign MPB experience is the use of amplitude modulation permitting the simplest receiver to be obtained.

The adopted frequency spectrum of the TPB system is provisionally presented in Fig 2.6.

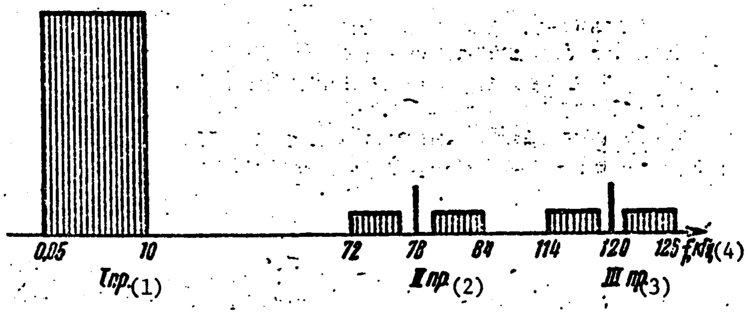


Figure 2.6. Normalized spectrum of the TPB system signals

Key:

1. Program I
2. Program II
3. Program III
4. f, kilohertz

2.5. Determination of the Initial Voltages of High-Frequency Signals in the WB Channel

The high-frequency signal voltages in the WB channel are determined beginning with the following arguments:

1) Obtaining sufficient noiseproofness of the TPB receivers with respect to airwave noise of the radio broadcast stations, industrial and atmospheric noise;

2) The creation of the simplest receiver with the least number of repeating stages;

3) The exclusion of interference from the carrier frequencies of the MPB system and their harmonics by radio broadcast receivers and communications services.

4) The creation of the transmitter with relatively small output power for convenience of its operation in connection to the lines.

As is obvious from the presented arguments, the first two are opposite to the next two, for the necessity of increasing the high-frequency signal levels follows from the first two arguments, and the necessity for lowering them, from the last two.

As measurements of airwave interference on the WB networks demonstrated, in order to obtain sufficient noiseproofness with respect to the high-frequency channels (more than 50 decibels) it is necessary to insure carrier frequency voltages on the order of hundreds of millivolts at the subscriber point. In the experimental MPB system developed by the LONIIS Institute, a voltage of 100 millivolts of carrier frequencies of 80 and 130 kilohertz has been set as the standard at the subscriber point. However, for reception of high-frequency programs, either a radio broadcast receiver with an attachment or a complex special tube receiver was used.

The studies of the city industrial interference in the frequency band to 150 kilohertz performed on introducing the TPB system (1966) demonstrated that with minimum normalized voltage of the high-frequency signal at the subscriber point of 0.25 volts, the protective signal/noise ratio equals 50 decibels at the input of the receivers is insured under the worst conditions (intensive simultaneous use of different electrical devices) with a reliability of 0.97-0.98.

When the NIIR Institute developed the MPB system with carrier frequencies of 46 and 78 kilohertz (1958-1959), for simplification and reduction of cost of the receiving attachment for the single-program loudspeaker, a study was made of the increase in carrier frequency voltage at the input of the receiver to 1.7-1.5 volts. Here the circuitry of the receiver was reduced to filters, a detector and output stage. However, the high-frequency signal levels on the WB networks turned out to be interfering with high-quality radio broadcast reception. With a final choice of carrier frequencies of 78 and 120 kilohertz for the TPB system, a receiver sensitivity of 0.25 volts was assumed insuring electromagnetic compatibility of the TPB system with radio broadcasting in the long-wave and medium-wave bands.

As was demonstrated in Section 2.4, the cost of the receiver C increases with a decrease in the rated input voltage of the carrier frequencies $U_{0\ inp}$.

It is necessary to assume that for any rated carrier frequency voltage the subscriber receiver is found to be relatively complex with respect to number of parts and production process.

The schematic of the existing subscriber receivers must contain input filters, adjustable controls, high-frequency repeater stage, operative control, preliminary and output low-frequency repeater stages and a rectifier.

The interference in the radio broadcast receivers from the AM signals of the TPB system occurs as a result of the fact that the carrier frequency harmonics fall directly in the frequency spectrum of radio broadcast stations, close to it or as a result of reception of the carrier frequencies of the high-frequency signals themselves by radio broadcast receivers by conversion of these carrier frequencies with high levels in the input nonlinear elements to the frequencies of the received long-wave and middle-wave bands or as a result of cross modulation with the carrier frequencies of the radio broadcast stations (attachments have been proposed for the radio broadcast receivers to receive the TPB programs operating on the basis of isolation of the carrier frequency harmonics of the high-frequency signals by nonlinear elements and their reception in the long-wave band of the radio broadcast receivers).

As the studies have demonstrated, the basic danger of having a negative effect on the noiseproofness of the reception of the radio broadcast stations as a result of the high-frequency TPB signals basically is determined by the levels of the second and third harmonics of the carrier frequencies at 78 and 120 kilohertz in the TPB channel. The frequencies of 78 and 120 kilohertz even with maximum voltages of 120 volts (in the main feeder) and 30 volts (in the distributing feeder) are not received directly by the radio broadcast receivers either as a result of the possible insufficient selectivity of the input circuits or by conversions of the carrier frequencies in the nonlinear elements of the input circuit.

The field intensity of the carrier frequencies on going away from the main feeder line quickly decreases (Fig 2.7) for 80% of the performed measurements. The radiation of the distributing feeder lines is appreciably lower [17].

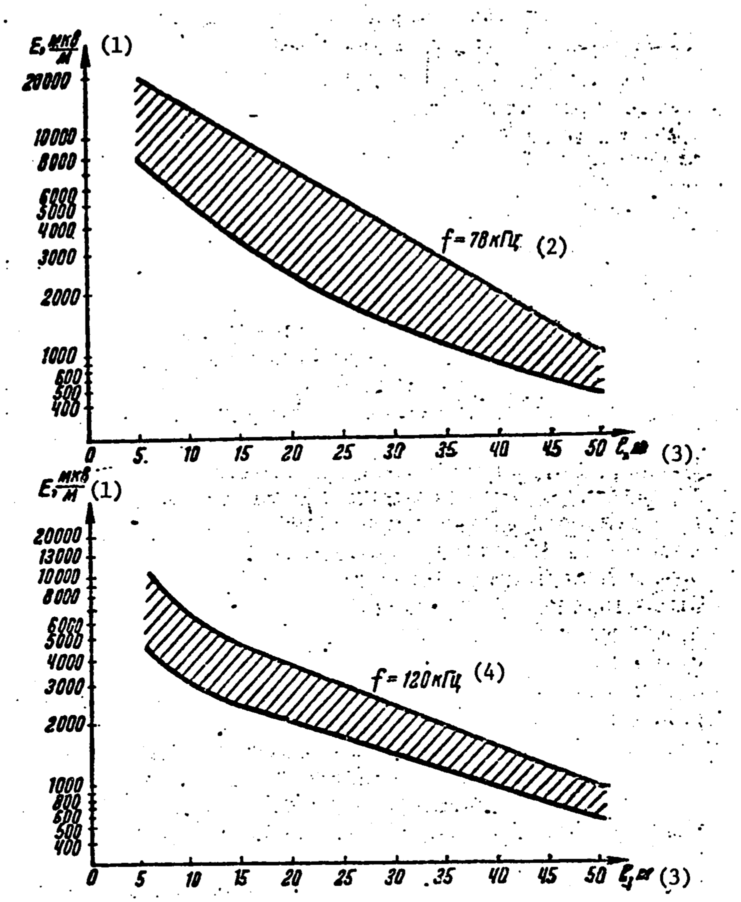


Figure 2.7. Dependence of the field intensity E of the carrier frequencies 78 and 120 kilohertz on the distance ℓ to the main feeder line

Key:
1. E, microvolts/m
2. f=78 kilohertz
3. ℓ, m
4. f=120 kilohertz

The radiation on the carrier frequencies can create interference with the long distance overhead communications line multiplexed by the V-12 system (occupying the frequency band from 36 to 143 kilohertz). The minimum admissible distances between the lines of the V-12 system and the TPB system for the worst case of a length of parallel run of ℓ=0.5λ and a protection norm for the channel of 46.9 decibels are presented in Table 2.3.

Table 2.3

Maximum voltage at the line input, volts	120	90	60	30
Minimum admissible distance between lines, meters	118	104	88	70

The measurements of the effect of the TPB networks on the long distance cable communications lines performed in Moscow, Riga and other cities demonstrated that the TPB system does not create interference on these communication lines.

Thus, it is possible to consider the presence of maximum carrier frequency voltages in the WB channel on the order of 120 volts possible beginning with the necessity for obtaining sufficient noiseproofness of the radio broadcast receivers and communication services directly from the carrier frequencies of 78 and 120 kilohertz or their harmonics.

It is necessary to keep in mind that with an increase in the maximum voltages of the carrier frequencies, the requirements on reducing the level of their harmonics increase. This causes the necessity for introducing the additional filters suppressing the harmonics in the transmitter or in the device for connecting the transmitters, for the interference from the TPB system basically is determined by the level of carrier frequency harmonics of the transmitter.

It is necessary also to be considered that the output voltage of the carrier frequency of the transmitter (maximum voltage in the WB channel) defines the output power and, consequently, the design complexity of the output stage, the sources of its feed, the output connection circuits for the transmitters.

On the other hand, the higher voltage would permit simplification of the circuitry of the subscriber receivers.

However, the increase in carrier frequency voltages at the WB station located at signficant distance from its subscriber (several kilometers) with large attenuations of the carrier frequency voltages in the WB channel has low efficiency in view of the fact that the basic part of the transmitter power is lost in the lines.

A more expedient solution is the maximum approximation of the powerful high-frequency signal repeaters to the receivers, for example, by installing the TPB transmitters or modulated oscillation repeaters at the transformer substations. Already on the modern level of engineering it is possible to build such devices from transistors.

In this case the maximum required power and voltage of the high-frequency signal sources is reduced while maintaining or increasing voltages of the high-frequency signal at the subscriber points.

However, during the development of the TPB system the powerful high-frequency transistors for mass application have not been produced, and the tube repeaters at the transformer substations would not insure sufficient reliability of the high-frequency channels.

Considering what has been discussed above, the structure of the high-frequency channels was selected analogous to the structure of the low-frequency channels; the maximum carrier frequency voltage was established at 120 volts at the beginning of the channel, and the minimum was established at 0.25 volts at the end (at the subscriber rosette).

2.6. Structure of the High-Frequency Channels of a TPB System

The structure of high-frequency channels of the TPB system determines the entire set of devices required to realize transmission and reception of high-frequency signals.

The basic factors determining the structure of the high-frequency channels are the structure of the single program WB network and the characteristics of the residential areas serviced by the system (the administrative buildings, the common necessities, hospitals, residential buildings -- large or small apartment complexes, their mutual placement within the city).

It is possible to separate the entire high-frequency channel with respect to functional attributes into three component parts: station, line and receiver.

The purpose of the station part of the channel is conversion of the low-frequency signals of the broadcast programs to AM signals of given power; the purpose of the line part of the channels is passive transmission of the high-frequency signals with minimum distortions and with given levels to the receivers; the receiving part deals with selecting the programs and conversion of the AM signals to low-frequency signals. The channels for transmitting two auxiliary programs are identical.

2.7. Structure of the Station Part of the High-Frequency Channel

The station part of the high-frequency channel contains the device for converting the low-frequency signals to high-frequency signals, the modulated oscillation power repeater and the device for connecting it to the line part of the channel. This breakdown of the station part of the high-frequency channel, independently of the location of the converting and repeating devices for the high-frequency signals, is based on the fact that this set of devices remains in essence the same, and is only structurally set up in the form of a united powerful transmitter or in the form of a low-power converter located at one station site and a powerful modulated oscillation repeater at the other station site joined together by a line. Here, as a rule, the requirements with respect to the electrical parameters (the power, the quality indexes) imposed on this set of devices are united independently of the territorial location of the component circuits of the complex.

The structure of the WB network determines the structure of the station part of the TPB system channel.

Let us consider the various versions of joint or separate location of the converters and repeaters at the station sites of the WB system.

With the centralized WB network, the station part of the high-frequency channel has a unique solution in which the high-frequency signal transmitters Π_2 and Π_3 are installed at the wire broadcast station, and the station part of the channel corresponding begins with the output of the transmitter and ends with the output of the transmitter connection circuit (Fig 2.8).

With a decentralized wire broadcast network with two-element distribution network two versions of the station part of the high-frequency channel are possible. In the first version (Fig 2.9), in addition to the equipment for the APU low-frequency channel, low-power transmitters Π_2 and Π_3 (generator-modulators) are installed at the central wire broadcast station, and the low-frequency and high-frequency signals are fed over a single connecting line to the repeater station at which final power repeating of the high-frequency signals is accomplished by the modulator oscillation repeaters with further transmission of them through the repeater connection circuit to the two-element WB network. Here the repeating of the high-frequency signals can be joint (wide-band) or separate (channel). As TPB practice has demonstrated, the most efficient is the channel repeating with the necessity of obtaining significant output power (several watts, tens of watts). In order to obtain separate repeating of the low-frequency and high-frequency signals without worsening of the noiseproofness of each channel at the input of the low-frequency repeater a low-frequency filter is included, and at the input of the modulated oscillation repeater, band filters. The repeater connection circuit is analogous with respect to its functions to the circuitry of the transmitter connecting circuit.

In the second version of the construction of the station part of the high-frequency channel (Fig 2.10) powerful transmitters Π_2 and Π_3 enter into the composition of the repeater station, and the low-frequency signals of all the programs are fed separately from the central station over the connecting line to the low-frequency repeater and the transmitters. In this case the station part of the channel corresponds completely to the version shown in Fig 2.8.

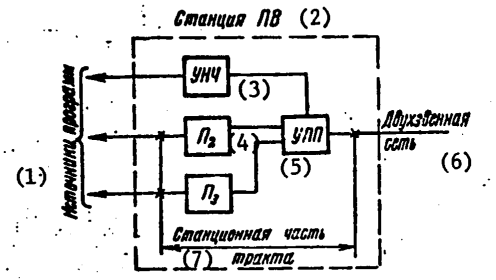


Figure 2.8. Construction of the station part of the channel for the centralized wire broadcast network

Key:

1. Program source
2. WB station
3. Low-frequency repeater
4. Transmitter
5. Transmitter connecting circuit
6. Two-element network
7. Station part of the channel

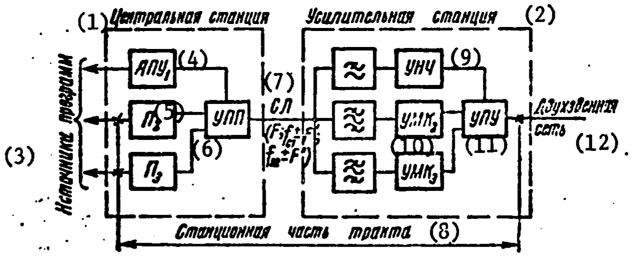


Figure 2.9. First version of constructing the station part of the channel for a decentralized wire broadcast network

Key:

1. Central station
2. Repeater station
3. Program source
4. APU_1
5. Transmitter
6. Transmitter connecting circuit
7. Connecting line
8. Station part of the channel
9. Low-frequency repeater
10. Modulated oscillation repeater
11. Repeater connection circuit
12. Two-element network

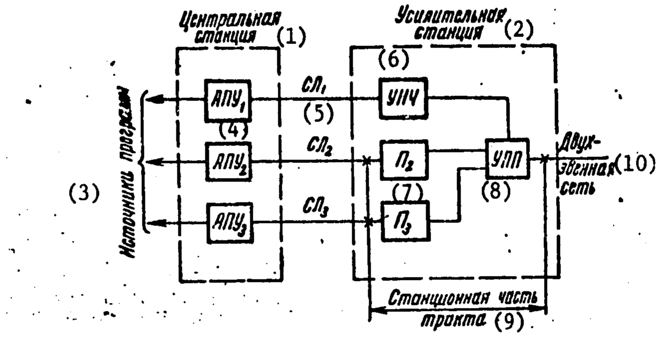


Figure 2.10. Second version of the construction of the station part of the channel for a decentralized network

Key:

1. Centralized station	6. Low-frequency repeater
2. Repeater station	7. Transmitter
3. Program sources	8. Transmitter connecting circuit
4. APU	9. Station part of the channel
5. Connecting line	10. Two-element network

In the given version in the central station the low-frequency signals of each program are shaped by means of the repeaters of the APU$_1$, APU$_2$ and APU$_3$ equipment, and the signals are fed over the connecting lines sℓ_1, sℓ_2, sℓ_3 to the repeater stations. The basic difference between the last two versions from the point of view of using the initial wire broadcast means consists in the fact that in the first version (Fig 2.9) theoretically one connecting line is required to feed all of the programs from the central station to the repeater stations at the same time as in the second version the minimum number of these lines must be equal to the number of transmitted programs. With respect to the set of devices entering into the composition of the central and repeater stations, the first version is also more preferable. The low-power transmitters Π_1 and Π_2 at the central station are no more complicated, if not simpler, than the low-frequency repeaters of the APU$_2$ and APU$_3$, and the repeaters of the UMK$_2$ [modulated oscillation repeater] and UMK$_3$ together with the input band filters are essentially simpler than the powerful transmitters Π_1 and Π_2 at the repeater station in view of the fact that the same modulated oscillation repeaters enter into the composition of the transmitters Π_1 and Π_2 (Fig 2.10), but the input band filters are much simpler than all the preliminary generators, repeaters and converters. The advantage of the first version is the presence of one transmitter with given carrier frequency for the entire city. This fact makes it possible to exclude the possible beats between the carrier frequencies in the presence of one city of several like transmitters as a result of deviations of the carrier frequencies and the presence of spurious couplings between the WB lines. In addition, the formation of the AM signals at one point, in the central station, is justified by insuring higher quality indexes and realization of stricter monitoring of the AM signal.

The possibilities of using the first or second version of the construction of the station part of the high-frequency channel for the decentralized WB system are determined by the characteristics of the connecting lines, and namely, by the attenuation and the crosstalk attenuation of these lines and also the presence in adjacent lines of signals falling in the frequency spectrum of the TPB signals transmitted over the connecting lines. In this sense the transmission of the signals from the central station to the repeater stations in the initial low-frequency spectrum is more available and checked out, for the attenuation of the telephone pairs leased for the program transmission line (the connecting lines) in the low-frequency spectrum is significantly lower, and the crosstalk attenuation in the spectrum is appreciably higher than the analogous characteristics in the high-frequency spectrum. The application of the high-frequency KRR and PCM systems on interstation communication lines of the city telephone exchanges in a number of cases complicates the use of the connecting lines for transmitting the high-frequency TPB signals.

The basic station sites of the decentralized WB network with a three-element network are the central station, the reference repeater stations and the transformer substations. The lines connecting these sites are as follows: the connecting lines between the central and reference stations; the connecting lines between the central station and the transformer substation; the main feeder lines between the reference stations and the transformer substations.

The large number of station sites and lines between them determine the larger number of versions of constructing the TPB system. However, the principle of the construction of these versions is the same as for the decentralized network with two-element network, and it consists in separate or joint use of the transforming and terminal repeaters of the station part of the channel. In the presented four in practice possible versions of constructing the high-frequency channel, in two cases the high-frequency signals of the required power are created at the reference repeater station (Fig 2.11 and 2.12) and in two versions, at the transformer substations (Fig 2.13 and 2.14).

The first two versions of the construction of the station part of the high-frequency channel for the decentralized network with three-element network (Fig 2.11 and 2.12) are completely analogous to the corresponding versions of the decentralized network with two-element network (Figures 2.9 and 2.10). The difference consists only in the fact that instead of the distributing feeder lines, main feeder lines are connected to the output of the repeater station. In these two versions the transformer substation performs the function of a passive transmission through channel for low-frequency and high-frequency signals from the main feeder line to the distributing feeder lines. In accordance with this purpose the transformer substation must solve the problem of matching the wave impedance of the main feeder line to the input impedance of the network of distributing

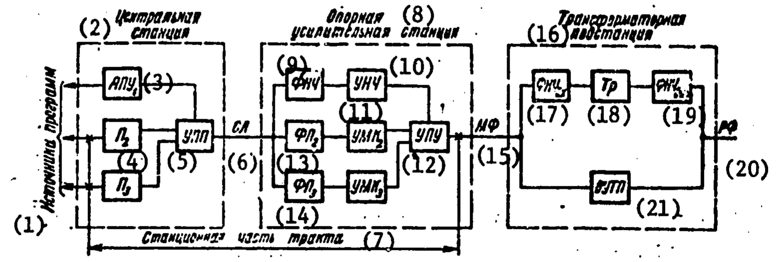


Figure 2.11. Structure of the station part of the channel with transmitters at the central station and repeaters at the reference repeater stations

Key:

1. Program sources
2. Central station
3. APU
4. Transmitter
5. Transmitter connecting circuit
6. Connecting line
7. Station part of the channel
8. Reference repeater station
9. Low-frequency filter
10. Low-frequency repeater
11. Modulated oscillation repeater
12. Repeater connection circuit
13. Band filter$_2$
14. Band filter$_3$
15. Main feeder
16. Transformer substation
17. Low-frequency filter$_{inp}$
18. Transformer
19. Low-frequency filter$_{out}$
20. Distributing feeder
21. Transformer substation bypass

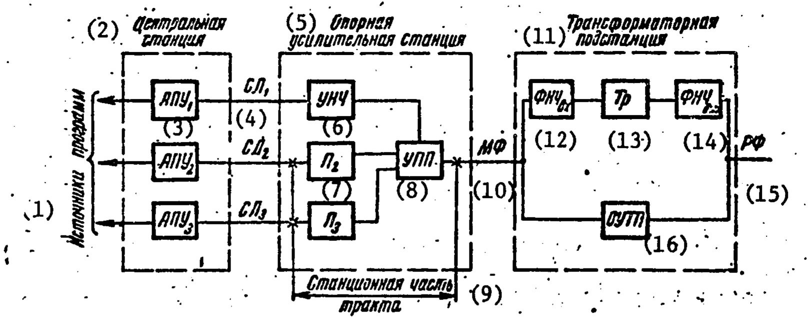


Figure 2.12. Structure of the station part of the channel for the three-element network of powerful transmitters at the reference repeater station

Key: 1 -- Program sources; 2 -- Central station; 3 -- APU; 4 -- connecting line; 5 -- Reference repeater station; 6 -- low-frequency filter; 7 -- transmitter; 8 -- transmitter connecting circuit; 9 -- station part of the channel; 10 -- main feeder; 11 -- transformer substation; 12 -- low-frequency filter$_{inp}$; 13 -- transformer; 14 -- low-frequency filter$_{out}$; 15 -- distributing feeder; 16 -- transformer substation bypass

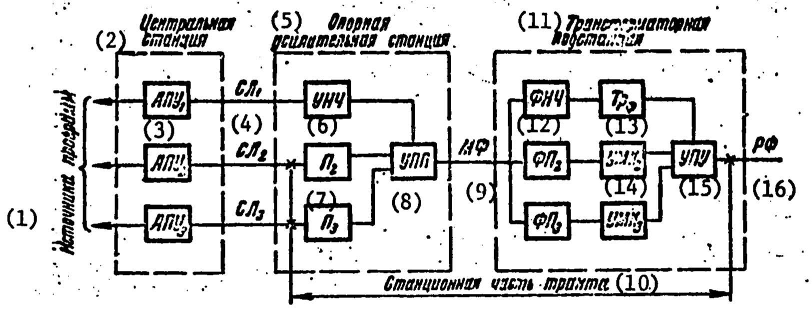


Figure 2.13. Structure of the station part of the channel with low-power transmitters at the reference repeater stations and repeaters at the transformer substations

Key:

1 -- Program sources; 2 -- central station; 3 -- APU; 4 -- connecting line; 5 -- reference repeater station; 6 -- low-frequency repeater; 7 -- transmitter; 8 -- transmitter connecting circuit; 9 -- main feeder; 10 -- station part of the channel; 11 -- transformer substation; 12 -- low-frequency repeater; 13 -- transformer; 14 -- modulated oscillation repeater; 15 -- repeater connecting circuit; 16 -- distributing feeder; 17 -- band filters

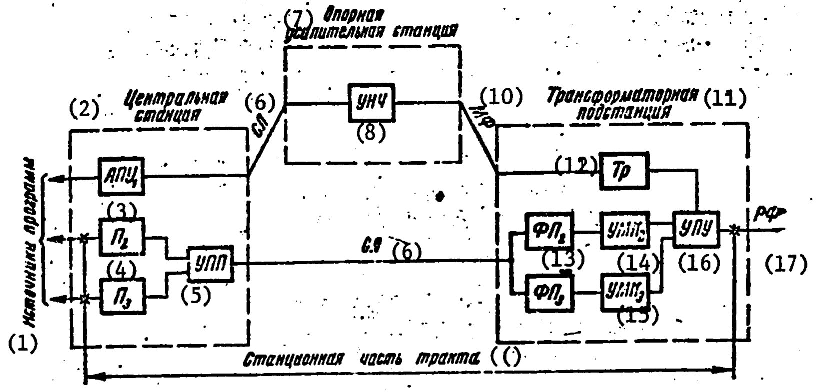


Figure 2.14. Structure of the station part of the channel with transmitters at the central station and repeaters at the transformer substation

Key:

1 -- Program sources; 2 -- central station; 3 -- APU; 4 -- transmitter; 5 -- transmitter connecting circuit; 6 -- connecting line; 7 -- reference repeater station; 8 -- low-frequency repeater; 9 -- station part of the channel; 10 -- main feeder; 11 -- transformer substation; 12 -- transformer; 13 -- band filter; 14 -- UMK_2 - modulated oscillation repeater; 15 -- UMK_3 -- modulated oscillation repeater; 16 -- repeater connection circuit; 17 -- distributing feeder

feeder lines with respect to the high-frequency signals. This matching is done by bypassing the low-frequency transformer with respect to high-frequency signals by the OUTP [transformer substation bypass] bypass, which is a high-frequency filter with matching transformer. In order to prevent shunting by the transformer of the high-frequency signals, low-frequency filters (FNCh_{inp} and FNCh_{out}) are connected on its input and output sides with high input impedance with respect to high-frequency signals.

In these two versions, the main feeder line and the transformer substation bypass have the mission of transmitting the power and the quality indexes of the AM signals from the repeater station to the distributing feeder lines with the least losses. Therefore, use of the given versions will be preferable in the presence of uniform main feeder lines with low attenuation and distributing feeder lines with low scattering of the values of the attenuation. However, under actual conditions of the majority of city WB networks the indicated requirements, as a rule, are not satisfied. This is entirely natural inasmuch as the initial WB network does not impose such rigid requirements on the given parts of the channel with respect to transmission of low-frequencies, for neither the number of cable inserts in the main feeder line or the number of distributing feeder lines connected to the transformer subsystem within the limits of the norm (no more than 10) distributing feeders) do not have significant influence on the power transmission and the quality indexes of the low-frequency signals. On transmitting high-frequency signals the attenuation in the main feeder increases, the cable inserts require processing either by compensation for their capacitance or by matching their wave impedance with the wave impedance of the overhead sections of the main feeder which, however, is accompanied by some power losses of the high-frequency signals in these compensation and matching circuits. The fluctuation of the number of distributing feeder lines connected to the transformer substation and, consequently, fluctuation of their total input impedance does not permit us to obtain complete matching of the main feeder with the input impedance of the transformer substation for high-frequency signals in all cases of the transformer substation load. The absence of complete matching of the main feeder to the input impedance of the transformer substation leads to an increase in power losses on transmission.

The efficiency $\eta_{\text{RRS-TS}}$ of the transmitter output (or modulated oscillation repeater at the reference repeater station)-transformer substation output channel is defined by the expression

$$\underset{(1)}{\eta_{\text{ОУС–ТП}}} = \underset{(2)}{\eta_{\text{УПП}}}\,\underset{(3)}{\eta_{\text{МФ}}}\,\underset{(4)}{\eta_{\text{УПТП}}}, \tag{2.4}$$

Key:

1. reference repeater station-transformer substation [RRS-TS]
2. transmitter connection circuit
3. main feeder
4. transformer substation connection circuit

where $\eta_{\text{УПП}}$, $\eta_{\text{МФ}}$, $\eta_{\text{УПТП}}$ are the efficiencies of the transmitter connection circuit (or the repeater connection circuit), the magin feeder line and the transformer substation connection circuit respectively.

For real values of $\eta_{\text{transmitter connection circuit}}$ and $\eta_{\text{transformer substation connection circuit}}$ equal to 0.7 and for attenuation in the main feeder made of bimetal equal to 1 decibel, $\eta_{\text{RRS-TS}}=0.4$, and for the average length with attenuation of 4 decibels, $\eta_{\text{RRS-TS}}=0.2$.

In the presence of cable inserts with matching circuits and compensation circuits the efficiency of this channel will be

$$\underset{(1)}{\eta_{\text{РУС-ТП}}} = \underset{(2)}{\eta_{\text{УПП}}}\,\underset{(3)}{\eta_{\text{МФ}}}\,\underset{(4)}{\eta_{\text{СУ}}^{n}}\,\underset{(5)}{\eta_{\text{КУ}}^{m}}\,\underset{(6)}{\eta_{\text{КВ}}^{p}}\,\underset{(7)}{\eta_{\text{УПТП}}}, \tag{2.5}$$

Key: 1. RSS-TS; 2. TCC; 3. MF; 4. MC; 5. CC; 6. CI; 7. TSCC

where $\eta_{\text{СУ}}$, $\eta_{\text{КУ}}$, $\eta_{\text{КВ}}$ are the efficiencies of the matching circuit, compensator circuit and cable inserts; n is the number of matching circuits; m is the number of compensating circuits; p is the number of cable inserts.

Under these conditions $\eta_{\text{RRS-TS}}$ reaches a value of 0.1. Thus, under actual conditions the main feeders with transformer substations do not provide for the transmission of high-frequency signal power without significant losses as occurs in the three-element network for the low-frequency channel; a significant part of the power is lost in this channel. The quality indexes of this channel also undergo changes in connection with the fact that in practice there is no possibility for complete matching of the main feeder with the input impedance of the transformer substation in the entire band of modulated frequencies of the AM signal for two programs with fluctuations of the load resistance of the transformer substation with respect to modulus and angle. The relations presented in Figures 2.15-2.18 for the input impedance of the transformer substation Z_{inp}, its phase angle and ratio of the output-input voltages of the transformer substation, U_{II}/U_{I} for the carrier frequencies 78 and 120 kilohertz with different load resistance clearly indicates the impossibility of obtaining a matched operating condition for the main feeder with transformer substation for given limited frequency conditions (only for carrier frequencies) with possible fluctuations of Z_{load} within the limits of 50-100 ohms. Judging by the presented juxtaposed functions Z_{inp} (Z_{load}) for the carrier frequencies of 78 and 120 kilohertz, this opposite nature is maintained for side bands of $f_0 \pm F$ of the AM signal, which complicates the matching and obtaining of equality of the conditions for transmission of the side frequencies of the AM signal, especially with an increase in the modulating frequency F.

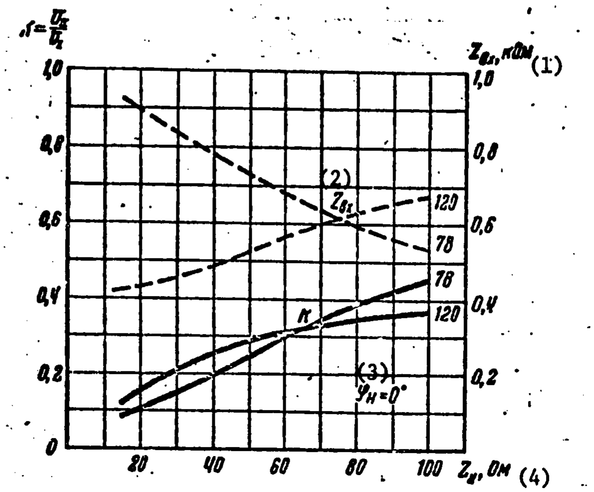


Figure 2.15. Transmission coefficient K and input impedance Z_{inp} of the transformer substation bypass as a function of the load impedance Z_{load} (active load)

Key:

1 -- Z_{inp}, kilohms; 2 -- Z_{inp}; 3 -- ϕ_{load}; 4 -- Z_{load}, ohms

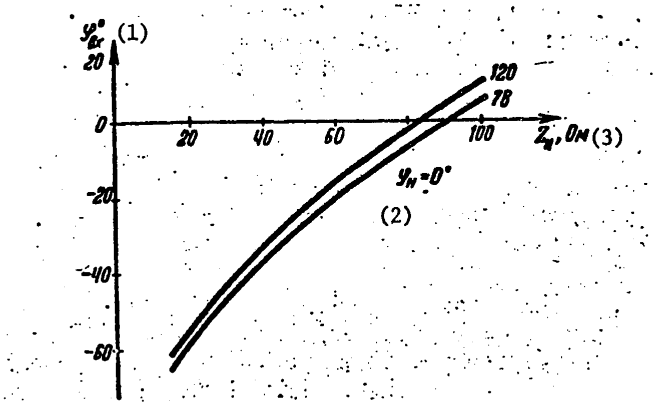


Figure 2.16. Phase angle ϕ_{inp} of the input impedance of the transformer substation bypass as a function of the load resistance Z_{load} (active load)

Key:

1 -- ϕ_{inp}; 2 -- ϕ_{load}; 3 -- Z_{load}, ohms

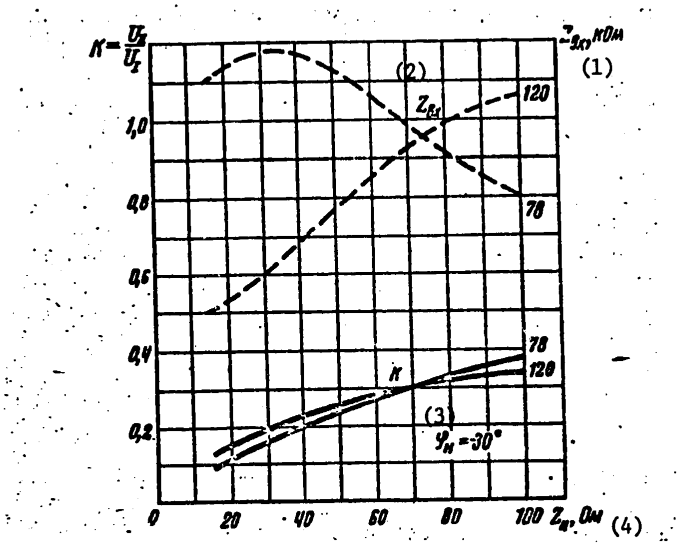


Figure 2.17. K and Z_{inp} of the transformer substation bypass as a function of Z_{load} (complex load)

Key:

1 -- Z_{inp}, kilohms; 2 -- Z_{inp}; 3 -- ϕ_{load}; 4 -- Z_{load}, ohms

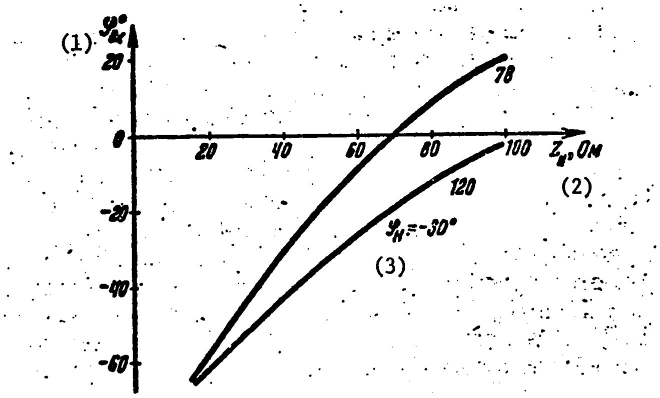


Figure 2.18. ϕ_{inp} input impedance of the transformer substation bypass as a function of Z_{load} (complex load)

Key:

1 -- ϕ_{inp}; 2 -- Z_{load}, ohms; 3 -- ϕ_{load}

The difference in the conditions of transmission of the side frequencies leads to nonlinear distortions of the envelope of the AM signal and, consequently, to nonlinear distortions of their detection.

The frequency distortions of the side frequencies of the AM signal (the steep slope of the side frequencies with respect to carrier frequency) lead to the appearance of frequency distortions of the low-frequency signal (steep slope of the high sonic frequencies). The cable inserts of the main feeder with the processing devices unavoidably introduce frequency and phase distortions of the AM signal, for complete matching or compensation in the entire frequency band of the AM signal are in practice unobtainable.

Thus, under actual conditions the passive section of the MF-TS channel with respect to high-frequency signals does not correspond to the important requirement of the WB network -- maximum power transmission with minimum distortions of the quality indexes of the signal. Under such conditions it is difficult to obtain high quality class indexes. Therefore, in spite of the structural simplicity of the investigated versions expressed by a small number of powerful high-frequency signal devices (the modulated oscillation repeaters or transmitters) located at the reference repeater station, other possible versions of the structure of the station part of the channel deserve investigation within the framework of the station sites of wire broadcasting it to insure the subscribers the guaranteed high-frequency signal level and more stable and higher quality indexes. As an example of this structure we have the versions of location of the terminal powerful modulated oscillation repeaters at the transformer substations (Fig 2.13 and 2.14).

In the version in Fig 2.13, low-power high-frequency signal converters $П_2$ and $П_3$ are installed at the repeater station which are connected to the main feeder by means of the transmitter connecting circuit. The AM signals of each program are isolated by means of the band filters ФП2 and ФП3, and they are amplified by the modulated oscillation repeaters $УМК_2$ and $УМК_3$. The low-frequency and high-frequency signals are combined by means of the repeater connecting circuit УПУ. The low-frequency channel contains a low-frequency filter at the transformer input, the basic purpose of which is elimination of the feedback between the output and input of the УМК modulated oscillation repeaters. In the given version of the construction of the station part of the high-frequency channel the main feeder is for the two programs a continuation of the program feed channel except that these programs are transmitted in the form of high-frequency AM signals. Therefore, strict requirements with respect to attenuation, frequency-amplitude and phase distortions in the AM signal band are not imposed on the main feeder, for these parameters are compensated for by the УМК modulated oscillation repeaters and can be corrected by the frequency correctors. The condition of the load at the transformer substation with respect to high-frequency signals has no effect on the operating conditions of the main feeder. The main feeder line can operate in a number of cases without complex, labor-consuming processing of the cable inserts by the compensating and matching circuits. This processing is required only in the extreme cases where the high-frequency circuits of the transformer substation cannot completely eliminate the attenuation of the main feeder and correct the distortions. In the case of redundancy the transformer substation on the main feeder side to exclude possible difference between high-frequency signal levels and the frequency-amplitude characteristics of one high-frequency channel on making the transition from one main feeder to the other, correctors and regulators are introduced into each high-frequency channel to correct the frequency distortion and establish a united output level for each main feeder. The structure of the high-frequency channels of the transformer substations for this case is illustrated in Fig 2.19. The switches Π_1-Π_5 are connected with the existing automation of the transformer substation connecting them to one main feeder or the other, and certain correctors K_{2-1} or K_{2-2} of one high-frequency channel and K_{3-1} or K_{3-2} of the other high-frequency channel are connected correspondingly. The level regulators P_{2-1}-P_{2-2}, P_{3-1}-P_{3-2} insuring united operating conditions with each main feeder after one time correction and adjustment of the high-frequency channels of the transformer substation are switched analogously. Independence of the operating condition of the main feeder with respect to the transformer substation load in this version permits achievement of greater operation conditions of the distributing feeder lines. Inasmuch as the distributing feeders have large fluctuations with respect to attenuation of high-frequency signals, from 1 to 24 decibels, for more efficient level distribution of the high-frequency signals between the distributing feeder and reduction of the required power of the YMK repeaters, the distributing feeders can be grouped with respect to magnitude of attenuation, for example, groups with attenuation of 0-9 decibels, 5 distributing feeders; 9-18 decibels, 4 distributing feeders, 18-24 decibels, 1 distributing feeder. These groups are created by using the repeater connection circuits $Y\Pi Y_1$, $Y\Pi Y_2$, $Y\Pi Y_3$ (Fig 2.19) with different transformation coefficients. This permits equalizing the high-frequency signal levels in the distribution network as a result of lowering the number of distributing feeders with maximum input levels which, in turn, decreases the level gradient of the high-frequency signals between the different TPB subscriber points. Nevertheless, the possibility of feeding a higher level to some of the distributing feeders with large attenuation insures longer range with respect to high-frequency signals in many cases without the application of intermediate repeaters at the distributing feeder. The latter fact takes on decisive significance for organizing TPB in populated areas adjacent to a city and receiving low-frequency programs from the city. On the whole, the reduction in the high-frequency signal levels in the main feeder (in the basic feeder) and a large number of distributing feeders decreases the possibility of interference from the high-frequency signals in the radio broadcast reception.

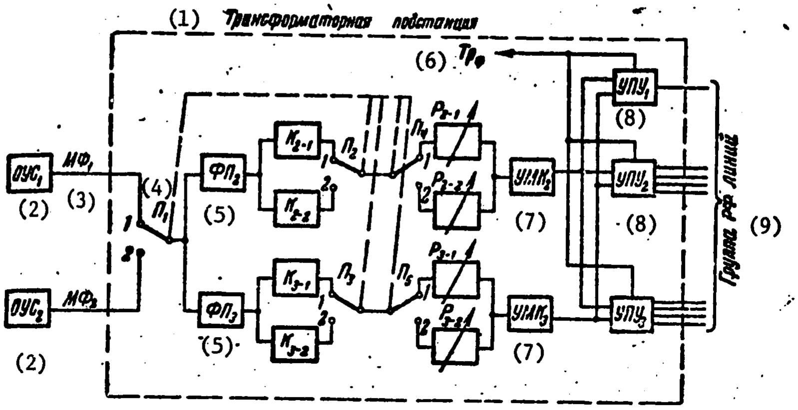


Figure 2.19. Structure of the high-frequency channels of the transformer substation with repeaters for main feed redundancy

Key:

1. Transformer substation
2. Reference repeater station
3. Main feeder
4. Switch
5. Band filter
6. Transformer
7. Modulated oscillation repeater
8. Repeater connecting circuit
9. Group of distributing feeder lines

In the version of construction of the station part of the channel with the modulated oscillation repeaters of the transformer substation (Fig 2.14), the connecting line between the central WB station and the transformer substation is used as the high-frequency program feed channel. The low-frequency and high-frequency channels are independent of each other up to the transformer substation exit. Here the possibility of the appearance of mutual interference between the low-frequency and high-frequency channels is excluded in the section from the central wire broadcast station to the transformer substation; the structure of the repeater station is simplified. The presence of this high-frequency signal feed line will permit double reduction in the number of correctors and regulators as opposed to the circuit in Fig 2.19. The circuits for connecting the repeaters YПY play the same role as in Fig 2.19. In spite of the possible large attenuation of the high-frequency signals in the connecting lines which are low-frequency telephone cables, the realization of this version is possible, for the high-frequency channel of the transformer substation not connected with respect to input to the low-frequency channel will permit us to gain a sufficiently large gain on the order of 40 to 50 decibels. Therefore, the basic factor determining the possibility of using the given version is noiseproofness of the high-frequency signals and the connecting line from the high-frequency multiplexing systems of the city telephone exchange (KRR, PCM). The power, the output levels of the transmitters Π_2 and Π_2 at the TsUS [central repeater station?] must be determined by the number of connected lines and their attenuations.

The use of the versions of constructing the station part of the channel with repeaters at the transformer substation will permit conversion to complete transistorization of the equipment of the high-frequency channels, for the maximum required initial powers of the high-frequency signals will be lowered significantly, for from 200-400 watts at the reference repeater station to 10-15 watts at the transformer sub-station. The station equipment of the high-frequency channels will become standardized also advantageously simultaneously for the WB networks of any structure.

Among the investigated versions, the versions with installation of the transmitters at the repeater station of the centralized system (Fig 2.8), at the repeater stations of the decentralized system with two-element network (Fig 2.10), at the reference repeater stations in the three-element network (Fig 2.12) have found practical application in the existing TPB system. The application of the indicated versions during the growth period of the TPB system is entirely natural and justified, for on introduction of the TPB system in large cities the indicated versions required a smaller number of active station installations.

The versions of constructing the station part of the channel with installation of repeaters at the transformer substation appeared a significant time after the beginning of introduction of the TPB system [36, 37] as a consequence of the difficulties arising in realizing the energy and quality indexes of the high-frequency channels for the necessity detected in large cities for increasing the output power of the transmitters from 200 watts to 400 watts; in individual cases, the installation of intermediate repeaters on the distributing feeders, difficulties in processing various cable inserts. The modern technical level makes it possible to create simple and reliable repeaters for installation at the transformer substations.

2.8. Structure of the Line Part of the High-Frequency Channel

By the line part of the high-frequency channel we mean the entire set of line structures and high-frequency devices between the last station site creating high-frequency signals of a given power and the input of the receiver.

In the adopted TPB system the line part of the channel in the three-element network includes the main feeder lines, the transformer substations, the distributing feeder lines, the subscriber transformers, the subscriber lines or the building networks, using individual receivers. In the two-element network the line part of the high-frequency channel begins with the distributing feeder lines respectively. When using group receivers the line part of the channel ends with the subscriber transformer.

The requirements imposed on the line part of the high-frequency channel consist in transmission of high-frequency signals from the WB station to the input of the receivers with the least energy losses and distortions of the AM signals. Considering that the WB network used to transmit the high-frequency signals was not designed for this purpose, it is necessary to carry out a number of measures on the WB network with respect to organization of the high-frequency channels. The specific nature of transmitting the high-frequency signals over the WB lines consists in the fact that in contrast to transmitting the low-frequency signals, the basic power of the high-frequency signals is lost in the lines, and therefore the power of the station active high-frequency devices (transmitters, repeaters) is determined only by the lines and not by the receivers as in the low-frequency channel.

A second characteristic of the behavior of the lines when transmitting high-frequency signals is the fact that the WB lines are commensurate with respect to length with the wave length of the transmitted carrier frequencies of 3800 and 2500 meters; another nature of the operating conditions is characteristic of them which depends on the length of the line and the load resistance at the end of it. The third characteristic of the version of the lines is that, with the exception of the main feeder lines they are not electrically uniform as a result of the presence of various wire and lead materials, low distribution with respect to length.

The presence of cable inserts on the main feeder excludes these lines from among the uniform long lines. The distributing feeders and subscriber lines, as a rule, are nonuniform, for the feeder lines are loaded along the entire length with subscriber transformers and have feeder leads, and the subscriber lines have building leads. In addition, an important factor is obtaining voltages that are identical or differ little for the high-frequency signals of both channels at the subscriber rosette along the entire distributing feeder line. Thus, from the point of view of transmission of high-frequency signals alone, without discovering the noiseproofness of the high-frequency signals with respect to the low-frequency signals and airwave interference, it is obvious that the high-frequency transmission lines are the most critical element in the structure of the high-frequency channels. In foreign MPB systems over the city telephone exchanges, the design of the line part of the channel presents significantly fewer difficulties, for the subscriber lines of the city telephone exchange are uniform lines with load at the end.

The preparation of the line part of the WB network for creating the high-frequency channel consists in the application of the required high-frequency devices to obtain the optimal conditions for transmitting the high-frequency signals.

The entire set of measures with respect to optimal transition of high-frequency signals over the lines is determined by the high-frequency processing of the distributing feeder lines, transformer substations and main feeder line.

The high-frequency processing of the main feeder lines is done only in the presence of cable inserts by applying compensating and matching devices KU-M [compensating devices for the main feeder lines] and SU-M [matching devices for the main feeder lines]. The high-frequency processing of the transformer substations is accomplished in all cases by connecting the high-frequency transformer substation connection circuits. On the distributing feeder lines the high-frequency processing is used for the cable inserts by means of the high-frequency KU-R [compensating circuits for the distributing lines] and SU-R [matching circuits for the distributing lines]; the feeder leads, by the high-frequency automatic transformers ATO.

In the case of transmission voltages of the high-frequency signals on the subscriber network, high-frequency processing of the subscriber transformers is carried out by connecting the OUA[1] bypasses. At the end of the distributing feeder line, the matching resistance is included (SS) equal to the arithmetic mean equivalent wave impedances of the line $Z_{\text{equivalent wave impedance}}$ (see Appendix 2) on the carrier frequences of 78 and 120 kilohertz.

The structural diagram of the line part of the high-frequency channel used in practice is presented in Fig 2.20.

It must be noted that the equality of the carrier frequency voltages for all parts of the TPB network would permit simplification of the receivers and their operation and maintenance. In addition, the WB of the higher quality of broadcasting by comparison with wireless broadcasting must provide the subscribers with smoother signal levels independently of their location along the length of the distributing feeder line. If the level dispersion with respect to low-frequency signals at the subscriber points is within the limits of 3 decibels, then with respect to high-frequency signals this dispersion will reach more than 20 decibels (from 0.25 to 3 volts); here dispersion of up to decibels is permissible between the levels of the two carrier frequencies. The high admissible dispersion of the levels of the high-frequency signals between the subscriber points causes the necessity for introducing preset regulators into the individual receivers with significant adjustment range, which complicates the receivers and their operation and maintenance. The dispersion of the levels between the carrier frequencies at the rosette of the subscriber point, as was demonstrated in formula (2.3) also complicates and increases the cost of the receiver.

The complication is caused by the fact that the selectors of the receiver must insure the required noiseproofness with worse ratio of the interference and signal levels, that is, in the given case when the interference level exceeds the signal level by 10 decibels.

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[1] Subscriber transformer bypasses

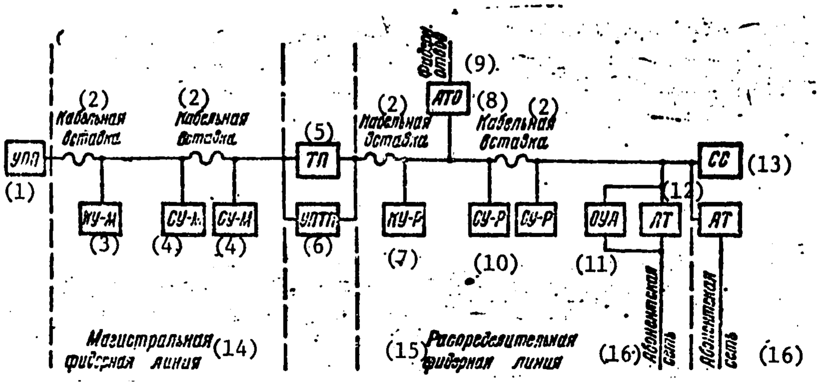

Figure 2.20. Structure of the line part of the high-frequency channel of the TPB system

Key:

1. Transmitter connection circuit
2. Cable insert
3. KU-M [compensating circuit for the main feeder line]
4. SU-M [matching circuit for the main feeder line]
5. Transformer substation
6. Transformer substation connection circuit
7. KU-R [compensating circuit for the distributing feeder line]
8. ATO [feeder leads processed by high-frequency automatic transformers]
9. Feeder lead
10. SU-R [matching circuit for the distributing feeder line]
11. OUA [subscriber transformer bypass]
12. Subscriber transformer
13. Matching impedance
14. Main feeder line
15. Distributing feeder line
16. Subscriber network

It is necessary to set the high-frequency signal levels as close as possible to the subscriber points, for setting united levels far from the subscriber points does not make it possible to eliminate the level of dispersion which is accumulated on the length of the line. Therefore, it appears to be most advantageous to set the high-frequency signal levels at the beginning of the building network (Fig 2.21), the attenuation of which is low for the carrier frequencies. The high-frequency signal levels can be set by the high-frequency signal regulators P_1 and P_2, respectively, at 78 and 120 kilohertz established at the beginning of the building network.

The principle used to adjust the high-frequency signal level consists in the fact that the transmission coefficient of the divider consisting of the variable resistance of the regulator and input impedance of the building network, changes.

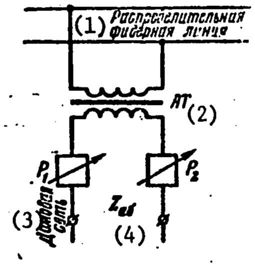

Figure 2.21. Installation of high-frequency signal level correctors in the building network

Key:

1. Distributing feeder line
2. Subscriber transformer
3. Building network
4. $Z_{subscriber}$

The regulator, in addition to the variable resistance, contains circuits for bypassing it with respect to unregulatable low-frequency and high-frequency signals. Thus, separate grouping and setting of the high-frequency signal levels is accomplished by removing the redundant voltages.

The possible level dispersion of the carrier frequencies when installing the given regulators will be determined only by the parameters of the building network and can be no more than 5 decibels for each carrier frequency (at the present time 21 decibels is permitted) and no more than 4 decibels between carrier frequencies (instead of the now admissible 10 decibels).

The principles and the devices for high-frequency processing of the WB networks used at the present time do not permit us to obtain equality of the voltages at all of the subscriber rosettes in sufficient measure.

A detailed description of the preparation of the line part of the channel of the WB network for transmission of the high-frequency signals is presented in Chapter 7, and the normalization of the high-frequency devices and lines, in Chapter 3.

2.9. Structure of the Receiving Part of the High-Frequency Channel

The receiving part of the TPB system is determined by the structural build-up of the city: large or small apartment houses, categories of buildings with respect to purpose (residential buildings, administrative buildings, hospitals, hotels, hospitals) and also capital expenditures and operating characteristics required for the creation and servicing of one type of receiving network or another, and the interests of the subscribers.

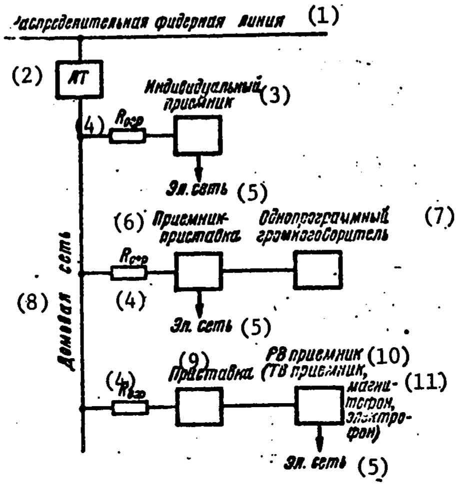

Figure 2.22. Structure of the receiving part of the channel with individual receivers

Key:
1. Distributing feeder line
2. Subscriber transformer
3. Individual receiver
4. R_{lim}
5. Electric circuit
6. Receiver attachment
7. Single-program loudspeaker
8. Building circuit
9. Attachment
10. RB receiver
11. (TB receiver, magnetophone, electrophone)

Beginning with the indicated factors, two versions of the receiving part of the TPB channel are possible: with individual (Fig 2.22) and group receivers (Fig 2.23). The version with individual receivers is the most justified technically and economically for small apartment buildings; the group receivers are most expedient for administrative, public buildings, hospitals, hotels, especially when they are introduced in new buildings under construction. If we consider this problem from the point of view of the interests of the subscribers, then the version with the group receivers is more preferable for the subscribers. When building the group receivers, the type of receiver (the single program loudspeaker) does not change, it is only necessary to add a program switch to it. Therefore, significant additional expenditures to acquire new receivers is not required of the subscribers, and the maintenance of the existing single-program loudspeaker remains as simple as possible, having only two required functions -- program selection and volume control. In the version with individual receivers, the subscriber must acquire an individual receiver at higher cost to receive two additional programs, and installation of it

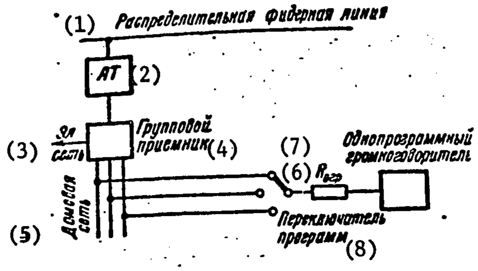

Figure 2.23. Structure of the receiving part of the channel with group receivers

Key:

1. Distributing feeder line
2. Subscriber transformer
3. Electric network
4. Group receiver
5. Building network
6. R_{lim}
7. Single-program loudspeaker
8. Program switch

is complicated by the necessity for connecting the receiver into the electric network and furthe adjustment of the input level of the high-frequency signals by the adjustment regulators of the receiver. On the other hand, for the operating enterprises of the WB, the construction of the receiving network with individual receivers permits the least difficulty for in this case the subscriber network remains unchanged, and all of the operations on the building network reduce to insuring normal high-frequency signal levels and elimination of poor contacts -- sources of interference. Here the operating responsibility for the receivers is with the subscribers themselves, the owners of the receivers.

When introducing the group receivers in residential buildings, the operating enterprises for WB [wire broadcasting] become responsible for acquiring the group receivers, installing them, reequipping the building network of the three-pair network with acquisition and laying of the three-pair cable and installation of the distribution boxes and program selectors. The operating and maintenance responsibility for the group receivers also lies with the WB enterprises. In the administrative and public buildings, the choice of the version of constructing receiving part of the channel is determined by the least capital and operating expenditures, for, independently of the type of receivers all of the expenditures are borne by the user organizations.

The version with individual receivers (Fig 2.22) can be solved using various types of devices for receiving WB programs. These individual receivers must be divided into two types: the individual receivers (three-program loudspeakers) designed especially to receive the TPB programs and the combined devices consisting of certain sound reproducing devices (radio broadcast receivers, tape recorders, electrophones, subscriber loudspeakers) and attachments for them to receive the TPB programs. The individual receiver is an integral complete device with the set of all electrical and acoustic elements designed to receive all three TPB programs. The low-frequency programs in the existing three-program loudspeakers are realized just as in the single-program loudspeakers. The attachments to the existing sound reproducing devices represent the set of additional electrical elements required to receive high frequencies or the TPB programs.

The receiver-attachment for the single-program loudspeaker is a receiver-amplifier for reception of high-frequency signal, reception of low-frequency signals is directly on the single-program loudspeaker.

The attachment for the radio and television receivers, tape recorders and electrophones is a receiver which ends in an AM signal detector. As the low-frequency repeater channel, the low-frequency repeaters of the above-indicated sound reproducing devices are used. The low-frequency program can be received both through the low-frequency amplifier and directly on the loudspeakers. All the individual receivers, just as the single-program loudspeakers, are connected to the building network through the limiting resistor R_{lim}.

Out of all the investigated individual means of receiving TPB programs, the individual receivers (three-program loudspeakers) have received basic development. The attachments, in spite of the lower cost, have not become widespread as a result of inconvenience connected with the connection of all the devices and the absence of a single structural form of the attachments with the sound reproducing devices. However, in the future it appears to be most prospective to combine the attachments with tape recorders and electrophones which, in contrast to the radio broadcast and television receivers do not have their own sources for reception of broadcast programs. The TPB attachment is most expediently built into a tape recorder (used to record the programs transmitted over the TPB networks). .

When connecting the three-program loudspeakers, as a rule, the building network is not subjected to any treatment if the attenuation of the carrier frequencies and its lines does not exceed 5 decibels. In the subscriber network of the high rise buildings, the amount of attenuation can turn out to be above the admissible; then corresponding replacements of the wiring is required.

The version of the receiving part with group receivers (Fig 2.23) is characterized by transmission of the signals for each program over the building network in the sound frequency spectrum. The conditions of the transmission of these signals over the building network for all programs are identical and are determined by the electrical norms for the single-program, WB.

The group receiver is made up of two receivers (for each high-frequency channel) insuring the required output power on low frequencies. With respect to the low-frequency program the building network is connected directly to the subscriber transformer (through the bypass circuit in the group receiver). In the subscriber sets it is recommended that one limiting resistor R_{lim} be used, installing it after switching programs. The application of R_{lim} in each pair (to the program selector) increases the number of resistances and complicates the structural design of the branch box.

It must be noted that the group receivers will permit insurance of higher quality of the production than the individual receivers. In the group receivers, various circuit supplements and complications are justified economically, permitting improvement of the quality and operating indexes, for in this case the proportion of the additional expenditures for one point is negligible, and the effect is significant. This fact has made it possible to introduce relatively complex automatic level adjustment into the group receivers and to obtain sufficiently even and stable levels of all three programs with inequality and instability of the high-frequency signal levels at the group receiver input.

The intrabuilding network of the three-pair wiring and the group receiver is more reliable than the single-pair network with individual receivers on which the influence of the poor contacts is more felt.

The mass introduction of certain receivers of the TPB system will permit a change in the appearance of the initial frequency channel. With an increase in the introduction of the TPB receivers, unloading the low-frequency channel takes place; therefore, with a sufficiently equipped network with TPB receivers, it is possible to state the question of re-examination of the standardization and the design of the network and the station sites of the TPB system. Here it is possible to consider that the basic criterion for normalization and design of the TPB networks will be the high-frequency channels.

Then in order to improve the indexes of the low-frequency channel it appears expedient to use the three-program receiver repeaters also for the low-frequency channel.

Here it becomes possible to increase by several times the input impedance of the subscriber sets with respect to the low-frequency signals, compensation for the attenuation of the low-frequency signals in the network, improvement of the output power and adjustment of the tone. The increase in input impedance will permit still greater unloading of the WB network and the station repeaters and reduction of the levels of crosstalk interference from the low-frequency channel to the high-frequency channels.

Actually, in this version of the individual receiver, the possibility of the usual passive reception of the low-frequency program is maintained (in the absence of feed from the building electric network or failure of the electric circuitry of the receiver).

2.10. Interference in the TPB System

The introduction of two additional broadcast programs into the WB system with transmission over the TPB network in the form of AM signals in the high-frequency spectrum acutely states the problem of noiseproofness of these programs.

Understanding interference to be any outside signals heard at the output of the receivers of the TPB system and considering the different nature of the interference in the TPB system and the various methods of eliminating and diminishing it respectively, it is possible to arrive at the following classification of them:

1. With respect to audio reception: intelligible crosstalk interference, noise and background.

2. With respect to origin: additive and multiplicative.

3. With respect to location of the source of interference with respect to the TPB system: extrasystem, intrasystem.

4. With respect to frequency arrangement with respect to the signal spectrum transmitted in the line part of the TPB system channel: extraband and intraband.

5. With respect to nature of the effect between the TPB system channels: from the low-frequency channel to the high-frequency channel, from the high-frequency channel to the low-frequency channel, between high-frequency channels.

6. With respect to point of origin in the TPB system: in the transmitters, in the line part of the channel, in the receivers.

In the single-program wire broadcasting the basic type of interference is the AC background occurring in the low-frequency amplifiers or induced in the WB line from the electric networks. However, with such high voltages of the low-frequency signal, from 960 volts on the main feeder lines to 30 volts on the subscriber network, and sufficiently good symmetry of the WB lines it is possible to consider that the single-program low-frequency WB system is protected against outside noise. The interference of the intelligible crosstalk and noise type, as a rule, have a relation to the information sources (the broadcast program receivers) or the program feed channels using the city telephone exchange pairs themselves (the central wire broadcast station to the reference repeater station).

On converting to the multiprogram WB system, the situation with the interference theoretically changes. The most important role is played by the intrasystem intelligible crosstalk interference, the point of origin of which can be any part of the TPB system channel, beginning with the output of the transmitters and ending with the receivers. In addition, the presence of intelligible crosstalk interference from outside radio broadcast signals in the closest long-wave band is possible. When creating and introducing the existing TPB system, the multiplicative interference from the low-frequency channel to the high-frequency channel formed on joint transmission of low-frequency and high-frequency signals over the WB lines turned out to be most significant. The mechanism of the origin of this interference occurring basically in steel lines consists in the following.

The fact that the multiplicative interference from the low-frequency channel to the high-frequency channels arises to the greatest extent (to -30 decibels) in the steel lines and the least extent in the bimetal lines (-50 to -55 decibels) permits the conclusion to be drawn that the given interference is caused by the conductor material through which the high-frequency (carrier frequency) currents pass. As is known, with an increase in frequency the cross section of the conductor for transmitting the current is reduced, and it is reduced to the outside ring of the conductor.

In bimetal conductors, this ring is copper; in steel wire it is steel. The primary parameters of the two types of wires on the carrier frequencies of 78 and 120 kilohertz are such as to give significant predominance of the inductive resistance over the active resistance.

Thus, for steel circuits 4 mm in diameter, the kilometer induction resistances $X_L=2\pi\ fL=1400$ ohms on a frequency of 78 kilohertz and 2050 ohms on a frequency of 120 kilohertz; the active resistances on these frequencies are 365 and 434 ohms respectively. The bimetal networks of the same diameter on the same frequencies have a kilometer inductive resistance of 980 and 1510 ohms respectively; the active resistance is 12.2 and 14.7 ohms. With a quadratic law of addition of the inductive and active resistances, in the given case it is possible to neglect the active resistances.

The low values of the predominant inductive resistances of steel and bimetal wire with significant difference in the multiplicative interference between these types of wires will permit the conclusion to be drawn that in steel wire the inductance is a variable parameter, a function of the low-frequency signal current transmitted. Inasmuch as the inductance is determined by the structural data of one electrical element or another which is in the given case constant and the magnetic permeability μ of the materials entering into the magnetic circuit, the proposition naturally follows of dependence of the magnetic permeability of the steel wires at carrier frequencies μ_ω on the low-frequency current I_Ω.

The steel wires have ferromagnetic properties and, consequently, for them the dependence of the magnetic induction B on the field intensity H (the magnetic current) have a nonlinear nature caused by the hysteresis loop (Fig 2.24).

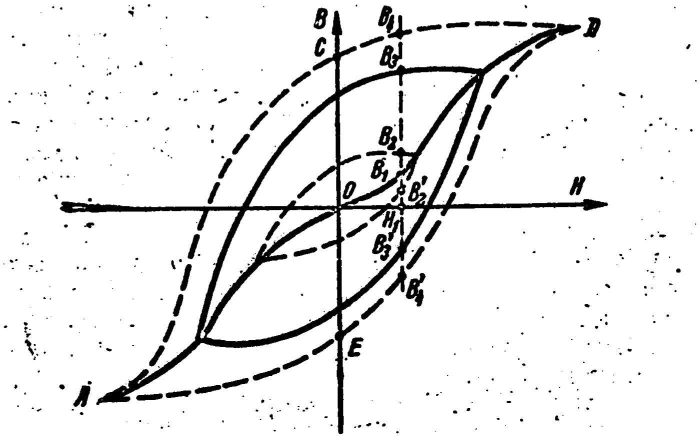

Figure 2.24. Hysteresis loops of ferromagnetic material

The induction B does not have a one-to-one relation to the field intensity H, and it is determined both by the magnitude of this intensity and the history of the magnetization process. Thus, depending on the direction of variation of the field intensity H of the initial hysteresis loop the value of the magnetic induction will correspond to one value of the field intensity H_1: B_1, B_2, B'_2, B_3, B'_3, B_4, B'_4 for the indicatedthree hysteresis loops in Fig 2.24. Actually under real conditions of transmitting a low-frequency signal current over a steel line, one value of the field intensity H_1 will correspond to an infinite set of values of B (from B_4 to B'_4) under the condition that the loop ACDEA corresponds to the maximum low-frequency signal current. Therefore, the approximation of the function B(H) with conversion to the function $\mu_\omega(I_\Omega)$ appears to be theoretical difficult.

However, considering that the types of steel used for the wires are magnetically soft materials with relatively narrow hysteresis loop and also that the variation of the induction corresponds to variation of some differential magnetic permeability $\mu_\omega = dB/dH$ determined by the tangent of the angle of the inclination of the branches of the hysteresis loop to the H axis, for the initial investigation of the process of occurrence of the multiplicative interference from the low-frequency signal it is possible that μ_ω is basically determined by the current I_Ω and to a lesser degree by the history of the magnetization process. This assumption makes it possible to approximate the function B(H). The approximation of the following type is appropriate for the given case;

$$B = A\,\mathrm{arctg}\,H, \tag{2.6}$$

where A is a constant.

Expression μ_ω as the derivative of the adopted function, we obtain

$$\mu_\omega = \frac{dB}{dH} = \frac{A}{1+H^2} \tag{2.7}$$

or, making the transition to the initial argument I_Ω, we have

$$\mu_\omega = \frac{A}{1+c^2 I_\Omega^2}, \tag{2.8}$$

where c is the coefficient relating the values of H and I_Ω.

In the final analysis, determining the series resistance of the steel line on the carrier frequencies, $Z_{m\omega}$ has the function of the current $i_\Omega(t)$, we obtain the expression

$$Z_{m\omega}[i_\Omega(t)] = \frac{1}{a + b i_\Omega^2(t)}, \tag{2.9}$$

Thus, for further investigation of the process of the appearance of multiplicative interference, it is possible to take the following simplified model of the transmission channel (Fig 2.25), in which $i_\Omega(t)$ is the low-frequency signal current in the line; $e_\omega(t)$ is the emf of the high-frequency signal source (transmitter), Z_B is the wave impedance of the steel line matched at the end. For the circuit it is necessary to determine the voltage $\mu_\omega(t)$ at its output:

$$u_\omega(t) = \frac{z_B}{z_{л\omega}[i_\Omega(t)] + z_B}\, e_\omega(t). \tag{2.10}$$

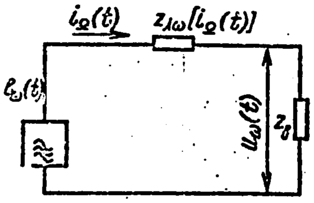

Figure 2.25. Equivalent diagram of the steel line for determining the multiplicative interference

As the initial signals let us take the voice-frequency, low-frequency signal:

$$i_{\Omega}(t) = I_{\Omega} \cos \Omega_1 t \tag{2.11}$$

and the amplitude-modulated signal with modulating frequency Ω_2:

$$e_{\omega}(t) = E_0 (1 + m \cos \Omega_2 t) \cos \omega_0 t. \tag{2.12}$$

Considering that $Z_{\ell\omega}$ is proportional to the length of the line, and Z_B is constant, and considering the cases where the lines are sufficiently long and the interference is large and also considering the different nature of the resistances $Z_{\ell\omega}$ close to inductive and Z_B close to active, it is possible to consider $Z_{\ell\omega} >> Z_B$ and neglect the value of Z_B in the denominator (2.10).

Using expressions (2.9), (2.10), (2.11) and (2.12), we obtain

$$\begin{aligned} u_{\omega}(t) &= E_0 (1 + m \cos \Omega_2 t) \cos \omega_0 t \frac{Z_{в}}{\dfrac{1}{a + b I_{\Omega}^2 \cos^2 \Omega_1 t}} = \\ &= E_0 Z_{в} \Big[a (1 + m \cos \Omega_2 t) + \frac{1}{2} b I_{\Omega}^2 (1 + \cos 2\Omega_1 t) + \\ &+ \frac{1}{2} b m I_{\Omega}^2 \cos \Omega_2 t + \frac{1}{4} b m I_{\Omega}^2 \cos (2\Omega_1 + \\ &+ \Omega_2) t + \frac{1}{4} b m I_{\Omega}^2 \cos (2\Omega_1 - \Omega_2) t \Big] \cos \omega_0 t. \end{aligned} \tag{2.13}$$

Expression (2.13) is an AM signal, modulated, in addition to the useful frequency Ω_2, by the frequencies connected with the frequency of the low-frequency signal: $2\Omega_1$, $2\Omega_1 + \Omega_2$, $|2\Omega_1 - \Omega_2|$.

The obtained AM signal spectrum at the output of the investigated channel is presented in Fig 2.26.

The noise/signal ratio at the output of the receiver for interference with a frequency of $2\Omega_1$

$$N/S = \frac{\frac{1}{2} b I_{\Omega}^2}{m \left(a + \frac{1}{2} b I_{\Omega}^2 \right)}, \tag{2.14}$$

and for interference with frequencies of $|2\Omega_1 \pm \Omega_2|$

$$N/S = \frac{\frac{1}{4} b I_\Omega^2}{a + \frac{1}{2} b I_\Omega^2}. \tag{2.15}$$

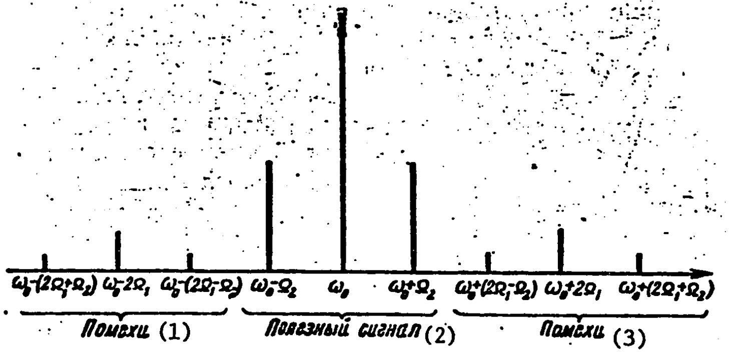

Figure 2.26. Spectrum of the AM signal formed on joint transmission of the AM signal with the carrier frequency ω_0, the modulating frequency Ω_2 and the low-frequency signal with frequency Ω_1 over steel wires

Key:

1. Interference
2. Useful signal
3. Interference

For high nonlinearity, when $(1/2)bI_\Omega^2 \gg a$, the expressions (2.14) and (2.15) acquire the following form respectively:

$$N/S = \frac{1}{m} \tag{2.16}$$

and

$$N/S = \frac{1}{2}. \tag{2.17}$$

Expressions (2.16) and (2.17) must be considered as the maximum worst value of the N/S ratio. In reality, for steel wires it is possible to consider the nonlinearity small, for it in practice does not create nonlinear distortions of the low-frequency signal, that is, it is possible to set $a \gg (1/2)bI_\Omega^2$ and the expressions (2.14), (2.15) assume the form:

$$N/S = \frac{1}{2} \frac{b}{am} I_\Omega^2; \tag{2.18}$$

$$N/S = \frac{1}{4}\frac{b}{a}I_2^2. \tag{2.19}$$

Thus, the noise/signal ratio depends on the nonlinearity b/a and sharply (by a quadratic law) on the low-frequency current (interfering current) of the signal, and it does not depend on the amplitude of the AM carrier signal. The magnitude of the interference with frequency $2\Omega_1$ does not depend on the presence of the useful modulation, the values of the interference with frequencies of $|2\Omega_1 \pm \Omega_2|$ are proportional to the depth of the useful modulation. Therefore, for frequencies of $2\Omega_1$ the noise/signal ratio and, consequently, the noticeability increase with a decrease in depth of the useful modulation (Fig 2.27) and in the useful signal interval it will be the worst case, and for frequencies of $|2\Omega_1 \pm \Omega 2|$ the noise/signal ratio remains unchanged (Fig 2.28); the interference disappears together with the signal in the interval. The presented arguments indicate that the interference with the frequency $2\Omega_1$, especially in the useful signal interval presents the greatest danger. The investigated noise/signal ratio pertains to all the levels of the useful signal in the dynamic range, for it permits estimation of the noticeability of the interference for any levels (depth of modulation) of the useful signal.

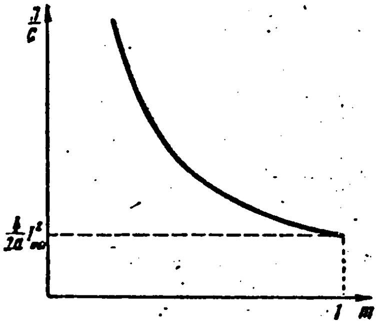

Figure 2.27. The noise/signal ratio as a function of depth of modulation m of the useful signal for the interference with a frequency $2\Omega_1$

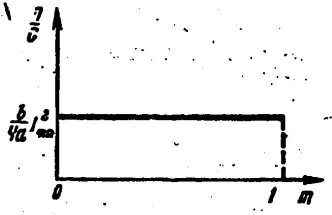

Figure 2.28. The noise/signal ratio as a function of depth of modulation m of the useful signal for interference with the frequency of $|2\Omega_1 \pm \Omega_2|$.

Hereafter the given noise/signal ratio will be called the instantaneous ratio; in contrast to it, the assumed normalized ratio of the interference in the useful signal interval to the rated magnitude of the useful signal will be called normalized $(N/S)_n$.

The ratio $(N/S)_n=0$ for interference with frequencies of $|2\Omega_1 \pm \Omega_2|$, but this does not indicate the actual noticeability of this type of interference.

For interference frequencies of $2\Omega_1$

$$(N/S)_n = \frac{1}{2} \frac{b}{am_{\text{макс}(1)}} I_2^2 . \qquad (2.20)$$

Key: 1. max

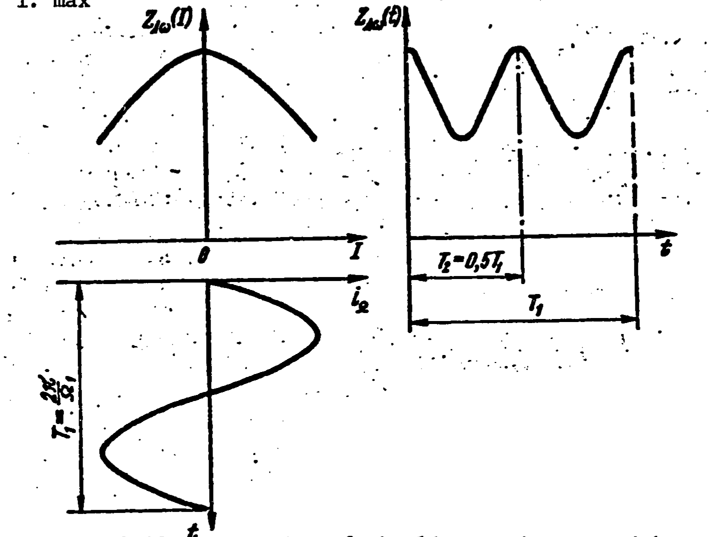

Figure 2.29. Variation of the line resistance with respect to high-frequency under the effect of a low-frequency signal current

The graphical representation of the origin of the interference with a frequency $2\Omega_1$ is illustrated in Fig 2.29. In one period of variation of the low-frequency signal current the resistance $Z_{\ell\omega}(t)$ varies twice as frequently as a result of symmetry of the function $Z_{\ell\omega}$ (I) with respect to the y-coordinate axis. This modulation of the resistance $Z_{\ell\omega}$ with double interference frequency also leads to the appearance in the AM signal spectrum of interference with a frequency of $2\Omega_1$. Thus, it is possible to consider the process of the appearance of multiplicative interference in steel wire the result of parametric modulation by variation of the resistance $Z_{\ell\omega}$ by the law

$$Z_{л\omega}(t) = \frac{1}{a + bi_2^2(t)} .$$

The presented process of the appearance of multiplicative interference with a number of simplifications reflects only one energy aspect. On the whole, the multiplicative interference of the steel wire must be defined as the function $N/S=\varphi\left(I_\Omega, l, \frac{F_1}{f_0}\right)$, where ℓ is the length of the line; F_1 is the low-frequency signal frequency; f_0 is the given carrier frequency. The analytical representation of the dependence of the magnitude of the nonlinear crosstalk interference on the ratio of the low-frequency and high-frequency signal frequency presents great complexity; it requires determination of the frequency dependence of the ferromagnetic properties of the steel wire and at the present time has not been obtained.

The experimental data obtained clearly indicate the dependence of the relative level of the crosstalk interference $(N/S)_n$ on the low-frequency signal current, and the frequency ratio (Fig 2.30) also confirms the quadratic dependence of the crosstalk interference on the low-frequency signal current.

The noticeable dependence of the nonlinear crosstalk interference on the length of the line is manifested under the condition $Z_{\ell\omega}>Z_B$; therefore, it is possible to consider that for steel lines with load at the end, the magnitude of the crosstalk interference increases proportionally to the line length (for a length of more than 1 km). For the majority of actual distributing feeder lines with distributed load on the line the crosstalk interference does not increase proportionally to the length, for in each subsequent section the low-frequency signal current decreases and at the same time the increment in the interference with respect to the unbranched line decreases.

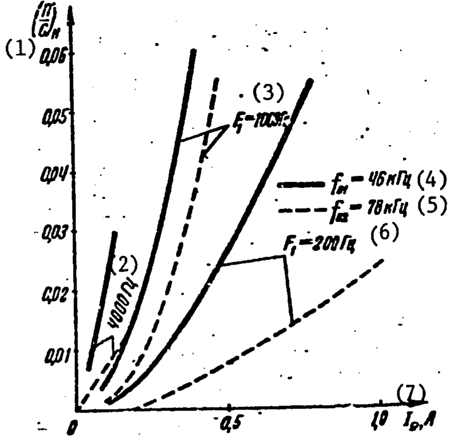

Figure 2.30. Relative level of the crosstalk interference on steel lines for ordinary amplitude modulation (line length 4 km, load at the end, steel wire 4 mm)

Key:

1. $(N/S)_n$; 2. 4000 hertz; 3. F_1=1000 hertz; 4. f_{01}=46 kilohertz;
5. f_{02}=78 kilohertz; 6. F_1=200 hertz; 7. I_Ω, amps

The crosstalk interference that arises between the high-frequency signals as a result of nonlinearity of the wires is negligibly small as a result of the small currents of the signals. The line transformers in practice do not introduce crosstalk interference, which is explained by the weak influence of the ferromagnetic material of these transformers on the transmission coefficient on the carrier frequencies.

Another cause of the appearance of nonlinear crosstalk interference in the lines is the poor contact at the points of connecting the wires having nonlinear properties. The mechanism of appearance of multiplicative interference in the poor contacts is analogous to the appearance of crossmodulation in the nonlinear elements (tubes, transistors).

The devices in which multiplicative interference occurs include the transmitters and tandem (intermediate) high-frequency signal repeaters. In the transmitters the nonlinear crosstalk interference occurs in the output stage, as a rule, between the high-frequency signals by crossmodulation in the nonlinear amplifying elements or ferromagnetic high-frequency transformers. In the tandem repeaters this type of interference occurs in the input and output amplifying stages. However, the interference level created by these devices is low and can be reduced by increasing the selectivity of the input and output frequencies separating circuits.

The additive interference in the WB channel can occur as a result of direct incidence of the outside signals in the low-frequency signal spectrum, incidence of the foreign signals in the AM signal spectrum; reception of foreign signals not entering into the spectrum of the useful AM signal, with insufficient selectivity of the receiver.

The additive interference with direct incidence of the outside signals in the spectra of the useful low-frequency signal can appear in the low-frequency program feed channels at the WB station by line crossovers between adjacent lines. On the receiving side, this type of additive interference can appear as a result of the incidence of the low-frequency program signals from the input of the receiver at the input of the low-frequency repeater of this device. Thus, this type of additive interference appears before and after the multichannel TPB channel.

The second type of additive interference incident in the AM signal spectrum appears in cases where the WB network receives (the antenna effect) signals of other services operating in this frequency spectrum. In addition, this interference is also manifested as a result of the low-frequency signal harmonics incident in the transmitted spectrum of the AM signal. As a rule, this additive interference is unintelligible.

The third type of additive interference is manifested only in the channel of the receiver and can be expressed in the form of hearing adjacent channels of the TPB system and also the WB stations.

The interference of the background and noise type of the high-frequency channels is manifested only in the AM signal reception and transmission devices.

In the receiver the background and noise appear basically in the low-frequency channel. Considering the quite high signal levels of the TPB system, the noise level can be neglected and the background level considered.

2.11. Methods of Decreasing the Interference with the High-Frequency Channels of the TPB System

The procedures for decreasing the interference of the high-frequency channels are determined depending on the nature of the origin of the interference and the location of its occurrence. The most important role in the existing TPB system is played by multiplicative interference from the low-frequency channel to the high-frequency channels occurring basically in the line part of the WB channel.

The necessity for decreasing this nonlinear crosstalk interference is determined by the fact that its magnitude greatly exceeds the other types of interference, and the methods of decreasing it are not simple.

The physical process of the origin of this interference was investigated above, and by using some simplifications, the analytical expressions were derived for the noise/signal ratio (N/S).

The magnitude of this interference basically determined for the steel lines by the low-frequency signal current, the line length, the frequency ratio of the low-frequency signal and the carrier. Consequently, the decrease in nonlinear crosstalk interference from the low-frequency signal can be achieved by decreasing the indicated parameters.

The simplest and most obvious means of significantly decreasing the nonlinear crosstalk interference would be replacement of the steel wires by bimetallic wires, which would lead to a decrease in attenuation of the high-frequency signals. However, this replacement would require great expenditures of copper and means on rebuilding the WB network.

Hereafter it is proposed that the WB networks be converted to cable lines, and the situation with nonlinear crosstalk interference will improve significantly, but in the first stage of introduction of the TPB system and at the present time the steel feder lines are a reality, and this reality will exist for a significant time to come. Therefore, other solutions to this problem are needed.

The dependence of the crosstalk interference and the attenuation of the high-frequency signals on the line length proposes the problem of reducing the length of the steel lines. This solution would require rebuilding the TPB network in the direction of increasing the number of such station sites as the transformer substations with a reduction in the service radius of each substation. It is natural that this solution too would require large expenditures of means and time of its implementation.

Thus, the solutions with respect to redesigning the WB network in one form or another, in spite of the radical improvement of a number of indexes of the TPB system could not be adopted, for they would require significant material means, capital investments, reconstruction operations and time. Therefore, the search for the solution of the given problem will be aimed at electrotechnical measures.

Considering the significant dependence of the given crosstalk interference on the low-frequency signal current, a solution to the problem can be a decrease in this current. This is achieved by using the low-frequency GT repeater for amplifying the low-frequency signal ("active version"), which permits a significant increase in the input impedance (to 30 kilohms) of the GT when receiving the low-frequency signal. The effectiveness of applying the "active version" is determined by the volume of its introduction. In addition to the solution to the problem of reducing the low-frequency signal current in the overall WB network, the introduction of the "active version" will permit a decrease in this current in the individual sections of the subscriber network, which, in turn, will lead to a reduction in the nonlinear crosstalk interference in these sections as a result of poor contacts.

The noise/signal ratio for the basic interference with a frequency of $2\Omega_1$ according to (2.18) will be defined by the expression

$$S/N = \frac{1}{2}\,\frac{b}{am}\,I_{\Omega}^{2}.$$

Consequently, on reducing the low-frequency signal current I_{Ω} by n times the N/S ratio decreases by n^2 times, and the normalized signa/noise ratio expressed in decibels

$$(S/N)' = S/N + 40\lg n, \qquad (2.21)$$

where S/N is the initial signal/noise ratio, decibels, before decreasing the low-frequency signal current.

Thus, if we take S/N=30 decibels, the value measured on the steel lines, as the initial ratio, then assuming potentially n=10, it is possible on steel lines to obtain a value of (S/N)'=70 decibels, which corresponds to the class II requirements of All-Union State Standard 11515-65 for channels with respect to the signal/noise ratio.

The methods of decreasing the crosstalk interference such as the application of frequency modulation and single-band modulation without carrier, increasing the carrier frequency, the introduction of frequency distortions on the transmitting side were investigated and partially tested. The application of frequency modulation required significant expansion of the transmitted frequency band to 60 kilohertz for one channel. A decisive deficiency of the frequency modulation and signal-band modulation without a carrier is complication of the subscriber receiver.

Increasing the carrier frequency of the high-frequency signals permits a reduction in the level of the crosstalk interference in connection with an increase in the service effect for the high-frequency signal current and correspondingly a decrease in the magnetic interaction in the steel wires of the low-frequency and high-frequency signals. However, a significant increase in the carrier frequencies of the high-frequency signals is impossible as a result of an increase in the attenuation and limited nature of the free frequency range before the beginning of the radio broadcast range. Some increase in the signal/noise ratio can be obtained by an increase in depth of modulation according to the expression (2.18) on frequencies in sound range having reduced level, that is, by introducing distortions in the form of a rise in the level of the upper modulation frequencies in the transmitter with the corresponding reduction of it in the receiver.

The effectiveness of this method is highly limited with respect to magnitude, on the order of several decibels, and with respect to frequency spectrum above 2-3 kilohertz modulating frequencies.

Under these conditions the most acceptable turns out to be the method of decreasing the cross talk interference by using amplitude modulation with an adjustable carrier frequency amplitude proposed by L. Ya. Kantor when developing Soviet TPB system [1].

Decrease in the Nonlinear Crosstalk Interference by the Application of an AM Signal with Adjustable Carrier Level

The basis for this method is the proportional dependence of the crosstalk interference at the output of the receiver as a function of the carrier frequency level.

Beginning with expression (2.13), the amplitude of the interference envelope with a frequency of $2\Omega_1$

$$U_{2\Omega_1}=\frac{1}{2}bI^2_{\Omega_1}Z_{\text{в}}E_0. \qquad (2.22)$$

Consequently, decreasing the amplitude of the carrier frequency E_0, it is possible to obtain the corresponding decrease in the crosstalk interference at the output of the receiver.

However, this should not be understood as a decrease in the initial rated voltage with constant carrier frequency voltage, for in this case, according to expression (2.18) no gain takes place with respect to the noise/signal ratio.

A decrease in the noise/signal ratio with adjustable carrier frequency voltage can be achieved with respect to the constant voltage of the carrier under the condition that all the levels of the useful broadcast signal at the output of the receiver remain the same as for constant carrier voltage.

Inasmuch as the signal at the output of the receiver is determined for linear detection by the magnitude of the AM signal envelope U_{env}, in order to reduce the constancy of this value it is necessary that the following condition be satisifed for any signal level:

$$U_{\text{or}} \underset{(1)}{=} m_0U_0 = m_xU_{0x}, \tag{2.23}$$

Key: 1. env

where m_0 is the depth of modulation corresponding to some level of the broadcast signal, with constant voltage of the carrier frequency U_0; m_x is the depth of modulation corresponding to the same broadcast signal level with unchanged carrier frequency voltage U_{0x}.

From expression (2.23) we have the basic condition of proper voltage regulation of the carrier frequency:

$$\frac{U_{0x}}{U_0} = \frac{m_0}{m_x}. \tag{2.24}$$

The noise/signal ratios for some level of broadcast signal with constant carrier voltage $(N/S)_0$ and variable carrier voltage $(N/S)_x$ can be represented in the form:

$$(N/S)_0 = \frac{1}{2}\frac{b}{a}\Gamma^2_{\Omega_1}\frac{U_0}{m_0U_0}; \tag{2.25}$$

$$(N/S)_x = \frac{1}{2}\frac{b}{a}\Gamma^2_{\Omega_1}\frac{U_{0x}}{m_xU_{0x}}. \tag{2.26}$$

Consequently, a decrease in the noise/signal ratio with adjustable voltage of the carrier U_{0x} with respect to the constant voltage level

$$(N/S)x/(N/S)_0 = \frac{U_{0x}}{U_0}. \tag{2.27}$$

The signal/noise ratio expressed in decibels for any voltage of the carrier frequency U_{0x}

$$\left(\frac{S}{N}\right)_x = \left(\frac{S}{N}\right)_0 + 20\lg\frac{U_0}{U_{0x}}\,. \qquad (2.28)$$

Inasmuch as the initial voltage of the carrier frequency with maximum broadcast signal remains unchanged and is maximal, the degree of increase in the ratio $(S/N)_x$ is determined by the decrease in voltage for the reduced levels of the broadcast signal. Graphically the function $(S/N)_x = \phi(U_{0\,max}/U_{0x})$ is presented in Fig 2.31; the crosshatched region corresponds to the additional gain with respect to the signal/noise ratio.

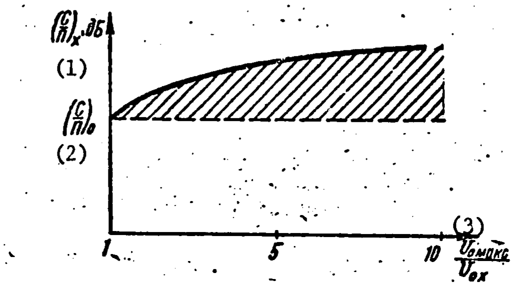

Figure 2.31. Signal/noise ratio with relative reduction in carrier voltage

Key:
1. $(S/N)_x$, decibels
2. $(S/N)_0$
3. $U_{0\,max}/U_{0x}$

It is necessary, however, to note that the adjustment of the carrier frequency voltage does not permit a decrease in the second type of interference with the combination frequencies $|2\Omega_1 \pm \Omega_2|$. This form of interference is proportional with respect to its magnitude to the amplitude of the envelope AM of the signal $m_x U_{0x}$ which remains invariant with respect to the condition (2.23) for any level of broadcast transmission on variation of the carrier voltage. Consequently, the noise/signal ratio for this interference remains unchanged when regulating the carrier frequency voltage.

The regulation of the AM carrier signal voltage beginning with what has been stated cannot be accomplished other than as a function of the level of useful modulating signal U_Ω.

In general form the law of this regulation

$$U_0 = \varphi(U_\Omega) \qquad (2.29)$$

can take any form when observing the condition (2.23) and the condition

$m_x < m_{max}$. The gain with respect to the transition interference for any level of broadcast signal would be determined by the form of the regulating function (2.29); therefore, it is important to discover the limiting form of this function given the greatest gain with respect to the crosstalk interference. According to (2.28), the gain with respect to the interference is proportional to a reduction in the carrier voltage; consequently, it is necessary to determine the maximum possible voltage of the carrier frequency for any value of U_Ω. On making the transition from the constant carrier to variable, the voltage of the variable carrier for any level of the broadcast signal

$$U_{0x} = \frac{m_0}{m_x} U_0. \tag{2.30}$$

Considering that with the DC carrier $m_0 = nU_\Omega$, where n is a proportionality coefficient and that for the greatest decrease in voltage U_{0x} it is necessary to observe the condition $m_x = m_{max} = const$ and also considering the initial unregulated voltage $U_0 = U_{0\ max}$, we obtain

$$U_{0x} = \frac{nU_{0\,\text{макс}\,(1)}}{m_{\text{макс}\,(1)}} U_\Omega, \tag{2.31}$$

Key: 1. max

that is,

$$U_{0x} = kU_\Omega, \tag{2.32}$$

where $k = \frac{nU_{0\,\text{макс}\,(1)}}{m_{\text{макс}\,(1)}}.$

Key: 1. max

Thus, the most advantageous with respect to interference is the rectilinear function $U_{0x}(U_\Omega)$ known as amplitude modulation with constant modulation coefficient (CMC). In Fig 2.23 and 2.33 graphs are presented for the functions $U_0 = \phi(U_\Omega)$ and $m = \psi(U_\Omega)$ for the AM signal with constant carrier and CMC, where $U_{0\ rated}$, m_{rated}, $U_{\Omega\ rated}$ are the rated (maximum) values of the carrier frequency voltage, the depth of modulation and the low-frequency signal voltage at the input of the receiver respectively. After obtaining the optimal relation for the carrier voltage as a function of the modulating signal voltage, it is possible to compare the function $(N/S)_x = f(U_\Omega)$ for the AM signal with DC carrier and CMC for interference with the frequency of $2\Omega_1$.

For constant carrier

$$\left(\frac{N}{S}\right)_{\text{э}} = \frac{1}{2}\,\frac{b}{am} I^2_{\Omega_1} = \frac{1}{2}\,\frac{b}{a} I^2_{\Omega_1} \frac{1}{nU_{\Omega_1}}, \tag{2.33}$$

that is

$$\left(\frac{N}{S}\right)_0 = \frac{N}{U_{\Omega_1}}, \tag{2.34}$$

where $N=(1/2)(b/an)I^2\Omega_1$ is the generalized proportionality coefficient.

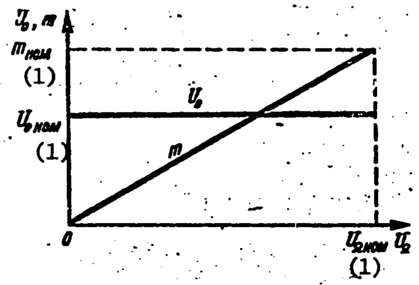

Figure 2.32. Depth of modulation as a function of the magnitude of the modulating signal with constant carrier

Key:
1. rated

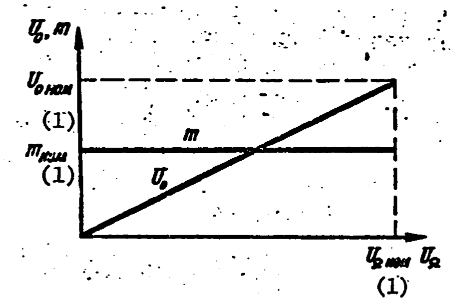

Figure 2.33. Carrier voltage as a function of the magnitude of the modulating signal with a constant modulation coefficient

Key:
1. rated

For a variable carrier

$$\left(\frac{N}{S}\right)_x = \frac{1}{2}\,\frac{b}{a}\,I^2_{\Omega_1}\,\frac{U_{0x}}{m_x U_{0x}} = \frac{1}{2}\,\frac{b}{a}\,I^2_{\Omega_1}\,\frac{kU_{\Omega_1}}{km_x U_{\Omega_1}}. \tag{2.35}$$

Consequently

$$\left(\frac{N}{S}\right)_x = f(U_{\Omega_x}) = \text{const.} \tag{2.36}$$

Thus, whereas with a constant carrier the N/S ratio and the noticeability of the interference increases with a decrease in the broadcast signal level and reach a maximum in its interval, with CMC the noise/signal ratio remainds unchanged.

In Fig 2.34 the functions N/S=f(U_Ω) are presented for constant carrier and CMC.

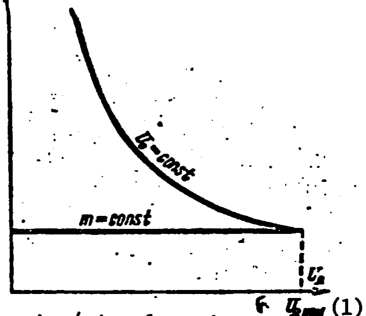

Figure 2.34. Graphs of the noise/signal ratio as a function of the magnitude of the modulating signal with constant carrier (U_0=const) and CMC (m=const)

Key:

1. U_Ω, kilohms

The total magnitude of the noise/signal ratio for all interference with frequencies $2\Omega_1$, $2\Omega_1+\Omega_2$, $|2\Omega_1-\Omega_2|$ with CMC does not depend on U_Ω, and it is determined by the following:

$$\sum\left(\frac{\overset{(1)}{П}}{\underset{(2)}{С}}\right) = \sqrt{\left(\frac{\overset{(1)}{П}}{\underset{(2)}{С}}\right)^2_{2\Omega_1} + \left(\frac{\overset{(1)}{П}}{\underset{(2)}{С}}\right)^2_{2\Omega_1+\Omega_2} + \left(\frac{\overset{(1)}{П}}{\underset{(2)}{С}}\right)^2_{|2\Omega_1-\Omega_2|}} =$$
$$= \sqrt{\left(\frac{1}{2}\frac{b}{am}I^2_{\Omega_1}\right)^2 + \left(\frac{1}{4}\frac{b}{a}I^2_{\Omega_1}\right)^2 + \left(\frac{1}{4}\frac{b}{a}I^2_{\Omega_1}\right)^2} =$$
$$= \frac{b}{a}I^2_{\Omega 1}\sqrt{\frac{1}{4m^2}+\frac{1}{8}}. \tag{2.37}$$

Key: 1. N; 2. S

The total value of (2.37) exceeds the noise/signal ratio for the basic interference with a frequency of $2\Omega_1$ by only $\sqrt{3/2}$=1.22 times (1.85 decibels) for a value of m=1.

The normalized ratio of the rated signal to the interference in the broadcast transmission interval

$$\left(\frac{S}{N}\right)_{\text{п}} = 2\,\frac{am_{\overset{(1)}{\text{з макс}}}}{bl_{\Omega}^{2}}\,\frac{U_{0\,\overset{(1)}{\text{макс}}}}{U_{0\,\text{мин}}},\ (2) \qquad (2.38)$$

Key: 1. max ; 2. min

where $U_{0\ \min}$ is the carrier voltage in the broadcast signal interval.

In the existing TPB system the ratio $U_{0\ \max}/U_{0\ \min}=10$, which permits an increase in the $(S/N)_n$ ratio by 20 decibels and bringing it approximately from 30 to 50 decibels for steel lines up to 6 km long.

In spite of the fact that the indicated method of decreasing the nonlinear crosstalk interference was obtained on the basis of investigating the interference in steel wires, it is also applicable to any type of nonlinear interference occurring in the TPB system whether from the low-frequency signal to the high-frequency signal or between high-frequency signals, at poor contacts, at the output of the transmitters, and so on. This is explained by the fact that in the majority of cases the spurious modulation takes place with constant modulation coefficient which does not depend on the amplitude of the carrier frequency. With a decrease in amplitude of the carrier, the amplitude of the noise envelope decreases proportionally. In the worst case of noticeability of the interference -- in the broadcast transmission interval -- the suppression of the carrier and, consequently, suppression of any nonlinear interference reaches the highest value. This conclusion is also applicable to modulation of the carrier by the background in the transmitters and repeaters, which simplifies the structural solutions of these devices. In addition, the introduction of the adjustable carrier increases the efficiency of the powerful repeaters and facilitates the thermal conditions of their operation, which is especially noticeable for transistorized systems.

Methods of Decreasing the Additive Interference

The types of additive interference and the causes of their appearance were investigated above. The methods of decreasing this interference are determined by the nature and location of its appearance.

The interference which falls directly in the spectrum of the low-frequency signal in the connecting feed lines of the programs can be decreased by insuring sufficiently high crosstalk attenuation between the connecting lines of all the programs. A decrease in the same type of interference in the receivers is achieved by small coupling between the input of the receiver and the input of the low-frequency repeater of the receiver.

The interference incident in the spectrum of the AM signal in the multichannel transmission channel can be decreased by reducing the level of the harmonics of the powerful station low-frequency amplifiers in the frequency band of 70–130 kilohertz and also improving the symmetry of the TPB lines under the effect of wireless interference. Some symmetrizing of the subscriber transformers is achieved by applying the device in (2.35), the series LC circuits of which are tuned to the external interference frequency. In order to exclude the transmission of the interference to the subscriber network over the "two-wire-ground" system, the subscriber transformer can be used with electrostating shielding between its I and II windings. These methods permit a reduction in the level of wireless interference by 10 to 12 decibels. The use of carrier regulation with suppression of the carrier in practice to zero permits us to obtain suppression of this interference in the receiver detector by 15–20 decibels in the useful signal interval. Obtaining the given interference level between the adjacent high-frequency channels is possible by using the corresponding selectors in the receivers.

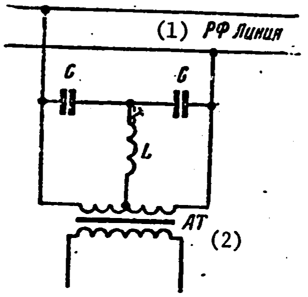

Figure 2.35. Circuit diagram for suppression of interference from a radio station

Key:
1. distributing feeder line
2. subscriber transformer

2.12. AM Signal with Regulatable Carrier and Its Application

The application of the AM signal with regulatable carrier permits us to reduce the crosstalk interference for all levels of the broadcast signal less than rated and especially significant in the most critical case, in the broadcast transmission interval. Let us now consider the AM signal with regulatable carrier, its characteristics, the relation of these characteristics to the quality indexes of the high-frequency channel and the operating peculiarities of some of the devices for the given AM signal.

The usual AM signal can be represented by the expression

$$u = U_0\left(1 + \frac{cU_\Omega}{U_0}\cos\Omega t\right)\cos\omega_0 t, \qquad (2.39)$$

where U_0 is the carrier amplitude; c is the proportionality factor between the amplitude of the modulating voltage U_Ω and amplitude of the envelope.

Correspondingly, the AM signal with slowly varying carrier amplitudes $U_0(t)$ and modulating signal $U_\Omega(t)$ can be expressed as

$$u = U_0(t)\left[1 + \frac{cU_\Omega(t)}{U_0(t)}\cos\Omega t\right]\cos\omega_0 t. \qquad (2.40)$$

For simplification let us assume that the amplitude of the modulating signal varies according to a harmonic law with angular frequency Ω_A from $U_{\Omega\ \min}$ to $U_{\Omega\ \max}$ (Fig 2.36). Then the variable amplitude

$$U_\Omega(t) = U_{\Omega\,\text{мин}}^{(2)} + \frac{U_{\Omega\,\text{макс}}^{(1)} - U_{\Omega\,\text{мин}}^{(2)}}{2}(1 + \cos\Omega_A t). \qquad (2.41)$$

Key: 1. max; 2. min

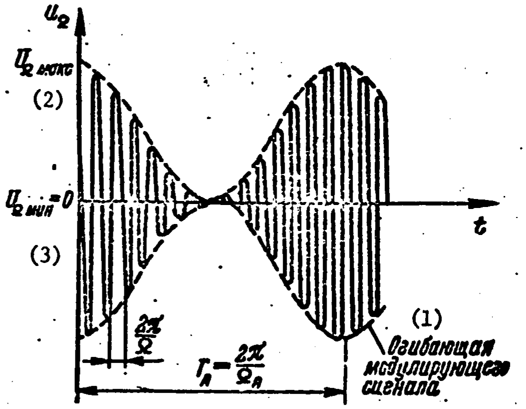

Figure 2.36. Variation of the amplitude of the modulating signal with respect to harmonic law

Key:
1. Envelope of the modulating signal
2. $U_{\Omega\ \max}$
3. $U_{\Omega\ \min}=0$

For $U_{\Omega\ \min}=0$ expression (2.41) is simplified:

$$U_\Omega(t) = \frac{U_{\Omega\,\text{макс}}^{(1)}}{2}(1 + \cos\Omega_A t). \qquad (2.42)$$

Key: 1. max

The given expression is the envelope of the modulating signal.

For the AM signal with CMC the amplitude of the carrier must vary also by law (2.42), and the expression (2.40) acquires the following form:

$$u = k\frac{U_{\Omega\,\text{макс}}^{(1)}}{2}\left(1+\cos\Omega_A t\right)\left(1+\frac{c}{k}\cos\Omega t\right)\cos\omega_0 t, \qquad (2.43)$$

Key: 1. max

where k is the proportionality factor between U_0 and U_Ω.

Comparing expression (2.43) with the expression for the ordinary AM signal (2.39), it is easy to see that the signal obtained is an AM signal with variable carrier amplitude $(kU_{\Omega\ \max}/2)(1+\cos\Omega_A t)$ and constant modulation coefficient $m=c/k$. The product $(kU_{\Omega\ \max}/2)(1+\cos\Omega_A t)\cos\omega_0 t$ of the expression (2.43) gives two components on conversion of the term $(kU_{\Omega\ \max}/2)\cos\Omega_A t\cos\omega_0 t$:

$$k\frac{U_{\Omega\,\text{макс}}^{(1)}}{4}\cos\left(\omega_0+\Omega_A\right)t;\ k\frac{U_{\Omega\,\text{макс}}^{(1)}}{4}\cos\left(\omega_0-\Omega_A\right)t,$$

Key: 1. max

analogous to the side frequencies of the ordinary AM signal. Inasmuch as in the ordinary broadcast signal the frequency $\Omega_A<\Omega$, after detection the frequency Ω_A of the AM signal with regulatable carrier will be outside the limits of reproducibility of the frequency band, that is, $\Omega_A<\Omega_H$ (Ω_H is the lowest angular frequency of the reproducible frequency band), which does not cause the appearance of side products in the received frequency band.

Thus, the AM signal with regulatable carrier is an AM signal with double amplitude modulation of the carrier: with respect to the law of variation of the amplitude $U_\Omega(t)$ of the modulating signal and with respect to the law of the modulating signal $u_\Omega(t)$ (Fig 2.37).

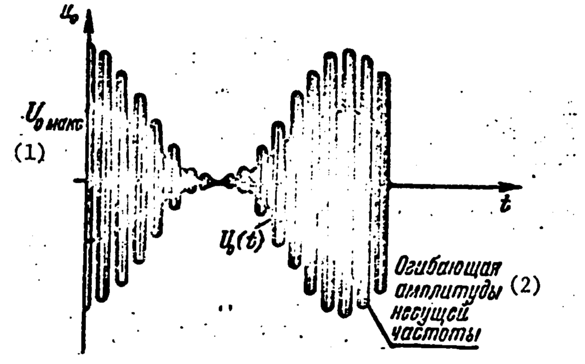

Figure 2.37. AM signal with regulatable amplitude of the carrier with respect to the law of the envelope of the modulating signal for CMC with m=1

Key: 1. $U_{0\ \max}$; 2. envelope of the carrier frequency amplitude

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31 JANUARY 1980 B. N. FILATOV, A. V. SHERSHAKOVA (FOUO) 2 OF 4

The spectrum of the AM signal with regulatable carrier for $U_{\Omega\ \min}=0$ is illustrated in Fig 2.38.

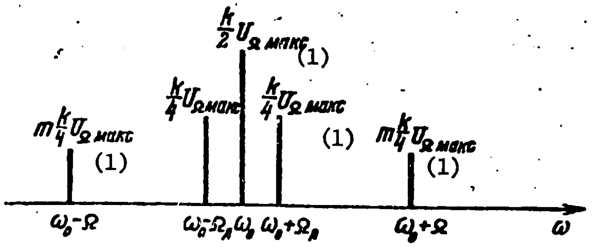

Figure 2.38. Spectrum of the AM signal with regulatable carrier for m<1 (the component side frequencies $\omega_0+\Omega\pm\Omega_A$ and $\omega_0-\Omega\pm\Omega_A$ are not shown)

Key:
1. max

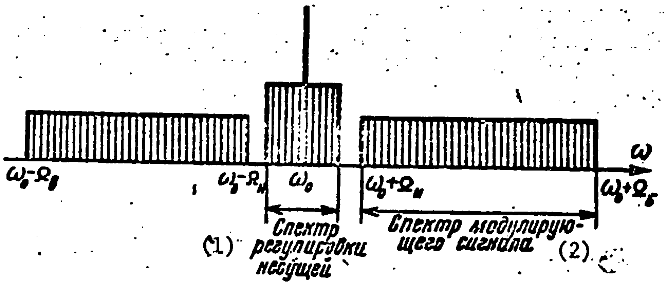

Figure 2.39. Spectrum of the AM signal with regulatable carrier with broadcast modulating signal

Key:
1. Carrier regulation spectrum
2. Modulating signal spectrum

Under actual conditions of transmitting the broadcast signal the modulating signal and its envelope vary in accordance with the more complex laws, which leads to the appearance of a spectrum of carrier regulation frequencies, but this spectrum must not overlap the spectrum of the modulating signal to avoid the appearance of distortions of the broadcast signal (Fig 2.39).

In order to evaluate the AM signal with regulatable carrier, along with the basic assumed normalized parameters, it is necessary to introduce the characteristics which would be connected with regulation of the carrier.

Inasmuch as the regulation process on the carrier is determined by the levels of the modulating signal and the time parameters of the increase and decrease in the carrier, in order to estimate the total AM signal with regulatable carrier it is sufficient to introduce the static characteristics $U_0=\phi(U_\Omega)$ (the regulation curve) and $m=\psi(U_\Omega)$ and the time characteristics $U_0=\theta(t)$ with an increase and a decrease in the carrier voltage.

In the general case the expression for the AM signal with regulatable carrier has more complex form:

$$u = \underset{(1)}{U_{0\text{макс}}} h[d(t)] \left[1 + \frac{cU_{\Omega\,\text{макс}}\,d(t)}{\underset{(1)}{U_{0\text{макс}}} h[d(t)]} \cos\Omega t\right] \cos\omega_0 t, \tag{2.44}$$

Key: 1. max

where

$$h[d(t)] = \frac{U_0(t)}{\underset{(1)}{U_{0\text{макс}}}}; \tag{2.45}$$

$$d(t) = \frac{U_\Omega(t)}{\underset{(1)}{U_{\Omega\text{макс}}}}. \tag{2.46}$$

Key: 1. max

Thus, the regulating curve can also be represented by the dependence of two variable coefficients h and d:

$$h = \phi(d). \tag{2.47}$$

The indicated characteristics determine the effectiveness of the suppression of the nonlinear crosstalk interference and distortions introduced by regulation of the carrier.

As was demonstrated in (2.32), the most effective regulation of the carrier from the point of view of the decrease in the crosstalk interference is the rectilinear function $U_0=\phi(U_\Omega)$, that is, the function for AM signal with CMC.

However, the investigated AM signal with CMC was not used, for with detection of such a signal the appearance of quadratic nonlinear distortions increasing with a decrease in the voltage of the carrier frequency at the detector input of the receiver is unavoidable. Therefore, in order to insure linear detection in the receiver without a significant increase in voltage of the carrier frequency at the input of the sector (which would lead to complication and an increase in cost of the receiver) the regulation function $U_0=\phi(d)$ was varied (Fig 2.40), which was naturally reflected on variation of the function $m=\psi(D)$ (Fig 2.40).

The absence of regulation of the carrier with large modulation frequencies in practice is not felt in the noticeableness of the crosstalk interference, for under these conditions the interference is well masked by the useful signal. Thus, the regulation of the carrier is carried out with a decrease in the modulation coefficient, which facilitates the operating conditions of the detector in the receiver. In the absence of the modulating signal the voltage of the carrier does not drop to zero as in the case with CMC, but remains small. This remainder of the carrier assumed equal to 0.1 $U_{0\ max}$ defines the maximum suppression of the interference in the broadcast signal interval. In order to obtain the AM signal with regulatable carrier it is first necessary to obtain the regulatable carrier and then modulate it.

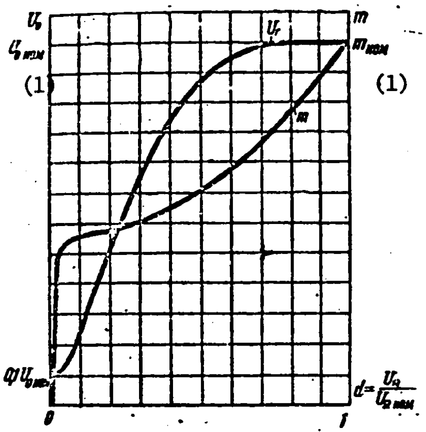

Figure 2.40. Regulation curve and variation of the modulation coefficien. assumed in the existing transmitters

Key:
1. rated

The presence of a remainder of the carrier in the broadcast transmission interval is a deficiency of the assumed regulation curve, for it limits the use of the proposed method of decreasing the crosstalk interference. Therefore, in the future another regulation curve will be proposed (see Fig 2.41) in which the initial function $h=\phi(d)$ is retained within the limits of the dynamic transmission band of 45 decibels, that is, at $0.05 \leq d \leq 1$, and for a level of the broadcast signal less than -45 decibels ($d<0.005$) the carrier is in practice suppressed to zero, that is, $h_{min}=0$. This permits in practice suppression of the nonlinear crosstalk interference to zero in the useful signal interval.

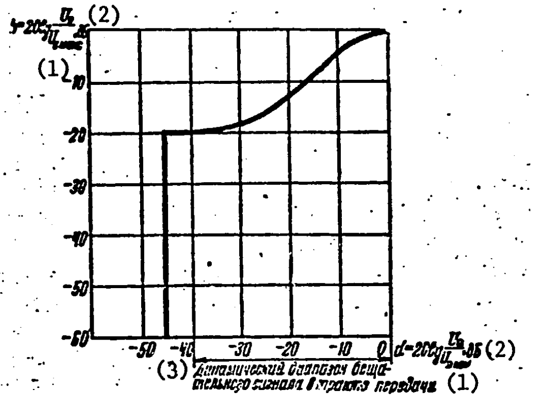

Figure 2.41. Regulation curve with complete separation of the carrier in the broadcast signal interval

Key:
1. max
2. decibels
3. Dynamic broadcast signal range in the transmission channel

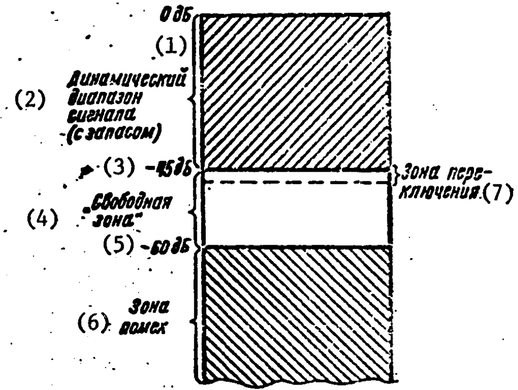

Figure 2.42. Location of the broadcast signal and interference levels for the program feed channel

Key:
1. Decibels
2. Dynamic signal band (with reserve)
3. -45 decibels
4. Free zone
5. -60 decibels
6. Interference zone
7. Switching zone

The possibility of realizing this proposition is determined by the fact that the interference level at the input of the transmitter is appreciably below the minimum signal level, that is, there is a sufficient "free zone" (Fig 2.42) between these levels for stable operation of the threshold device for switching the carrier on and off. The total magnitude of all of the interference according to All-Union State Standard 11515-65 at the input of the reference repeater station must not exceed -60 decibels, and in this case the "free zone" will be 15 decibels. The switching zone must be sufficiently low on the order of 2-3 decibels to avoid interference in it, and it is located near the minimum signal level. The threshold for switching off the carrier in the given case is established 5 decibels below the minimum signal level.

The total suppression of the carrier permits us to obtain a gain in the signal interval not only with respect to the nonlinear crosstalk interference, but also with respect to all forms of interference occurring at the input of the transmitter and in the transmitter itself. Fig 2.43 shows one of the possible methods of switching the carrier on and off by means of the controlled switch K which closes and opens the input circuit of the tube L located in the transmission channel of the carrier or the AM signal of the transmitter.

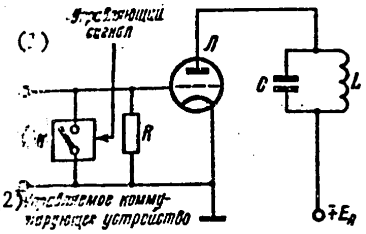

Figure 2.43. Functional diagram of the suppression of the carrier in the interval by means of the controlled switching device

Key:
1. Controlling signal
2. Controlled switching device

The role of the time characteristics of the carrier regulation reduces to the following. The time of buildup of the carrier is determined by the rate of buildup of the modulating signal and the charge time constant τ_{charge} of the controlling detector. The buildup delay of the carrier voltage with large τ_{charge} can lead to remodulation of the carrier, that is, to the appearance of nonlinear distortions, too small a carrier buildup time can lead to the appearance of nonstationary processes in the receiver expressed in audible clicks. Therefore, the carrier buildup time must be matched with the buildup time of the natural sounds. This time is no less than 5 milliseconds so that the buildup time of the carrier to 0.9 $U_{0\ max}$ can be taken equal to 5-6 milliseconds, which is less than the duration of 20 milliseconds for which the nonlinear distortions begin to be heard.

The time of decay of the carrier is determined by the decay time of the modulating signal and the discharge time constant of the controlling detector of the transmitter $\tau_{discharge}$. With a large carrier **decay** time, that is, with a delay in the decay of the carrier with respect to the decay of the modulating signal, a delay in the decay of the level of the nonlinear interference takes place determined by the carrier level, which leads to the appearance of noticeableness of the crosstalk interference. On the other hand, too small a decay time leads to worsening of the filtration of the detection products which, in turn, increases the nonlinear distortions of the envelope of the AM signal as a result of spurious modulation of the carrier by the detection products in the regulated device. In addition, a decrease in the decay time of the carrier can also lead to the appearance of clicks in the receiver. Let us consider in general form the increase in the harmonic coefficient of the envelope when regulating the carrier.

The harmonic coefficient of the envelope of the AM signal

$$K_r = \frac{\sqrt{m_2^2 + m_3^2 + \ldots + m_n^2}}{m}, \qquad (2.48)$$

where m is the modulation coefficient of the basic frequency; m_2, m_3, m_n are the modulation coefficients of the corresponding harmonics of the basic frequency.

Relating the values of m_2, m_3, m_n to the voltage of the modulating signal U_Ω, the carrier voltage U_0 and the regulation curve $U_0=\phi(U_\Omega)$, it is possible to obtain the expression for the modulating coefficient of each harmonic:

$$m_i = S\frac{U_{\Omega i}}{U_0}, \qquad (2.49)$$

where $U_{\Omega i}$ is the harmonic voltage at the output of the detector; $S=dU_0/dU_\Omega$ is the steepness of regulation of the carrier and the point of given voltage U_Ω.

After a number of transformations

$$K_r = \frac{S}{S_0 m}\sqrt{p_2^2 + p_3^2 + \cdots + p_n^2}, \qquad (2.50)$$

where $S_0=U_0/U_\Omega$ is the static coefficient for the investigated point on the regulation curve $U_0=\phi(U_\Omega)$; p_1, p_2, p_n are the pulsation coefficients for each harmonic at the output of the controlling detector.

The performed experimental studies have confirmed the dependence of the harmonic coefficient on the values of F, $\tau_{discharge}$, S.

Fig 2.44 shows the harmonic coefficient as a function of F and $\tau_{discharge}$ for different regulation curve points. For the point of the regulation curve with large steepness of regulation in the frequency range below 600 hertz, the total harmonic coefficient of the transmitter is higher (the dotted curves, in addition, for $\tau_4=120$ milliseconds), in spite of the lower magnitude of the AM signal at this point. Thus, in spite of all of the desirableness of reducing the decay time of the carrier in order to decrease the noticeableness of the crosstalk interference, it is impossible not to consider the buildup of $K_Г$ in this.

Recently in the new developments of transmitters, a regulation curve is used with directly proportional function $U_0=\phi(U_\Omega)$ within the limits from $U_{0\ max}$ to $0.1\ U_{0\ max}$ in order to obtain some additional gain with respect to the crosstalk interference with average signals. The increase in steepness of the regulation curve in this case with maximum signals leads to the necessity for better filtration of the harmonics of the controlling detector.

The time characteristics of the operation of the switch K (Fig 2.43) must be such that the switching time will be appreciably less than the buildup time of the carrier with smooth regulation, and the switching-off time of the carrier, less than the decay time. The switching off of the carrier is expediently carried out at the time of its minimum level as demonstrated in Fig 2.45, which decreases the noticeableness of switching off the carrier.

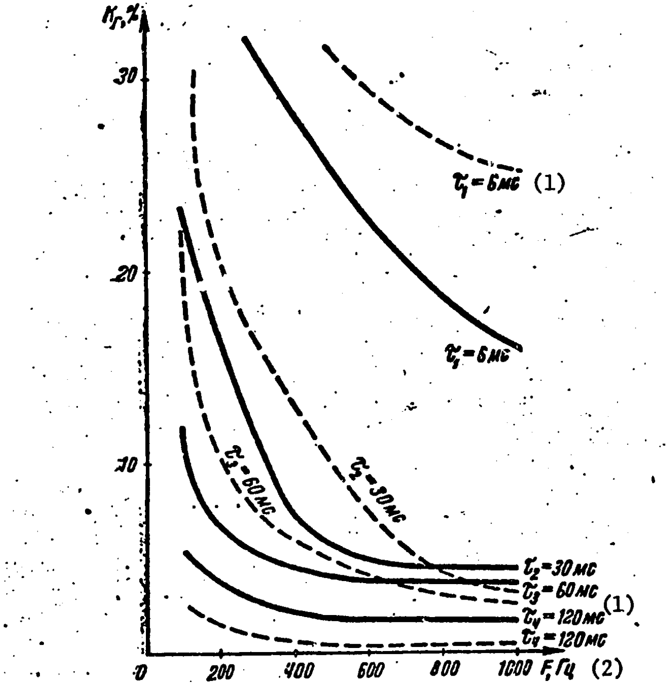

Figure 2.44. Dependence of $K_Г$ of the envelope of the AM signal on F, $\tau_{discharge}$ with the rated modulating signal and reduced by 10 decibels (dotted line)

Key: 1 -- milliseconds; 2 -- F, hertz

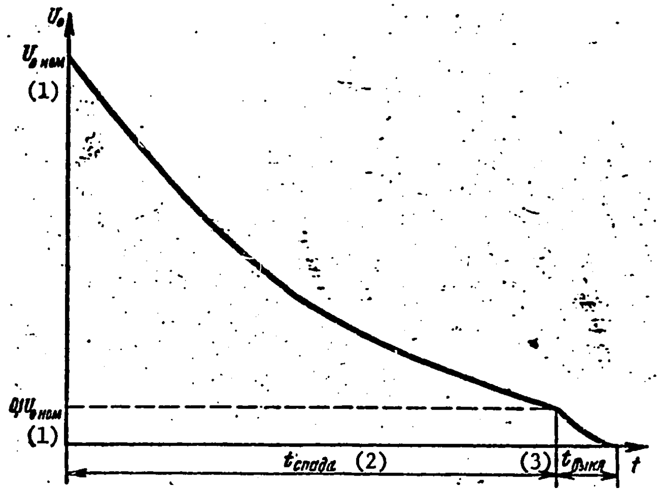

Figure 2.45. Time characteristic of the decay and switching off of the carrier

Key:
1. rated
2. decay
3. switch off

In Fig 2.46 and 2.47 oscillograms of the AM signals are illustrated with the remains of the carrier and the total suppression of the carrier in the broadcast signal interval.

The application of the AM signal with regulatable carrier poses some new problems when developing receivers.

These problems include creation of an automatic gain control, determination of the operating conditions of the diode detector and selectivity of the filters.

The use of an ordinary automatic gain control system is unacceptable under conditions of a variable carrier, for it would lead to automatic gain control by the law of the envelope of the broadcast signal, which would cause compression of the dynamic transmission band. The most acceptable form of automatic gain control is control of the receiver gain with respect to variation of the maximum carrier level, for the maximum level is given uniquely by the transmitter, and its variation indicates variation of the line attenuation, which also is subject to correction by means of the automatic gain control.

[Photo illegible]

Figure 2.46. Oscillogram of the AM signal with remains of the carrier in the interval

[Photo illegible]

Figure 2.47. Oscillogram of the AM signal with total suppression of the carrier in the interval

Here, considering the unique relation between the maximum levels of the carrier and the modulating broadcast signal, it is possible to relate the operation of the automatic gain control to the variation of the maximum broadcast signal level, which permits simplification of the automatic gain control circuitry, using connection of it to a powerful output stage.

The tracking by the automatic gain control system only of the variation of the maximum signal level without any reaction to the ever smaller signal levels is achieved by the application of a peak detector with small charge time constant on the order of 10 milliseconds and large discharge time constant on the order of 10 minutes. The use of this automatic gain control permits us to have amplification variation of no more than 2 decibels even with the longest pauses in the actual transmissions (2 minutes). It is necessary to consider that the initial voltage at the output of the receiver with such a large discharge time of the detector of the automatic gain control will be determined not only by the input voltage, as for the ordinary automatic gain control, but also the direction of variation of the input signal -- from smaller to larger or vice versa. On variation of the input signal from smaller to larger the output signal will vary according to the automatic gain control characteristic $U_{out}=f(U_{inp})$, with inverse variation of the input signal, obtaining the corresponding output voltage $U_{out\ 1}$ for the given input signal $U_{inp\ 1}$ takes place after a significant time in accordance with the discharge characteristic of the RC-circuit of the receiver detector. Therefore, in the given case it is expedient to consider the entire operating cycle of the automatic gain control presented in Fig 2.48.

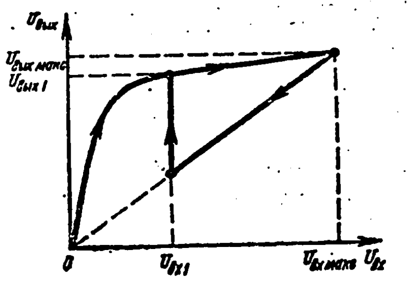

Figure 2.48. Operating cycle of the automatic control in the group receiver

Key:

1. U_{out}
2. $U_{out\ max}$
3. $U_{out\ 1}$
4. $U_{inp\ 1}$
5. $U_{inp\ max}$
6. U_{inp}

A natural deficiency of this automatic gain control system is the long recovery of the output voltage with an instantaneous drop of the input signal of the receiver, but the basic cause of variation in level of the input signal consists in variation of the line attenuation from weather conditions, which takes place with still greater duration, and the automatic gain control can fully follow these variations. The investigated type of automatic gain control is used in group receivers; its use in individual receivers is possible as a result of the addition of a relatively large number of circuit elements.

The voltage regulation of the carrier again poses the problem of the operating conditions of the AM signal detector in the receiver. With a constant carrier, the required voltage of the carrier frequency at the input of the detector is determined only by the condition of absence of the nonlinear distortions of the envelope as a result of detection of the AM signal, which is achieved for input voltages of the carrier on the order of 0.5 to 0.8 volts for germanium diodes with a modulation coefficient of m=0.7. With variable carrier, another condition is imposed on the operation of the detector -- transmission without distortions of the entire dynamic range of the broadcast signal.

The distortions of the dynamic range naturally occur as a result of a decrease in the transmission coefficient of the detector in the nonlinear initial section with small carrier voltages. This fact requires an increase in the initial maximum carrier voltage at the input of the detector to 1.5-2 volts.

The suppression of the carrier in the interval, partial or complete, reduces the additional interference suppression from the adjacent high-frequency channel in the inertialess detector. Consequently, decreasing the carrier in the broadcast transmission interval by 10 times requires an increase in selectivity of the receiver filters.

The use of the AM signal with regulatable carrier will permit us to obtain a more economical operating condition of the powerful stages of the AM signal transmitters and amplifiers.

2.13. Stereophonic Broadcasting in the TPB System

The creation of the TPB system permits us to investigate the possibilities of its use to transmit stereophonic programs. For this purpose it is necessary to determine whether the channels of the TPB systems satisfy the requirements of transmission of stereophonic programs, which two channels out of the three available ones it is more expedient to use for transmission of the programs and also what the possibility is for creating a stereophonic system compatible with the monophonic reception for subscribers having only single-program speakers.

The low-frequency channel of the TPB system in the majority of cities has quality class I of All-Union State Standard 11515-65, and the high-frequency, approximately class II. The use of the channels distinguished by quality class I for stereophonic transmission is admissible. Here it must be noted that class II stereosound is subjectively preferred to the higher class of monophonic sound. The requirements with respect to imbalance of the levels and the crosstalk attenuation between the stereophonic channels are satisfied by the forms for the TPB system channels. The studies made of the Riga WB network of the phase shift between the channels in the frequency band of 100-6000 hertz demonstrated that a phase shift basically determined by the three-program speakers is within the limits of the required norms. Thus, the TPB system insures all the required conditions for transmission of stereophonic programs.

Stereophonic broadcasting can be organized with respect to any two out of three available channels [28].

The variations in the use of the low-frequency channel and one of the high-frequency channels are the most preferable by comparison with the version of using two high-frequency channels, for in the first case the presence of a single program and three-program speakers ast the subscriber is required, and in the second case, two three-program speakers. In the majority of cases for reception of stereophonic programs using the low-frequency channel the subscribers must acquire a three-program speaker for the existing single-program speaker.

Out of the two versions of wire stereo broadcasting using the low-frequency channel, the most expedient is the version with the high-frequency channel located with respect to the transmitted frequency band closer to the low-frequency channel, that is, the high-frequency channel for transmission of program II. In this version the stereo broadcasting and the monophonic broadcasting over channel III have the greatest mutual noiseproofness by comparison with all other versions. Moreover, it is possible to assume that for organization of wire stereophonic broadcasting it is sufficient to create another high-frequency channel on the carrier frequency of approximately 45-50 kilohertz. Worsening of the noiseproofness of this channel from the low-frequency channel is not critical, for the admissible crosstalk attenuation between the stereo broadcast channels can be within the limits of 26-30 decibels, which is satisfiable.

The use of the low-frequency channel to transmit stereo programs poses the problem of compatibility of the reception of the full valued monophonic programs on the single program speakers. The known sum-difference method of creating compatibility of reception of stereo and mono programs are unacceptable in the TPB system as a result of rigidity of the requirements imposed on identicalness and the frequency-amplitude and phase characteristics of the total and the difference channels. The TPB channels do not correspond to these requirements. In addition, the necessity arises for significant complication and increased cost of the three-program speaker as a result of introduction of the sum-difference converter into it and also the additional "stereo-mono" switch for the corresponding commutation to take place. The most acceptable method of compatibility is the method based on using the lead effect (the "Haas effect"). This effect consists in the fact that in the presence of two separate sources of sound transmitting the same information and in the case of nonsimultaneousness of feed of the information to them the sound turns out to be originating from only one source, included first. In this case if the signal B (Fig 2.49) is introduced with some delay in time into the channel A, then the listener perceives the signal of channel B only from speaker B. Only the signal of the left channel A will be perceived from the A speaker. Thus, the introduction of the signal B' delayed in time into the A channel does not disturb the stereophonic reception. At the same time the transmission over the A channel of the total signal A+B' insures compatibility of the monophonic reception on the signal-program speakers. Some time delay B' is not reflected in practice in the audio reception of the signal of a monophonic transmission. In order to obtain the required delay time (10 milliseconds in the entire audio frequenty range), an LC-delay line is used.

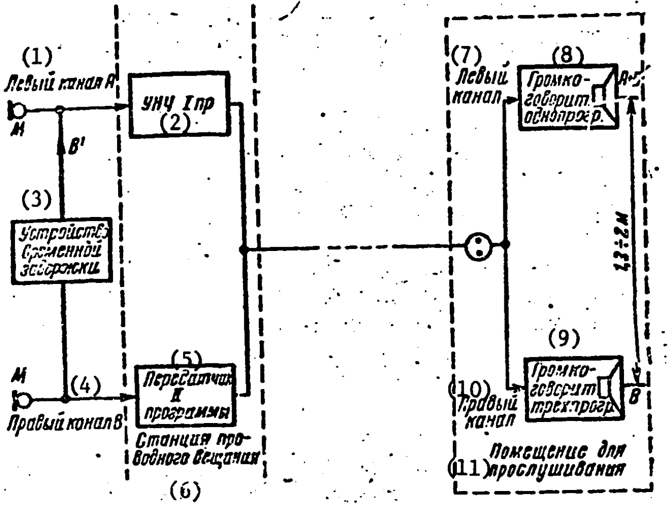

Figure 2.49. Structural diagram of the organization of stereophonic broadcasting in the TPB system

Key:
1. Left channel A
2. Low-frequency amplifier
3. Time delay circuit
4. Right channel B
5. Transmitter of program II
6. Wire broadcast station
7. Left channel
8. Single program speaker
9. Three-program speaker
10. Right channel
11. Listening facility

A comparison of the two versions of compatible stereo broadcasting with transmission of the signals A+B or A+B' indicates that the method of transmitting the signals A+B' has significant qualitative advantages over the procedure based on simple summation of A+B. When summing the signals A+B, distortion of the tone appears caused by troughs of the individual sections of the frequency characteristic in the upper frequency range as a result of phase shift of the sound field for the two microphones. When the sound source moves relative to the microphones the tone changes continuously. On addition by the A+B' principle the tone distortions are not perceived. The nature of the sound does not change when the sound source moves.

The structural diagram of the stereo broadcasting in the TPB system is presented in Fig 2.49. The quality of the stereophonic reception is affected by the polarity of the inclusion of the single-program speaker.

A further development of this method of stereo broadcasting is the cross introduction of the signals with delays into the two channels and obtaining a signal time delay on the tape recorder [51].

The organization of stereo broadcasting in the TPB system is the cheapest and most available for the listeners by comparison with the wireless stereo broadcasting transmitted in the ultrashort wave band. The cost of the receivers for stereo reception in the TPB system is approximately more than 10 times less than the cost of the existing stereophonic radios.

The transmission of stereophonic programs over the WB network using the indicated procedure has received positive evaluations.

2.14. Basic Principles with Respect to Equipping Links of the TPB System

General Information

Depending on the structure of the WB networks, a different combination of standard equipment devices is used for the TPB transmission system.

The investigation and description of the system equipment are carried out separately with respect to the most important elements: station, line structures and receivers.

Figures 2.50-2.52 show the schematics of the equipment of the mixed and decentralized WB networks.

Station Structure of the WB Networks

In all of the central wire broadcast stations of all cities except Moscow the following basic standard equipment has been installed which is produced industrially (Fig 2.50, 2.51):

1. Preamplification equipment of the APU-2, APU-3 type for commutation of the basic and the reserve program sources, preamplification of the broadcast signal programs and distribution of them with respect to the sites or the program feed equipment developed for the TPB networks. The APU-2 and APU-3 have two independent channels with output power of 15 and 25 volts respectively. For TPB three sets of preamplification equipment must be installed calculating that each program will have two independent channels. Sometimes only two sets are installed: one for the low-frequency programs and the other for two additional programs. However, in this case when any amplifying channel is damaged, the feed of one of them is interrupted.

2. The command semimodule of the UPK-1 or UPK-2 type from the remote monitoring and control equipment of the reference repeater station, UP of the UPK-2 or UUP-1 type (previously produced) or the new equipment (command) of the TU-TK-TS complex for the TPB networks.

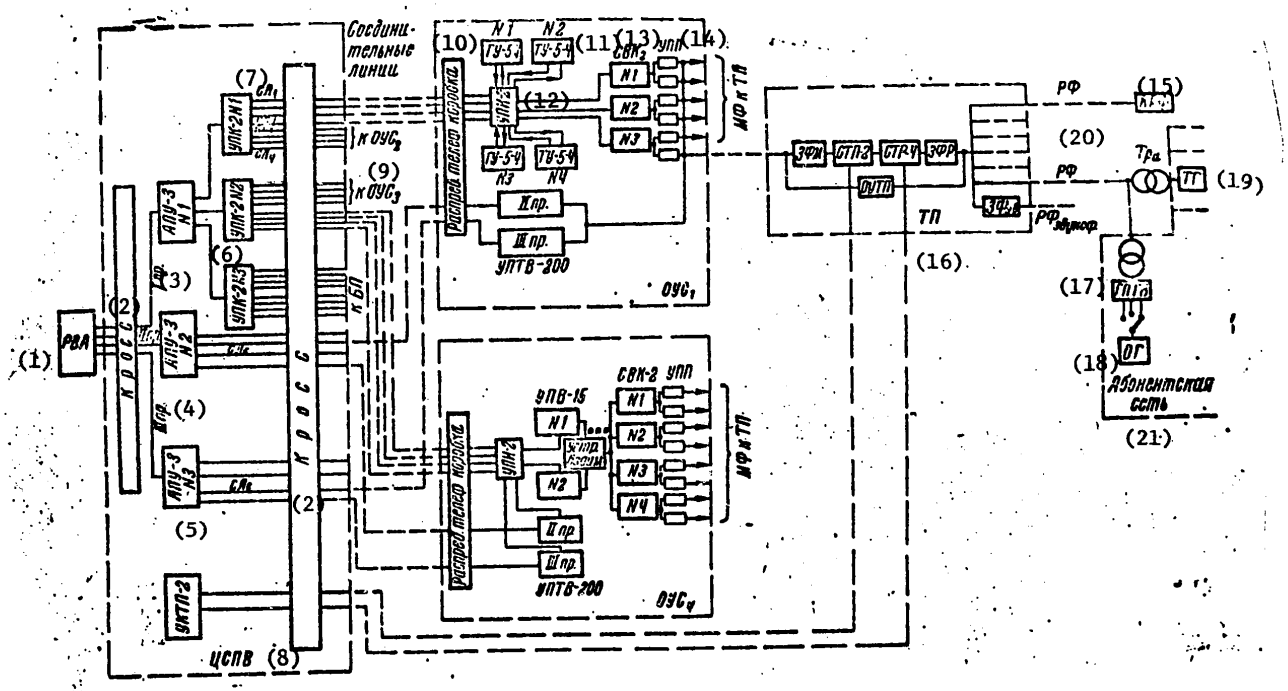

Figure 2.50. Schematic of the equipment for the TPB system for the decentralized network

Key: 1 -- radio broadcast equipment; 2 -- distributing frame; 3 -- program I; 4 -- program II; 5 -- pre-amplifying equipment; 6 -- UPK-... -- command semimodule;7 -- connecting lines; 8 -- central wire broadcast station; 9 --to the reference repeater station; 10 -- telephone distributing head; 11 --repeater; 12 -- UPTV; 13 -- SVK; 14 -- UPP = transmitter connecting circuit; 15 -- KRF; 16 -- transformer; 17 -- GPTV; 18 -- OG; 19 -- TG; 20 -- distributing feeder line; 21 -- subscriber network

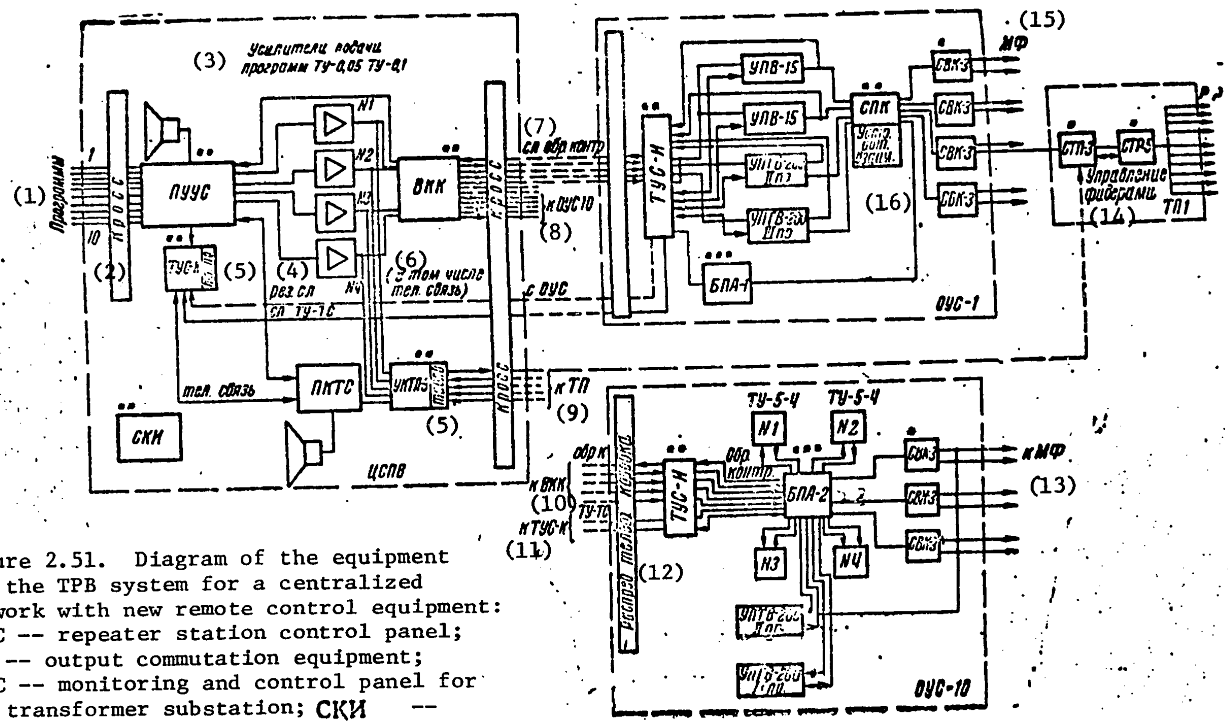

Figure 2.51. Diagram of the equipment for the TPB system for a centralized network with new remote control equipment: ПУУС -- repeater station control panel; ВКК -- output commutation equipment; ПКТС -- monitoring and control panel for the transformer substation; СКИ -- monitoring measurement bay; ТУС-К, ТУС-И -- remote control, monitoring and signal equipment; К -- command; И -- servo; БПА -- intermediate automation unit for different axis of the repeater and transmitting equipment УС: СПК -- intermediate commutation rack.
Key: 1 -- programs; 2 -- distributing frame; 3 -- TU-0.05 TU-0.1 program feed repeaters; 4 -- reserve connecting line; 5 -- display; 6 -- (including the telephone communications); 7 -- return monitoring connecting line; 8 -- to the reference repeater station; 9 -- to the transformer substation; 10 -- to the output commutation equipment; 11 -- to the remote control, monitoring and signal command equipment; 12 -- telephone distributing head; 13 -- to the main feeders; 14 -- feeder control; 15 -- main feeder; 16 -- automatic mutual redundancy of the repeaters; 17 -- PUUS; 18 -- TUSK; 19 --PKTS; 20 -- SKI; 21 -- UKTP: 22 -- VKK; 23 -- BPA-1; 24 -- SPK; 25 -- STP-3; 26 -- STR-5; 27 --SVK-3

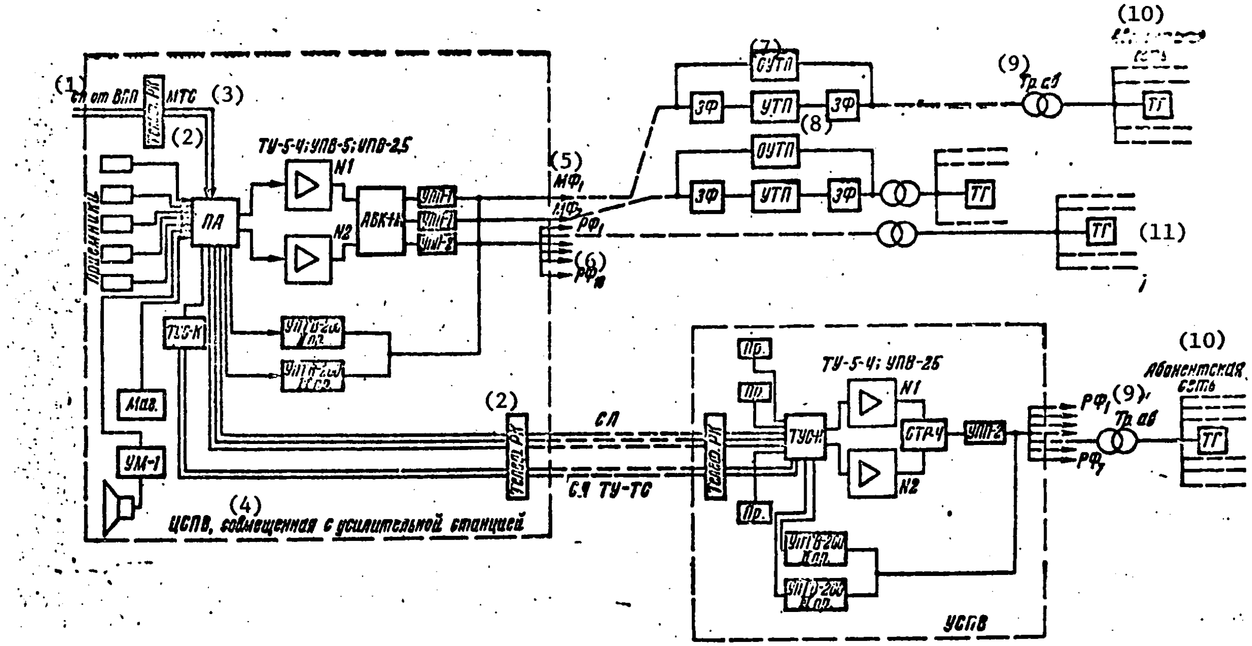

Figure 2.52. Diagram of the equipment for the TPB system for a mixed WB network.
ПА -- intermediate automation equipment

Key: 1 -- connecting lines from the VPP; 2 -- telephone distributing head; 3 -- MTS; 4 -- central wire broadcast station combined with repeater station; 5 -- main feeder; 6 -- distributing feeder; 7 -- OUTP; 8 -- UTP; 9 -- subscriber transformer; 10 -- subscriber network; 11 -- TG;

The UUP-2 complex makes it possible to control two reference repeater stations or UP, BP in the presence of no more than four control objects in each of them (low-frequency amplifier and transmitters).

The UUP-1 set also controls two repeater stations in the presence of each of them of no more than three control objects.

The UUP-1 and UUP-2 complexes are designed for operation over the connecting lines -- the telephone pairs. When using the UUP-1 the central wire broadcast station must be connected to each reference repeater station by three connecting lines, and when using the UUP-2 equipment, four connecting lines.

In order to transmit the control commands, individual strands of the connecting lines are used. The programs are set by simultaneous feed to the 80 volt DC pulse (defined polarity) and alternating current line. Noiseproofness of the system is achieved in this way. The command DC message is fed over the "conductor-ground" network, and AC, over the "two-wire-ground" network.

The command message is the switch; on return of the switches to the initial position the voltage of the command message is picked up from the line. The command output is accompanied by obtaining a verification of execution.

Sl_1 connecting line is used only to sheathe the low-frequency programs; Sl_2 is a reserve line. Over the "strand-ground" Sl3 line a control command is transmitted for one low-frequency module; over the circuit made up of the "other strand to ground", the control circuit for module II is low frequency. A command is transmitted over the Sl_3 line for modules III and IV or for control of the transmitters of programs II and III.

The return sound monitoring with respect to low frequency from the outputs of the low frequency repeaters installed at the reference repeater station, the PP, UP and the telephone service communications are realized over the Sl_3 and Sl_4 telephone pairs. With respect to individual circuits (fifth and sixth) from the APU-3 No 2 and APU-3 No 3 (Fig 2.50) the transmission of the signals of two additional programs to the transmitters of several reference repeater stations.

3. The equipment of the UKTP type [transformer substation connection circuit] for remote monitoring and control of the sound transformer substations and monitoring of the distributing feeder lines. The equipment is designed for the control of 6 and 12 transformer substations equipped with SGR and SGP bays. For this purpose the central wire broadcast station is connected to each transformer substation by two pairs of the city telephone exchange lines, and in the presence of feeder lines for outdoor sound systems (FUZ), three pairs.

4. The reserve program sources are special receivers for receiving AM and ultrashort wave broadcast stations, a tape recorder, sound pickup and microphone.

The following types of equipment are installed at the reference repeater stations:

1. Low-frequency amplifier with output power of 5 kilowatts, type TU-5-3, TU-5-4, UPV-5 or 15 kilowatt type UPV-15. In Moscow and Leningrade more powerful amplifiers are used (by 30 and 60 kilowatts).

At the newly designed reference repeater stations up to four repeaters of the TU-5 (OUS_1) type are installed; at the individual existing reference repeater stations up to six TU-5 repeaters or two UPV-15 repeaters [OUS_4 (Fig 2.50)] are installed. The quality indexes of the repeaters correspond to the requirements imposed on the first quality class (All-Union State Standard 11515-65): rigid output voltage 240 volts; total power intake by the repeater from the feed network in the rated output power mode, UPV-15, 33 kilowatts; UPV-5, 13 kilowatts. In the UPV-15 repeater the tubes have forced cooling -- by an exhaust fan.

2. The servo semimodule is a bay of the UPI-2 or UPI-1 type from the set of remote monitoring and control equipment of the UUP-2 or UUP-1 type (previously produced by industry) for reception and execution of control and sending return verficiations and also for preamplification of the programs coming from the central wire broadcast station to the reference repeater station or the servo semimodule of the TU-TK-TS equipment developed for the TPB networks. In the UPI there is a device for automatic mutual redundancy of the TU-5 repeaters.

The input level of preamplification of the UPI is zero (0.775 volts). The UPI-2 bay is designed to control four controllable objects, and the UPI-1 bay, three.

3. The SVK-2 type output commutation bays are equipped with voltage step-up transformers on sonic frequency coming from the output of the low-frequency amplifier, from 240 to 480/960 volts and transmission of it to the main feeder. In one SVK bay there are two independent cells, each of which is designed to connect one main feeder.

Each SVK cell contains a 5 kilowatt feeder transformer; the switching element; protection and signalling.

4. The set of UPV-200 transmitters made up of two program II and III transmitters.

For TPB, a device is installed in each SVK cell for connecting the transmitters of programs II and III (UPP) to the main feeder line. The reference repeater station for insuring uninterrupted operation requires special ventilation units and electrical equipment and the laying of power cables.

Other types of station sites are encountered in the cities where the repeating equipment is installed. These include the substation block BP and the USPV repeater stations. The substation block is a transformer substation connected by the main feeder to one reference repeater station and equipped with a reserve repeater (instead of a second main feeder). A simplified device is required for monitoring and control for it.

In the BP [substation block], as a rule, the TP-STR and STP equipment is installed, and for the TPB, the UPTV-200 transmitter.

The wire broadcast repeater station is designed to feed a two-element or mixed city network or remote region (Fig 2.52). The USPV is set up by analogy with the reference repeater station. As the output switching equipment, the STR bay is installed from the transformer substation complex with two-element network or the AVK type bay designed for connecting 10 distributing feeders and two main feeders. The transformer substation is designed to step down the audio frequency voltage and distribute the low-frequency and high-frequency power of the distributing feeders.

Two bays are installed at each transformer substation: STP-1, STR-3 or STP-2, STR-4.

In the STP-1 bay there are cells for connecting two main feeders: operating and reserve. In each cell the 5 kilowatt feeder transformer is installed which steps down the audio frequency voltage from 480/960 to 120/240 volts. Each transformer substation can feed up to 12500 subscriber units. Over the main feeder lines connecting the SVK and the STP equipment, an audio frequency is transmitted from the reference repeater station to the transformer substation. The control commands for the system for starting the given main feeder line are transmitted over the artificial circuit of the "feeder line wire to ground."

The STR-3 or STR-4 bay is designed to connect 10 distributing feeder lines and two feeder lines for the outdoor sound system. The automation elements for remote control transformer substation are located in the bay.

The transmission of the signals of the high-frequency channels to the distributing network takes place through the bypass of the step-down transformer, for which a transformer substation connection circuit (UPTP) is installed at the transformer substation, including the following:

a) ZFM and ZFR blocking circuits (for the main feeder and distributing network respectively) for the high-frequency currents. The coils of the filters -- air executed from quite thick wire to insure minimum attenuation of the low-frequency currents going through the coils;

b) The bypass for the OUTP to create a bypass of the high-frequency transformer for the high-frequency currents and matching of the load of the main feeder (the distributing network) with the wave impedances of the main feeder. The transformation coefficient of the standard OUTP is 3.15; it is assumed here that one main feeder line feeds 10 distributing feeder lines.

The high-frequency voltage at the input of the distributing network (on the STR bay) must be within the limits of 20 to 30 volts.

As was stated above, the remote monitoring and control of the operation of the transformer substation, the distributing feeder and the FUZ are realized on the UKTP bay of the central wire broadcast station using two or three connecting lines.

A structural diagram of the connection of the UKTP-1 bay to three transformer substations is given in Fig 2.53. The Sl_1 connecting line is used for remote monitoring and control of the main feeder. The control, monitoring and signalling of the main feeder are realized over two artificial sl_1 channels formed by each wire of this line and the ground. The wires of this line are used for return sound monitoring from the buses of the transformer substation and telephone communications TsSPV [central wire broadcast station] with the transformer substation.

Sl_2 is used for monitoring and control of the feeders of the outdoor sound system over the same artificial circuits as in the sl_1 connecting line. The pair of sl_2 wires are used for return sound monitoring of the FUZ.

The Sl_3 connecting line is provided for emergency signals (that the fuses are burned out at the entrance of each distributing feeder of the STR) and remote monitoring of the voltage from the ends of each distributing feeder line.

In the mixed network for areas with small load (2500 to 5000 radio points), a simplified type transformer substation (UTP) is installed with one-way feed without remote control and monitoring (see Fig 2.52).

The repeater stations and substations OUS, UP, BP and TP, as a rule, are placed in the facilities allocated by the local admissible organizations in the residential and public buildings.

In a number of cities, especially newly built ones, the plans call for the location of a central wire broadcast station jointly with the reference repeater station [OUS] in the same building with the ATS, MTS. In the majority of cities the central wire broadcast station is placed in the same facility with one of the OUS [reference repeater stations].

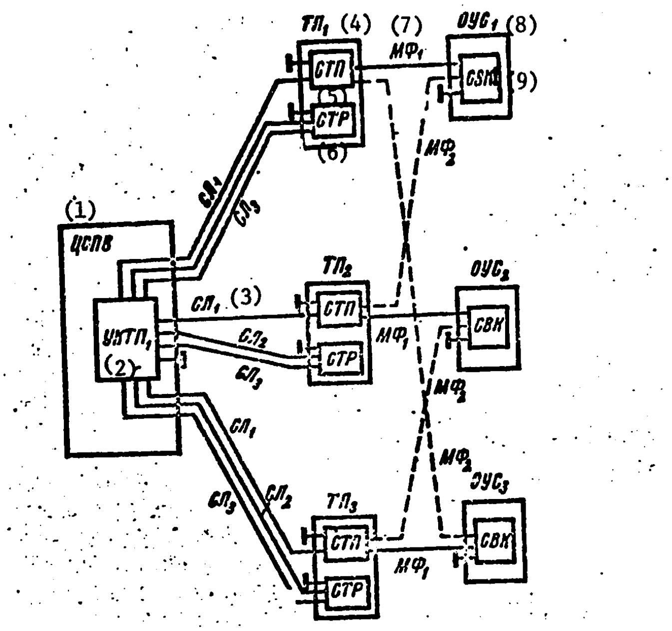

Figure 2.53. Structural diagram of the connection of the UKTP to the transformer substation

Key:
1. Central wire broadcast station
2. UKTP$_1$
3. Sl $_1$ connecting line
4. TP$_1$ [transformer substation]
5. STP
6. STR
7. Main feeder line
8. Reference repeater station
9. SVK

For powerful OUS -- 30, 60 kilowatts -- special work areas are built, in which there is a whole set of stations including power equipment and ventilation.

Line Structures

The line structures are a responsible part of the WB network. The introduction of the TPB system on the existing WB networks imposes additional requirements on the lines considering the application of the high-frequency channels.

In large cities the main feeder line is a post and more rarely, pole line. The wires, as a rule, are bimetal, 3, 4 mm in diameter or steel, 4 mm in diameter. The line length is from hundreds of meters to 10 kilometers. The average length is 4 km. The inputs to the amplifying and transformer substations are cable. Along the path of the line, cable inserts are used which are made up of the MRM type cable and large capacity power cable. The rated low-frequency voltages are 480, 680, 720, or 960 volts; the transmitted power is up to 5 kilowatts.

The high-frequency voltage is to 120 volts, the transmitted power 25-30 watts. The voltage attenuation along the low-frequency channel (at a frequency of 1000 hertz) is 1-2 decibels. The attenuation of the high-frequency channel is determined by the expression $a_{\text{main feeder}}=\alpha\ell$ and with a matched regime for the lines without cable inserts it is within the limits of 1 to 10 decibels. In the presence of several cable inserts, depending on the type of cable used and the accuracy of matching the input impedances, the attenuation of the section can reach 15 decibels. The input impedance of the main feeder can differ from wave (as a result of impossibility of insuring exact matching) by ±20%.

The distributing feeder lines can be post, pole and cable. The wire material is bimetal and steel, 3 and 4 mm in diameter and copper, 1.2 mm in diameter. The attenuation on low-frequency (at a frequency of 1000 hertz) must not exceed 3 decibels; on high frequency it reaches 10 to 12 decibels.

The distributing feeders in the cities, as a rule, are lines with uniformly distributed load. The role of the latter is played by the subscriber transformer, the input impedance of which on high frequency is from 5 to 20 kilohms, and the transmission coefficient is 0.01 to 0.1 depending on the power of the subscriber transformer and its load.

The subscriber lines -- post or pole -- are made, as a rule, from steel wires. Their extent is from 100 to 200 to 700-800 meters and more rarely 1 km. The load of the subscriber line is the subscriber inputs ending in a subscriber set. The attenuation of the high frequency voltage of the long subscriber lines can reach 10 decibels. The layout of a subscriber line with single program loudspeakers (OΓ) and three program loudspeakers is presented in Fig 2.22.

The last section of the city WB network, as a rule, is the building networks. By the building network we mean the network fed from one subscriber transformer. The most typical subscriber networks for the cities are the intrabuilding networks of large apartment buildings. The building network is made up of attic and staircase wiring laid in the vertical shaft of the building (sometimes called a "riser") and made as a rule of PVZh type wire with a strand diameter of 1.8-2.5 and intraapartment wiring made of the PTPZh and PTVZh type cables. The input impedance of the building network on the low-frequency channel is determined by the number of speakers connected to the network, and on the high-frequency channels, in addition, by the parameters (primarily, the capacitance) of the wiring.

On the carrier frequencies of the TPB system the building networks acquire new electrical properties -- they become electrically long lines, and in a number of cases require matching to avoid the wave processes. The magnitude of the input impedance of the building network on the multiplexing frequencies fluctuates within the limits of 20-100 ohms (for 5 to 16 story buildings) and attenuation to 6 decibels. As an example, in Fig 2.54 a circuit diagram is drawn for the length of the building network of a 16-story building.

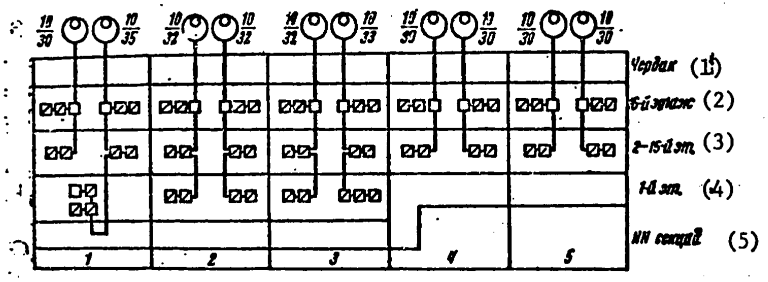

Figure 2.54. Schematic of the staircase wiring of a 16-story residential building

Key:

1. attic
2. 16th floor
3. 2d to 15th floor
4. 1st floor
5. NN sections

In the WB networks, single-program speakers of third or second quality class are used as the subscriber sets. They have input impedance in the frequency range from 50 kilohertz to 10 kilohertz correspondingly of 3-12 kilohms and a phase angle of 30 to 25°. In the high-frequency band these speakers have an input impedance with respect to modules on the order of 5 to 7 kilohms and a phase angle of 60 to 70°.

The Avrora and Mayak type three-program speakers that are manufactured have an input impedance within the range of 2.5 kilohms, and on the high-frequency channel the modulus of the input impedance to 4.5 kilohms and a phase angle of about 40°.

Additional specialized high-frequency devices are used on the TPB networks to correct the WB lines, a description of which is discussed in detail in the following sections.

Program Sources, Connecting Lines for Feeding the Programs, Remote Monitoring and Control

The basic program source is the radio broadcast equipment(RVA) and in individual cities, the interurban broadcast channels or the segregated receiving stations (VPP).

The union central broadcasting progrms obtained over the interurban cable lines reach the central wire broadcast station most frequently via the RVV, but in individual small cities they go directly to the central wire broadcast station.

The local program sources are professional specialized AM and ultrashort wave FM receivers of the radio broadcast stations or tape recorder and sound pickups of the local broadcasts studios. At all of the reference repeater stations, UP receiving programs from the central wire broadcast station, professional receivers and tape recorders are installed as the reserve sources. In many cities the central and oblast broadcast programs of the wire broadcast station are received by the professional receivers.

The programs are fed from the RVA to the central wire broadcast station in tandem over special cables with shielded strands or with a connection to the automatic telephone office distributing frame in a common cable in the central wire broadcast station to automatic telephone office section. The length of the cable lines in this section is from 0.1 to 3 km.

A multipair telephone cable, most frequently type T with strands 0.5 mm in diameter, a capacity of 150, 100, 80, 50 and 30 pairs, the most different length from hundreds of meters to 2 km, is laid between the central wire broadcast station and the closest automatic telephone office. Between the automatic telephone office and each object of distribution of the reference repeater station, BP, UP and TP telephone pairs are used in the cable lines of the city telephone exchange. In these sections are used with strands 0.5, 0.6, 0.7 and 1.2 mm in diameter. The skeletal diagram of the connecting lines for the decentralized networks in the cities is presented in Fig 2.55.

For the existing TPB system and standard remote control and monitoring equipment, the following number of telephone pairs of the city telephone exchange are required:

1. Between the central wire broadcast station and the reference repeater station at 20 kilowatts, 8 pairs, including considering the reserve, 4 pairs for feeding the programs and 3 for remote monitoring and control of the low-frequency amplifiers and the UPTV-200.

2. Between the central wire broadcast station and the reference repeater station at 15 and 30 kilowatts (with two UPV-15), 7 lines; of them, 4 are for feeding the programs and 3 for remote monitoring and control.

3. Between the central wire broadcast station and the transformer substation three lines in the presence of FUZ and two if they are absent.

4. Between the central wire broadcast station and the substation block, 4 for program feed and 4 for remote monitoring and control of the substation block.

At the present time a system and equipment for program feed, monitoring and control are being built for the city TPB networks using modern remote control methods, in particular, the frequency coding systems insuring high reliability and noiseproofness [21].

This equipment has great possibilities for operative remote control, remote monitoring and obtaining broad information about the condition of the remotely controlled objects using only one telephone pair in all. The diagram of the equipment of the TPB system for the decentralized networks appears in Fig 2.51.

For the new remote monitoring and control equipment (TU, TK) between the central wire broadcast station and each OUS [reference repeater station], UP or BP [substation block] 6 telephone pairs are required, of which considering the reserve, 4 are for the program feed and 2 for TU-TK; there are 2 pairs between the central wire broadcast station and the transformer substation.

The connecting lines in the sections from the central wire broadcast station to the reference repeater station, substation block or UP have a length from 2 to 25.3 km, and in the TsSPV-TP section, from 2 to 26 km. In the TsSPV-OUS section 67% of the lines have a length of up to 12 km, and in the TsSPV-TP section, 78% of the lines. It is necessary to install the intermediate repeaters on the connecting line for the program feed on cable lines with strands 0.5 mm in diameter, and with a diameter of 0.7 mm, 19 km long and more.

The existing remote control equipment operates with a loop resistance no more than 4000 ohms, which corresponds to a cable length of 21 km with strands 0.5 mm in diameter; with strands 0.6 mm in diameter, 30 km long and 0.7 mm in diameter, 37 km. The voltage level of the broadcast transmission at a frequency of 1000 hertz at any point of the connecting line must not exceed +17 decibels. The minimum admissible voltage of the sound broadcast transmission on the load resistance at the end of the line must be no less than 0.775 volts. The crosstalk attenuation between each pair of cables used for broadcasting and other pairs of the same cable measured on a frequency of 1000 (800) hertz must be no less than 78 decibels for the two pairs used, no less than 80 decibels for 6 pairs and no less than 85 decibels for 7 or more pairs. The connecting lines of the program feed must correspond to the indexes of one or more quality class with respect to All-Union State Standard 11515-65. In order to improve the frequency characteristic of the telephone lines when using them in the sections of the WB channels, correcting circuits are used which are installed on the ends of the line.

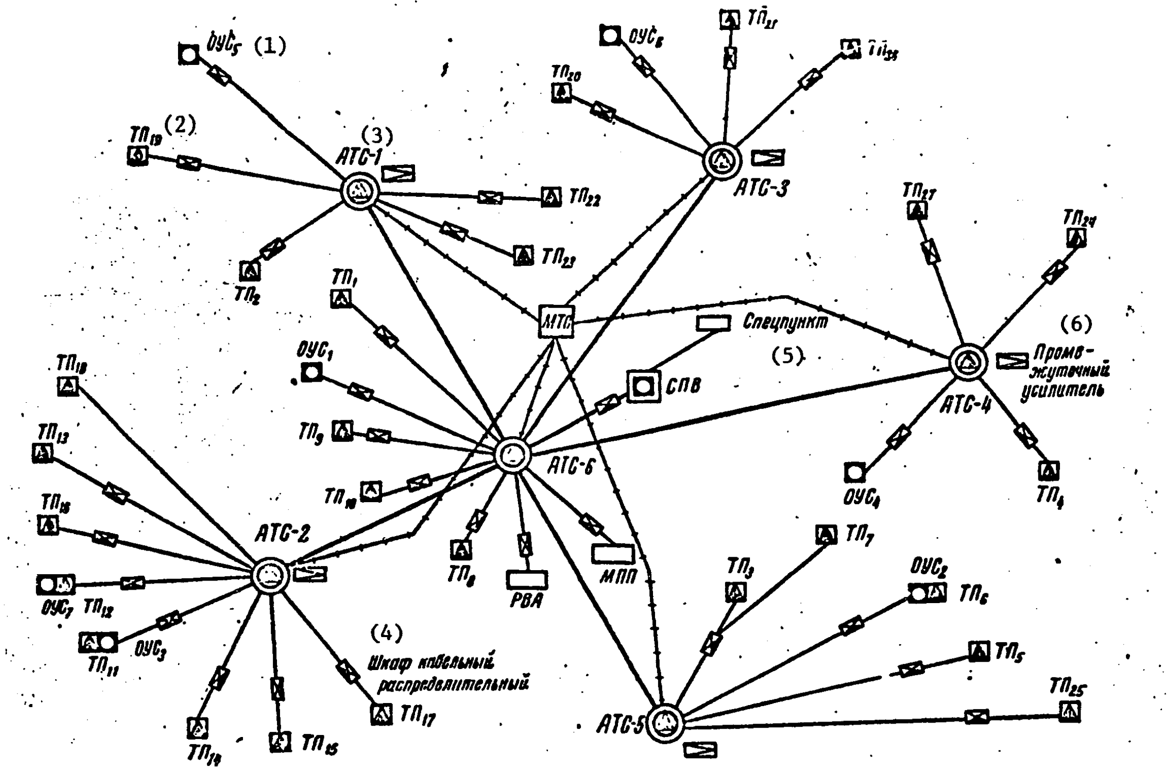

Figure 2.55. Skeletal diagram of the connecting lines for feeding programs, remote monitoring and control (in the city telephone exchanges divided into districts)

Key: 1 -- OUS$_5$ reference repeater station; 2 -- TP$_{19}$ transformer substation; 3 -- ATS ... [automatic telephone office]; 4 — cable distributing bay; 5 -- special station; 6 -- intermediate repeater

CHAPTER 3. INTRODUCTION OF NORMS FOR THE TPB SYSTEM

3.1. General Information

The introduction of norms for the TPB system consists in establishing norms for the low-frequency and high-frequency channels and also individual devices and lines entering into these channels. The introduction of norms for the high-frequency channel is at the present time complete from the point of view of the presence of materials on standardization and design. At the same time the introduction of standards for the high-frequency channel and the devices entering into it is in the state of development and improvement; therefore, primary attention will be given in this chapter to the problems of introducing norms for the high-frequency channel, its devices and lines.

3.2. Introduction of Norms for the Low-Frequency Channel

The introduction of norms for the low-frequency WB channel is defined by the All-Union State Standard 11515-65 "Radio Broadcast Channels. Classes. Basic Quality Indexes." In accordance with this standard, the amount of introduction of norms for the low-frequency channel is determined consisting of the normalized objects (radio relay[1] channels of different types) and the standardized quality indexes (the reproducible range of frequencies), the harmonic coefficient, and so on). The introduction of norms for the low-frequency channels has been carried out in the following form: through, from the beginning of the WB channel to the end (for example, the input of the central wire broadcast station to the subscriber unit), and by parts, (for example, the central wire broadcast station and the reference repeater station separately).

Here the standardized through WB channel is electrically perfected, that is, a channel after which the electrical signal conversions capable of

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[1] The name "radio relay" is presented in accordance with All-Union State Standard 11515-65.

causing a change in its quality indexes does not take place, and the sound quality afer this channel is determined in practice only by the properties of the reproducing sound system. Actually, between the end of the normalized through channel (subscriber rosette) and the voice coil of the speaker there are only passive elements -- the line control and transformer entering into the subscriber speaker.

The beginning of the normalized through WB channels is the first station object of the WB service: the central wire broadcast station -- for the centralized WB network -- or the WB junction station, for the centralized network.

The through low-frequency WB channels belong entirely to the WB branch of the Communications Ministry and from the realizational point of view, the normalization and responsibility for observation of the quality indexes are concentrated in their hands alone, which facilitates the solution of the problems of normalization and control. From the technical point of view the normalization of the through low-frequency channel and parts of it also present special difficulties, for in the entire channel there is only one type of signal -- low frequency -- and all the channel elements from the point of view of normalization belong to two types: the low frequency repeaters and the transmission lines, which determines the likeness of the normalized characteristics and the measurement techniques. The basic goal in introducing norms for the low-frequency channel reduces to optimal distribution of the normalized quality indexes by parts of the through channel. In addition to the standard, for the low-frequency channel there are standards for the repeaters, transformers and subscriber speakers.

Thus, from the organizational and technical points of view the normalization of the initial low-frequency channel presents no special difficulties. In contrast to the low-frequency channel, the normalization of the high-frequency channels presents great difficulties: organizational and technical.

3.3. Introduction of Norms for the High-Frequency Channels

By the high-frequency channel of the TPB system we mean the entire set of devices and lines designed to obtain high-frequency signals, transmit and receive them. In the most complete form for the three-element WB network the high-frequency channel is presented in Fig 3.1. For determination of the volume of the introduction of norms for the high-frequency channel it is necessary to define the normalized objects and the normalized indexes of these objects.

The normalized objects of the high-frequency channel must be the through channel and parts of it as is assumed for other sound broadcast channels and, in particular, for the low-frequency channel and also individual devices and lines.

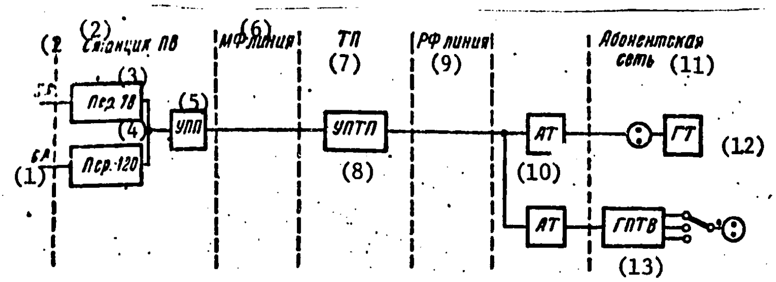


Figure 3.1. High-frequency channel of the TPB system for the three-element network

Key:

1. Connecting lines
2. WB station
3. Trans. 78
4. Trans. 120
5. Transmitter connection circuit
6. Main feeder line
7. Transformer substation
8. Transformer substation connecting circuit
9. Distributing feeder line
10. Subscriber transformer
11. Subscriber network
12. 3-program speaker
13. Group-program speaker

In accordance with the specific nature of the normalized objects, they can be divided into the following groups:

1) The through channel and parts of it;

2) The transmitters and repeaters;

3) Receivers;

4) High-frequency devices and lines.

The normalized indexes are of two types:

1) Quality indexes;

2) Electrical characteristics.

The quality indexes pertain to the introduction of norms for the through channel and parts of it and also the transmitters, repeaters and receivers. The electrical characteristics pertain to the introduction of norms for all the station, line and receiving devices, and they are determined specifically for each type of device and line.

3.4. Determination of the Through Channel

The through channel at the high-frequency channel of the TPB system is defined beginning with the most complete identity and comparableness of the low-frequency and high-frequency channels among each other with respect to normalization. Beginning with these arguments, the through channel ends with the output of the electrical part of the individual receiver or the subscriber rosette in the case of the application of a group receiver. With this definition of the end point of the through channel, the complete possibility of comparing the low-frequency and high-frequency channels among each other is achieved, for in both cases the electric channels are perfected, and conversion of the electric energy to acoustic energy takes place after them. In addition, the normalization of such a through channel offers the possibility of defining the norms for the receivers and the parts of the channel beginning with observation of only the basic norms for the entire through channel. In this case the guarantee of quality indexes is also insured with recording on a tape recorder which is done from the output of the individual receiver.

The input of the transmitter is taken as the beginning of the through high-frequency channel, for this device marks the beginning of the high-frequency channel, and the program feed channel up to this point is normalized with respect to All-Union State Standard 11515-65. With possible variation of the structure of the station part of the channel in accordance with the diagrams investigated in Section 2.7, the beginning of the through channel naturally is carried over to the input of the first conversion unit for converting the low-frequency channel to a high-frequency channel.

The high-frequency through channel adopted in this way is the initial object of the normalization of the high-frequency channel and can be normalized considering the quality classes of All-Union State Standard 11515-65.

The through channels for different types of WB networks are illustrated in Figures 3.2 and 3.3.

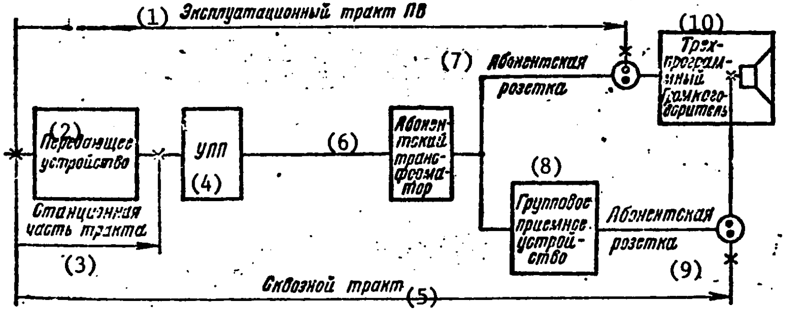


Figure 3.2. Schematic of the introduction of norms for a wire broadcast channel with a three-element line section

Key:
1. Operating WB channel
2. Transmitter
3. Station part of the channel
4. Transmitter connection circuit
5. Through channel
6. Suscriber transformer
7. Subscriber rosette
8. Group receiver
9. Subscriber rosette
10. Three-program speaker

3.5. Definition of the Normalized Parts of the Through Channel

The normalized parts of the through channel are defined as follows:

1) By the limits of operating responsibility of the WB services;

2) By the selection of the channel points for monitoring and operating measurements;

3) The necessity for normalizing the individual devices.

The normalization of all parts of the channel is carried out with one common origin -- the origin of the through channel -- and different terminal points.

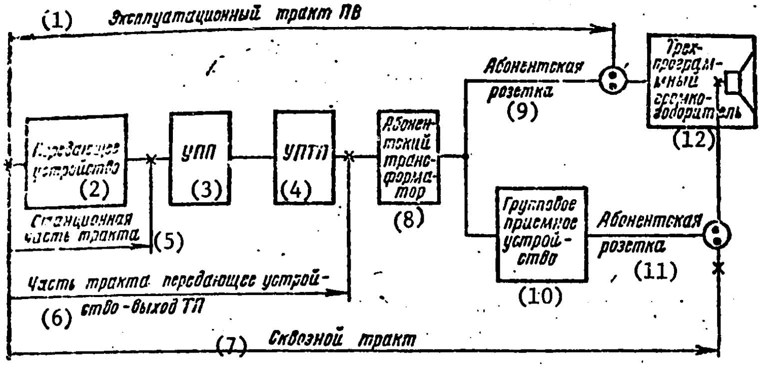


Figure 3.3. Schematic of the normalization of a wire broadcast channel with a two-element line section

Key:

1. Operating WB channel
2. Transmitter
3. Transmitter connection circuit
4. Transformer substation connecting circuit
5. Station part of the channel
6. Part of channel from the transmitter to the output of the transformer substation
7. Through channel
8. Subscriber transformer
9. Subscriber rosette
10. Group receiver
11. Subscriber rosette
12. Three-program speaker

The entire set of high-frequency devices and lines for which the WB services have responsibility is defined as the operating WB channel (Figures 3.2 and 3.3). In the case of a group receiver the through and operating WB channels coincide. The introduction of the concept of the operating channel completely makes the low-frequency and high-frequency channels united for the WB services with respect to degree of responsibility for them, for the channel data end identically -- with the subscriber rosette.

Two channel points are normalized inside the operating channel: the output of the wire broadcast station, that is, the output of the transmitter (Figures 3.2 and 3.3) and the output of the transformer substation, that is, the output of the transformer substation connecting circuit (Fig 3.2).

The introduction of the norms for the station part of the channel determines all the basic initial quality indexes and electrical characteristics of the AM signals at the beginning of the high-frequency channel and provides a basis for standardizing the transmitter and the transmitter connection circuit. The monitoring of many of the quality indexes and the electrical characteristics at the WB station is simultaneously monitoring of these indexes and characteristics of the entire operating channel, which greatly simplifies the performance of the entire volume of measurements on the network.

The introduction of norms for the indexes at the output of the transformer substation for the high-frequency channel is carried out in order to maintain the quality indexes within the norms which can undergo alterations on transmission of the AM signals from the output of the transmitter to the output of the transformer substation.

All of the above-investigated channels and parts of the channels are fully or partially standardized in accordance with the adopted list of quality indexes of All-Union State Standard 11515-65. A number of the elements of the high-frequency channel are normalized by simpler method: two or three electrical characteristics (the input impedance, the transmission coefficient, attenuation). These elements include the lines and the high-frequency devices of the line part of the channel, the common purpose of which is passive transmission of the high-frequency signals without converting the spectrum. The normalization of the lines and the high-frequency devices with respect to electrical characteristics are carried out separately.

3.6. Quality Indexes of the Through Channel and Parts of It

When developing and introducing the TPB system it was established that the most realistic for the through high-frequency channel is obtaining a quality class close to class II of VTU 526-58 [29], beginning with a number of economic and technical arguments. Hereafter when introducing the standard for the broadcast channels All-Union State Standard 11515-65 in place of VTU 526-58, the norms for the quality classes underwent significant alterations; therefore the normalization of the through high-frequency channel remains in class II of All-Union State Standard 11515-65. The through high-frequency channel is normalized with respect to all the quality indexes of the All-Union State Standard 11515-65:

The reproducible frequency band; nonuniformity of the frequency characteristic in the reproducible frequency band; the harmonic coefficient; the signal/background ratio; the signal/noise ratio; the signal/intelligible crosstalk ratio.

The introduction of norms for the indicated quality indexes and their significance for the high-frequency channels have some peculiarities. Thus, nonuniformity of the frequency characteristic is normalized by the commonly accepted "normative standard" (Fig 3.4) only for the through channels. For the operating channel and the station part, the nonuniformity of the frequency characteristic is determined by other standards, Figures 3.5 and 3.6. In these standards the distortions of the frequency characteristic are reflected in the region of upper modulating frequencies introduced into the transmitters. Here it is natural that the tolerance on the magnitude of the distortions for the operating channel is increased by comparison with the tolerance on the transmitting part of the channel.

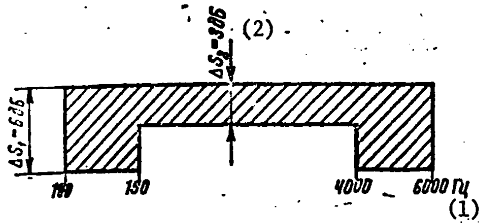


Figure 3.4. Nonuniformity of the frequency characteristic of the through channel

Key:
1. hertz; 2. 3 decibels

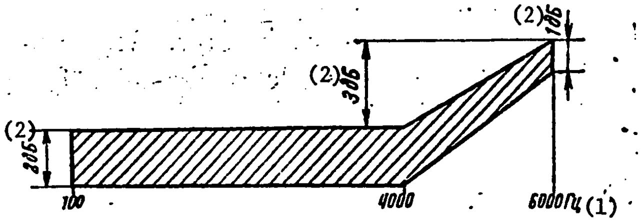


Figure 3.5. Nonuniformity of the frequency characteristic of the station part of the channel

Key:
1. hertz; 2. decibel

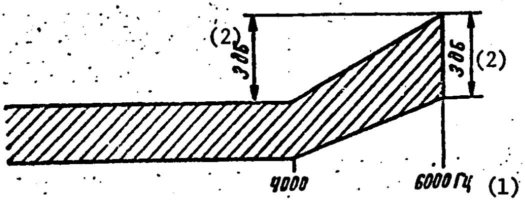


Figure 3.6. Nonuniformity of the frequency characteristic of the operating channel

Key: 1. hertz; 2. decibels

The harmonic coefficient is normalized in three frequency bands instead of two as indicated in All-Union State Standard 11515-65. The normalization of the harmonic coefficient in the 200-4000 hertz band is broken down into two bands: above 200 to 2000 hertz and above 2000 to 4000 hertz. The introduction of the last frequency band is caused by an increase in the harmonic coefficient in this frequency band as a result of the presence of asymmetry of the side frequencies of the AM signal on transmission of it over the TPB line channel.

The harmonic coefficient is normalized just as in the All-Union State Standard 11515-65 by two norms: for the rated level and the levels reduced with respect to the ratedlevel from 6 to 20 decibels.

The second norm pertains only to the channels with devices having two-cycle low-frequency stages.

The signal/noise background, signal/noise, signal/intelligible crosstalk indexes are normalized in the interval and in the All-Union State Standard 11515-65. However, when suppressing the carrier in the interval not only does a change in the signal/intelligible crosstalk ratio take place, but also two others. Therefore, for proper coordination of the norms with respect to these indexes, all the channels and devices of the high-frequency channel must be normalized and measured for the suppressed carrier. Considering the different nature of the origin of the crosstalk interference from low frequency and high frequency signals and the different magnitudes of these interferences in the intermediate points of the channel, the signal/intelligible crosstalk ratio is normalized separately for interference from low frequency and adjacent high-frequency channels.

In spite of the orientation toward quality class II, some of the indexes of the through channel are lower. The basic deviation from the norms in class II represents the signal/intelligible crosstalk ratio (50 instead of 70 decibels) defined by the effect of the nonlinear crosstalk from the low-frequency channel on the high-frequency channels. However, if we compare even the value of 50 decibels with the admissible interference of the radio receivers and the long wave and medium wave bands (not talking about the short wave band), it is obvious that this standard significantly exceeds the standards for the radio receiver interference. Thus, for the WB radio receivers according to All-Union State Standard 5651-64, selectivity with respect to the adjacent radio ±10 kilohertz wide with respect to frequency, 34 decibels for class II and 46 decibels for class I is admissible; the admissible attenuation of the signal from the mirror channel is 40 decibels for class II and 46 decibels for class I. Here the 50 decibel standard is limited for all admissible signal/noise ratios at the input of the TPB receivers at the same time as for the radio receivers the actual magnitude of the interference is determined to a great extent by the reception conditions. On introduction of complete separation of the carrier in the interval, the signal/intelligible crosstalk from the low-frequency channel ratio can reach 70 decibels or more in the broadcast transmission interval. The increase in mutual protection between the high-frequency channels pertains basically to the receivers and requires increased selectivity of them.

The signal/background ratio is inferior by 10 decibels to the class II norms on the channels only for the three-program speakers. This assumption was adopted beginning with the low rated sound pressure of these receivers and the correspondingly lower noticeability of the background when listening. However, during tape recorder recording of the programs of the high-frequency channels and reproduction of them by the devices with high sound pressure the noticeability of the background rises. Later the signal/background ratio for the channel with the three-program speaker in class II will be increased from 40 to 45 decibels.

Insignificant deviation with respect to the harmonic coefficient from the norms in class II of All-Union State Standard 11515-65 (5% instead of 4%) is permissible in the frequency range of 2000-4000 hertz as a result of specific distortions of the envelope of the AM signal occurring in the WB lines as a result of asymmetry of the extreme side frequencies of the AM signal.

When introducing the norms for the operating channel and parts of it, the normalized quality indexes for each point of the channel are defined beginning with efficiency of the measurement of certain quality indexes at the given point of the channel. It is known that the labor consumption of performing the measurements in the WB channels increases in the direction from the station to the subscriber point. Therefore, in the intermediate channel points it is sufficient to limit ourselves to the normalization and measurement of only the indexes which in practice undergo changes on transmission of the AM signal from the preceding point to the investigated one. Beginning with these arguments, it is sufficient to normalize the operating channel to the subscriber rosette of the three-program speaker by the nonuniformity of the frequency characteristic in the given frequency band. Here it is sufficient to perform the measurements of this nonuniformity in the frequency range of 1000 to 6000 hertz and also to normalize the harmonic coefficient in the frequency band of 2000-4000 hertz and the signal/intelligible crosstalk from the low-frequency and high-frequency channels ratio separately.

For the part of the channel ending with the output of the transformer substation, the number of normalized quality indexes can be reduced to two: the harmonic coefficient in the frequency band of 2000 to 4000 hertz and the signal/intelligible crosstalk from the low-frequency ratio. The WB station is normalized, just as the through channel, with respect to all the quality indexes. This procedure for normalizing the quality indexes of the through channel and parts of it is regulated by the draft of the branch standard "High-Frequency Channels of the Three-Program Wire Broadcasting System. The Basic Parameters," developed by the Scientific Research Institute of Radio. The norms in the draft of the indicated standard for the through channel and parts of it are presented in the appendix.

3.7. Introduction of Norms for the Transmitters and Repeaters

The normalized electrical characteristics of the transmitter must reflect three of its functions: as the transmitter of an AM signal, as the device connected to the WB network, and as the transmitter of the AM signal with regulatable carrier.

The first fact makes it possible to introduce the norms for the transmitter with respect to the series of parameters analogously to the broadcast transmitters of the long wave and medium wave bands in accordance with All-Union State Standard 13924-68 "Transmitters, Radio Broadcast, Station. Basic Parameters."

Accordingly, the carrier frequencies, the relative deviations of the carrier frequencies, the rated modulation coefficient, the relative harmonic levels of the carrier frequency, the rated powers and voltages of the carrier frequencies, the rated input level and the input impedance of the low-frequency input are subject to normalization.

The connection of the transmitter to the WB network requires consideration of the actual dispersion of the load resistance with respect to modulus and phase; therefore, the normalization of the output power must be carried out not only for the rated active load as for the radio broadcast transmitters, but also for a load equal with respect to modulus to the rated one, and with the positive and negative angles.

In order to maintain constancy of the output voltage of the carrier frequency on variation of the load resistance it is necessary to introduce norms for the output impedance of each transmitter or increase the voltage when dropping the load analogously to introduction of norms for the low frequency repeater.

The presence of a regulatable carrier requires introduction of norms for the limits of automatic gain control of the carrier frequency, the buildup time and the decay time.

The standardization of the carrier frequencies for the two high-frequency channels is necessary, for the TPB system, independently of its territorial application in the country, must have the same carrier frequencies; in the given case these are 78 and 120 kilohertz, wherein lies its significant difference from the introduction of radio broadcast norms in which the frequency band is given and the carrier frequencies of the radio broadcast stations are distributed by the territorial principle.

The standardization of the relative deviation of the carrier frequencies pursues two goals: exclusion of the noticeable draft of the carrier frequencies in the presence of fixed tuning of the receivers and the appearance of noticeable beats of the carrier frequencies from the two like transmitters with significant parallel run of the feeder lines from the transmitters.

The relative deviation of the carrier frequency

$$\frac{\Delta f}{f_0}=\frac{|f-f_0|}{f_0}, \qquad (3.1)$$

where f_0 is the standard carrier frequency, kilohertz; f is the actual carrier frequency, kilohertz.

The relative levels of the carrier frequency harmonics basically falling in the long wave radio broadcast band are normalized to exclude the interference of the radio receivers in this band from the TPB system.

The harmonics of the carrier frequency are normalized with respect to each harmonic individually and this pertains only to the most noticeable harmonics -- the second and third for each carrier (156, 234, 240, 360 kilohertz). The relative level of the carrier frequency harmonic is

$$A_{\text{г}}=-20\lg\frac{U_{0\,\text{ном}}^{(1)}}{U_{fn}},\ \text{дБ},(2) \qquad (3.2)$$

Key: 1. rated; 2. decibels

where $U_{0\ \text{rated}}$ is the rated voltage of the carrier frequency; U_{f_n} is the voltated of the n-harmonic of the carrier frequency.

The rated power with respect to the carrier frequency for each transmitter is determined in the active rated load resistance for the AM signal with rated depth and modulation frequency of 1000 hertz.

The criterion for the rated power pickup by the transmitter is satisfaction of the norm with respect to the harmonic coefficient for the indicated modulation frequency; here the output power is

$$P=\frac{U_0^2}{\underset{(3)}{R_{\text{н}}}}\geqslant \underset{(1)}{P_{\text{ном}}},\ \text{Вт},\ (2) \qquad (3.3)$$

Key; 1. rated; 2. watts; 3. load

where U_0 is the voltage of the carrier frequency, volts; P_{rated} is the rated output power; R_H is the rated load resistance, ohms.

For transmitters with two secondary windings of the output transformer the resistances $2R_H$ are connected to each winding, and the output power is defined by the formula (3.3).

However, in contrast to the radio broadcast transmitters, the basic guaranteed value for operation of the transmitter in the WB channel is not the rated power, but the rated voltage of the carrier just as for the station low-frequency repeater it is the output voltage of the low-frequency signal.

The rated voltage of the carrier frequency

$$U_{0\,\underset{(1)}{\text{ном}}} = \sqrt{P_{\underset{(1)}{\text{ном}}} R_{\underset{(2)}{\text{н}}}},\ \text{В}. \tag{3.4}$$

Key: 1. rated; 2. load

The modulation coefficient m for a regulatable carrier has complex dependence on the magnitude of the modulating signal (Fig 2.40), and basically its maximum value is normalized corresponding to the rated voltage of the carrier. The maximum modulation coefficient is assumed equal to 0.7 considering the difficulties of detecting the AM signal with variable carrier.

The limits of automatic control of the carrier in the given dynamic range of levels of the modulating signal

$$\underset{(4)}{h_{\text{макс}}} = 20\lg\frac{U_{0\,\text{ном}}^{(2)}}{U_{0\,\text{мин}}\,(3)},\ \text{дБ},\,(1) \tag{3.5}$$

Key: 1. decibels; 2. rated; 3. min; 4. max

where $U_{0\ \min}$ is the minimum voltage of the carrier corresponding to the minimum given level of the modulating signal.

The voltage buildup time of the carrier frequency is defined by the time during which the ratio of the carrier frequency reaches a value of 0.9 $U_{0\ \text{rated}}$ for feed of a voice signal to the receiver input with a frequency of 1000 hertz and rated input level (Fig 3.7).

The time for the voltage drop of the carrier frequency is defined by the time during which the voltage of the carrier frequency at the output of the transmitter decreases from rated to 0.2 $U_{0\ \text{rated}}$ after picking up the modulating signal from the transmitter input under the conditions that the limits of regulation of the carrier are 20 decibels (Fig 3.7).

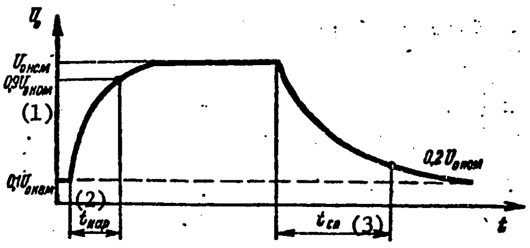


Figure 3.7. Determination of the buildup time and the decay time of the carrier frequency voltage U_0 at the transmitter output

Key:
1. rated ; 2. outside; 3. connecting line

The high-frequency amplifiers installed in the high-frequency channel at the present time include the two-channel intermediate repeater (DPU). With respect to the output part the repeater is analogous to the transmitter; therefore the standardization procedure and the procedure for determining the quality indexes basically is the same as for the transmitter. However, there are some peculiarities.

A distinguishing feature is the normalization of the nonuniformity of the frequency characteristic and the harmonic coefficient. Inasmuch as in the repeater of the AM signal there are no causes for variation of the nonuniformity of the frequency characteristic and the harmonic coefficient in the range of low modulating frequencies, the nonuniformity of the frequency characteristic of the repeater is sufficiently normalized and defined in the frequency spectrum of the AM signal, that is, for the DPU [two-channel intermediate repeater] in the $f_0 \pm 6$ kilohertz band, both for resonance and band repeaters, and the harmonic coefficient can be normalized beginning with 1000 hertz and more.

All of the signal/noise type ratios are normalized and defined by the relatively normalized suppressed carrier.

The norms for the quality indexes for the DPU were obtained beginning with the actual possibilities of introducing minimum additional distortions into the through channel. The normalized electrical characteristics of the DPU are as follows: the rated output power and the output voltage of the carrier; the maximum gain; the gain control limit; the input impedance in the AM signal band. Inasmuch as the two-channel intermediate repeater can be used for a significant interval of input voltages, it is not the rated input voltage that is normalized, but the maximum gain and the limits of the gain control. Under actual operating conditions the output voltage of each carrier frequency is defined by insuring sufficient voltages of the high-frequency signal in the entire segment of the line included after the repeater (Fig 3.8).

The specific norms for the quality indexes and the electrical characteristics are presented in the corresponding sections of the description of the given devices.

3.8. Introduction of Norms for Receivers

The receivers in the TPB system can be divided into two groups: individual and group. The introduction of norms for each of these devices has its own specific nature.

At the present time basically two types of receivers have become widespread: the three-program speaker (GT) and the group receiver (GPTV). The characteristic features of their standardization are investigated below.

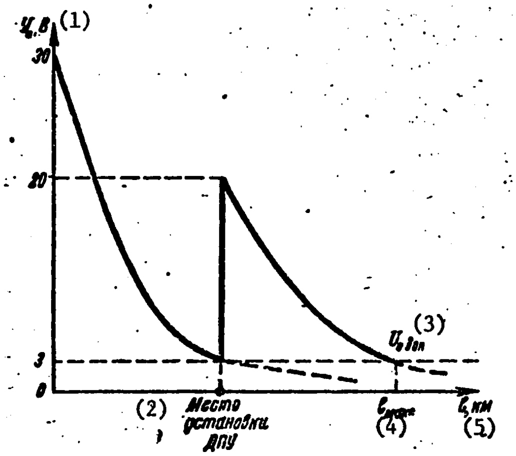


Figure 3.8. Diagram of the carrier frequency voltage on the distributing feeder line with two-channel intermediate repeater

Key:
1. volts; 2. point of installing the two-channel intermediate repeater;
3. U_0 ad; 4. ℓ_{max}; 5. ℓ, km

The introduction of norms for the three-program speaker is done in accordance with All-Union State Standard 18286-72 "Three-Program Speakers. Technical Specifications." The group receivers are normalized with respect to technical conditions. Here the three-program speakers are normalized as electroacoustic devices, and the group receivers, as electrical devices.

The three-program speaker is normalized with respect to acoustic and electrical indexes. The introduction norms for the low-frequency channel of the three-program speaker corresponds basically to the All-Union State Standard 5961-66 for the single-program subscriber speakers. The norms for the acoustic and electrical indexes of the three-program speaker on reception of high-frequency signals have been established with respect to classes I, II and III.

The acoustic indexes of the three-program speaker are determined by the sound pressure, and they include the following: the rated frequency band, nonuniformity of the frequency characteristic in this band; the average sound pressure and the harmonic coefficient. These indexes have the same definition as the corresponding indexes of the radio receivers and the subscriber speakers. Here the normalized nonuniformity of the frequency characteristic of the average sound pressure must be satisfied considering distortions in the upper frequency range of modulation (Fig 3.5). The harmonic coefficient is also normalized and defined without considering the distortions.

The normalization of the quality indexes of the electrical channels of the three-program speaker and the group receiver (GPTV) is carried out identically except that for the three-program speaker the electrical channel is normalized on the voice coil of the given speaker, and for the group receiver, at its output for any real load. For the three-program speaker of classes I and II, these quality indexes must satisfy the requirements of obtaining the corresponding quality classes for the through WB channel. For the three-program speaker of class II, the satisfaction of this condition is not mandatory. The nonuniformity of the frequency characteristic with respect to the electric voltage in the rated frequency band is also defined considering the distortions of modulating frequencies in the subscriber rosette of the three-program speaker or at the input of the group receiver. Simultaneous satisfaction of the requirements of nonuniformity of the frequency characteristic with respect to sound pressure and electric voltage for the three-program speaker does not cause any mutual difficulties and, moreover, the observation of the nonuniformity with respect to the electric channel promotes obtaining of the given nonuniformity with respect to the acoustic channel. Inasmuch as the normative "standard" for nonuniformity of the frequency characteristic of the through channel with respect to All-Union State Standard 11515-65 can have any form within the limits of the given nonuniformities F_1 and F_2, it appears possible to correct the frequency characteristic for the electric channel correspondingly for satisfaction of its nonuniformity with respect to the acoustic channel, which has significance for the edge, especially the low frequencies of the standardized range.

The standardization of the harmonic coefficient of the electrical channel of the TPB receivers has several peculiarities by comparison with the normalization of the radio broadcast receivers.

The harmonic coefficient of the radio broadcast receivers is normalized with respect to the sound pressure for a rated modulation coefficient and average sound pressure. In the presence of the regulatable carrier the normalized basic harmonic coefficient of the electric channel of the TPB receivers must be observed in the entire range of carrier regulation for the corresponding modulation coefficients. This requirement pertains to the AM signal detector creating nonlinear distortions of the envelope for small carrier voltages at its input. In the presence of the low-frequency channels of the receivers of the two-cycle repeaters the harmonic coefficient for output voltages equal to 0.1-0.5 of the rated must not exceed 0.5 of the basic one. The latter condition pertains to the GPTV [group receiver] and the GT [three-program speaker], classes I and II, entering into the through channel. For the three-program speaker having a high-frequency amplifier, the standard with respect to K_Γ must be observed for the given increase in the input signal.

Out of all of the types of interference the greatest complexity is offered by the normalization of the signal/intelligible crosstalk ratio. This ratio must be defined for all types of interference when receiving AM signals.

The interference from the low-frequency signals of program I, the high-frequency signals of the adjacent high-frequency channel, and the signals from the radio broadcast stations are of this type.

All of this interference in the TPB receivers is determined by the characteristics of the input frequency selectors, their structural execution and the presence of communications between the low-frequency amplifier of the receiver and the low-frequency program channel.

When normalizing the existing TPB receivers with respect to the indicated interference there is no united terminology. The terms "mutual protection," "interference protection" for the three-program speaker, and "crosstalk interference" for the GPTV group receiver are encountered. Therefore, hereafter we shall use the term adopted in All-Union State Standard 11515-65: signal/intelligible crosstalk ratio or, for short, the signal/noise ratio with indication of the type of noise.

The signal/noise from the low-frequency channel ratio is normalized with respect to the maximum voltage of the low-frequency signal at the input of the receivers equal to 30 volts. For interference with the low-frequency and high-frequency channels the signal/noise ratio is normalized on the average interference frequency of 1000 hertz and upper interference frequencies of 6000 hertz for the three-program speaker and 10000 hertz for the group receiver with constant value of the input interference signal.

The adopted signal/intelligible crosstalk from the adjacent high-frequency signal ratio must be insured for the worst conditions of noise protection of the receivers, that is, for maximum voltage of the carrier of the adjacent high-frequency channel of 3 volts and for a ratio of the voltages of the carriers of the adjacent and received high-frequency signals of 30:1 corresponding to suppression of the useful signal carrier by 10 times.

When defining the signal/noise ratio for the given type of interference it is necessary to use joint inclusion of the signal and interference sources at the input of the receiver.

The normalization of the signal/noise ratio from the radio broadcast stations pursues the goal of insuring noiseproofness of the TPB receivers with respect to this type of interference. In this case it is necessary to consider the different effect of it on the circuitry of the TPB receivers. In order to determine the given interference it is sufficient to limit ourselves to the long wave radio broadcast range.

The volume of the signal/intelligible crosstalk ratio for all of the indicated types of interference in the receiver is taken from a comparison with the magnitude of the nonlinear crosstalk occurring in the line and it is equal to 53 decibels at a frequency of 1000 hertz.

The introduction of norms for the signal/background and signal/noise ratios does not have significant peculiarities and is carried out for the suppressed carrier or in practice in the absence of it. Actually, considering the noticeable excess of the background level of the noise level, it is possible to limit ourselves to the normalization of the signal/(background+noise) ratio or the signal/background ratio. Here, by the background voltage U_{ϕ} we mean the value of

$$U_{\text{ф}} = \sqrt{U_{50}^2 + U_{100}^2 + U_{150}^2}, \qquad (3.6)$$

where U_{50}, U_{100}, U_{150} are the harmonic voltages of the background with frequencies of 50, 100 and 150 hertz respectively.

All of the above-presented signal/noise ratios are defined by the formula

$$A_{\text{п}} = 20\lg \frac{U_{\text{ном}}^{(1)}}{U_{\text{пом}\,(3)}},\ \text{дБ},\,(2) \qquad (3.7)$$

Key: 1. rated; 2. decibels; 3. interference

where U_{rated} is the rated output voltage of the electric channel; $U_{\text{interference}}$ is the voltage of the corresponding interference.

The rated output power P_{rated} is normalized for the rated load resistance and the modulation frequency of 1000 hertz; the criterion for picking up the rated power is the satisfaction of the given harmonic coefficient. The rated output voltage used when determining the signal/noise ratio is as follows:

$$\underset{(1)}{U_{\text{ном}}} = \sqrt{\underset{(1)}{P_{\text{ном}}}\,\underset{(1)}{R_{\text{ном}}}}, \qquad (3.8)$$

Key: 1. rated

where R_{rated} is the rated load resistance. For the three-program speaker this resistance is equal to the resistance of the voice coil of the speaker.

The sensitivity of the three-program speaker and the group receiver is normalized for the rated output power and the input AM signal with modulation frequency of 1000 hertz and modulation coefficient of 70%, and it is determined separately with respect to the high-frequency channels. The variation in sensitivity of the three-program speaker is accomplished by preset regulators. The limits of their control are normalized, beginning with the possible difference between the maximum and minimum values of the high-frequency signal voltages obtained on the subscriber rosettes depending on the point of connection to the distributing line.

Inasmuch as the receivers are connected to the TPB distribution network, it is necessary to normalize their input impedances for elimination of their effect on the quality indexes of the channels and the electrical characteristics of the line part of the TPB systems channel.

The input resistances are normalized in the band of received signals of the given high-frequency channel and in the bands of the adjacent high-frequency and low-frequency channels given by the selected quality class of the system.

When using the low-frequency repeater of the three-program speaker for receiving low-frequency signals ("active version" of low-frequency reception), the parameters of the channel are also normalized. The normalization of the quality indexes is carried out with respect to the sound pressure and with respect to the electric voltage analogously to the investigated method of normalizing the high-frequency channels. The norms of the quality indexes of the active low-frequency channel can be established just as for the high-frequency channel or higher, taking into account the higher quality indexes of the low-frequency channel on the subscriber rosette. In order to avoid the appearance of interference from the detection of AM signal in the amplifying channel, the signal/noise ratio from the high-frequency channels is normalized for maximum input voltages of the high-frequency signals. Among the electrical characteristics for the "active version" of reception of the low-frequency signals, the sensitivity and the input impedances are normalized for all signals. The sensitivity is normalized with respect to the united rated output power of the electric channel, and it is taken equal to the minimum admissible voltage of the low-frequency signal at the subscriber point, which permits compensation and the attenuation of the low-frequency channel. The input impedance in the frequency band of the low-frequency channel is normalized several times (4 to 8 times) higher than the corresponding input impedance of the signal-program speakers and the passive low-frequency channels of the three-program speakers which permits the load of the low-frequency TPB channel to be decreases. On the whole the normalization of the three-program speaker with respect to the active low-frequency channel corresponds to obtaining greater output power with lower input voltage and greater input voltage with respect to the preserved passive channel.

The presence of the active low-frequency channel of the three-program speaker makes it possible to reduce the norms that are difficult to satisfy with respect to the passive channel, for example, with respect to the average sound pressure.

The group receivers are normalized with respect to static and time operating parameters of the automatic gain control. The static characteristics of the automatic gain control are the control range with respect to input and the limits of variation of the output voltage. The normalization of these characteristics is carried out jointly in the form of determination of the minimum range of variation of the output level for the given limits of variation of the input level (Fig 3.9). The norm for the limits of variation of the output level of the group receiver of 3 decibels is taken from comparison with the admissible variations in level with respect to the low-frequency channel equal to 4 decibels. The norm for the regulation band with respect toinput is determined from calculating the maximum fluctuations of the input level as a function of the weather conditions. The range of control with respect to the input D_{inp} and the limits of variation of the output level D_{out} are defined by the existing formulas:

$$D_{\text{вх}}^{(5)} = 20\lg\frac{U_{\text{вх макс}}^{(1)}}{U_{\text{вх мин}}^{(2)}},\ \text{дБ};^{(7)} \qquad (3.9)$$

$$D_{\text{вых}}^{(6)} = 20\lg\frac{U_{\text{вых макс}}^{(3)}}{U_{\text{вых мин}}^{(4)}}\ \text{дБ}^{(7)} \qquad (3.10)$$

Key: 1. inp max; 2. inp min; 3. out max; 4. out min; 5. D_{inp}; 6. D_{out};
7. decibels

Here the rated voltage is taken as the maximum output voltage.

When putting the group receiver into operation it is necessary to establish some mean initial output voltage $U_{out\ mean}$ by the regulator in order to insure the possibility of operation of the automatic gain control in the direction of increasing and decreasing the input voltage. In practice $U_{out\ mean}$=26-27 volts is no less than the voltage at the subscriber point with respect to the low-frequency channel, and the equality of the volume of all three programs is not disturbed.

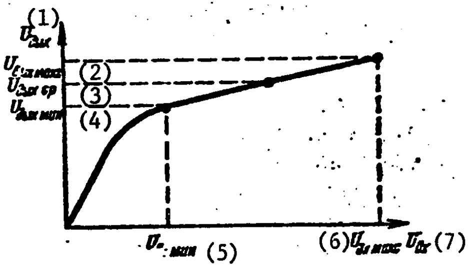


Figure 3.9. Determination of the control range of the automatic gain control with respect to input

Key:

1. U_{out}	4. $U_{out\ min}$
2. $U_{out\ max}$	5. $U_{inp\ min}$
3. $U_{out\ mean}$	6. $U_{inp\ max}$
	7. U_{inp}

The time characteristics of the automatic gain control are the response time of the automatic gain control and the time of increasing the gain of the receiver by a given amount. The response time of the automatic gain control is determined by the time during which the output signal is distorted (limited) on heating the AM signal to the receiver input with maximum input voltage and rated depth of modulation with the initial discharged capacitor of the detector of the automatic gain control. The time for increasing the gain is determined by the time during which the output level of the signal increases by a given amount after the decrease in input maximum voltage by several times.

As is assumed for the repeaters operating on a variable load, for the group receiver, the increase in output voltage on dropping the load is normalized.

3.9. Introduction of Norms for High-Frequency Devices and Lines

The introduction of norms for high-frequency devices and lines is done to provide for transmission of high-frequency signal power with least losses and observation of the quality indexes of the envelope of the AM signal within the limits of the admissible values.

The transmission of the high-frequency signal power is determined by the normalization of the transmission coefficients of the high-frequency devices, the attenuations of the lines and moduli of the input impedances of the high-frequency devices and the lines on the carrier frequency.

The reduction of the additional distortions of the quality indexes to a minimum is provided for by normalization of the transmission coefficients, the attenuation, the modulie of the input impedances and the phase angles of the frequency bands of the AM signals.

The transmission coefficient of the high-frequency devices is a value

$$K=\frac{U_2}{U_1}, \qquad (3.11)$$

where U_1, U_2 are the input and output voltages of the given frequency respectively.

For convenience of the overall calculation of the line attenuation and the attenuation of the high-frequency devices, the attenuation of the high-frequency devices is used

$$a=20\lg\frac{1}{K}, \text{ дБ. } (1) \qquad (3.12)$$

Key: 1. decibels

The transmission coefficient is normalized for equivalent load resistance.

The modulus of the total input impedance Z_{inp} and the phase angle ϕ are components of the complex input impedances $z_{inp}=Z_{inp}e^{i\phi}$. For the high-frequency devices Z_{inp} and ϕ are normalized for equivalent load resistances, and for the line they are normalized for a real load.

The devices of the low-frequency channel used to transmit high-frequency signals, just as the subscriber transformer, or included parallel to the high-frequency channel through the blocking filters (ZF), as the feeder transformer of the transformer substation and the KRF box and also the single-program speakers, are not normalized with respect to the high-frequency signals. The average characteristics of the subscriber transformers Z_T and a_T and the single-program speakers are determined by measurements, and they are used when calculating the attenuation of the distributing feeder lines and the subscriber network.

The necessity for normalizing the high-frequency devices and lines in the frequency band of the AM signal is determined by the fact that with an increase in the modulating frequency the frequency band of the AM signal expands, and the asymmetry of transmission of the lower f_0-F and upper f_0+F transmission of the side frequencies of the AM signal appears. This asymmetry is expressed in inequality of the transmission coefficients and their phase angles for the frequencies f_0-F and f_0+F (Fig 3.10). Here the value of the resultant vector of the AM signal U_p (Fig 3.11b) varies not according to a sinusoidal law, which leads to the appearance of nonlinear distortions of the envelope of the AM signal (Fig 3.12), and, consequently, distortion of the low-frequency signal at the output of the receiver detector. Thus, the given nonlinear distortions of the envelope of the AM signal are caused not by nonlinearity of the transmission channel, but its asymmetric frequency and phase characteristics in the frequency band of the AM signal, which gives rise to the necessity for normalization of the values of K, a, Z, ϕ in the frequency band of the AM signal for insuring the given K_Γ at the input of the receivers. The practical noticeability of the given nonlinear distortions occurs for the modulating frequencies above 2000 hertz, which is one of the obstacles for expanding the reproducible frequency band of the high-frequency channels and improvement of their quality indexes.

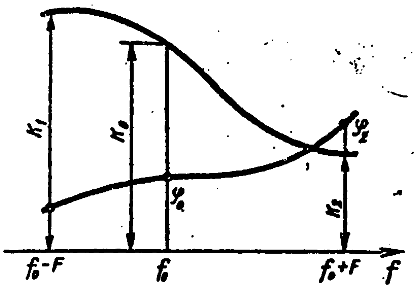


Figure 3.10. Asymmetric frequency-amplitude and frequency-phase characteristics

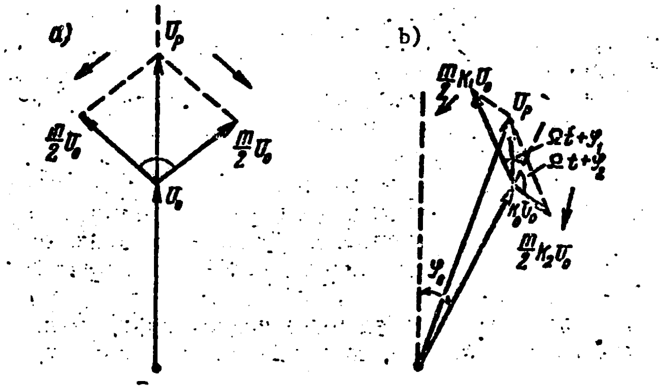


Figure 3.11. Vector diagram of the input and output AM signals: a) undistorted; b) distorted

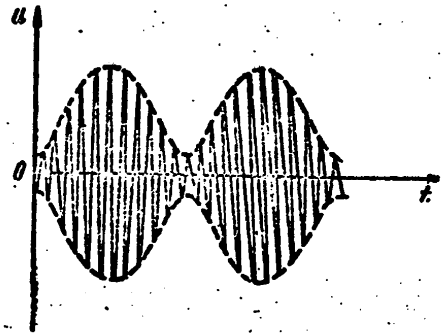


Figure 3.12. One of the types of distortions of the envelope of the AM signal for asymmetry of the side frequencies

A characteristic feature of the normalization of the feeder lines and the devices with respect to the high-frequency channel is the necessity for insuring matched operating positions of the feeder lines. The wave impedance of the distributing feeder line, but not the pure line as in wire communications but the real line loaded on the subscriber transformers, appears in the role of the initial normalizing parameter. This equivalent wave impedance $Z_{\text{wave equiv}}$ determines the norms for the Z_{inp} of all the high-frequency devices installed on the distributing feeder lines and also the total magnitude of the load resistance with respect to the high frequency signals of the transformer substation for the stations with two-element network. The value of Zwave equiv is determined by the type of wires, the density of the included subscriber transformers per km of line S and their type.

As the performed studies and calculations have demonstrated, insurance of the matched operating conditions of the main and distributing feeder lines can be connected with normalization of the admissible harmonic coefficient occurring as a result of asymmetry of the side frequencies. Thus, it appears possible to join the energy and quality criteria of the operating lines into one. Moreover, it is possible to estimate these two indexes by using the total input impedance of the feeder line as the initial parameters $z_{inp}=Z_{inp}e^{i\phi}$, that is, the parameter fixed at one point, and not distributed along the line.

In order to estimate the operating conditions of the lines it is possible to introduce the indexes of the degree of matching with respect to input impedance for the carriers and side frequencies:

$$\Pi_0 e^{i\psi_0} = \frac{\overset{(1)}{z_{\text{в}}}}{\underset{(2)}{z_{\text{вх}0}}};\ \Pi_1 e^{i\psi_1} = \frac{z_1}{\underset{(3)}{z_{\text{вх}1}}};\ \Pi_2 e^{i\psi_2} = \frac{z_{\text{в}}}{z_{\text{вх}2}\ (4)}, \qquad (3.13)$$

Key: 1. wave; 2. inp 0; 3. inp 1; 4. inp 2

where z_{wave} is the total wave impedance of the line equal to $z_{wave\ equiv}$, $z_{inp\ 0}$, $z_{inp\ 1}$, $z_{inp\ 2}$ for the distributing feeder lines as the total input impedances of the line respectively on the carrier, lower and upper side frequencies.

In order to estimate the degree of deviation of the modulus and the phase angle of the input impedance from symmetric, the asymmetry coefficients are introduced:

$$\sigma_1 = \frac{1}{2}\left(\frac{Z_{\text{вх}0}}{Z_{\text{вх}2}} - \frac{Z_{\text{вх}0}}{Z_{\text{вх}1}}\right);\ \sigma_2 = \frac{1}{2}\left(\frac{Z_{\text{вх}0}}{Z_{\text{вх}1}} + \frac{Z_{\text{вх}0}}{Z_{\text{вх}2}}\right) - 1;$$

$$\theta_1 = \frac{\psi_2 - \psi_1}{2};\ \theta_2 = \frac{\psi + \psi_2}{2} - \psi_0. \qquad (3.14)$$

Beginning with the condition for the through channel $K_\Gamma \leqslant 5\%$ on a modulation frequency of 4000 hertz, the maximum admissible K_Γ is defined for the line part of the channel:

$$K_{\text{г}} < \sqrt{5^2 - 4^2} = 3\%. \qquad (3.15)$$

Correspondingly, the asymmetric coefficients of the frequencies of $f_0 \pm 6$ kilohertz and the degree of matching with respect to the carrier frequency must be the following:

$$\sigma_1 \leqslant 0{,}15;\ \sigma_2 \leqslant 0{,}15;\ \theta_1 < 10^\circ;\ \theta_2 \leqslant 10^\circ;\ 0{,}7 \leqslant \Pi \leqslant 1{,}5;$$

$$\psi_0 < 15^\circ. \qquad (3.16)$$

The calculation of the damping of the line part of the high frequency channel is carried out beginning with the condition that the main and the distributing feeder lines have been processed, and traveling wave conditions with respect to high frequency signals are insured for them.

The total attenuation of the three-link network channel from the output of the transmitter to the input of the receiver is defined as:

$$a_{\text{рз}} = a_{\text{упп}} + a_{\text{мф}} + a_{\text{оутп}} + a_{\text{рф}} + a_{\text{т}} + a_{\text{аб}}, \ \underset{(1)}{\text{дБ}}, \quad (3.17)$$

Key: 1. decibels

where $a_{\text{упп}}$, $a_{\text{мф}}$, $a_{\text{оутп}}$, $a_{\text{рф}}$, $a_{\text{т}}$, $a_{\text{аб}}$ are the attenuation of the transmitter connection circuit, the main feeder line, the transformer substation bypass, the distributing feeder line, the subscriber transformer and the subscriber network respectively.

For the same two-link network channel the attenuation

$$a_{\text{р2}} = a_{\text{упп}} + a_{\text{рф}} + a_{\text{т}} + a_{\text{аб}}, \ \underset{(1)}{\text{дБ}}. \quad (3.18)$$

Key: 1. decibels

The maximum admissible attenuation of the network a_{ad} is defined by the rated output voltage of the transmitter carrier $U_{0\ trans}$ and the minimum admissible voltage $U_{0\ rec}$ at the input of the three-program speaker:

$$\underset{(1)}{a_{\text{доп}}} = 20\lg \frac{U_{0\,\text{пер}}^{(2)}}{U_{0\,\text{пр}}(3)} = 20\lg \frac{120}{0{,}25} = 53{,}5 \ \underset{(4)}{\text{дБ}}. \quad (3.19)$$

Key: 1. ad; 2. trans; 3. rec; 4. decibels

For any point of the TPB network the following condition must be satisfied:

$$a_{\text{р}} \leqslant a_{\text{доп}}. \quad (3.20)$$

The components of the total attenuation or the attenuation of the individual devices and lines. The attenuations of the transformer substation bypass [OUTP] and the AT [subscriber transformer] are determined depending on the load resistance or the number of subscriber points in accordance with the graphs in Figures 2.15, 2.17 and 3.13.

The attenuation of the transmitter connection circuit for the three-element network does not exceed 2 decibels, and for the two-element network, no more than 10 decibels.

The attenuation of the main feeder line in general form is

$$\underset{(1)}{a_{M\Phi}} = \alpha l + \underset{(2)}{\alpha_B l_B}, \qquad (3.21)$$

Key: 1. main feeder; 2. insert

where αl is the attenuation of the overhead part of the lines; $\alpha_B l_B$ is the attenuation of the cable insert.

The attenuation of the short cable inserts is not taken into account.

The attenuation of the distributing feeder line in general form

$$\underset{(1)}{a_{P\Phi}} = \alpha_э l + \underset{(3)}{\alpha_B l_B} + \sum_{n=1}^{m} \underset{(2)}{\Delta a_{n\,отв}}, \qquad (3.22)$$

Key: 1. distributing feeder; 2. lead; 3. insert

where $\alpha_э l$ is the attenuation of the overhead section of the line; $\alpha_э$ is the equivalent attenuation per kilometer; $\alpha_B l_B$ is the attenuation introduced by the long cable inserts; $\Sigma\Delta a_{n\ lead}$ is the total attenuation introduced by the lead; the attenuation introduced by one lead Δa_n is determined by the point of connection of the lead (Fig 3.15 and 3.15).

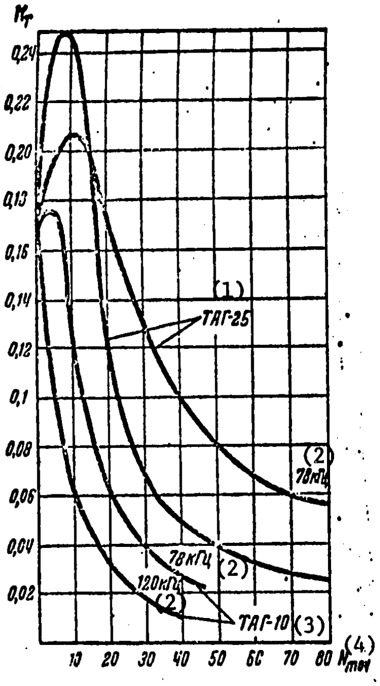


Figure 3.13. Transmission coefficient, k_T of the TAG-10 and TAG-25 subscriber transformer as a function of load

Key:
1. TAG-25; 2. kilohertz; 3. TAG-10; 4. N_{point}

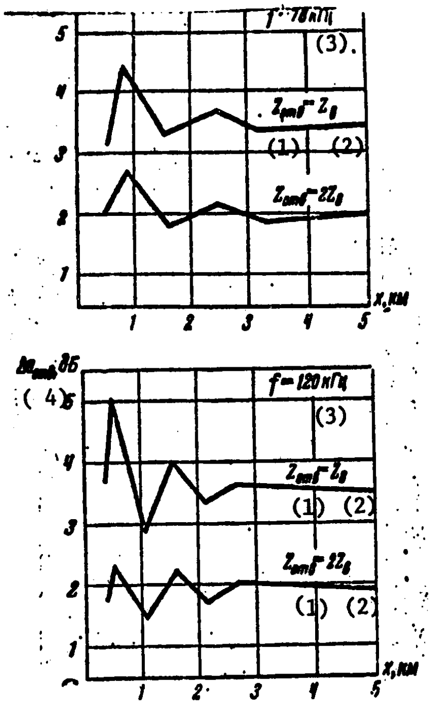


Figure 3.14. Attenuation introduced by the lead as a function of the point of connection of it for a steel line (x is the distance from the beginning of the line)

Key:

1. lead	4. Δa_{lead}, decibels
2. wave	
3. kilohertz	

The attenuation of the subscriber network a_{ab} is determined separately for the building networks and the subscriber lines. Depending on the number of floors, the attenuation of the building networks does not exceed the following: 2 decibels for 5 to 9 story buildings, 5 decibels for 12 to 19 story buildings.

For the subscriber lines it is recommended that the following damping be used: for a length of 0.3 km, $a_{ab}=3$ decibels; for a length of 0.3 to 0.6 km, $a_{ab}=5$ decibels; for lines of more than 0.6 km, $a_{ab}=10$ decibels. Here, by the length of the subscriber line we mean the length of the line from the subscriber transformer to the most remote point plus the length of all the branches included in the second half of the subscriber line.

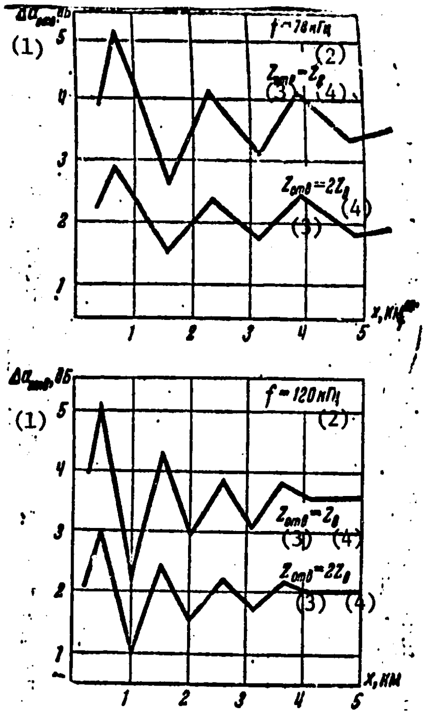


Figure 3.15. Attenuation introduced by the lead as a function of the point of its inclusion for a bimetal line

Key:

1. Δa_{lead}, decibels
2. kilohertz
3. lead
4. wave

When calculating the attenuations of the high frequency channels it is sufficient to begin with the greatest attenuation of one of the carrier frequencies of 78 or 120 kilohertz.

The distortion of the attenuation increases on going away from the station and approaching the subscriber points.

The presented radiation pattern of the carrier frequencies for the three-element network (Fig 3.16) clearly indicates the increase in the voltage tolerance of the carrier frequencies on approaching the subscriber point.

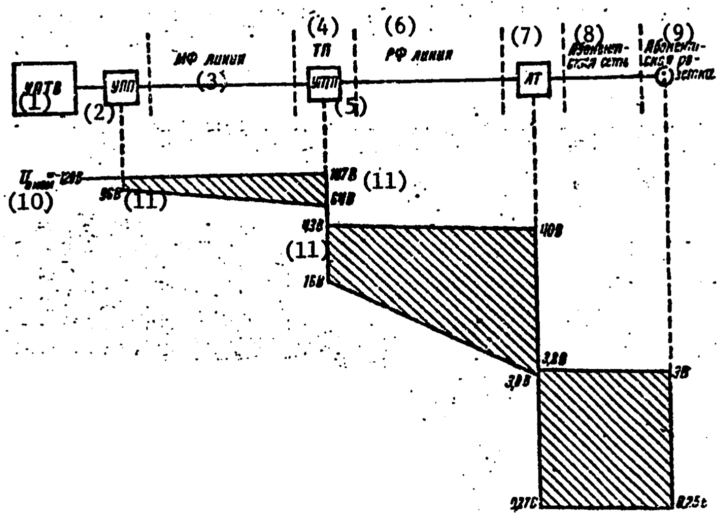


Figure 3.16. Diagram of carrier voltages of high frequency channels for the three-level systems considering decay of high-frequency equipment and lines

Key:

1. UPTV -- transmitter
2. Transmitter connection circuit
3. Main feeder line
4. Transformer substation
5. UTP
6. Distributing feeder line
7. Subscriber transformer
8. Subscriber network
9. Subscriber rosette
10. $U_{0\ rated}$=120 volts
11. volts

CHAPTER 4. TRANSMITTERS AND REPEATERS

4.1. General Information

The transmitter of the TPB system is a set of two transmitters of AM signals with carrier frequencies of 78 and 120 kilohertz designed to transmit two broadcast programs by frequency multiplexing of the WB network. Thus, in contrast to the radio broadcast transmitters operating on the emitting antenna, the transmitters of the TPB system are loaded on the WB line, the emission of which must be reduced to a minimum. The transmitters investigated later are designed for use in the systems for building the station part of the channel in which the conversion of the low-frequency signal to the AM signal and obtaining the required power of the high-frequency signals at the input of the TPB network is concentrated at one station site (Fig 2.8, 2.10 and 2.12).

A significant characteristic of the transmitters of the TPB system, in contrast to the radio broadcast transmitters of AM signals is regulation of the carrier voltage with respect to the corresponding law with variation of the broadcast signal level. The introduction of the indicated regulation leads to variation of the functional diagram of the transmitters. The distinction of the radio broadcast transmitters of AM signals is the introduction of the frequency characteristic correction of the modulating frequencies (raising it in the frequency range of 3000 to 6000 hertz).

At the present time the UPTV-60 and UPTV-200 transmitters have been developed. On the basis of the UPTV-200 transmitter, by increasing the output power of the terminal stage, a transmitter UPTV-400 has been built. The rated output powers of each transmitter of these transmitting installations on the carrier frequency are 60, 200 and 400 watts respectively. The quality indexes of the indicated transmitters are determined from the condition of obtaining quality indexes of the entire through channel which are close to class II of All-Union State Standard 11515-65. At the present time the PTPV-400 transmitter for channels of quality class I with output power of 400 watts and the transmitter based on transistors for the rural TPB system with an output power of 40 watts have been developed.

The indicated transmitters contain the basic devices for the shaping and the amplification of the AM signal and also the feed sources, the devices for monitoring, automation, control and protection.

The structural diagrams of the UPTV-200 and the UPTV-400 transmitters are identical and they differ from the diagrams of the UPTV-60 transmitters by the feed sources, the monitoring, automation and protection devices. The functional diagrams of the basic channel for shaping and amplifying the AM signal of all the indicated transmitters are identical; moreover, the transmitters of each carrier frequency of one type of transmitter are distinguished only by the electrical data of the elements of the resonance circuits in the high-frequency signal transmission channel.

Let us consider the functional diagram of the channel for shaping and amplifying the AM signal of the indicated transmitters (Fig 4.1). The system contains the amplification channel for the input low-frequency signal (low-frequency repeater), the high-frequency channel made up of the carrier frequency master oscillator (ZG), the adjustable carrier frequency repeater, the modulator (M) and the modulated oscillation repeater (UMK) and also the channel for shaping the control signal (regulating device). Thus, in contrast to the radio broadcast AM transmitters, the given transmitters do not contain the frequency multiplier, powerful modulator for modulation of the output stage; the modulation and regulation of the carrier level are performed in the circuits with low signal levels.

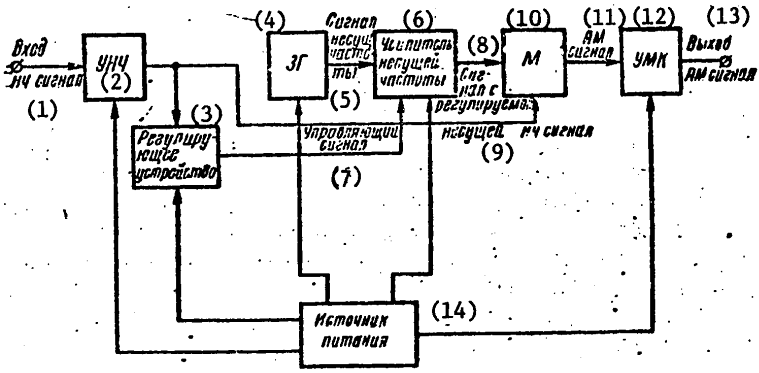


Figure 4.1. Functional diagram of the shaping and amplification of the AM signal of the TPB transmitters

Key:

1. Low-frequency signal input
2. Low-frequency repeater
3. Regulator
4. ZG master oscillator
5. Carrier frequency signal
6. Carrier frequency repeater
7. Control signal
8. Signal with regulatable carrier
9. Low-frequency signal
10. Modulator
11. AM signal
12. Modulated oscillation repeater [UMK]
13. AM signal output
14. Power supply

The operating principle of the given system consists in the following. The carrier frequency obtained in the master oscillator goes to the controlled high-frequency repeater and the control signal shaped in the regulator and corresponding envelope of the modulating signal (broadcast signal) go together with it to the repeater. Under the effect of the control signal the gain of the controlled high-frequency repeater changes, which leads to the adjustment of the carrier frequency level by the law of the envelope of the modulating signal, that is, to primary modulation in practice not noticeable when heard. Then, in the modulator, under the effect of the low-frequency signal coming from the output of the low-frequency repeater, secondary, basic amplitude modulation of the carrier takes place, as a result of which the information of the broadcast signal is transmitted. The AM signal shaped in this way is amplified by the stages of the modulated oscillation repeater.

This structure of the functional diagram of the basic channel for which at the beginning total shaping of the AM signal with adjustable carrier is carried out and then amplification of it, is more expedient. The use of anode modulation in the terminal stage would require the creation of another powerful controllable rectifier in addition to the powerful low-frequency amplifier of the modulator, which would cause significant difficulties. With relatively low powers of the transmitters (on the order of hundreds of watts) the energy advantages of the anode modulation cease to be decisive. In the transmitters developed at the present time this principle of constructing the basic channel is retained. All of the indicated transmitters have quartz stabilization of the carrier frequency of the master oscillator, which insures stable reception of the AM signals in the presence of fixed tuning of the TPB receivers. With the exception of the diode modulator, all of the elements for amplification and conversion of the signals are executed from electron tubes, which imposes additional requirements with respect to protection against high-voltage feed voltages.

In the existing systems for construction of the station part of the high-frequency channel (Fig 2.12), the output power is determined by the received maximum voltage of the carrier frequency of 120 volts and the load resistance. For the majority of cities the number of simultaneously connected main feeder lines does not exceed 5-6, and the power of 200 watts is sufficient. For a part of the reference repeater stations of such cities as Moscow and Leningrad, with a large number of connected main feeder lines, a power of 200 watts turned out to be insufficient, which also led to the necessity for increasing the output power to 400 watts. The most widespread is the UPTV-200 type transmitter; the UPTV-60 transmitter is in practice not widespread. At the same time, for the TPB systems of many small cities a power on the order of 40 watts is sufficient.

When calculating the energy indexes of the UMK in the rated regime (the output power, the dispersion power, the voltage and current amplitude, and so on), in spite of the regulation of the carrier level, all of the relations used for an ordinary AM signal are applicable. For the given maximum normalized modulation coefficient m=0.7, the calculation relations are as follows:

Maximum power

$$P^{(1)}_{\text{макс}} = \underset{(2)}{P_{\text{н}}}(1+m)^2 \approx 2{,}9P_{\text{н}}, \qquad (4.1)$$

Key: 1. max; 2. rated

where P_H is the average carrier power in the absence of modulation for the signal with rated carrier voltage;

The average power during the frequency period of the AM signal envelope

$$P_{\tau} = P_{\text{н}}\left(1+\frac{m^2}{2}\right) \approx 1{,}25P_{\text{н}}. \qquad (4.2)$$

The maximum voltage and current amplitudes of the AM signal are as follows:

$$U^{(1)}_{\text{макс}} = U_{\text{н}}(1+m) = 1{,}7U_{\text{н}}; \qquad (4.3)$$

$$I^{(1)}_{\text{макс}} = I_{\text{н}}(1+m) = 1{,}7I_{\text{н}}, \qquad (4.4)$$

Key: 1. max

where U_H and I_H are the rated voltage current amplitudes of the carrier in the absence of modulation.

For the transmitter with regulatable carrier when suppressing the carrier voltage in the interval by 10 times the output power in the interval $P_{H\ min}$=0.01 P_H, which leads to reduction of the dispersion power under class B conditions.

Thus, the presence of the regulatable carrier significantly reduces the average real dispersion power of the tubes and transistors when transmitting the broadcast signal. The operating conditions for the rated output power of the carrier in the given case are maximal and correspond to the maximum broadcast signal of it. The actual average carrier level is appreciably less than rated for the broadcast signal. This fact can be especially used to decrease the dimensions of the thermal leads of the modulated oscillation repeater transmitters.

At the present time the AM signal repeaters include only the two-channel intermediate repeater (DPU) installed on the distributing feeder lines to insure the required high-frequency signal voltage along the entire length of the feeder line (Fig 3.8). The DPU [two-channel intermediate repeater] is made from transistors and is fed from the AC electric network.

4.2. Automatic Gain Control of the Carrier Frequency

In essence, with insignificant variations in all three types of transmitters the same circuit is used to shape the controlling signal and the controlled carrier frequency repeater. Let us discuss the circuit for regulating the carrier in the UPTV-200 transmitter (and also in the UPTV-400) illustrated in Fig 4.2. The low-frequency signal voltage from the output of the two-stage low-frequency amplifier goes through the cathode repeater in the tube L_{2b}, the transformer 111, to the double halfperiod detector (in the tube 112, double diodes). In the RC-load of the detector (113-114), the envelope of the modulating signal is isolated. Then the voltage of the envelope is also filtered by the left diode of the tube 116 and transmitted to the RC-circuit (115, 117). The DC voltage which is opposite in polarity to the received envelope voltage is introduced successively between the lower point of the circuit and the common point of the entire circuit through the 120 "carrier suppression" potentiometer. Both voltages are successively applied to the antidynatron grid of the pentode 50. The variation of the envelope voltage leads to variation of the bias voltage on the third grid, which also causes variation of the amplification coefficient of this pentode. In Fig 4.3 the relation is presented for the relative variation of the carrier voltage as a function of the bias on the third grid E_{c3} indicating the simple possibility of regulating the carrier by 20 decibels. The initial suppression of the carrier in the interval is established by the potentiometer 120 and according to Fig 4.3, consists in feeding the bias voltage on the order of 1.5 volts for suppression by 20 decibels. When feeding the rated input signal the negative bias is compensated by the positive voltage at the output of the circuit 115, 117, which leads to restoration of the rated carrier level. The right diode of tube 116 included in parallel to the third grid of the pentode, blocks it at positive potentials, which permits the formation of the required dependence of the carrier level on the modulating signal level, that is, the extent of the upper section of the regulating curve with constant carrier voltage (Fig 2.40). The required low-frequency signal voltage at the input of the controlling detector for creation of the given regulating curve is established by the "control signal" potentiometer 30. The buildup time of the controlling voltage of the RC circuit (115, 117) is basically determined by the output impedance of the cathode repeater on the L_{2b} tube (34) by the transformation coefficient of the transformer 111, the internal impedances of the diodes of the tube 112 and the left diode of the tube 116 and also the capacitance of the capacitors 114, 115. This time correspondingly determines the buildup time of the carrier at the output of the tube 50. The steepness of the buildup of the carrier is determined only by the indicated elements in the case where the steepness of the buildup of the modulating signal significantly exceeds the steepness of the charge of the capacitance 115. The decay time of the controlling voltage on the circuit 115, 117 is determined by the resistances 113, 117 and the capacitances 114, 117. The decay time of the controlling voltage determines the decay time of the carrier.

In the UPTV-200 and UPTV- 400 transmitters the buildup time of the carrier to a value of 0.9 $U_{0\ rated}$ is on the order of 6 milliseconds, and the decay time of the carrier to 0.2 $U_{0\ rated}$ is approximately 200 milliseconds.

For further increase in noise suppression in the interval of the modulating signal in 1967 another method of regulating the carrier frequency level was proposed in which the existing smooth regulation of the carrier is maintained within the limits of the established dynamic range of the broadcast signal

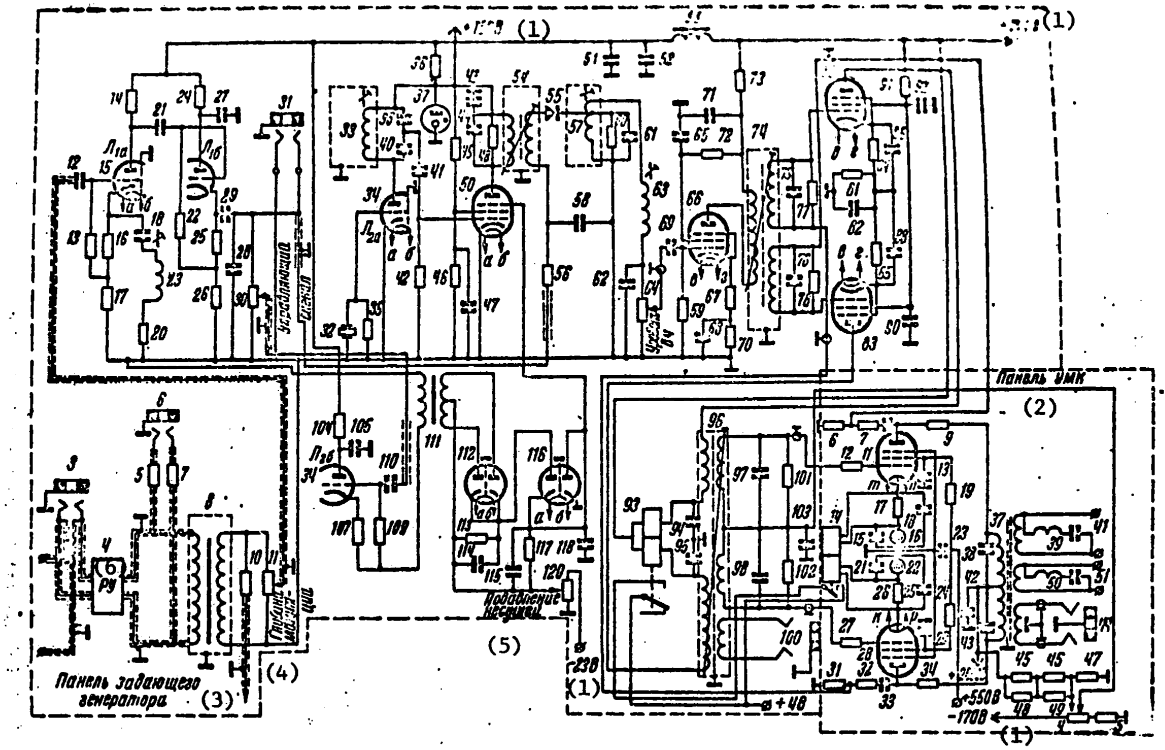


Figure 4.2. Schematic diagram of the channel for shaping and amplifying the AM signal of the UPTV-200 transmitters

Key: 1 -- volts; 2 -- modulated oscillation repeater panel [UMK panel]; 3 -- master oscillator panel; 4 -- depth of modulation; 5 -- carrier suppression; 6 -- level control

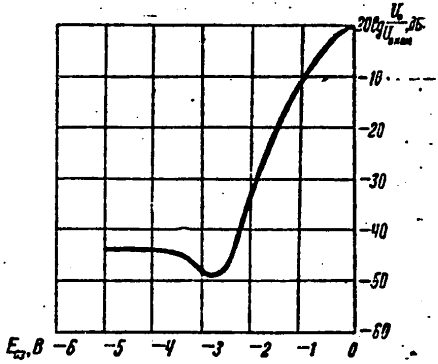


Figure 4.3. Output level of the carrier frequency as a function of the bias voltage $E_{c\ 3}$ on the third grid of the 6Zh2P tube

of 40 decibels, and with the level below this range the carrier voltage is sharply suppressed by another 30-40 decibels, which on the whole makes it possible to obtain carrier suppression in the interval of 50-60 decibels (Fig 2.41). The schematic of the device for additional suppression of the carrier for the UPTV-200 transmitter was developed in 1969. The initial operating principle of the given device was investigated in Section 2.12 and illustrated in Fig 2.43. The schematic diagram of the device is illustrated in Fig 4.4. The circuit elements which belong to the UPTV-200 transmitter are denoted only by the numbers in accordance with Fig 4.2; the circuit elements of the device are designated in accordance with the type of element.

The device consists of a two-stage amplifier-limiter based on the L_1 tube (6N2P), a rectifier with respect to the voltage doubling circuit based on semiconductor diodes D_1 and D_2 (D226D), the parametric stabilizer R_8, E_3 (D809), the DC amplifier based on the transistor T_1 (MP37A) and the switching diode D_5 (D226D). The device operates as follows. The amplifier-limiter of the instantaneous values maintains the initial dynamic range of the broadcast signal at 40 decibels to several decibels at the input of the rectifier. The parametric stabilizer reduces the limits of variation of the DC voltage still more, reducing in practice the entire dynamic range of the broadcast signal to one value of the DC voltage on the D_3 stabilitron. A voltage determined by the broadcast signal and the DC voltage on the resistor R_{11} are applied to the base of the transistor T_1 in opposite polarity.

In the presence of the broadcast signal, the voltage of inverse polarity on the stabilitron D_3 exceeds the voltage of direct polarity on the resistor R_{11} as a result of which the transistor T_1 is closed and the diode D_5 does not shunt the carrier frequency at the input of the pentode 66.

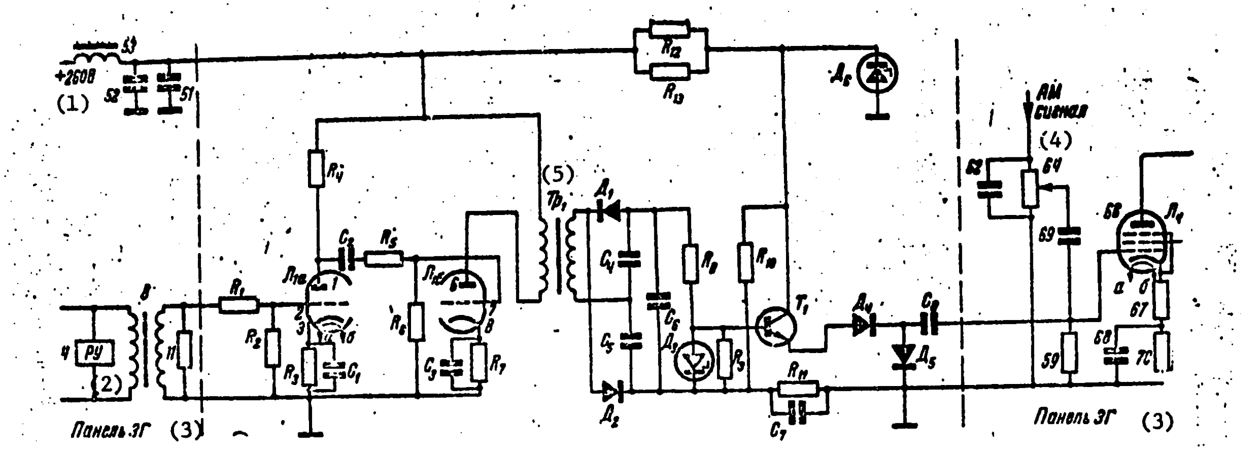


Figure 4.4. Schematic diagram of the device for additional suppression of the carrier frequency level in the broadcast transmission interval

Key:

1. +260 volts
2. Level control
3. Master oscillator panel
4. AM signal
5. Transformer

In the broadcast transmission interval the voltage on the stabilitron D_3 decreases sharply, and the transistor opens under the effect of the direct voltage, which causes transmission of the current through the diode D_5 and in practice short circuiting of the input of the tube 66 with respect to the carrier frequency.

The device can be placed in the UPTV-200 master oscillator unit, and all of the feed voltages are taken from its circuitry. The obtained total suppression of the carrier in the interval was 65-68 decibels; for the switching zone (Fig 2.42) it was 2-3 decibels. The performed operating tests of the device in the MGRS [Moscow City Radio Wire Broadcasting Network] over a period of several months in 1970 demonstrated its reliable operation and absence of additional distortions of the AM signals.

4.3. UPTV-200 and UPTV-400 Transmitters

General Information

The UPTV-200 and UPTV-400 transmitters have to a great extent similar structural diagrams and structural executions.

The UPTV-200 transmitter was developed by the Scientific Research Institute for Radio of the Ministry of Communications in 1962, and at the present time it is basic [16]. The UPTV-400 transmitter was built at the MGRS in 1963 on the basis of the UPTV-200 by increasing the output power of the terminal stage to 400 watts.

The UPTV-200 and UPTV-400 transmitters have the following basic electrical characteristics:

1. Carrier frequencies of 78 and 120 kilohertz.
2. Amplitude modulation. Rated modulation coefficient of 70%.
3. Regulation of the carrier level of 20 decibels.
4. Rated carrier voltage of 120 volts.
5. Rated load resistance for the UPTV-200 transmitter of 72 ohms and for the UPTV- 400 transmitter of 36 ohms.
6. Rated frequency band of 50-6000 hertz.
7. Admissible nonuniformity of the frequency characteristic within the limits of the frequency band to 3 kilohertz is 2 decibels. On a frequency of 6 kilohertz the increase in the frequency characteristic reaches +4 decibels.
8. The harmonic coefficient with respect to the envelope for the rated modulation level in the frequency band of 200-4000 hertz is no more than 2.5%, and in the 100-200 hertz band no more than 4%.

9. The signal/background ratio on frequencies of 50 and 100 hertz is no less than 60 decibels.

10. The rated input signal level for the broadcast transmission is 0 decibels (0.775 volts).

The functional diagram of the channel for shaping and amplifying the AM signal is presented in Fig 4.1 and it is investigated in Section 4.1. Let us consider the structural diagram of the transmitters in accordance with their structural execution (Fig 4.5).

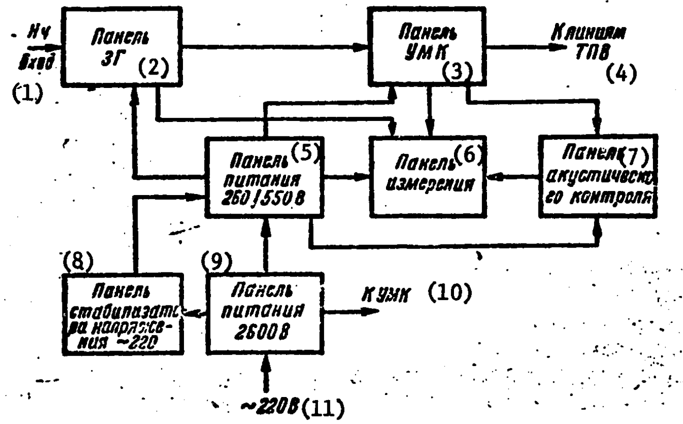


Figure 4.5. Structural diagram of the UPTV-200 and UPTV-400 transmitters in the panel execution

Key:
1. Low-frequency input
2. Master oscillator panel
3. Modulating oscillation repeater panel
4. To the TPB lines
5. 260/550 volt shade panel
6. Measurement panel
7. Acoustic monitoring panel
8. Voltage stabilizer ~220 volt panel
9. 2600 volt feed panel
10. To the modulating oscillation repeater
11. ~220 volts

The structural diagram of each transmitter consists of seven panels: the modulating oscillation repeater panel (UMK); the master oscillator panel (ZG); the measuring panel; the acoustic monitor panel; the 260/550 volt feed panel; the 2600 volt feed panel; the voltage stabilizer panel.

The ZG and the UMK panels are the channel for shaping and amplifying the AM signal. The remaining panels perform the functions of measurement, monitoring and feed of the basic channel for shaping and amplifying the AM signal.

ZG and UMK Panels

The total schematic diagram of the master oscillator and modulated oscillation repeater panels of the UPTV-200 transmitter is presented in Fig 4.2. The low-frequency input signal goes through the level control (PY) 4, the transformer 8, the "demodulation control" 11 to the two-stage low-frequency amplifier executed from a double triode 15 (6M3P). The left triode of this tube is included by the circuit with common cathode, and the right triode, by the cathode repeater circuit.

The control 4 is used to set the rated (0) low-frequency level in the I winding of the input transformer 8. The regulator 11 is used to set the rated depth of modulation. In order to improve the noiseproofness of the AM signals with respect to the low-frequency signals of program I, an increase in the frequency characteristic in the upper modulating frequency range is formed in the low-frequency amplifier by introducing frequency-dependent current feedback realized by a series circuit of elements 18, 23 and 20. The given circuit has resonance on approximately a frequency of 8 kilohertz. On frequencies about 2 kilohertz the depth of the current feedback decreases, as a result of which an increase in the upper modulating frequencies is created. Remodulation does not occur on the upper frequencies as a result of diminished level of these frequencies in the broadcast signal spectrum. In the receivers the given increase is compensated by the corresponding trough. From the low-frequency amplifier output the total level of the low-frequency signal is fed to the diode modulator, and part of the low-frequency signal from the "controlling signal" regulator (30) is fed to the cathode repeater based on the L_2 tube (34). The shaping of the control signal by the elements 112-117, 120 and the gain control of the tube 50 are investigated in Section 4.2. The generation of the carrier frequency is carried out on the L_2 triode of the 6M3P tube (34). The generation frequency is stabilized by a vacuum quartz operating by the parallel resonance scheme.

Part of the carrier voltage is picked up from the anode circuit 33, 38, 40 of the master oscillator and is fed through the capacitor 41 to the first grid of the pentode 50. For stabilization of the operating conditions of the master oscillator and the controlled high-frequency amplifier the feed voltage of their anode circuits is stabilized by the SG1P stabilitron (37). From the anode circuit of the pentode 50 the carrier voltage is transformed by means of the high-frequency transformer 54 to the diode modulation circuit.

Thus, the diode 55 (D2Zh) is under the effect of two successfully applied carrier voltages and the low-frequency signal, which leads to obtaining the AM signal in the circuit made up of the inductance 57 and the capacitor 61. The modulation is realized by varying the cutoff angle of the carrier frequency current in the diode circuit. The cutoff angle always remains normal, as a result of which proportionality is retained between the amplitude of the modulating low-frequency signal and the amplitude of the first harmonic of the carrier on the circuit 57, 61.

This modulator corresponds well to the requirement of independence of the amplitude of the envelope of the modulated oscillation with respect to the amplitude of the carrier required when using the carrier with regulatable level. In addition, the diode modulation insures very small nonlinear distortions even with a reduction in the carrier level while maintaining the deep modulation. In order to suppress the carrier frequency harmonics, the AM signal is fed from the circuit 57, 61 through the low-frequency filter 63, 62 to the input of the first stage of the modulated oscillation amplifier based on the 6P15P tube (66). In order to establish the required output voltage of the transmitter, the "high-frequency level" regulator is used (64) at the input of the tube 66. The amplifier based on the 6P15P pentode operates in the class A regime. Then the AM signal goes through the symmetric transformer 74 tuned to the high-frequencies to the preterminal double-cycle stage based on the 6P15P tubes (80, 83) operating as the voltage amplifier in the class A regime. The cathode circuits of all the 6P15P tubes (66, 80, 83) include the resistances 70, 84, 85 for measuring the currents of these tubes. The differential relay 93 is included in the anode circuit of the preterminal stage.

The preterminal stage is connected to the terminal stage by means of the high-frequency transformer 96, two secondary windings of which form parallel circuits with the capacitors 97, 98. The output stage of the UMK [modulated oscillation amplifier] located on the UMK panel is executed in accordance with the double-cycle circuit based on the GU-81 tubes (11, 28, the number of the circuit elements of the UMK panel is separate). The GU-81 tubes operate in the AB class regime without grid currents. The output transformer 37 is executed from a torus made up of four Alsifer halfrings type VChK-22 (outside diameter 75 mm). It is necessary to note that the high voltage transformer executed from the torus of relatively small diameter requires careful manufacture from the point of view of the electrotechnical characteristics of the insulating materials of the inserts and the winding wires.

The primary winding of the output transformer is tuned to resonance on the carrier frequency by the capacitors 38 and 43. In order to exclude the mutual effect of the transmitters on successive inclusion of them, two secondary windings of the output transformer are created. The series circuit (39, 41, 50, 51) tuned to the carrier frequency of the adjacent transmitter is included in parallel to each winding. This makes it possible in practice to exclude the power losses of this transmitter. The terminal and the preterminal stages of the UMK are encompassed by negative feedback with respect to voltage with depth on the order of 18 decibels, which insures sufficiently small output impedance of the transmitter (on the order of 7 ohms) and an increase in voltage on dropping the load of no more than 1 decibel. The negative feedback is fed from the dividers 6, 7 and 31, 32 of the UMK panel to the first grids of the 6P15P tubes (80, 83) in series through the secondary circuits of the transformer 74. The required bias voltage of the terminal tubes is established by the potentiometer 4 led to the face of the UMK panel. In order to decrease the voltage variation of the anode feed of +2600 volts, a ballast resistance (45-49) is included in parallel to the power supply. For monitoring the constant components of the anode currents of the GU-81 tubes, their cathode circuits include milliammeters 16 and 22 and a differential relay 14. In order to monitor the low-frequency and high-frequency voltages in the master oscillator and modulated oscillation amplifier panels [ZG and UMK panels] there are control plugs.

In the plugs 6 and 31 of the ZG panel, the low-frequency voltages are monitored; in the plug 100 of the same panel, the high-frequency voltage is monitored. In the plug 44 of the UMK panel the output carrier voltage is monitored.

The filament feed of all tubes of the ZG and UMK panels is realized from special filament voltage transformers installed on these panels. The stabilized voltage of 220 volts is fed to the filament transformer of the ZG panel.

The UPTV-400 transmitters are distinguished with respect to the UMK only by the schematic and structural execution of this panel. The final stage of the UMK is made in accordance with the two-cycle circuit of 4 type GU-81 tubes (two tubes in each arm) operating in the class B regime. The characteristic feature is the execution of the output high-frequency transformer. The transformer is executed from an armored core of eight pairs of unitized Π-type ferrite cores type F-600, which makes it possible to decrease the transformer dimensions and losses in the core. The variation of the magnetic induction from 450 to 50 gauss causes variation of the resonance frequency of the output circuit in the primary winding of the transformer from 120 to 121 kilohertz, which is admissible with low Q-factor of the circuit (Q=5). The output circuit is tuned by varying the air gap of the transformer, to prevent overheating the magnetic induction in its core must not exceed 450 gauss. The calculated gap is 5 mm.

The output resistance of the transmitter is 4 ohms, and the variation of the output voltage when dropping the load does not exceed 1.2 decibels.

Measuring Panel

The measuring panel is designed to measure all of the DC feed voltages, the currents of the individual tubes of the ZG panel, the AC network voltage and also for visual monitoring of the AM signal.

For measurements of the voltages and currents, one indicating instrument is used which measures the current of the 6P15P tube (66) of the ZG panel, the currents of the 6P15P tubes (80 and 83) of the ZG panel (each tube individually and their total current); the voltage of the 220 volt AC network, the anode voltage of +2600 volts of the UMK panel, the grid voltage of the tubes of +550 volts of the UMK panel, the bias voltage of the tubes of -170 volts of the UMK panel, the bias voltage of -23 volts for suppression of the carrier in the ZG panel, and the anode voltage of +260 volts of the tubes of the ZG panel for various positions of the measurement switch.

Visual monitoring is realized by the oscillograph using the 5L038 tube.

With a sufficient degree of accuracy for practice with respect to the tube grid divisions it is possible to determine the modulation coefficient and the depth of control of the carrier and also to estimate the maximum depth of modulation in time of a real transmission. The monitoring AM signal is fed to the tube from the output of the band filter of the acoustic monitoring panel. The feed of the anode circuits of the tubes in the tube of the measuring panel is provided from the +550 volt power supply.

Acoustic Monitoring Panel

The acoustic monitoring panel monitors the fitness of the basic channel by means of the "input-output" comparison circuit, acoustic monitoring, the creation of a bias voltage of -170 and -23 volts.

The "input-output" circuit compares the envelopes of the low-frequency signals at the input and output of the transmitter. For this purpose the output voltage of the AM signal is detected initially for isolation of the low-frequency signal, and then the low-frequency signal obtained is detected for isolation of the envelope of the low-frequency signal. The low-frequency input signal is detected once for isolation of its envelope. The voltages obtained for the envelope of the low-frequency signal are fed to the individual windings of the polarized relay which responds and attenuates an emergency signal for the relative variation of input and output levels of the transmitter of ±5 decibels. The polarized relay used with fixed extreme positions permits an emergency signal to be obtained even at transmission peak. In order to return the relay armature to the initial position, a separate button is used.

For acoustic monitoring, a low-frequency signal is used which is obtained after detection of the AM signal for the "input-output" circuit. As the sound reproducing device, the dynamic 1GD-18 speaker is used with an intake power of 250 milliwatts. Its volume control is realized by a step regulator with constant input impedance. The low-frequency signal obtained after detection of the AM signal is also used to feed the return monitoring to the TsUS with a voltage of 5.5 volts. This low-frequency signal voltage is picked up from a separate winding of the transformer.

The bias rectifier with a voltage of -170 volts is made by the bridge system from the D7Zh type diodes. In order to smooth the pulsations, the LC-filter is used. Part of the voltage equal to -23 volts stabilized by two reference diodes of the D811 type is fed to the ZG panel for creation of the initial bias on the 6Zh2P regulatable pentode and to the "input-output" circuit for feeding the transistorized repeater. By means of another divider, a voltage of -48 volts is selected for feeding the emergency bell and two relays in the 260/550 volt feed panel.

260/550 Volt Feed Panel

The 260/550 volt feed panel is designed for creating a feed voltage of +260 volts of the anode circuits of the ZG panel tubes and a feed voltage of +550 volts of the second grid of the tubes of the modulated oscillation repeater panel and also the tubes and the electron-beam tube of the measuring panel. Two rectifiers with voltages of +260 and +550 volts are placed on the panel.

The feed rectifier at +260 volts is executed by the grid circuit from D7Zh type diodes, two diodes in each arm. For filtration of the pulsations the LC-filter is used. A divider is connected to the filter output from which a voltage of +4 volts is picked up for the emergency relay contacts.

The rectifier with a voltage of +550 volts feeds the second grids of the GU-81 tubes and the measuring panel tubes. The rectifier circuit is a bridge circuit made of D7Zh type diodes, three diodes in each arm. The output of the rectifier has the LC-filter connected to it which is loaded on an additional ballast resistance of 20 kilohms. A rectifier of +550 volts is fed from the ferroresonance stabilizer. The toggle switch for switching on the transmitter and the switch for the type of control of the transmitter "local-remote," are taken out to the face of the panel.

2600 Volt Feed Panel

The anode feed rectifier of the GU-81 tubes is designed for an intake current of 0.5 amps, and it is made by the bridge circuit from silicon diodes of the D205 type included in series, 12 each in an arm. The rectifier operates from the LC-filter. In order to improve the stabilization of the rectified voltage, a ballast resistance located on the modulated oscillation repeater panel which consumes a current of 90 milliamps is included in parallel to the load.

A rectifier of +2600 volts of the UPTV-200 transmitters has significance differences. It is made by the six-phase Larionov circuit from 54 D205 type silicon diodes, nine in each arm. In the presence of a three-phase electric network at the station the application of this rectifier circuit is the most expedient. The multiphase rectifier circuit insures low output impedance and the necessity drops out for a ballast resistance. The execution of the smoothing filter is simplified, the rectifier efficiency is increases with the same rectified power. The rectifier is designed for maximum intake current of 1.2 amps, the actual current in the maximum power regime does not exceed 0.6 amps, which makes it possible to get along without the radiators to the diodes.

Voltage Stabilizing Panel

In this panel there is a 200-watt ferroresonance stabilizer of the SN-200 type which feeds the +550 volt rectifier and the filament transformer of the ZG panel.

Control, Monitoring and Protection

The UPTV-200 and UPTV-400 transmitters are designed for local and remote control. For remote control, protection and monitoring of the transmitters, automation elements are introduced into the circuitry of each transmitter. The automation circuitry permits us to switch the transmitters on and off, receive signals about the execution of the commands, realize monitoring of the operation of the transmitter and perform some protective functions. The control of the set of transmitters can be realized either with the help of a free panel of the UPI servounit (from the remote control set for the UUP-1 or UUP-2 amplifier substations) or direct current over the connecting line for feeding the programs over the circuit made up of the "two wires to ground" using the UVA-1 panel. The filament feed and anode voltages are connected to the UMK [modulated oscillation repeater] panel and the measuring panel separately in time. On response of the first servorelay the feed voltage is fed to the bias rectifier; the anode rectifier of +260 volts, the ferroresonance stabilizer and the winding of the delayed relay which with a delay of 18 seconds feeds a low-frequency voltage from the input of the ZG panel to the "input-output" circuit. This delay is sufficient to exclude the false response of the "input-output" circuit on random inclusion of the transmitter with the previously fed modulating signal. The inclusion of the anode rectifier of +2600 volts and the rectifier of +550 volts is accomplished with a delay of 2 seconds; after inclusion of the bias rectifier this delay is realized by the relays included in the bias rectifier circuit.

The automation system which realizes the monitoring of the correctness of operation of the transmitter includes the "input-output" comparison circuit which generates the emergency signal with relative noncorrespondence of the input and output levels at ±5 decibels. The polarized relay used in the system receives emergency signals from all of the protective relays, including the differential relays installed in the two-cycle stages of the modulated oscillation amplifier. In the transmitters there are sound and light signals about emergencies and failures. The sound signals usually bell in case of local control for all emergencies recorded by the polarized relay of the acoustic monitoring panel, and the light signal indicates the presence of feed voltages on the corresponding panels and also burning of the fuses in the AC feed circuits of the +2600, +550 and +260 volt rectifiers. When opening up the rear doors of the transmitter the blocking picks up the high voltage feed voltages and discharges the capacitors of the +2600 volt rectifier.

The connection of the feed voltage of the electric network, the low-frequency signal, the remote control and monitoring devices and picking up high-frequency voltages are accomplished by means of the terminals installed on one plate of the inputs located below the transmitter, on the rear side.

4.4. UPTV-60 Transmitter

The UPTV-60 transmitter was developed in 1960, and it is the first type of transmitter used in the adopted TPB system.

The functional diagram of the channel for shaping and amplifying the AM signal is the same as for the UPTV-200 and UPTV-400 transmitters and it was investigated in Section 4.1.

Structurally each transmitter will contain four panels of the modulated oscillation repeaters, the ZG panel, the anode rectifier panel, the bias rectifier panel and the voltage regulator.

The functional diagram of the master oscillator panel is the same as the UPTV-200 transmitter. Moreover, the schematic diagram of this panel differs insignificantly from the ZG panel in the UPTV-200 transmitter.

In contrast to the UPTV-200 and the UPTV-400 transmitters, the output power of the UPTV-60 transmitter is created by four UMK, 15 watts each. The output of each amplifier is designed for connection of one main feeder line for a distributing feeder line when providing a carrier frequency voltage at the input of the 95-volt line.

The output carrier voltage is set by the high-frequency level regulator included at the input of the first stage of the modulating oscillation repeater. For monitoring the output voltage of the carrier, an electronic display based on the 6Ye5S type tube is used. The dark section of the display is closed for values of U_{out}=90 volts and m=70%.

A toggle switch permitting the feed of the individual module of the UMK to be disconnected is led out to the face panel of the UMK panel.

The acoustic monitoring panel contains a dynamic speaker and receiver. The output transformer of the low-frequency repeater of the receiver has a separate winding for connection to the reverse monitoring line. The input of the monitoring receiver can be connected to the output of any of the four UMK modules with the help of a switch.

The modular construction of the transmitters during operation of each module on a separate load complicates obtaining the inverse acoustic monitoring in the case of remote control of the transmitter, for transmission of the instructions to switch the return monitoring line to each module or the four return monitoring lines is required. In order to overcome this deficiency it is possible to use addition of the powers of the individual modules on a common load. Comparatively low carrier frequencies, a common master oscillator, a wide UMK transmission band and short lengths of the mounting wires create the possibility of strict cophasal addition of the output signal without power losses. For low resistance of the UMK outputs, series inclusion of them is possible (Fig 4.6).

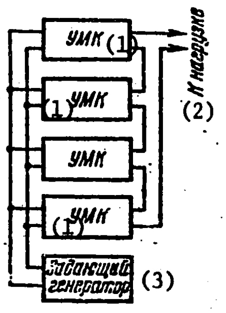


Figure 4.6. Schematic of the power addition of the UMK in the UPTV-60

Key:

1. UMK [modulated oscillation repeater]
2. to the load
3. Master oscillator

With this circuit diagram the unavoidable differences in the output voltages and the distances do not cause additional power losses. In order to insure rated output voltage of 95 volts, a lead from the quarter of the turns of the secondary winding is used. Here the output resistance of each UMK module decreases approximately to 4 ohms. It is possible to connect up to 8 feeder lines with an output voltage of no less than 75 volts to the common output of the transmitter with addition of the UMK powers.

The electrical characteristics of the UPTV-60 transmitter, with the exception of the output power, basically are the same as the UPTV-200 transmitter.

4.5. Connection of the Transmitters to the TPB Circuit

General Information

The investigated TPB transmitters are designed for installation of a centralized network at the stations and also at the reference repeater stations (OUS), the repeater substations (UP) and the substation blocks (BP) for the decentralized network. In accordance with this definition, the transmitters must have the possibility of the connection to the three-element, the two-element and mixed WB circuits. Let us consider the circuitry for connecting the transmitters to the TPB network.

Connection to the Main Feeder Lines

The connection of the UPTV-200 and the UPTV-400 transmitters to the main feeder lines is made through the devices for connecting the UPP-1 transmitters (Fig 4.7) which are symmetric high-frequency transformers with transformation coefficient of n=1:1 and tuned in the primary winding circuit to carrier frequencies of 78 and 120 kilohertz. The secondary windings of the high-frequency transformer of the transmitter connecting circuit are connected to each other through two series circuits tuned to the carrier frequencies.

The two secondary windings taken from each output transformer of the two transmitters and included in series form the joint output of the two transmitters to which several main feeder lines are connected through their own UPP-1 [transmitter connecting circuits]. The secondary windings of the two transmitters are connected to each other in the sequence such that the currents from the adjacent transmitter will flow in the secondary windings of one output transformer in opposite phase. The total load resistance connected to the two UPTV-200 outputs must be no less than 72 ohms and no less than 36 ohms for the UPTV-400. Here it is necessary insofar as possible to distribute equally the load resistance between the two outputs of the transmitters in order to decrease the mutual effect of the transmitters.

The UPP-1 are installed in the output commutation phase (SVK) and they are connected between the II winding of the step-up meter transformer and the linear protection elements (fuses and lightning arrestors).

When connecting the transmitters to the main feeder lines having cable insert with the input with a capacity to 5600 picofarads identical for frequencies of 78 and 120 kilohertz it is necessary to decrease the capacitance C_3, achieving tuning of the L_1C_3 circuit to a frequency of 120 kilohertz considering the input capacitance of the cable insert. With a capacitance of the cable insert of 5600 picofarads the capacitor C_3 is completely disconnected. The tuning of the $L_1C_3C_6$ circuit to a frequency of 78 kilohertz is not required, for its tuning is maintained on connection of the capacitance C_6=7500 picofarads to the invariant total capacitance of the capacitor C_3 and the cable insert. With different input capacitance of the feeder line for frequencies of 78 and 120 kilohertz it is necessary to tune separately for each carrier frequency. Initially, the tuning to a frequency of 120 kilohertz takes place by variation of the capacitance C_3, and then, the tuning to a frequency of 78 kilohertz, by selection of the capacitance C_6.

Connection to the Distributing Feeder Lines

For connection of the transmitters to the distributing feeder lines, two versions can be used. In the first version, the distributing feeder lines are connected through the common UPP-3 device analogous to the UPP-1 device (Fig 4.7), but having a transformation coefficient of n=3.16:1 and correspondingly altered values of the elements of the secondary circuit L_2, L_3, L_4, C_1 and C_2. The input impedance of all the feeder lines must be no less than 60 ohms (approximately 10 distributing feeder lines) on carrier frequencies of 78 and 120 kilohertz. The output voltage of the carrier frequencies on a common bus of the distributing feeder will be on the order of 30-40 volts. The tuning of the UPP-3 to carrier frequency of 78 and 120 kilohertz will be carried out analogously to the tuning of the UPP-1. Here the limiting magnitude of the input capacitance of all the feeder lines must not exceed 5600 picofarads.

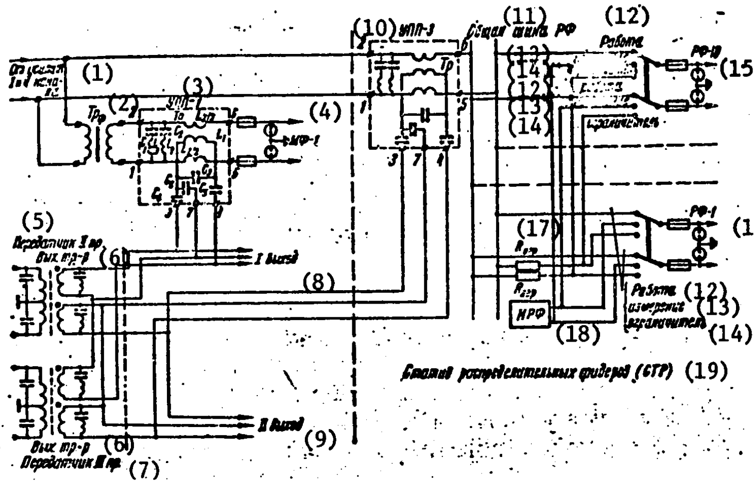


Figure 4.7. Connection of the transmitters to the main and the distributing lines

Key:

1. From the repeater I of the low-frequency channel
2. Transformer
3. UPP-1
4. Main feeder
5. Transmitter for the II program
6. Output transformer
7. Transmitter of the III program
8. I output
9. II output
10. UPP-3 transmitter connecting circuit
11. Common bus of the distributing feeder
12. Operation
13. Variation
14. Limiter
15. RF-10 distributing feeder
16. RF-1 distributing feeder
17. R_{lim}
18. NRF
19. Distributing feeder bay (STR)

In the second version in the absence of UPP-3, the connection of the transmitters to the distributing feeder lines can be made by using elements of the structure for connecting the transformer substation (Fig 4.8).

The feeder lines are connected to the transmitter through the bypass (OUTP) having the same transformation coefficient as the UPP-3. Between the output of the low-frequency repeater and the common bus of the distributing feeder, blocking filters are included (ZFR). The compensation for the input capacitance of the feeder lines is accomplished in this case on inclusion of a series circuit tuned to a frequency of 100 kilohertz parallel to the output of the low-frequency repeater to the terminals 5-6. In order to compensate for the capacitance of the lines it is necessary to decrease the capacitances in the parallel ZFR circuits, achieving tuning of them to frequencies of 78 and 120 kilohertz with input capacitance of the lines. This tuning is accomplished with respect to the maximum transmission coefficient of the OUTP when feeding high-frequency signals to the OUTP through the series resistance R=600 ohms.

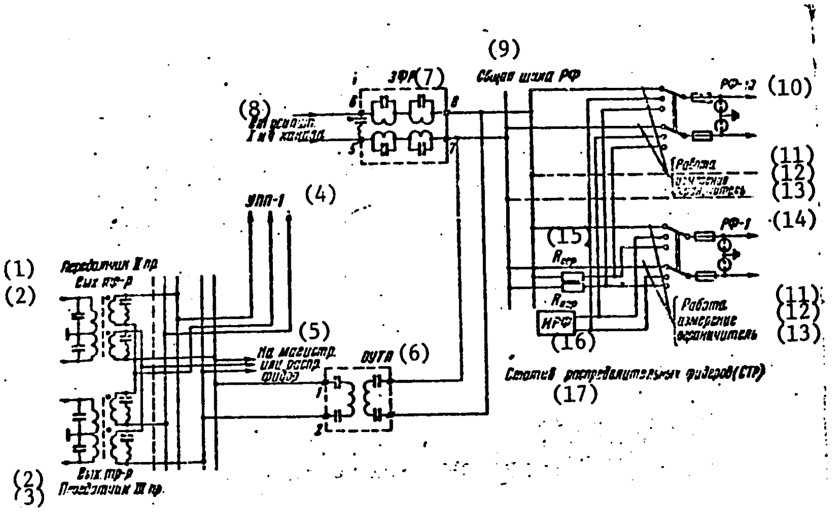


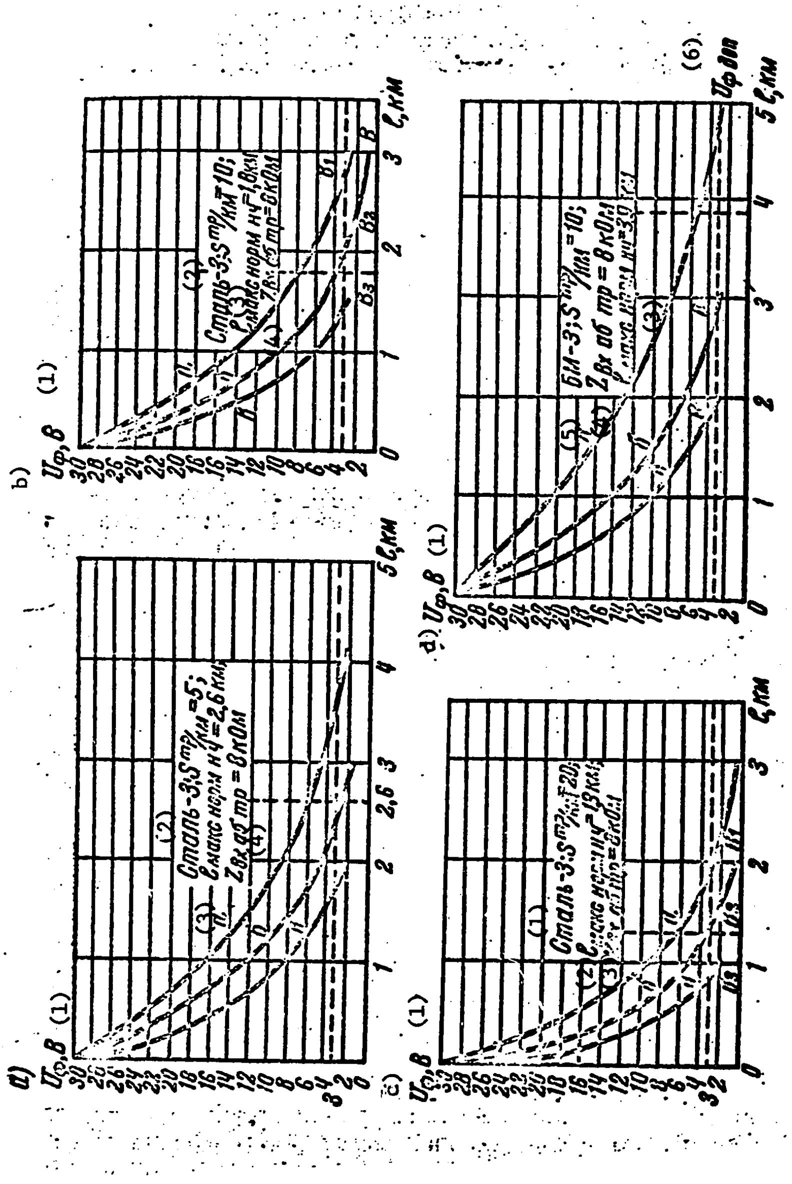
Figure 4.8. Connection of transmitters to the distributing feeder lines (Version II)

Key:

1. Transmitter for program II
2. Output transformer
3. Transmitter for program III
4. UPP-1 transmitter connection circuit
5. To the main or distributing feeders
6. OUTP [Transformer substation bypass]
7. ZFR
8. From the repeater I of the low-frequency channel
9. Common bus of the distributing feeders
10. RF-10 distributing feeder
11. Operation
12. Measurement
13. Limiter
14. RF-1 distributing feeder
15. R_{lim}
16. IRF
17. Distributing feeder bay (STR)

Connection of the Transmitters to the Mixed Circuit

The connection of the transmitters to the mixed circuit made up of the main and distributing feeder lines can be made by the circuits in Fig 4.7 and 4.8. For each type of wire network, its own version of connection of the transmitters is used. Here it is necessary that the total load resistance reduced to the secondary windings of the output transformers of the transmitters be no less than the rated and it be distributed uniformly between two secondary windings. In the presence of long distributing feeder lines


a)
Uф,В (1)
30 28 26 24 22 20 18 16 14 12 10 8 6 4 3 2 0
1 2 2,6 3 4 5 ℓ,км
(2) Сталь-3;Sтр/км=5;
ℓмакс норм нч=2,6 км
Zвх аб тр = 8 кОм
(3) (4)
b)
Uф,В (1)
30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0
1 2 3 ℓ,км
(2) Сталь-3;Sтр/км=10;
(3) ℓмакс норм нч=1,8 км
Zвх аб тр=8 кОм
(4)
c)
Uф,В (1)
30 28 26 24 22 20 18 16 14 12 10 8 6 4 3 2 0
1 2 3 ℓ,км
(1) Сталь-3;Sтр/км=20;
(2) ℓмакс норм нч=1,3 км
(3) Zвх аб тр=8 кОм
d)
Uф,В (1)
30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0
1 2 3 4 5 ℓ,км
(5) БИ-3;Sтр/км=10;
Zвх аб тр = 8 кОм
ℓмакс норм нч=3,0 км
(2) (3) (4)
(6) Uф доп

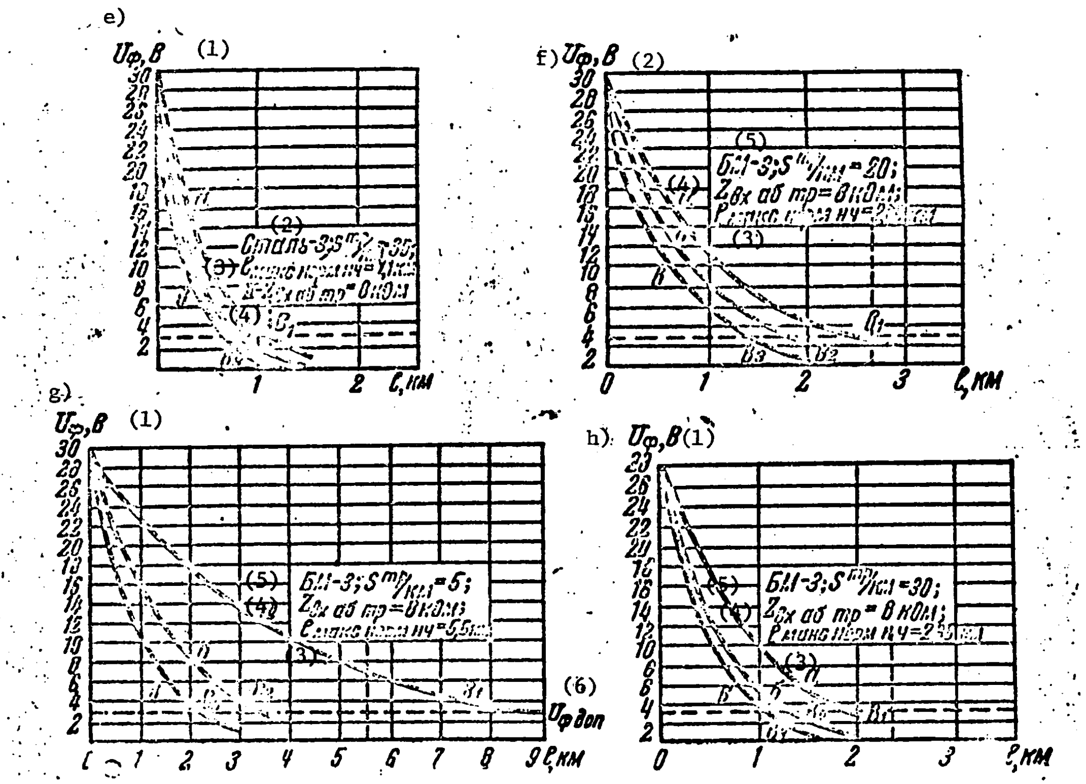


Figure 4.9. Diagram of the voltages of the high-frequency TPB channels for various distributing feeder lines

Key:
1 -- U_f, volts; 2 -- Steel-3; S tr/km=5; 3 -- ℓ_{max} norm low frequency; 4 -- $Z_{inp\ ab\ tr}=8$ kilohms;
5 -- BM-3; S tr/km=10; 6 -- U_f aux.

with attenuation of more than 20 decibels, the UPP-2 can be used with transformation coefficient n=1.73:1 and rated load resistance of 200 ohms.

4.6. Two-Channel Intermediate Repeater (DPU)

The introduction of the TPB on the city networks demonstrated that there are cases where on satisfaction of the norms for attenuation of the first (low-frequency) channel, the requirement of insuring minimum admissible level for the high-frequency programs of channels II and III is not satisfied.

This occurs on the distributing feeder lines having long leads and cable inserts, and with long lengths of the basic direction. In these cases, in practice it is recommended that a distributing network be constructed, the load be redistributed between the distributing feeder lines, the structure of the line be changed with a decrease in the number of leads, and their length.

However, this procedure is not always expedient because it is connected with construction operations. The increase in voltage at the input of such feeder lines also is inexpedient as a result of the energy expressions which disturb the effects during emergencies on the lines and overloads with respect to the input for the receivers.

A simpler solution can be the application of additional amplification of the high-frequency signals in the channel by installing the repeater and the distributing line circuit.

For qualitative and quantitative estimation of the set of possible cases, let us use the previously calculated hypothetical versions of the lines distinguished by the load density S, the number of leads and the materials of the lines. The leads more than 300 meters long are taken into account.

The effect of the leads on the attenuation of the high-frequency signals for various loads is well illustrated by the graphs depicted in Fig 4.9.

The value of the voltage corresponding to the voltage at the beginning of the line and taken equal to 30 volts is plotted on the y-axis.

The line drawn as the dotted line corresponds to the minimum admissible value of the whole equal to 3 volts for which high-quality reception of the high-frequency programs is insured. The value of the length of the lines expressed in kilometers is plotted on the x-axis. A segment is marked off on it which is in the form of the maximum length of the lines normalized with respect to attenuation analogously to the requirements of the low-frequency channel in accordance with the electric norms ($\ell_{\text{max low frequency}}$).

Curve a and the dotted line intersect beyond the limits of the maximum length of the line (point B_1). This means that from the point of view of the required level of high-frequency signals the line without leads has a reserve.

The curves b (1 response/km) and c (2 responses/km) indicate the effect of the leads on the attenuation of the high-frequency signals, and they confirm that in spite of the satisfaction of the attenuation norms with respect to low frequency, the levels of the high-frequency signals for such lines will be reduced (after the points B_2 or B_3).

The two-channel intermediate repeater is designed for repeating the high-frequency signals on such lines.

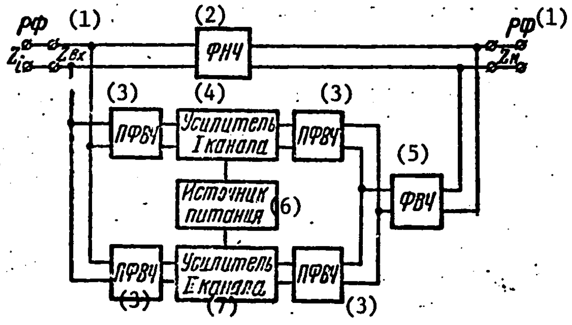


Figure 4.10. Block diagram of the DPU

Key:

1. Distributing feeder
2. Low-frequency filter
3. High-frequency band filter
4. Repeater of channel I
5. High-frequency filter
6. Power supply
7. Stage II repeater

The structural diagram of the repeaters is presented in Fig 4.10. The DPU is included in the circuit break of the distributing feeder line. The signals of each high-frequency channel have been amplified separately, and the amplified signals again are fed to the distributing line. The source resistance Z_i is the output resistance of the part of the line from its beginning to the point of connection of DPU, and the load resistance, the second segment of the line (after the DPU).

The operating principle of the device consists in the following. The frequency spectrum of the three channels is fed to the input separation junction made up of three filters: low-frequency filter (FNCh), the band filters II and III of the channel (the PFVCh [high-frequency band filter]), the PFVCh filter transmits the frequencies of the channel itself with minimum distortions, it significantly attenuates the signals of the adjacent channels. After filtering the signals are amplified by channel amplifier at the exit of each of which a band filter is installed.

Then the signals from both intensifiers of the high-frequency signals are felt in one element of the high-frequency filter and they go to the line.

The channel high-frequency repeater is fed from the stabilized rectifier. The repeater operates the conditions of small fluctuations of the source resistance of the signal and the load resistance which are equal to the wave impedance of the process line. For the bimetal, steel and copper lines the wave impedance is equal to 600 ohms±20%; for steel lines it is 800 ohms±20%. Therefore the creation of input and output filters for the channel repeaters gives rise to no difficulties. The situation is different with the high-frequency filters on which the following requirements are imposed: the signals of the low-frequency program must be transmitted without noticeable frequency distortion band, in addition, the low-frequency filter must perform the functions of the blocking filter so as to insure that the feedback with respect to high frequency from the output to the input of the channel repeaters is essentially weakened. The feedback can be the cause of distortions of the frequency characteristics of the channel repeaters. The low-frequency filter operates under the conditions of large variations of the input and load impedances which depend on the frequency, the wire material, the voltage of the low-frequency channel and the number of subscriber points serviced by the DPU.

The source resistance Z_i for the low-frequency filter is defined as follows. A segment of the line, the secondary winding of the transformer of the transformer substation-input DPU can be considered as a line loaded under small resistances. Then $Z_i = \frac{Z_{\text{к}} + Z_{\text{л}}}{1 + Z_{\text{к}} Y_{\text{л}}}$ where Z_k is the inside impedance of the source of the low-frequency program; Z_ℓ, Y_ℓ are the parameters of the line expressed per kilometer.

Inasmuch as $Z_k \ll Z_\ell$, $Z_i = (R + i\omega\ell)\ell_i$ where ℓ_i is the length of the section of line from the transformer substation to the point of inclusion of the DPU. Thus, the source resistance is determined only by the type of line, the length, the wire material, and it does not depend on the magnitude of the load.

The resistance of the load Z_H for the low-frequency filter is the resistance of the segment of the distributing line after the DPU.

Considering the segment of the lines uniformly loaded, we have

$$Z_{\text{н}} = \frac{Z_{\text{э}}}{\operatorname{th} \gamma_{\text{э}} l_2},$$

where $Z_{\text{э}}, Y_{\text{э}}$ are the equivalent parameters of the line expressed per kilometer taking into account the load; ℓ_2 is the length of the line from the end of the line to the point of inclusion of the DPU.

Performing the corresponding transformations considering the fact that $(G_{\text{л}} + i\omega C_{\text{л}}) \ll \frac{N}{Z_{\text{г}} n^2}$, we obtain

$$\frac{\sqrt{\frac{Z_{\text{л}} Z_{\text{г}} n^2}{N}}}{\operatorname{th}\left(\sqrt{\frac{Z_{\text{л}} N}{Z_{\text{г}} n^2}}\, l_2\right)},$$

where $Z_Г$ is the internal resistance of the speaker; n is the transformation coefficient of the subscriber transformer; N is the number of subscriber sets in the segment ℓ_2.

The results of calculating Z_1 and Z_H for the various normalized lines on three frequencies are presented in Table 4.1, 4.2 and correspondingly for the BM-3 and ST-3 type wires. The point of inclusion of the DPU was determined by the point B3. From the tables large variations of the resistances are obvious.

Table 4.1

f, кГц (1)	(2) S=10 тр/км				(3) S=20 тр/км			
	Z_l	φ	$Z_н$	φ	Z_l	φ	$Z_н$	φ
0,1	13,4	6	218	6	26,8	6	206	27
1	20	44	298	15	40	44	270	20
10	139	83	920	11	278	83	865	31

Key:
1. f, kilohertz
2. S=10 tr/km
3. S=20 tr/km

Table 4.2

f, кГц (1)	(2) S=10 тр/км				(3) S=20 тр/км			
	Z_l	φ	$Z_н$	φ	Z_l	φ	$Z_н$	φ
0,1	40	12	510	31	64	12	520	30
1	92	44	672	15	147	44	680	16
10	390	62	1770	39	624	62	2570	26

Key:
1. f, kilohertz
2. S=10 tr/km
3. S=20 tr/km

For this reason with invariant remaining part of the circuit two types of low-frequency filters are selected.

The rated output voltage of each channel is 20 volts on a load of 400 ohms.

The basic quality characteristics of the DPU are selected so as not to have a negative influence on the quality indexes of the TPB system.

With an amplified frequency band of 12 kilohertz, nonuniformity of the frequency characteristic is no more than 2 decibels.

The coefficients of the nonlinear distortions in the modulated frequency band of 100-6000 hertz is no more than 1.5%. The crosstalk interference from the low-frequency channel to the high-frequency channel and also the background level on frequencies of 50 and 100 hertz are no more than -60 decibels. The frequency distortions of the low-frequency channel are no more than 4.5 decibels. The gain of the DPU is 10. The input impedance is 600 ohms±20% and essentially does not interfere with the matched operating conditions of the lines when installing the DPU.

The quality indexes are not negatively affected during fluctuations of the electrical network within the limits of -20% to +10% of the rated value, on variation of the ambient temperature from 0 to +45°C and with an increase in the signal level by 3 decibels.

The schematic diagram of the DPU is presented in Fig 4.11. The device is made up of two autonomous repeaters, the circuits of which are identical with respect to structure, and they are distinguished only by the elements of the filters tuned to the corresponding frequency bands, depending on the carrier frequencies of 78 and 120 kilohertz.

It is sufficient to investigate the schematic for one channel repeater. At the input of the channel repeater an input band filter is installed made up of a T element of the type K band filter used to obtain the given low-frequency attenuation and the five-element semielement of the type M filter giving the required attenuation with respect to the adjacent high-frequency channel. The filter load is the input impedance of the channel repeater.

In view of the fact that the signal levels of programs II and III can be distinguished along the line, provision is made for an input level attenuator to equalize the output levels of the DPU.

The attenuators are assembled in accordance with the T-circuitry and they are included in the gap of the input filter as shown in the schematic diagram. They change the level of stepwise and have five positions (1, 2, 6, 9 and 12 decibels).

The channel repeater is a two-stage repeater assembled in accordance with the two-cycle schematic from like P605 transistors (T_1-T_6) installed on the radiators.

The repeater is assembled in accordance with the circuitry with common base and has high stability of the power gain and less dependence on the incoming lot of transistors.

The powerful output stage operates in the class B mode, and the preamplifier, in order to decrease the nonlinear distortions, in the class A mode. In order to stabilize the operating additions the thermoresistors R_{46} are installed in the bias circuits in the first stage and the R_{54} in the second stage. Simultaneously, in order to improve the linearity of the input characteristics of the stages and in order to decrease the influence of the variation of the circuit parameters when replacing the transistors, the auxiliary resistors R_{45}, R_{48}, R_{49}, R_{51}, R_{56}, and R_{57} are included in series in the emitter circuits.

Additional low-frequency attenuation is created by the high-frequency output filter in which the high-frequency programs signals amplified by the channel repeaters are added.

The low-frequency filter is included in parallel to the channel repeater and is a complex filter made up of two T-elements of the type M low-frequency filter and executed by the symmetric layout. The plug filters of the low-frequency filter make it possible to obtain high-attenuation on the amplified frequencies and attenuate the feedback. The parameters of the filter are selected so that the distortions of the frequency characteristics of the channel repeaters do not exceed 0.1 to 0.2 decibels.

In order to feed each channel repeater, a separate rectifier is used with voltage stabilizer, which decreases the probability of simultaneous disappearance of two high-frequency programs.

The voltage stabilizer is a two-stage emitter repeater built from the transistors T_{13} and T_{15}. The DC voltage is picked up from the two stabilizers D5 and D_6. The rectifier is executed from the silicon diodes D_1 and D_2. The L-type filter made up of the choke Dp and the capacitors C_{40} and C_{41}, is installed at the output of the rectifier to smooth the pulsations. A common power transformer is used to feed the two rectifiers. The fuses Пр_5, Пр_6, and Пр_7 protect the rectifiers and the channel repeaters from possible overloads.

In the DPU, the simplest lightning protection circuit is used -- the lightning arrestors P_1-P_4 and the spark arrestors ИР_1- ИР_4 are installed at the input and the output.

When installing the DPU, the level diagram at the distributing feeder line has the form depicted in Fig 4.12 and permits estimation of the effect of the DPU and determination of the possible length of the line insured sufficient voltage over the high-frequency channels.

Using the graphs depicted in Fig 4.9, it is also possible to determine the maximum line length, the point of connection and the level reserve for lines encountered in practice, reducing them to one of the hypothetical versions.

In the presence of a level reserve, the point of connection of the DPU is found from the arguments of convenience of maintenance in the presence of an appropriate facility.

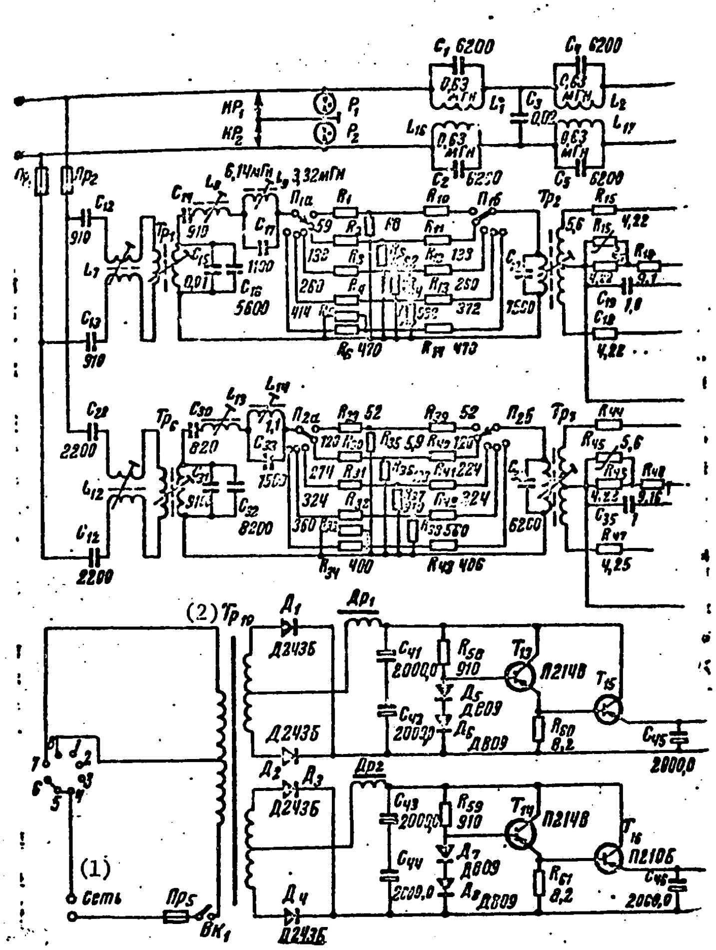
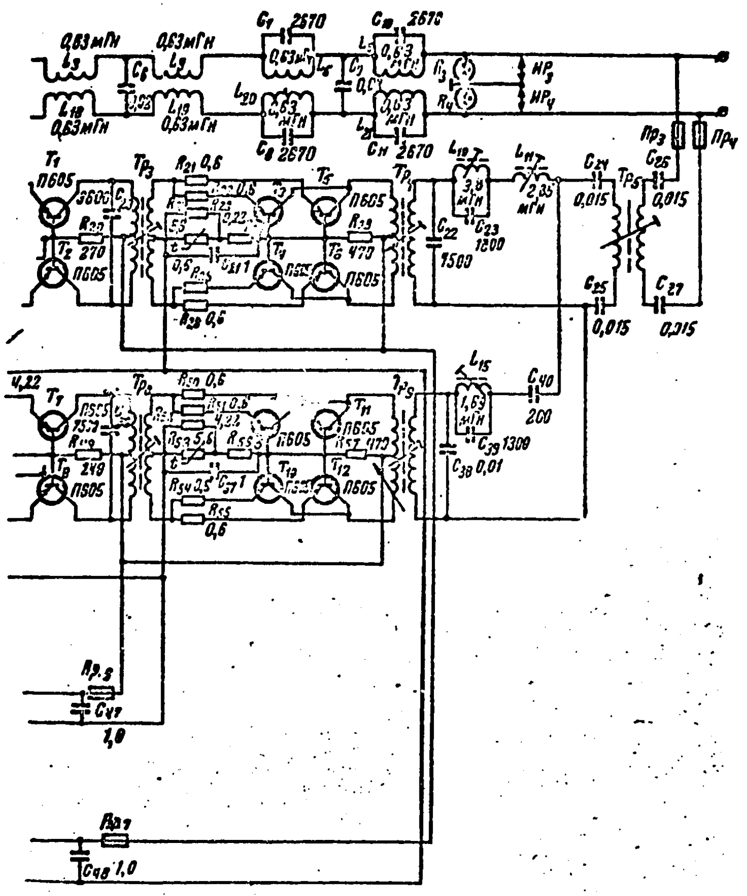


Figure 4.11. Schematic diagram of a two-channel

Key:
1. network
2. transformer



intermediate repeater [DPU]

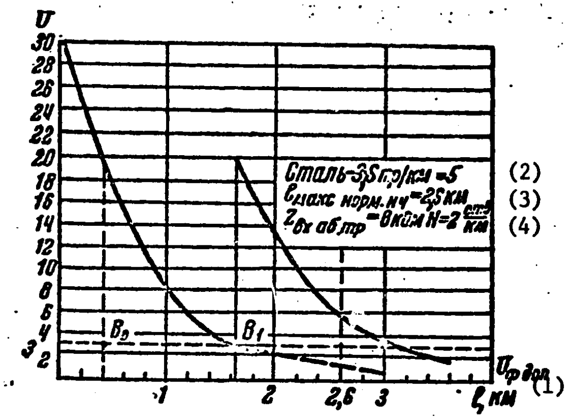


Figure 4.12. Voltage diagram of the distributing line when using the DPU

Key:

1. U_f auxiliary
2. Steel-3; S, tr/km=5
3. $\ell_{\text{max norm low-frequency}}$=2.6 km
4. $Z_{\text{inp ab tr}}$=8 kilohms, N=2 couplers/km

4.7. Prospects for Improving Transmitters and Repeaters

The prospects for improving the transmitters and repeaters of the high-frequency channels of the TPB [triple-program wire broadcast] system consist in improving the quality and the operating indexes of these devices.

The quality indexes of the transmitters and the repeaters can be improved to the norms required to insure quality class I of All-Union State Standard 11515-65 of the entire through high-frequency channel.

For this purpose at the present time a transistor-tube transmitter has been developed with an output power of 400 watts. In order to decrease the noticeability of the nonlinear crosstalk from the low-frequency program in the new transmitters it is proposed that the static and time characteristics of the carrier frequency level control be varied with respect to the existing control and that additional suppression of the carrier frequency in the broadcast transmission interval be used.

The improvement of the quality and operating indexes of the transmitters and the repeaters is connected with rebuilding the station part of the high-frequency channels. When installing the low-power AM signal shapers at the reference repeater stations and the modulator oscillation repeaters at the transformer substations (Fig 2.13), the problem of complete transistorization of the given devices is solved. Here the reliability of the head unit for shaping the AM signal at the reference repeater stations is improved significantly (the output power is decreased from 200 and 400 watts to 1-2 watts), the problems of satisfying the safety engineering requirements for the transmitters remain only for the electrical network voltages, for all of the anode voltages of +2600 volts, +550 volts and +260 volts are excluded, and the feed voltages do not exceed 70 volts. This improvement of the quality and operating indexes pertains to constructing the station part of the channel with the installation of the transmitters at the central station and the repeaters of the transformer substations (Fig 2.14).

CHAPTER 5. RECEIVERS

5.1. General Information

Inasmuch as the transmission of additional programs is realized on high-frequency and low level, a device must be installed at the end of the line (at the subscriber) which converts and amplifies the signal. In the triple-program wire broadcast system two versions of the receivers are used: individual, three-program loudspeakers (GT), and group, GPTV. In the first version the high-frequency signals are fed to the subscriber rosette. In the second version, over the feeder line to the group device which realizes separation, detection and amplification of them; from the output of the GPTV, the signals of each of the three programs are fed to the subscriber speakers over independent pairs with a level of 30 volts. The receivers are the element which determines successful introduction of system and must find demand among the population, that is, they must be cheap, they must have high reliability and good, varied external appearance. The application of the transistors insures increased reliability and simplicity of structural design with low electric power intake.

The technical specifications for the receivers are selected beginning with the given parameters of the TPB [three-program wire broadcast] system. The sensitivity of the GT is selected equal to 250 millivolts. It is obtained as a result of a compromise between the requirements of maximum simplification of the GT and also exclusion of the effect of industrial interference and interference from radio stations, on the one hand, and an effort to increase the range of the system and absence of interference with wireless reception, on the other hand.

An important index of the receivers is the input impedance (R_{inp}); inasmuch as the GT [triple-program speakers] can be connected to the circuit in large numbers, they constitute a significant load for the network RT [distribution points], and therefore their R_{inp} must be high (on the order of several kilohms). The power on a sound coil of the GT is selected equal to 150 milliwatts, which corresponds approximately to the power with respect to the high-frequency channel.

The first version of the GPTV-1 group receiver had a sensitivity of 300 millivolts. When putting it into operation at the end of the long feeder line the sensitivity did not insure stable reception of the high-frequency programs. Therefore it is necessary to connect the GPTV to the subscriber transformer through a bypass. In the GPTV-3 the sensitivity is increased to 100 millivolts. The output power of each high-frequency channel of the GPTV is selected equal to 25 watts by analogy with the power of the GT so as to retain the developed configuration of the distribution network. The excess power obtained as a result of low probability of connection of all subscribers for one auxiliary program or all speakers at full volume is useful as the reserve for the case of use of 2 to 3 points operating in the apartment by the subscribers. The GPTV input is connected in parallel to the subscriber network, the resistance of which at high frequency can vary from 50 to 200 ohms. In order that this not influence the characteristics of the GPTV filters and, conseqùency, the frequency characteristic, R_{inp} is selected equal to 400 ohms. The technical specifications of the receivers are presented in Table 5.1.

As is obvious from Table 5.1, the GPTV type receivers have higher quality indexes (the problem of maximum reduction of cost was not stated during their development). The subscriber network of the three-pair wire of the GPTV is more reliable than the single-pair wire network with high-frequency signals where poor contacts at the branch points and connections are sources of cross-talk. The number of transistors and radio parts used to build one GPTV is 15 to 20 times less than required to build the equivalent number of GT.

During the first years of development of the system there was orientation toward the development of attachments for the single-program speakers (Gr). This solution arose from an effort to use the large number of Gr [single-program speakers] available to the subscribers. This RT-61 type attachment was produced at the Riga VEF plant. Since the subscribers basically had quality class III Gr, it turned out to be impossible to realize the class II quality built into the attachment. The necessity arose for combining the receiving-repeating part with class II Gr and making them in a single case. Thus the Venta GT appeared with higher sound quality which has found high demand among the buyers. Later the improved GT were developed: "Riga," "Avrora," and "Mayak." In connection with the improvement of the processing of the networks for receiving TPB programs in recent years, in many cities of the country it has become necessary to provide a large assortment of receivers. The problem has again come up of developing attachment for the Gr. The circuitry for such an adapter has been developed and is in the experimental operational stage. The "Avrora" GT with somewhat simplified high and low-frequency amplifiers was taken as the basis for the system. Passive attachments are in the developmental stage which will permit the owners of the receivers, tape recorders and television sets to receive three programs without interference. They do not consume power and are simple to service.

The development of the receiving network will proceed in the direction of creating new types of individual devices for various quality classes, at different prices and with different external appearances.

Table 5.1

Name of parameter	Standardized values	
	GT	GPTV
Sensitivity, millivolts	250	100
Output power, watts	0.15	25
Frequency band, hertz	100-6300	100-6300
Harmonic coefficient, T:		
from 100 to 200 hertz	7	6
above 200 hertz	4	3.6
Modulus of input impedance over the high-frequency channels, ohms	2500	400
Background and noise level, decibels	-40	-55
Crosstalk attenuation between the high-frequency channels, decibels	-53	-60
Average sound pressure, newtons/m^2	0.25	-
Noise protection of the high-frequency channels:		
from the low-frequency program, decibels		
at a frequency of 1000 hertz	-53	-60
at a frequency of 6000 hertz	-40	-
at a frequency of 10000 hertz	-	-50
Admissible overload of high-frequency channels with respect to input level, decibels	10	10
Automatic gain control range with respect to input, decibels	-	14
Response time of the automatic gain control, milliseconds		20
Increase in output level on disconnecting the load, decibels	-	2.5
Limits of variation of the feed network voltage, volts	-	176-242

The group devices were developed in three versions: GPTV-1 [19] developed in 1962 had an output power of 25 watts; structurally it was made up of six modules: a replaceable filter module (or the filters and the automatic gain control system), the low-frequency amplifier module and feed module for one channel and the same three modules for the other channel. This structural design is complex and expensive. The GPTV-1 was produced in two versions: with automatic gain control and without it. Practice has shown that it is necessary to build the receiver only with automatic gain control inasmuch as its cost increases significantly, and the operating reliability and range of the TPB system are increased. The GPTV-2 had an output power of 7 watts, but simplification of the circuitry and the reduction in its cost turned out to be very small by comparison with the decrease in power; therefore the decision was made not to build it. The GPTV-3 which is built at the present time is made with a modified circuit and structural design. The AGS circuitry, filters and low-frequency amplifier have been simplified, the operating reliability has been improved as a result of using transistors with long service life (P214 instead of P210 in the GPTV-1) and as a result of a reduction in the number of parts; the structural design has been simplified: instead of six modules there are three. The operating characteristics have been improved:

1. The sensitivity has been increased by four times, and the operation of the automatic gain control, improved (it operates in practice without nonlinear distortions while insuring low voltage on the regulating diodes).

2. The input impedance has been doubled. This makes it possible to install the receiver on longer lines, and in combination with increased sensitivity, it can be installed where the GT cannot operate.

3. The increase in gain of the receiver in an interval of 2 minutes increased from 1.5 to 2 decibels. The high discharge time constant leads to a reduction in the average transmission level with respect to the rated level. In the given case the average level is closer to rated level. The range of the automatic gain control has been increased, which is more important for operation of the receiver. At the same time the dynamic range is not distorted, for the distortions come only during a total gain recovery time of the receiver of less than 1 minute.

4. The rectifier with stabilizer has been made common to both high-frequency channels. One stabilizer is cheaper and more economical. It has a higher stabilization coefficient. The reliability increases, for the thermal conditions of the transistors are equalized as a result of more uniform loading. The total number of subscriber points serviced by one receiver is

$$H = \frac{25 \text{ watts}}{0.25 \text{ watts } 0.7} = 140,$$

where 0.7 is the coefficient of simultaneous inclusion of all points of the given subscriber network. When using headsets (for example, in the hospital) the number of subscribers connected to the GPTV can be increased to 400-500.

5.2. Riga Type GT

The Riga GT (Fig 5.1) has two band filters tuned to channels II and III respectively, a detector, low-frequency amplifier with speaker at the output, a three-position program switch and power pack.

In position 1 of the switch Π_a the low-frequency program coming to the input terminals of the GT is connected through the loudspeaker regulator R_{15} to the transformer Tp_1, the secondary winding of which has a loudspeaker connected to it. In this case the AC network is disconnected. In position 2 of the switch Π_a of the RT, the network is connected to the input of the band filter tuned to a frequency of 78 kilohertz; simultaneously the filter output is connected to the input of the detector; the output of the low-frequency amplifier is connected to the primary winding of the transformer Tp_1, and the power pack, to the AC network. In position 3 of the RT, the network is connected to the input of the band filter tuned to a frequency of 120 kilohertz, and its output is connected to a detector, the output of the low-frequency amplifier is connected to the winding 1-4 of the Tp_1 transformer, and the power pack is connected to the AC network.

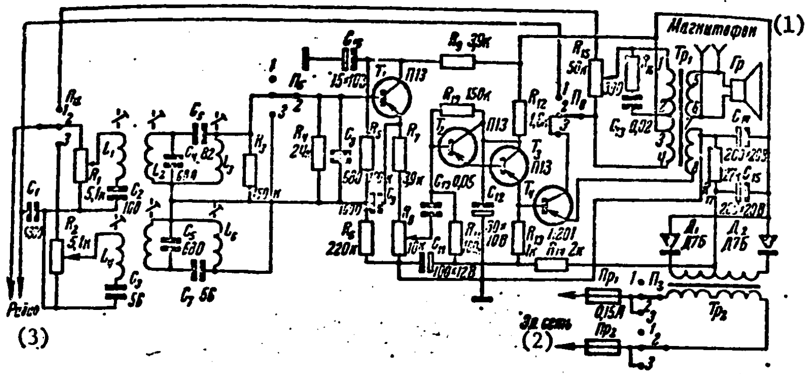


Figure 5.1. Electric circuit diagram of the Riga type GT

Key:

1. Tape recorder
2. Electric network
3. Radio

The capacitor C_1 blocks the path of the low-frequency program currents to the preset regulators R_1, R_2, which served to equalize the initial levels of the high-frequency programs and prevent overloading of the detector. Their shafts run to the face panel. Each band filter is made up of three loops; for example, the filter of channel II is made up of the series L_1C_2 circuit inductively connected to the parallel L_2C_4 circuit, and a third L_3C_8 circuit connected by the capacitor C_6 to the second circuit. The capacitor C_8 is common to both channels. The shunting resistor R_5 does not permit disconnection of the base circuit of the transistor T_1 at the switching time and prevents it from breakdown. From the filter output the modulated signal goes to the input of the emitter triode detector — the base-emitter junction of the transistor T_1. The detector has the least linear distortions when installing a transistor with a value of $\beta \geqslant 20$. This stage has high thermal stability, for the resistance to the direct current in the emitter circuit is high. The resistors R_5, R_6 feed the initial bias to the base of T_1. The voltage on its collector is reduced using the R_9R_5 divider. The low-frequency signal detected and amplified by the same transistor from the load divided into two parts (R_7, R_8) goes through the separating capacitor C_{10} to the input of the three-stage low-frequency amplifier operating in the class A mode. The resistor R_8 is simultaneously the volume control, which is mechanically connected to the volume control R_{15} for the first channel. This coupling eliminates the danger of short-circuiting of the output, which can occur on movement of the regulator to its extreme position. In order to simplify the commutation R_{15} is not disconnected from the primary winding T_1 on reception of the high-frequency channels. In this case it uses about 7% of the total output power in the maximum volume position.

The capacitor C_9 filters the remains of the carrier frequency and also increases the depth of the negative feedback for the higher sound frequency harmonics. The feedback depth depends on the position of the regulator R_8, which also increases the regulation limits. The first two stages of the low-frequency amplifier are the emitter repeater based on the transistors T_2, T_3. When using the transistor with $\beta>100$ it is sufficient to have one stage. The second stage of the low-frequency amplifier is made in accordance with the transformer circuit with common emitter based on the transistor T_4. The low-frequency amplifier mode is provided by the resistors R_{10}, R_{11}, R_{12} and R_{14}. The stability of the load with respect to direct current is insured as a result of connecting the resistor R_{17} to the emitter of the last stage. The feedback with respect to AC voltage is fed to the input to the first stage of the low-frequency amplifier. The feedback diminishes the nonlinear distortions. The $R_{16}C_{13}$ circuit corrects the frequency characteristic for high frequency and prevents receiver generation.

The electric power supply for the GT comes from the AC network. The rectifier is assembled in accordance with the double halfperiod circuit based on the diodes D_1, D_2 with a capacitive load of C_{15}. The null potential point with respect to alternating current does not coincide with the positive end of the rectifier. This made it possible to do away with two capacitors with a capacitance of 200 microfarads each (C_{14}, C_{15}) and to decrease the cost of the circuit. The filtration of the rectified voltage pulsations is accomplished by the $R_{17}C_{14}$ filter. The intake power in the network is 3.6 watts. In order to connect the receiver to the relay network with a voltage of 15 volts it is necessary to resolder to Tp_1 (the wire running from the sliding contact of the resistor R_{15} is unsoldered from the lead 1 and soldered to the lead 2).

The Riga GT [triple-program speaker] is made in a wooden case. On the front there are controls for the preset regulators, the volume control and the channel switch. On the back panel there are jacks for connecting a tape recorder and two cords for connecting the receiver to the radio network and the AC network.

5.3. Avrora Triple-Program Speakers [GT]

The Avrora GT [triple-program speaker] (Fig 5.2 and 5.3) is made in two versions: for operation on the subscriber networks with voltages of 30 volts and for Moscow, 15 volts. The basic parameters are the same as for the Riga GT [triple-program speaker], but as a result of introduction of the high-frequency amplifier stage into the circuit, its sensitivity is increased. The preset regulators are included here after the filter, which decreases the variation of the input impedance of the GT for various positions of the regulators. The program switch B_1 has an additional "off" position. When a low frequency program is received the switch must be set to position 1. The low-frequency voltage is fed to the primary winding of the output transformer TP_1 through the fuses Пр_1 and Пр_2 (which are included to keep the AC network voltage out of the RT network and exclude ruining the GT if the radio plug is erroneously plugged into the electric network) and the contracts 5, 6, 9, 10 of the switch B_{1b}.

On reception of programs II and III the GT is connected to the radio network by means of the switch B_{1b} and to the feed network B_{1a}. The band filter of the second channel consists of the connected circuits L, $C_2L_2C_4$; for the third channel, $L_3C_3L_4C_5$. The high-frequency amplifier is assembled from the transistor T_1; its collector circuit includes loops with tuning to the high-frequency channels which increase the selectivity of the receiver. The diode detector is assembled from the D9V diode. The detected high frequency signal goes through the volume control R_{10a} and the dividing capacitor C_{10} to the input of the low-frequency amplifier, the first stage of which is assembled from the transistors T_2 and T_3 included as a compositional transistor. The connection to the terminal stage is direct. The low-frequency amplifier is encompassed by negative feedback, the voltage of which is picked up from a sep-rate winding 6-7 of the output transformer.

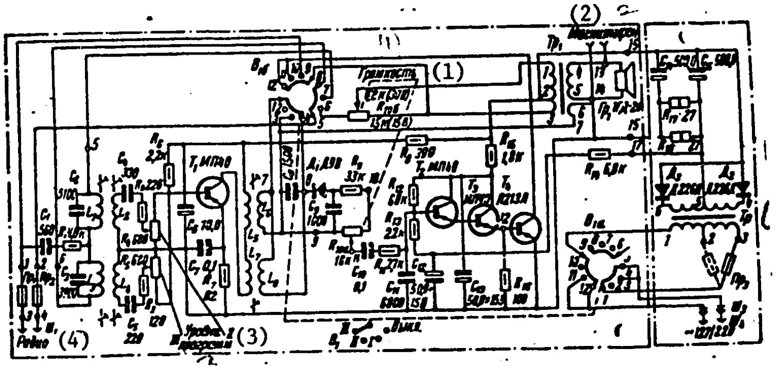


Figure 5.2. Circuit diagram of the "Avrora" type GT.

Key: (1) volume
(2) tape recorder
(3) Program II level
(4) radio

The depth of this coupling depends on the position of the volume control, which also increases the limits of its adjustment. The operating conditions of the low-frequency amplifier are stabilized by the resistors R_{17}, R_{18} and the DC feedback through the filter $R_{14}C_{12}R_{13}$. The power pack is made up of a power transformer, two-halfperiod rectifier and П-filter.

[Photo not reproduced.]

Figure 5.3. External appearance of the Avrora GT [triple-program speaker]

The Avrora receiver [35] is made in a wooden case weighing 2.9 kg. The GT circuitry is mounted on a printed board fastened parallel to the face plate in a case finished off with a plastic grating. This panel has the volume control and channel switch knobs. The knobs for the preset controls are located on the back of the case (they are rarely used). On the back there are also plugs for connecting the tape recorder, the network switch for 127 or 220 volts with fuse and the leads of the cords for the radio network and the AC network.

The "Mayak" GT (Fig 5.4) differs from the Avrora GT by changes in the input circuits and the structural design.

[Photo not reproduced.]

Figure 5.4. Outside view of the Mayak GT [triple-program speaker]

5.4. GT with Low-frequency Channel Gain (Fig 5.5)

It is known that the crosstalk from the low frequency to the high-frequency channels occurring in steel wire is reduced with a decrease in the low-frequency current. The magnitude of the current depends on the load on the line: the greater the load resistance, the less the current and the less the crosstalk. Consequently, in order to decrease the interference it is necessary to increase the input impedance of the GT connected to the subscriber points, that is, to decrease the power fed to their input. Since the volume of the GT on the low-frequency channel must not be less than the volume of an ordinary speaker, the decrease in power at the input must be compensated for by amplifying the low-frequency signal, for which it is impossible to use the amplifier available in the GT circuit which is used to amplify the signals of programs II and III. The receiver with amplification with respect to the low-frequency channel has certain advantages in addition to the decrease in crosstalk: the possibility of raising the low-frequency characteristic appears; with simultaneous use of several plugs installed in the apartment on the low-frequency channel, the power intake from the PV network in practice does not increase by comparison with the power intake by one ordinary speaker; the output power of the GT can be increased to 0.5-1 watt without increasing the network load; in the future it will be possible to increase the number of subscribers connected to the network without increasing the power of the station repeaters. The

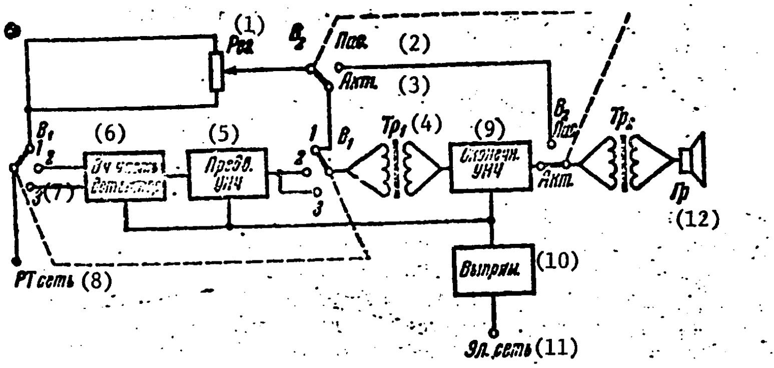


Figure 5.5. Structural diagram of the GT with low-frequency channel gain

Key:
1. Control
2. Passive
3. Active
4. Transformer
5. Low-frequency preamplifier
6. High-frequency part
7. Detector
8. RT network
9. Terminal low-frequency amplifier
10. Rectifier
11. Electrical network
12. Gr [speaker]

possibility of improving the volume of the low-frequency channel both for higher quality operation of the remote subscriber points and for introduction of stereophonic broadcasting requiring equal volume of both used channels, is important. The signals from programs II and III go through the GT exactly as in the ordinary GT without low-frequency amplification. The 78 and 120 kilohertz filters are installed at the receiver input. From the output of the high-frequency filters the signal goes to the detector; the detected signal goes to the low-frequency preamplifier. The input of the terminal low-frequency amplifier is connected to the output of the low-frequency preamplifier through the switch B_1, which makes it possible to connect the input of the terminal low-frequency amplifier to the PV*network when listening to the first program. The terminal amplifier is loaded on the speaker which can be connected directly to the network (without amplification) and it is possible to hear the first program in the case of absence of voltage in the feed electric network. As is obvious from Table 5.5, the GT with amplification with respect to the low-frequency channel contains two additional switches which provide for its operation with respect to the first program with or without amplification of it. In addition, the low-frequency amplifier of this receiver can be connected to the PV*network only through the transformer. The connection of the subscriber network to the input of the low-frequency amplifier cannot be made without a transformer as a result of the high background level occurring in the output of the GT.

These structural complications increase costs somewhat, and the introduction of an additional transformer into the circuit increases the copper consumption for the wire broadcast needs. The problem of introducing this type of GT has still not been solved.

5.5. GPTV-3 Group Device

The GPTV is made up of two independent receivers distinguished from each other by the filters and circuits in the high-frequency amplifier tuned to 78 and 120 kilohertz respectively and the common power pack. From the diagram of the GPTV [18] presented in Fig 5.6 it is obvious that the receiver of one channel is made up of the band filter, high-frequency amplifier, detector, low-frequency amplifier and automatic gain control system. The schematic diagram of the GPTV is presented in Fig 5.7. At the input the GPTV has a type K filter, one element of which can provide for attenuation with respect to the other high-frequency channel to 46 decibels. In this type of filter the series and parallel branches are return two-terminal networks, that is, $Z_1Z_2=R_2$. This condition is satisfied when their resonance frequencies are equal to $\omega_1=\omega_2=\omega=78$ kilohertz or $L_1C_1=L_2C_2$. In this case the selectivity of the filter is improved. In the GPTV the filter is made up of one element. Resistors are connected at its input in order to decrease the effect of the feeder line resistance on the frequency characteristic of the filter. The transformer L_2 suppresses the cophasal interference operating with respect to the "two wires-ground" circuit. The filter has an input impedance of

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*wire broadcasting

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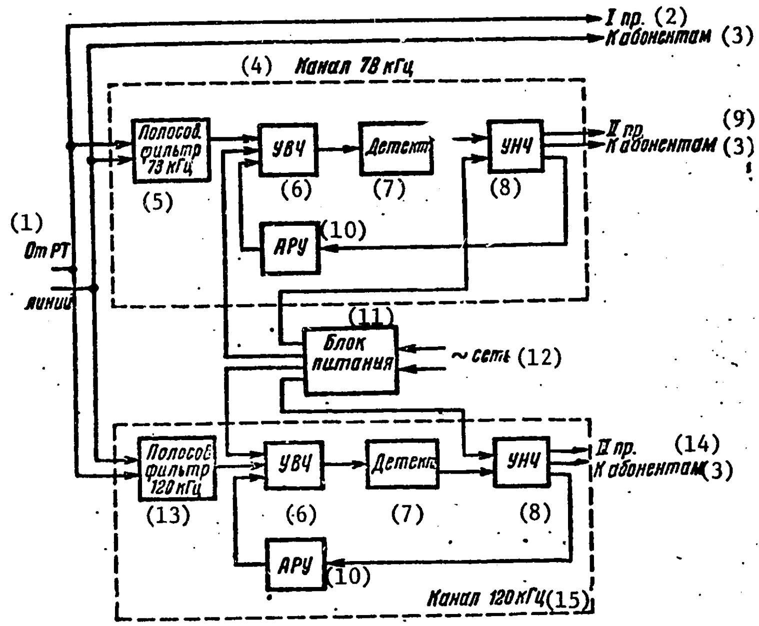


Figure 5.6. Structural diagram of the GPTV-3 receiver

Key:

1. From the RT lines
2. Program I
3. To the subscribers
4. Channel 78 kilohertz
5. Band filter 78 kilohertz
6. High-frequency amplifier
7. Detector
8. Low-frequency amplifier
9. Program II
10. Automatic gain control
11. Power pack
12. Network
13. Band filter 120 kilohertz
14. Program III
15. Channel 120 kilohertz

400 ohms (the average impedance of the subscriber transformer on high frequency).

The high-frequency amplifier with load in the form of a single two-stage circuit is based on the MP40 type transistors. It is used to amplify low voltage of 5-10 millivolts on the regulating diodes of the automatic gain control to a voltage sufficient for undistorted operation of the detector and also to insure additional selectivity with respect to the adjacent channel. The operating conditions of the high-frequency amplifier are stabilized by including the resistor R_9 in the emitter circuit of the transistor T_2. The input and output circuits are tuned to the carrier frequencies by the capacitors C_5 and C_{10}.

The signal detector is two-cycle based on D9G type diodes. The current running through the load has a frequency of 156 kilohertz, that is, the current with a basic frequency of 78 kilohertz is absent in the load, which facilitates filtration of the high-frequency component of the signal. The condition of absence of nonlinear distortions in the detector is equality of the load resistances of the detector for direct and alternating currents, that is, observation of the condition $R_{AC}/R_{DC} \geqslant 0.8$. For this purpose the load resistance of the detector is split into two parts: R_{11} and R_{12}. Then

$$\frac{R_{\text{пер}}^{(1)}}{R_{\text{пост}}\ (2)} = \frac{R_{11} + \dfrac{R_{\text{вх}} R_{12}}{R_{\text{вх}} + R_{12}}}{R_{11} + R_{12}} = \frac{11 + \dfrac{15 \cdot 5{,}1}{15 + 5{,}1}}{11 + 5{,}1} 10^3 \approx 0{,}9,$$

Key: 1. R_{AC}/R_{DC}

where R_{inp} is the input impedance for the alternating current of the low-frequency amplifier. The capacitance shunting the load of the detector is selected equal to 620 picofarads, which corresponds to a maximum transmission coefficient of the detector and facilitates an increase in selectivity of the receiver with respect to the other channel as a result of using the properties of inertialessness. The suppression of the interference at the detector output is proportional to twice the amplitude ratio of the signal and interference carriers at the input of the detector:

$$\left(\frac{U_{\text{сигн}}^{(1)}}{U_{\text{пом}\,(2)}}\right)_{\text{вых}\,(3)} = 2\left(\frac{U_{\text{сигн}}^{(1)}}{U_{\text{пом}\,(2)}}\right)^2_{\text{вх}\,(4)}.$$

Key: 1. signal; 2. interference; 3. output; 4. input

Let us assume that signals of identical level arrive at the inputs of the two channels. The interference of one of them, for example, II, is measured in the interval of the useful signal when the carrier amplitude is diminished by 20 decibels, that is, at the input of the channel the interference exceeds the signal by 20 decibels. In the filter this interference is attenuated by 40 decibels and becomes lower than the signal level by 20 decibels; in the high-frequency amplifier the interference is attenuated by another 15 decibels. The detector gives suppression by 35+6=41 decibels, that is, at the output of channel II the interference from channel III will be attenuated by 35+41=76 decibels. If the interference comes to the channel input, for example, 3 times the signal level (by 10 decibels), then it will be attenuated by 56 decibels in the receiver. The filter and the circuits of the high-frequency amplifier also provide for suppression of the crosstalk from the low-frequency channel to the high-frequency channel by 60 decibels.

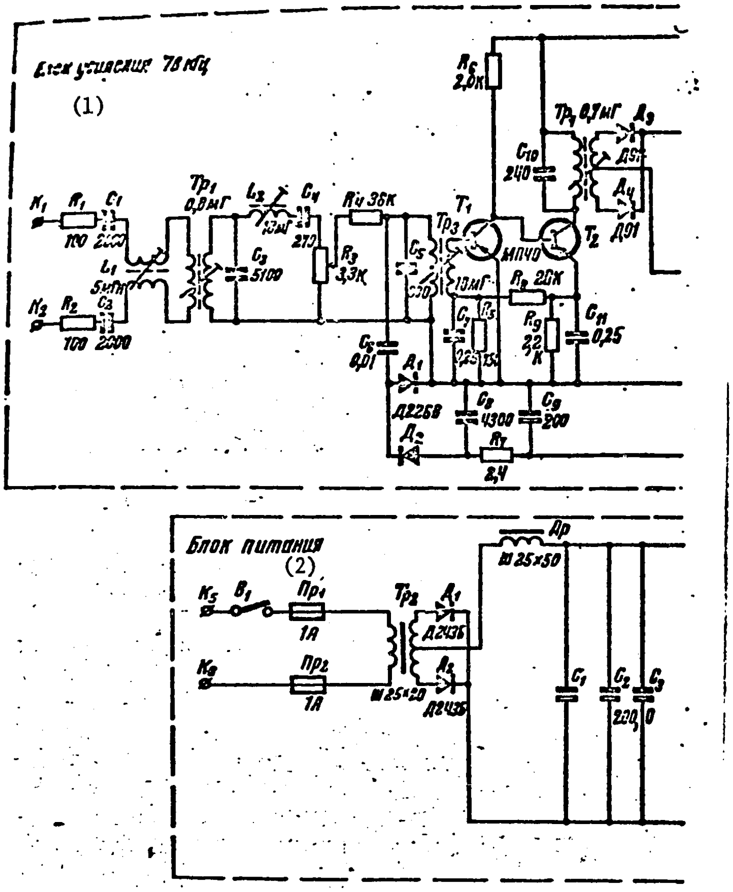
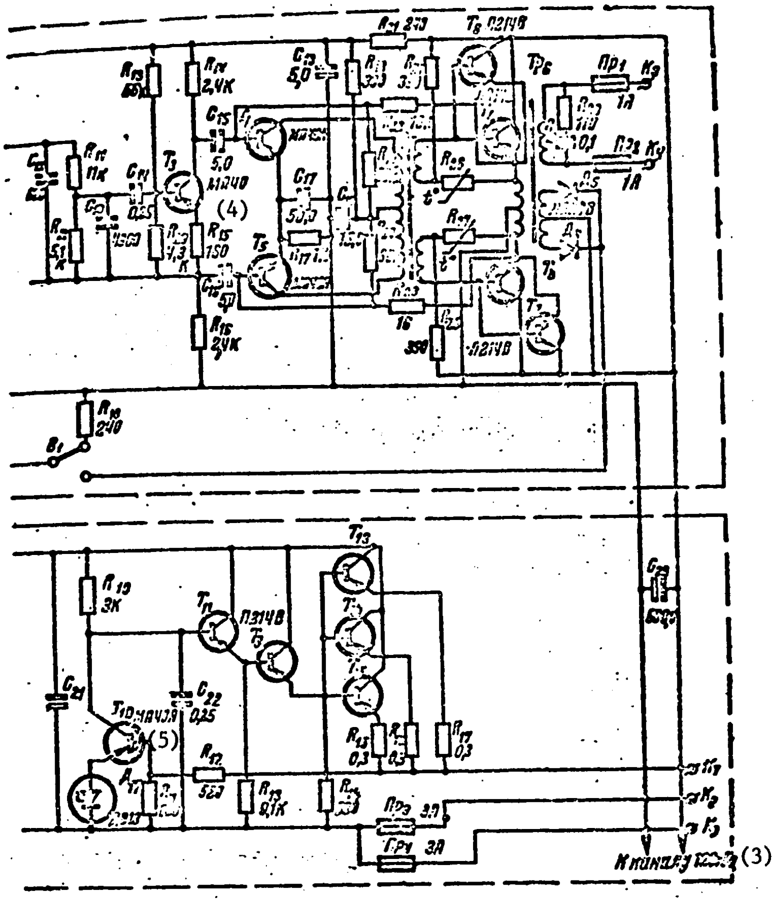


Figure 5.7. Circuit diagram of the GPTV-3

Key:
1. Amplification module 78 kilohertz
2. Power pack

The first stage of the low-frequency amplifier based on the MP40 type transistor operates by the system with separated load and is used for transition to the two-cycle stage. The load resistance is in the collector circuit and is divided into two parts: R_{14} and R_{16}. The high internal impedance offers the possibility of encompassing subsequent stages with feedback. Since the input impedance of the next to the last stage is low as a result of the negative feedback, the first stage does not give voltage amplification. The stabilization of the operating conditions of the transistor T_3 is realized by the resistors R_{15}, R_{16}. The coupling to the



3. To the channel 120 kilohertz
4. MP40
5. MP40A

next to the last stage is rheostat-capacitive. This two-cycle transformer stage executed from the MP40A transistors gives voltage amplification from 100 millivolts to 10 volts. The terminal stage is made from P214V type transistors in accordance with the circuitry with grounded emitter. It operates in the class B mode. In order to eliminate the nonlinear distortions of the central cutoff type, especially noticeable in the case of low signals and low air temperature, the initial bias is fed to the bases of the transistors T_6-T_9 through the resistors R_{24}, R_{25} and the thermal resistances which also stabilize the operating conditions of the stage on variation of the ambient temperature. Each pair of parallel-connected transistors is located on the radiator, which insures normal operating conditions of the receiver even under the conditions of short circuit load and high air temperature (+40°C). In addition, provision is made for two-stage protection of the transistors from short circuiting using fuses. The output and the next to the last stages are encompassed by parallel feedback as a result of which the low-frequency amplifier has low internal impedance and operates well on variable load. On disconnection of the load the output voltage increases from 30 to 32 volts. The RC circuit which eliminates possible generation when working with the disconnected or capacitive load is connected to the secondary winding of the output transformer. Inasmuch as the GPTV operates without constant servicing and operative level control at its output is impossible, an automatic gain control is introduced into the circuit which is designed for fluctuations of the high-frequency signal level within the limits to 14 decibels. Introduction of the automatic gain control offers the possibility of installing the GPTV at the end of the long lines and insurance of stable operation with a large number of subscribers. The fluctuations of the attenuation in the lines occur slowly, over a period of several hours, for they are basically determined by the meteorological conditions. The rapid jumps in level are possible in the case of damage to the line, and fast response of the automatic gain control is required with an increase in the input level, but slow recovery over a period of several minutes is admissible with a decrease in it. The response time of the automatic gain control is selected equal to 20 milliseconds (on connection of the broadcast programs the nonlinear distortions are undetectable to the ear), and the time for increasing the gain by 2 decibels (after picking up the input signal) is 2 minutes. The difficulty in building the automatic gain control consists in the fact that the known procedure using carrier frequency fluctuations is unsuitable in the case of 98M signals with variable carrier, for it leads to compression of the dynamic transmission band and to an increase in noticeability of the crosstalk in the intervals. It is also impossible to use a pilot signal for automatic gain control, for its frequency must differ from the carrier frequency by no less than 15 kilohertz so that the beats between the carrier and the pilot signal are not noticeable. However, in this case the relative difference between the frequencies of the carrier and the pilot signals is found to be large, and the attenuation in the signal for these frequencies can turn out to be different, that is, the variation in amplification as a result of the effect of the automatic gain control can fail to coincide quantitatively with the actual requirement of the variation. In the GPTV the automatic gain control is used with storage of the maximum carrier level. Since the output voltage of the low-frequency amplifier is proportional to the carrier level, a winding is wound on the output transformer to see to the operation of the automatic gain control. The selection of the regulator for the automatic gain control is conditioned by the sufficient range of control and comparatively low nonlinear distortions in the entire control range with maximum admissible level of the input signal (in order to have less amplification of the high-frequency amplifier). A regulator was selected which operates by the potentiometric system and has low high-frequency resistance so that shunting of it by the input impedance of the high-frequency amplifier will not decrease the control range. The semiconductor diodes used in the conduction region do not introduce distortions for a high-frequency signal level up to 5-10 millivolts. The D226V type diodes are used in the circuit. They are connected in series with respect to direct current and parallel with respect to low frequency. The control consists in variation of the transmission coefficient with respect to the high-frequency divider made up of the resistor R_4 and the diodes D_1, D_2 with variation of the magnitude of the direct current flow through these diodes.

The automatic gain control operates as follows: the low-frequency voltage is detected by the diodes D_5, D_6, and the direct current flowing through the diodes D_1 and D_2 changes their resistance with respect to high frequency. The resistor R_4 and the controlled resistance of the diodes form a divider with automatically variable ratio with respect to high frequency. With an increase in voltage at the input, the direct current increases, and this ratio decreases. The stabilizer voltage of 23 volts is used as the delay. The detector of the automatic gain control has large discharge time constant (several minutes), which keeps the amplification coefficient in the transmission intervals and the dynamic range invariant. This discharge time is created by a capacitor C_9 with a capacitance of 200 microfarads and the resistor R_7 with a resistance of 2.7 megohms. The sensitivity of the receiver in which the automatic gain control begins to operate is 10 millivolts. With an increase in the input level by 14 decibels, the output voltage varies from 23 to 33, that is, by 3 decibels. The automatic gain control does not introduce noticeable nonlinear distortions; the deficiency of it is an increase in noise after prolonged interruptions and a decrease in volume by 2 to 3 minutes after the pulse interference.

The electric power supply of the GPTV is autonomous --from the AC network. The feed module is common to both channels. The rectifier is double half-period. It is equipped with a filter which starts with the choke, which is better for operation on a variable load (at the filter output the DC voltage varies to a less degree than for the filter beginning with the capacitance). Inasmuch as the GPTV is fed from the household network, the voltage of which can vary significantly, and it operates without servicing, it is impossible to guarantee fail-safe operation of it without stabilization of the DC voltage. The AC voltage stabilizer does not fit here, for it has a large scattering field (which leads to a high background level of 50 hertz at the receiver output) and also in connection with the fact that the terminal stage of the low-frequency amplifier operates in the class B mode and is a variable load for the rectifier, the voltage at the output of the rectifier does not remain constant. The operation of the stabilizer is based on the fact that the magnitude of the emitter current in the transistor does not depend on the voltage variation of the collector. If we connect the load (the receivers) to the emitter circuit of the stabilizing transistor T_{13}-T_{15}, the emitter repeater circuit is obtained in which the voltage on the load is almost equal to the voltage on the base of the transistor. It is necessary to keep the voltage on the base constant. On variation of the load, the emitter and base currents vary; therefore in order to obtain a

DC voltage on the bases of the T_{13}-T_{15}, two stages based on the transistors T_{11-12} (P214V) are included. The voltage on the base of T_{11} is stabilized by the "parallel stabilizer" circuit using the transistor T_{10}. With an increase in voltage at the input of the stabilizer, the voltage increases somewhat also at its output. Here the voltage on the base of T_{10}, its collector current and voltage drop on the resistor R_{10} increase. The voltage on the base of T_{11} decreases, and the voltage at the output of the stabilizer decreases. Analogous processes take place with a decrease in feed voltage and on variation of the load. On variation of the network voltage from 176 to 242 volts and with simultaneous variation in the load current from 0 to 4 amps the voltage at the output of the stabilizer varies by no more than 4%. In order to increase the operating reliability of the stabilizer the output stage is assembled from three parallel-connected transistors of the P214V type with resistances in the emitters of 0.3 ohms each which equalize their current. In addition, the transistors are located on the radiators, which insures sufficient reserve with respect to the dissipation power. The stabilizer has low internal impedance with respect to alternating current; therefore the operation on both channels of the receiver without an increase in the crosstalk between them is possible. The power intake by the GPTV from the network in the rest mode is 33 watts and in the rated power mode in both channels, 180 watts.

Structurally the GPTV is executed in the form of a small bay in which there are three modules: the receiver module for channels II and III and the power pack. The bay is closed by a removable door to which a lock is fastened. The external appearance of the GPTV is presented in Fig 5.8. The GPTV is mounted on the stairwell wall of the upper story of the building as close as possible to the subscriber transformer, or it is installed on a table in the specially assigned facility. The receiver is connected to the TPV [triple-program wire broadcast] network by the scheme shown in Fig 5.9 (to the secondary winding of the subscriber transformer) or Fig 5.10 (to the distributing feeder through the bypass increasing the magnitude and the stability of the high-frequency program level if this level is below 50 millivolts). The outputs of all three channels are connected to the intermediate terminal block installed on the rear wall of the bay. The three-pair, intrabuilding network is made of KRVPM-3x2x0.5 or KRVPS-3x2x0.6 cable which runs from the GPTV to the subscriber switches through the KTVO splitter blocks.

[Photo not reproduced.]

Figure 5.8. External appearance of the GPTV-3

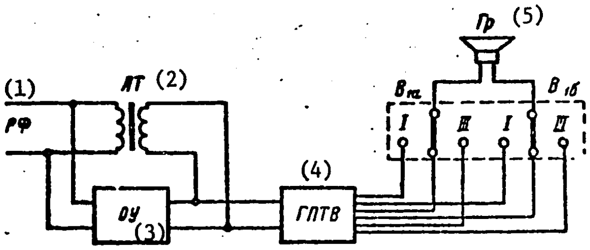


Figure 5.9. Connection at the GPTV through the OU sectional center

Key:

1. Distributing feeder
2. Subscriber transformer
3. Sectional center
4. GPTV
5. Speaker

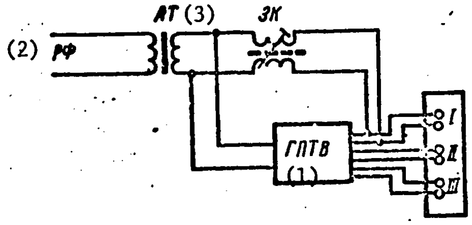


Figure 5.10. Connection of the GPTV tothe subscriber transformer

Key:

1. GPTV
2. Distributing feeder
3. Subscriber transformer

The output level of 30 volts is established in each channel by the level control on feeding the low-frequency signal to the input with modulation frequency of 100 hertz and depth of 70% on a load equivalent of 36 ohms.

CHAPTER 6. MEASURING DEVICES AND INSTRUMENTS

6.1. General Information

The proper operation and maintenance of the TPV [triple-program wire broadcasting] system requires the application of the corresponding measurement equipment for tuning the transmitters and receivers, amplifiers, measuring the electrical parameters of the low and high-frequency transmission channels.

The TPV system has a number of peculiarities which complicates the application of the existing measuring equipment and which must be considered when developing new instruments. These peculiarities include the following:

Amplitude modulation with adjustable carrier level within the limits of 10 to 100%;

A broad pass band with respect to the carrier equal to ±10 kilohertz;

Rigid requirements on the harmonic coefficient;

The presence of various channels (low and high frequency);

Significant voltage of the low-frequency channel subject to measurement (to 300 volts);

Great difference in magnitudes of the voltages of the low and high-frequency channels -- to 1000 times.

The stability of the signal level of programs II and III in the RT networks is appreciably worse than the signal of program I; therefore the demand for monitoring them increases. The measuring equipment for the TPV must have small nonlinear distortions, a wide modulating frequency band, small cross-talk between channels, adjustment of the output voltage within broad limits, symmetric input and output, relatively large input and small output resistances.

With respect to purpose the instruments can be divided into stationary and portable.

The stationary instruments make it possible to centralize the measurements at the TsUS, OUS and TP. Frequently they are built into the station equipment, for example, into the SVK and STP bays. Portable instruments have been designed for monitoring the networks and lines. They are produced in large quantities, because the line service personnel need them.

The modulation attachment and the test signal pickup with high indexes of standardized electrical parameters have been developed for the TPV.

The simplest measuring instruments are the lineman's display and the RTPV-2 pulse meter, by means of which it is possible to measure the voltage in each of three channels.

A complex resistance meter has been designed for introduction at the line development system -- measuring the resistances of the lines and sections of them. A high quality monitoring receiver (KPU) is also used to check the high-frequency network of development units.

It is possible to measure the level diagram of the high-frequency programs on the distributing feeders by using the high-frequency VRG-3 measuring oscillator [31]. A damage finder has been developed to find damage in the radio relay lines. All these instruments are transistorized. They are small in size and lightweight.

6.2. Modulation Attachment

The modulation attachment (MP) (Fig 6.1 and 6.2) is a source of AM signals of the carrier frequencies of 78 and 120 kilohertz, and it is needed to check out the receivers, amplifiers and line devices. In addition, in combination with the KPU the attachment can be used to check out the distortions of the shape of the AM signal envelope introduced by the passive network development units. In practice the attachment makes it possible to make an entire set of measurements of the quality indexes and electrical characteristics (with the exception of the time parameters) of all active and passive devices in the system.

The MP circuit contains the low-frequency filter $FNCh_1$, the phase shifters FV78 and FV120, modulator, the low-frequency filters $FNCh_2$ and $FNCh_3$, the modulated oscillation amplifier UMK, the circuits K78 and K120, the symmetrizing transformer (ST), the monitoring detector, the channel switch, the output voltage switch and regulator, and rectifier.

The attachment operates jointly with the oscillators: G3-33 is the source of carrier frequencies and G3-35 is the modulating frequency source. In the first case the voltage from the oscillator is fed to the high-frequency input, and in the latter case, to the low-frequency input. The resistance of the high-frequency input is nonlinear and small in magnitude. In order to decrease the voltage of the carrier frequency harmonics, the FNCh-1 low-frequency filter is included at the modulator input. Although the circuit

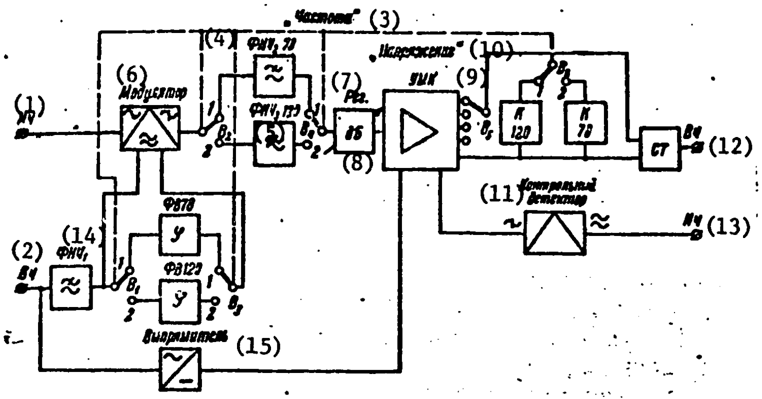


Figure 6.1. Modulation attachment

Key:

1. Low frequency
2. High frequency
3. Frequency
4. FNCh$_2$ low-frequency filter
5. FNCh$_3$ low-frequency filter
6. Modulator
7. Regulator
8. Decibels
9. UMK modulated oscillation amplifier
10. Voltage
11. Monitoring detector
12. High frequency
13. Low frequency
14. FNCh$_1$ low-frequency filter
15. Rectifier

[Photo not reproduced.]

Figure 6.2. Outside view of the modulation attachment

diagram of the modulator is more complicated than usual, it provides small nonlinear distortions with great depth of modulation. From the modulator output the AM signal goes to the input of the UMK, where the signal is power-amplified. Since carrier frequency harmonics occur in the modulator, the $FNCh_2$ and $FNCh_3$ low-frequency filters are included in the circuit to eliminate them.

In order to decrease the cross modulation in the UMK during testing of the various TPV devices for noiseproofness, the K78 and K120 circuits are connected to the output of the UMK. The symmetry of the output of the MP is insured by the transformer ST. In order to check out the operating quality of the attachment, that is, to measure the nonlinear and frequency distortions introduced by the modulator and the UMK, the circuits include the monitoring detector. Connecting a meter to measure the nonlinear distortion coefficient and a voltmeter to its output, it is possible to measure the frequency characteristic of the MP and the harmonic coefficient with respect to the envelope.

In order not to equip the portable device with a special power supply, the UMK is powered by rectifying the high-frequency voltage from the G3-33 generator output. At the output of the attachment, a modulated voltage is obtained with carrier frequencies of 78 and 120 kilohertz and a modulation depth of m=70%. It is possible to regulate the magnitude of this voltage from 15 mv to 6 volts. The rated voltages are switched from 0.3 to 6 volts with an output power of 40 milliwatts.

The MP is a high-frequency device. The range of modulating frequencies is from 50 hertz to 10 kilohertz with nonuniformity of 0.2 decibels. The harmonic coefficient in the frequency band of 50 to 5000 hertz is no more than 0.2% (at the monitoring detector output). The rated input voltage of 78 and 120 kilohertz is 12 volts; the modulating frequency voltage is 11 volts.

The rated voltage at the output of the monitoring detector on an active load of 100 kilohms with parallel capacitance of no more than 300 picofarads is 0.775 volts. The input impedance for frequencies of 78 and 120 kilohertz is 30 ohms; for the modulating frequencies it is 600 ohms. The crosstalk between the channels is 70 decibels.

6.3. Lineman's Indicator

The indicator is designed to measure alternating and direct voltages of three channels and resistances of two direct currents. Its circuit diagram is presented in Fig 6.3.

The indicator is made up of two switches, two voltage dividers, filters, a rectifier and microammeter. There are five jacks at the indicator input. One of them is common, and one of the wires of the line is connected to it.

Depending on the measured parameter it is necessary to connect the second wire to the jack: $V_{\sim}$ for measuring AC voltages; $V_{=}$ for measuring DC voltages; Rx1 and Rx100 for measuring resistances.

The limit switch Π_1 of the scales for measuring the voltages has five positions: from 0.5 to 1.5; 6, 30; 150 and 300 volts. The switch for the type of operation Π_2 also has five positions:

nch -- measurement of AC voltages;

78 -- measurement of the 78 kilohertz carrier voltage;

120 -- measurement of the 120 kilohertz carrier voltage;

$V_{=}$ -- measurement of the DC voltage;

Ω -- measurement of the resistances to direct current.

The first voltage divider -- I DH -- is connected to the AC circuit. It switches from the 1.5 scale to the 6 volt scale. On switching to the 30 and 150 volt scales it remains in the 6 volt position, and the variation of the scale limits is realized by the second divider -- II DH -- included in the DC circuit. On making the transition to the 300 volt scale the second divider remains in the 150 volt position and again enters into the operation of the I DH. This complication of the scale switches is intended to decrease the error in reading the instrument as a result of the effect of spurious capacitances and the possible asymmetry of the measured low-frequency voltage. The II DH decreases the power of the rectified current to the magnitude required for complete deflection of the instrument indicator, and it reduces the effect of the spurious current to a minimum. In order that during switching the filters not change the frequency characteristic, the resistance of the I DH must be constant. This is insured by inclusion of resistors R_1-R_5 and R_{13}. The second divider is made up of the resistors R_{22}-R_{24}; it insures constancy of the load resistance of the rectifier which is assembled on the basis of the diode D. The capacitor C_{15} filters out the variable components of the currents after detection.

The filter of the low-frequency channel is a П-type $L_1C_1C_2$ element with cutoff frequency of 15 kilohertz. The 78 kilohertz filter is made up of the three-element band filter $L_2L_3L_4C_4$-C_8, and the 120 kilohertz filter, from one element $L_5L_6C_{12}$-C_{14}.

The AC voltages are measured by the circuit in Fig 6.4. The scales of the indicator are calibrated in the effective values of the AC voltage. The instrument error does not exceed 7%. When measuring the voltage of the high-frequency channels as a result of the crosstalk between them the additional error does not exceed 3%. When measuring the low-frequency voltages the error as a result of the crosstalk from high-frequency channels is absent. When measuring the DC voltages the measurement limits are

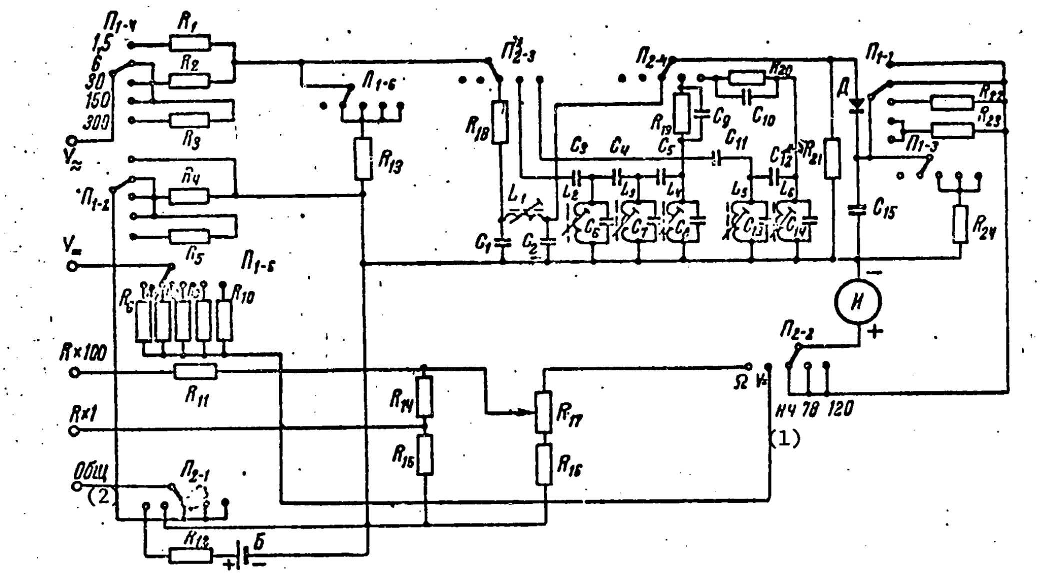


Figure 6.3. Lineman's Indicator

Key:
1. nch
2. common

determined by the resistors R_6-R_{10}. In this case the meter has a high input impedance caused by high sensitivity of the microammeter.

In order to measure the resistance to the direct current the indicator has a two-limit ohmmeter made in accordance with the series circuit with balance null control. The power supply of the indicator is the KBS-D-0.5 type dry cell.

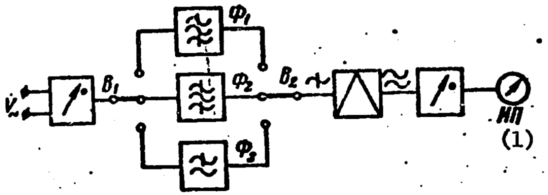


Figure 6.4. Circuit for measuring AC voltages MI

Key:
1. IP indicator

6.4. Complex Resistance Meter (IKS)

When introducing the TPV [triple-program wire broadcasting] it is necessary to carry out tedious high-frequency development of the RT networks in order to create conditions close to the traveling wave conditions and insure an input impedance with low reactivity, which varies little in the frequency bands from 72 to 84 and from 114 to 126 kilohertz.

The existing instruments do not permit measurements of the total resistances with unknown magnitude and sign of asymmetry on the required frequencies with given error. Thus, for example, when making the measurement by the MPP-300 bridge it is necessary to know in advance whether the resistance subject to measurement is symmetric, and if it is asymmetric it is necessary to know the sign of the asymmetry.

The IKS instrument can be used to measure the input impedances of lines and sections of lines, TP [transformer substations] and high-frequency devices having any asymmetry with respect to ground. Its operating principle is based on measuring AC voltage fed to the input of the line with a magnitude of current flowing through the line known in advance (Fig 6.5). Within the limits of one scale this current is always established at one and the same value by regulating the measured voltage of the line input. In this case, in order to discover the magnitude of the modulus of the input impedance of the line it is sufficient to measure the voltage at the input of this line, and it is possible to calibrate the voltmeter scale directly in ohms.

In accordance with this operating principle, the structural diagram of the IKS depicted in Fig 6.6 has been developed. It includes the following: the oscillator, the reactivity box, voltmeter and switching devices.

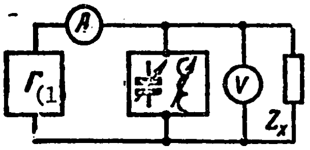


Figure 6.5. Operating principle of the IKS [complex resistance meter]

Key:
1. generator

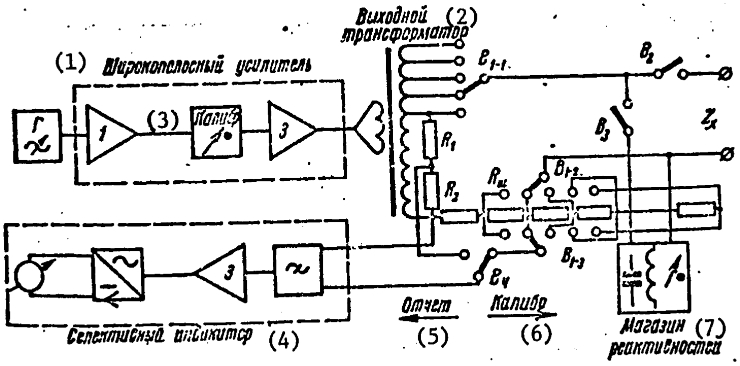


Figure 6.6. Complex resistance meter

Key:

1. Wide band amplifier	5. Reading
2. Output transformer	6. Calibration
3. Calibration	7. Reactivity box
4. Selective indicator	

The generator consists of the master stage and the wide band amplifier and is used for feeding sinusoidal signals of given frequency and power to the measuring circuit.

The generator can provide four fixed frequencies: 0.4, 3, 6 and 10 kilohertz; it covers two bands: from 68 to 88 kilohertz and from 110 to 130 kilohertz with smooth tuning.

The wide band amplifier (ShU) has a pass band from 300 hertz to 150 kilohertz with a nonuniformity of 4 decibels.

At the output the amplifier provides a power of 50 milliwatts on all operating frequencies on a load of any nature.

The gain control in the wide band amplifier (ShU) is used to calibrate the instrument, that is, the magnitude of the current flowing through the line of determined magnitude selected when designing the instrument is established. From the amplifier output the voltage goes to two output transformers: one for low frequencies and the other for high frequencies; and from their secondary windings it goes to the line, that is, the load of the amplifier is the measured resistance of the line, and when measuring the total resistances the reactivity box also. The calibration resistor R_{sh} is connected in series in the line circuit. The current in the line is established (the scale is calibrated) by measuring the voltage drop on this resistance. In order to increase the precision, the range of measured resistances from 20 ohms to 3 kilohms is broken down into four intervals: 20-100, 100-300, 300-1000 and 1000-3000 ohms in the frequency band of channels II and III. It is desirable that the power fed to the line input during calibration would be identical on all intervals. Therefore, the circuit includes the switch B_{1-1} which realizes discrete measurement of the voltage fed to the line input: the higher the input impedance, the higher the fed voltage. However, since at all limits the voltage corresponding to the lower limit is measured, in order to eliminate the error in the measurements the magnitude of the calibration resistance on variation of the measurement limits also is varied by the switch B_{1-2}.

The shunt resistance is selected small in order to decrease the errors when measuring the modulus of the reactances so that in the least favorable case (when measuring the resistance moduli near 20-30 ohms) this error does not exceed 10%.

The input of the ohmmeter is switched by means of B_4 from the calibration resistor R_{sh} to the output of the generator through the voltage divider R1, R_2. Since the scale of the voltmeter is not calibrated in volts, it is more correctly called an indicator. The selective indicator includes the band filters, a wide band amplifier, detector and the M265 type magnetoelectric microammeter with a sensitivity of 200 microamps.

The filters with an average frequency of 78 and 120 kilohertz pass only the first harmonic of the frequency on which the measurements are made, and the harmonics of this frequency are delayed which can occur both in the generator itself and in the real line. The elimination of these harmonics increases the accuracy of the measurements.

The anglesbetween the active and reactive components of the input impedance are measured by the compensation method: the reactance opposite with respect to sign to the reactance of the line input is connected parallel to the line input, and its magnitude is established so that these reactances are mutually compensated for. Here the modulus of the input impedance of the line reaches the maximum value and becomes purely active. The compensating reactivities are included in the composition of the IKS meter and are an inductance and capacitance box. The inductance box contains five stages: "off," "0.75," "0.25," "0.75" and "0.025" millihenries, that is, it can assume only discrete values. Therefore, for exact compensation of the capacitance of the line input, a variable-capacitance capacitor is connected in parallel to the inductance.

Thus, after obtaining the compensation for the reactivity of the input impedance of the line with respect to the scales of the boxes it is possible to reckon the values of the capacitances or inductances required for compensation and calculate by them the compensated magnitude of the reactance and the phase of the input impedance of the line. The basic instrument when measuring the angle will be more than 15%.

The instrument is fed from three of the KBS-0-0.5 type batteries during the summer operation of the instrument and KBS-Kh-0.5 in the winter. The rated feed voltage is 13.5 volts. In order to indicate the on condition and to check the voltage of the battery, a M4283 type indicator is used.

In spite of some complexity of the process of measuring the complex value of the input resistances of the line, the IKS greatly facilitates and accelerates the processing of the lines, insuring good quality of the high frequency channels.

6.5. High-Frequency Oscillator (VIG-3)

In order to record the level diagram on the distributing feeders and also to measure the modulus and the angle of the input impedances of the feeders, the VIG-3 type high-frequency measuring generator can be used. The oscillator permits voltages of the carrier frequencies of 78 and 120 kilohertz to be fed to the line simultaneously to pick up the level diagram of the channels or sections of the channel. It is connected to the distributing feeder gap instead of the feeder protectors at the transformer substations.

In contrast to the IKS, the VIG-3 feed is realized from the AC network (the intake power is no more than 25 watts), which limits the region of its application.

The structural diagram of the VIG-3 is depicted in Fig 6.7. The instrument is made up of the 78 and 120 kilohertz oscillators, a transformer designed for connection to the line and therefore called a measuring transformer, devices which measure the high-frequency voltage at the output of the line and the current in it and also a phasometer.

The feed unit is common to all of the modules of the circuit, and it is a rectifier with stabilizer, at the output of which a DC voltage of 12.5 volts is maintained.

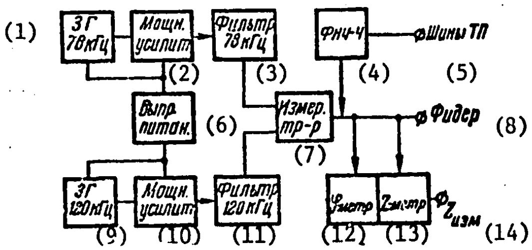


Figure 6.7. High-frequency VIG-3 oscillator

Key:

1. 78 kilohertz master oscillator
2. Power amplifier
3. 78 kilohertz filter
4. FNCh-4 low-frequency filter
5. Transformer substation buses
6. Rectified feed
7. Measuring transformer
8. Feeder
9. 120 kilohertz master oscillator
10. Power amplifier
11. 120 kilohertz filter
12. ϕ-meter
13. Z-meter
14. Z_{meas}

The oscillators are identical with respect to circuitry and are distinguished only by the magnitudes of the circuit capacitances and inductances. Each oscillator is made up of a master oscillator, buffer stage, terminal stage -- power amplifier -- the output circuit of which includes a band filter for the corresponding frequency filter. The oscillator can give a power of 1.2 watts on a resistance of 100 ohms.

Fig 6.3 shows the device by means of which the input impedance is measured, that is, the voltage at the input of the line, the current through it and the phase shift angle between the current and voltage.

A simple, convenient method of measuring the phase angle of the input impedance of the line is used in this instrument. This procedure consists in the fact that a voltage is fed to the pointing indicator through a ring modulator which in the given case is a controlled rectifier. It is assembled from four diodes D_1-D_4, the signal voltage sources Tp_1, C_1-C_2, R_1-R_2, the load resistances with the midpoint R_3, R_4 and the sources of the controlling voltage Tp_2, the primary winding of which is connected to the resistors R_7-R_{17}. The amount of a voltage drop on them and, consequently, on the windings of the transformer Tp_2 is directly proportional to the strength of the current running through the line. The secondary winding of this transformer is connected between the midpoints of the load and the oscillator, the role of which is played by the resistors R_1-R_2. It is obvious that in view of the symmetry of the circuitry this voltage will be absent between the ends of the resistors R_3 and R_4. The signal voltage from the Tp_1 through the capacitor C_1 or C_2 is fed to R_1, R_2. Since the amount of the capacitances is selected so that their resistance on frequencies of 78 (C_1) and 120 kilohertz (C_2) is appreciably greater than the sum of the resistances R_1 and R_2 with parallel-included R_3, R_4, the voltages on R_1, R_2 will be shifted with respect to the voltage on the windings of the Tp_1 by 90°.

The phase meter operates in the following way. Let us propose that instead of the line the capacitor is connected, the magnitude of the impedance of which corresponds with respect to modulus to the resistance of the real line. Then the current through the resistors R_7-R_{17} determined by the magnitude of the capacitance of the connected capacitor will be almost purely reactive, and the voltage on these resistors will be shifted by 90° with respect to phase relative to the voltage on Tp_1. This means that with the correctly included windings of Tp_2, there will be no phase shift between the signal voltage on R_1, R_2 and the controlling voltage on Tp_2. Then the signs of the voltage (+ or -) on the upper end of R_1 and the left end of the secondary winding of Tp_2 will always compare. Then we assume that the current strength through R_1 and R_2 from the controlling voltage is greater than from the signal voltage. Then a DC voltage is formed on R_3, R_4 with "plus" on the upper end of R_3. This occurs because if the voltage on the upper end of R_1 has a plus sign, the controlling voltage opens the diodes D_1 and D_4. The voltage from R_1, R_2 is fed through the diodes to R_3, R_4. If at another point in time the voltage on the upper end of R_1 has a minus sign, then on the left end of the secondary winding of Tp_2 there will be a voltage with the same sign, and the current from this winding will go through the diodes D_2, D_3, opening them and closing the diodes D_1, D_4. Since it is stipulated that this current is greater than the signal current, the signal current passes through the diode D_3 (where these currents flow in opposite direction) without cutoff and the voltage with the plus sign goes from the lower end of R_2 to the upper end of R_3. The indicator $И_2$ connected to R_3, R_4 indicates the presence of the DC voltage. Thus, if the current through the diodes created by the controlling voltage is sufficiently large, the ring modulator operates as a two-phase rectifier.

It is easy to see that if an inductance is connected in place of the line and is not a capacitor, the size of the voltages on R_1, R_2 and the left end of the secondary winding of Tp_2 will not coincide, that is, they will be 180° out of phase. The plus sign will always be on the lower end of R_4 in this case, and the indicator pointer will be deflected on the opposite direction in the same amount.

It is obvious that the input impedance of the line is purely active, the phase shift on the ring modulator between the signal voltage and the controlling voltage will 90° (capacitors C_1 and C_2 are included in the circuit for this purpose), and the constant component of the voltage on R_3, R_4 resistances. The indicator pointer will remain at zero.

For convenience of measurement, the type of indicator $И_2$ is selected so that it will be in the middle of the scale. In this case the total deflection of the indicator pointer in one direction or another will correspond to the phase shift between the voltage and current in the line by +90 or -90° and indicate inductive or capacitive nature of the input impedance of the line.

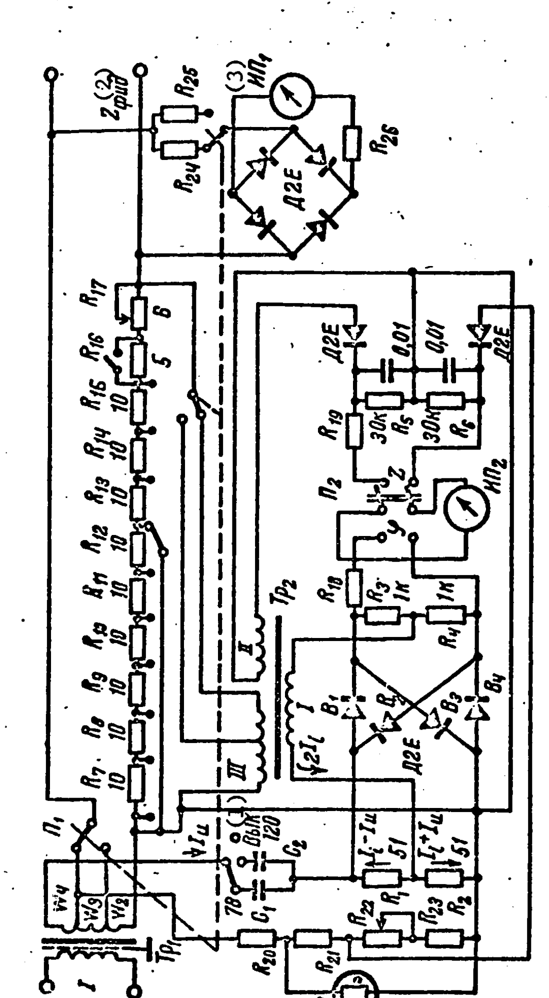


Figure 6.8. Device for measuring the input impedance

Key:
1. off
2. Z_{feed}
3. indicator

The measurement of the input impedance of the line is made by measuring the current flowing through the line, with known and previously established magnitude of the voltage at its input. Since when measuring the phase Z_{inp} of the input a pointing indicator is used with 0 in the middle of the scale, in order to use the entire scale of the same indicator to measure Z_{inp}, the meter circuitry is altered somewhat by comparison with the usual version. The difference in DC voltage is proportional to the magnitude of the current in the line and the voltage at its input is fed to the indicator. The voltage on the line is constant for all values of its input impedance, and the current decreases with an increase in Z_{inp}. Therefore the voltage difference to which the indicator reacts will be equal to zero for some value of Z_{inp}. For smaller values of Z_{inp} the indicator will basically be affected by the voltage obtained from the rectifier which is connected through Tp_2 to the resistances included in series in the line circuit. With an increase in Z_{inp} the current in the line decreases, the voltage at the output of the rectifier connected to Tp_2 decreases, and then this rectifier is blocked by the voltage formed on R_5 on passage of the current from the second rectifier connected to the output of the generator through it.

For monitoring the voltage at the output of the line a voltmeter is connected which is made up of a microammeter $И_1$, diode bridge and resistor R_{24}, R_{25}.

[Photo illegible]

Figure 6.9. Outside view of the VIG-3 oscillator

The accuracy of measuring the modulus of the resistance and phase angle is no worse than 5%. This high accuracy required separation of the entire measured range of resistances into two subranges: one from 20 to 100 ohms, and another from 100 to 1000 ohms. The phase angle is measured within the limits from -90 to +90° in the entire range. The outside of the instrument is shown in Fig 6.9.

6.6. Fault Detector (IPTV-1)

The detector is designed to determine the locations of short circuits in the low and high frequency channels on the overhead and underground feeder and subscriber lines and also on house distribution circuits for monitoring the presence of high-frequency programs; in order to find the section of line with damage causing an increase in the crosstalk between channels; in order to determine the path of damaged underground lines and the location of the hidden wire in house networks.

The instrument makes it possible to find the location of short circuits in the low-frequency channel of overhead lines from the ground, and in the absence of the interfering effect of the electrical network current field on the overhead lines running above the roofs of three to seven story buildings.

A short circuit beyond the limiting net resistance with respect to any of the three channels in the room wires using double lines, for example, TRVK, can be found with the search coil of the detector at a distance on the order of 5 to 10 cm from the wire, and up to the limiting resistance -- on the house network stands -- at a distance of 50 cm or more.

The operating principle of the instrument is based on the fact that the electromagnetic field of the current of the RT network is picked up by the search coil, it is amplified and fed to a headset. The structural diagram of the detector is shown in Fig 6.10. The search coil has three windings: low frequency and two high frequency made in such a way that the inductive coupling occurs only between the high frequency windings. Depending on the position of the channel switch either the low-frequency winding of the search coil is connected to the amplifier input or the output of the two-circuit concentrated selection filter tuned to 78 and 120 kilohertz is connected. On setting the switch to the low-frequency position all of the stages of the detector operate in the amplification mode. When receiving high-frequency signals and setting the switch to the 78 or 120 kilohertz position the last stage performs the functions of a detector, and all the rest, the high-frequency amplifier.

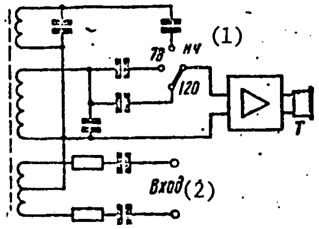


Figure 6.10. Fault detector IPTV-1
Key: 1 -- low frequency; 2 -- input

The input jacks are used to feed the programs of the high-frequency channels to the input of the amplifier through the coupling winding of the search coil. The principle of determination of the short circuit location is based on the fact that the magnitude of the carrier in the wires at this point changes sharply. If to the left of the short circuit point the current has significant magnitude exceeding the operating value of the current, then to the right of this point the current in the line decreases in practice to 0. When working with the detector this is manifested in the sharp change in strength of the sound on advancement of the search coil along the line past the short circuit point. The short circuit on the line causes different consequences for the sound frequency currents and the carriers of the high-frequency channels. On the sound frequencies the current increases by comparison with the operating value over the entire section to the left of the short circuit point. On the frequencies of the high-frequency channels in the presence of a short circuit as a result of reflection of energy in this segment, standing current and voltage waves occur before the short circuit point. In some sections in the presence of a short circuit the current can diminish by comparison with the operating value of the current at the same time as in other sections it increases. However, on any channel there is discontinuous variation of the current at the short circuit point, that is, variation in volume of the sound in the detector headphone.

The detector has the following quality indexes: a sensitivity of 40 microamps with inductive coupling through the search coil at rated output voltage;

An output voltage of 1 volt developed in the headphones with a resistance of 3000 to 4500 ohms;

A reproducible frequency band with respect to the high-frequency channels of 300-3500 hertz for nonuniformity of 15 decibels;

Coefficient of nonlinear distortions on the high-frequency channels of 7%.

The detector has two sensitivity adjustments: step by 40 decibels and continuous by 30 decibels. The instrument feed is from 3 of the 1, 3FMTs-0.25 type elements.

When building over overhead and cable lines, house RT circuits and also when detecting faults it is expedient to use the IPRL type detector which is made up of the IPRL-I fault detector itself and the oscillator G. The location of the break or short circuit is fixed by a sharp change in volume of the sound in the headphones of the detector beyond the location of the break or short circuit.

The detector detects the location of the following fault:

On pole subscriber lines at 15 and 30 volts with accuracy of ±10 meters when it is at a distance of no more than 6 meters from the path of the line and at an admissible noise level from the electric network;

Pole and stand distributing feeders suspended at a height of up to 20 meters with precision of ±20 meters when the detector is at a distance of no more than 10 meters from the path of the line;

House wiring laid open or hidden. The precision in this case is ±8 cm when the detector is at a distance of no more than 1 cm from the wall;

In sections of underground feeder lines laid using cable with nonmetallic shielding with precision to 1 meter.

The quality indexes of the detector are as follows: a voltage of 100 millivolts on the TON-2 headphones, frequency band of 700 to 1400 hertz with nonuniformity of 6 decibels, coefficient of nonlinear distortions of 10% with an output voltage of 0.5 volts; the detector has step adjustment of the amplification 20 decibels deep and the continuous 18 decibels deep, and the detector oscillator frequency is 1000 hertz.

6.7. ITPV-2 Type Triple-Program Wire Broadcast Pulse Meter

The portable ITPV-2 instrument [29] is designed to determine the quasimaximum values of the voltages of broadcast programs on the wire broadcast networks. The program can be heard on headphones. By using the instrument it is also possible to measure the magnitudes of the sinusoidal voltages at frequencies of 78 and 120 kilohertz and low frequency in the range of 50 to 10000 hertz. The structural diagram of the instrument is presented in Fig 6.11. At the input of the VU, two symmetrizing transformers are installed for low and high frequencies with different transformation coefficients, which permits the signals of the three programs to be reduced approximately to the same level at the input of the voltage divider (DH). Band filters Φ78 and Φ120 are included at its output for the carrier frequencies (the low-frequency filters pertain to the input circuit). From the filter output, and when measuring low-frequencies from the output of the divider the measured voltage goes to the input of the wide band amplifier (ShU) which passes a 50-hertz to 200 kilohertz band. The amplifier load is two detectors. The first is the pulse meter detector (DI), and the second detects the AM oscillations of programs II and III. From the output of the second detector -- the sound monitoring detector (DZK) -- and when listening to a low-frequency program from the output of the wide band amplifier, the low-frequency voltage goes to the low-frequency amplifier which insures a level sufficient for normal operation of the headphones (T). The detector of the pulse meter is loaded on the measuring bridge (IM) with a microammeter, the scale of which is calibrated in volts. In the absence of a signal the bridge is balanced and the pointer of the instrument is at zero. When a signal arrives, the balance is upset and the pointer is deflected proportionally to the maximum value of the voltage.

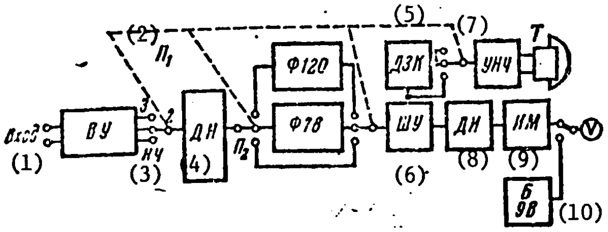


Figure 6.11. ITP-2 pulse meter

Key:

1. Input
2. P_1
3. low frequency
4. DH
5. DZK
6. ShU
7. Low-frequency amplifier
8. DI
9. IM
10. B, 9 volts

The limits of measuring the voltage of program I are as follows: 10, 30, 100 and 300 volts; the high-frequency programs: 0.5, 1.5, 5, 15 and 50 volts. The measurement error does not exceed +5% (on the 50 volt scale the error is +7%). The input impedance of the instrument in the frequency band of 50 to 10000 hertz is 12 kilohms; for the high-frequency channels with a pass band of every 10 kilohertz, 3 kilohms.

The crosstalk between the high-frequency channels is -36 decibels. The noise protection of the high-frequency channel from the low-frequency signal is 70 decibels. The integration time when feeding the low-frequency signal to the input is 30 milliseconds with 85% fidelity, and when feeding the high-frequency carriers modulated by a frequency of 1000 hertz to the input with m=70% the integration time is 50 milliseconds with 80% fidelity.

The power supply for the instrument is from a 9 volt battery; the intake current is 10 milliamps. In combination with the PZK-1 type sound monitoring attachment which has an amplifier, speaker and battery, the ITPV-2 permits loudspeaker sound monitoring of broadcast programs. The outside of the instrument is shown in Fig 6.12.

6.8. Monitoring Receiver (KPU)

The KPU [monitoring receiver] is the highest quality instrument designed to measure the qualitative and technical indexes of the low-frequency and high-frequency channels of the system and permitting measurements of the normalized parameters with respect to quality class I.

In order to perform all of the required measurements the instrument has two operating modes: in one mode it performs the functions of the high-quality monitoring receiver of AM signals, and in the other, it is a three-band, multilimit selective millivolt meter with symmetric input.

[Photo illegible]

Figure 6.12. Outside of the ITPV-2 pulse meter

Beginning with the problems of measuring all of the quality indexes the KPU contains the following assemblies: the amplifying channel of the receiver, attenuator, low-frequency and high-frequency filters for various purposes (including filters for separate measurement of background and noise), the symmetrizing low-frequency and high-frequency devices, the amplifying channel of the voltmeter and the sound monitoring, the switching devices and power supply.

In order to perform the set of measurements -- crosstalk, noise, background, frequency characteristics with respect to the envelope in the modulating frequency range and in the high-frequency and low-frequency channel bands -- the following instruments and devices are required: symmetrizing transformers, lineman's indicator, the Kazakhstan receiver, the GT Avrora, the tube voltmeter, cathode repeater and filters for separate measurement of background and noise.

All of these devices are replaced by one KPU instrument, the structural diagram of which is presented in Fig 6.13. The input circuits of the KPU are made up of the SU-VCh high frequency and SU-NCh low frequency symmetrizers, the AT_1 attenuator and the PF78 and PF120 band filters.

The SU symmetrizers make it possible to obtain symmetrizing input of the instrument and, in addition, the SU-VCh has additional selectivity with respect to the signals of the low-frequency channel. In order to insure the possibility of measuring voltages in a wide range from 0.25 to 300 volts, an 8-step attenuator with attenuation in the limits from 0 to 80 decibels is used.

Each band filter has a noiseproofness of 60 decibels wbetween the high-frequency channels. When measuring the low-frequency channel the required noiseproofness (30 decibels) from the high-frequency channels is insured by the $FNCh_1$ low-frequency filter. When measuring the background level, the $FNCh_2$ low-frequency filter is included which cuts off the frequencies above 200 hertz and has attenuation in the 200-1000 hertz band equal to 22 decibels.

In order to measure the noise level, the high-frequency filter is included in the circuit which cuts off frequencies below 200 hertz having attenuation of 21 decibels in the frequency band of 50-100 hertz.

The high-frequency amplifier is four stage. It is used to amplify the signal to the amount sufficient for linear detection. As a result of the application of negative feedback in the first two stages the high-frequency amplifier has high input impedance required for normal operation of the band filters.

The double halfperiod detector insures high linearity of loading the high-frequency amplifier and improves the suppression of the remains of the carrier frequencies and their harmonics.

The low-frequency amplifier is single-stage. Its load is the $FNCh_3$ low-frequency filter. The $UNCh_2$ low-frequency amplifier is three-stage with common amplification coefficient of about 140. It amplifies the voltage to the rated output value of 0.775 volts. It has low output impedance and is loaded on the attenuator AT_2 of the level indicator.

The voltmeter amplifier UV is four-stage, wide-band. It has a total amplification coefficient of about 1000. The rectification circuit is a bridge circuit. A microammeter for 100 microamps, type M265, is connected to one of the diagonals of the bridge. Part of the voltage of the UV voltmeter amplifier is fed to the monitoring amplifier UNChk which is made of 5 transistors and is loaded on the 1GV-1 speaker for listening to programs and interference.

The power supply for the KPU can either be from KVS type batteries placed in the instrument case or from the AC network. The power pack is made up of the step-down power transformer, filter rectifier and voltage stabilizer. The IP indicator monitors the inclusion of the instrument and the magnitude of the feed voltage. In order to include the instrument there is a flipflop switch $8B_1$ Pitaniye [feed]; for switching power supplies there is a toggle switch $8B_2$ Rod Pitaniya [type of feed]. The current intake by the instrument when powered from the battery is 55 milliamps. The power intake from the AC network is 4 volt-amperes.

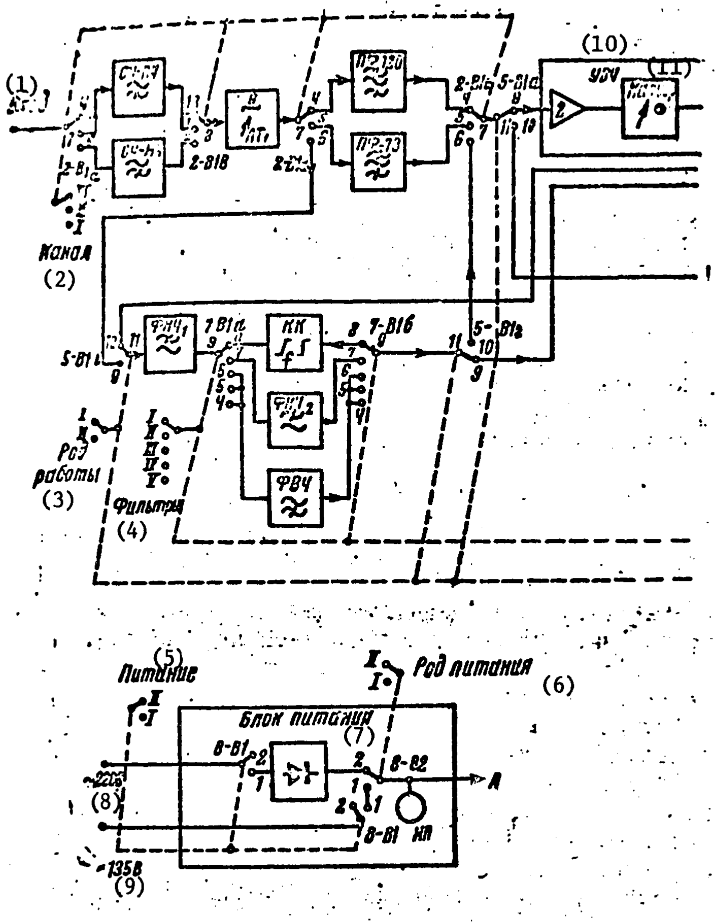
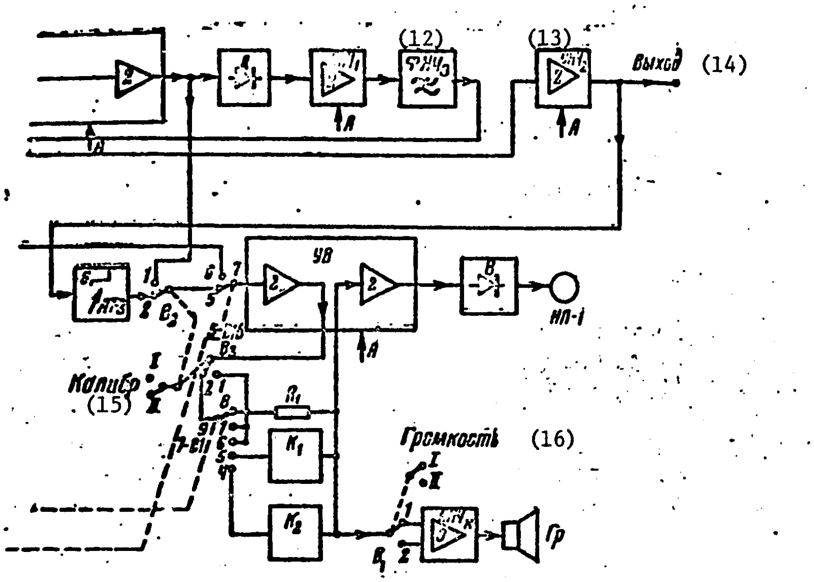


Figure 6.13. Measuring receiver KPU

Key:

1. Input
2. Channel
3. Type of operation
4. Filters
5. Power supply
6. Type of feed
7. Power supply module
8. 220 volts
9. 135 volts
10. High-frequency amplifier
11. Calibration



[Figure 6.13]

12. Low-frequency filter
13. Low-frequency amplifier
14. Output
15. Calibration
16. Volume

For separate explanation of the operation of the instrument let us consider two operating modes separately: 1 -- Vol'tmetr [voltmeter] and 2 -- Priyemnoye ustroystvo [receiver]. In the first operating mode the KPU makes it possible to measure the effective values of the AC voltage of all channels from 10 millivolts to 300 volts in the frequency bands from 50 to 10000 hertz, 68-88 and 110-130 kilohertz; the effective values of the carrier voltages of channels II and III in the presence of tone modulation or modulation by the broadcast signal with the carrier level adjustment included on the transmitters; the modulus of the input impedance for frequencies of all channels.

In addition, in this mode the KPU permits the performance of the following: separate measurement of the background and noise voltages of the low-frequency channel to 75 decibels; measurement of the frequency characteristic in the band of each channel, listening to the broadcast program of the low-frequency channel.

The Kanal [channel] switch is used to select one of three channels. The instrument has the following voltage scale: 30, 100 and 300 millivolts; 1, 3, 10, 30, 100 and 300 volts. The measurement error is no more than ±6%; the nonuniformity of the frequency characteristic is 2 decibels.

When measuring the voltages the low-frequency signal goes to the low-frequency symmetrizers SU-NCh, from the output of which the voltage is fed through the attenuator AT_1, the groups 5-V1V of the type of operation switch, the $FNCh_1$ low-frequency filter, the KK correction circuit, the 5-V1V type of operation switch group, the 2V1V channel switch group, the 5V1a and 5-V1b groups to the input of the UV voltmeter amplifier and then to the rectification circuit of the IP_1 microammeter, type M265, calibrated in millivolts (volts).

When measuring the voltages of the high-frequency channels the signal goes to the input of the SU-VCh device, then to the attenuator and to the corresponding filter which insures the required selectivity. From the output of the filter the measured voltage goes through the 5-V1a and 5-V1b groups to the UV and the instrument.

In the second operating mode the instrument makes it possible to measure the following quality indexes with respect to quality class I and II: the frequency characteristic, interference protection of the high-frequency channels, background and noise voltage, and by means of the nonlinear distortion meter, the harmonic coefficient. In this mode with a sensitivity of the instrument of 25 millivolts the output voltage is 0.775v. The voltmeter has 6 scales: from 0 to 3, 10, 30, 100, 300 and 1000 millivolts. Its basic error is ±6%. The nonuniformity of the frequency characteristic of the instrument is 2 decibels, the harmonic coefficient is 0.5%. The noiseproofness between the high-frequency channels is 77 decibels, from the low-frequency program 105 decibels, from the radio broadcast band on frequencies above 180 kilohertz, 70 decibels.

The signal to be measured goes by means of the 2-V1 channel switch "78" or "120" to the input of the high-frequency symmetrizer SU-VCh and then to the AT_1 attenuator and the PF 78 or PF120 band filter. Then the signal is amplified using the UVCh high-frequency amplifier, it is detected and again amplified with respect to low frequency ($UNCh_1$). The setting of the required sensitivity (calibration) is made by adjusting AT_1 (rough) and variation of the amplification coefficient UVCh (smoothly). Here the IP_1 instrument is connected by means of the switch B_2 to the output stage of the high-frequency amplifier.

From the output of the $UNCh_1$ low-frequency amplifier the signal goes through the $FNCh_3$ low-frequency filters, the 5-V1 switch group and the $FNCh_1$ low-frequency filter, the KK circuit, the 5-V1 group to the $UNCh_2$ low-frequency amplifier connected to the "output" terminals. The voltage at the output of the KPU is measured by a built-in voltmeter which is made up of the attenuator AT_2, the K-circuits (K_1 and K_2), the rectifier B and the instrument calibrated in decibels.

Depending on the type of measured parameter the "filters" switch is set to the required position and the following measurements are made:

1. In the ShP position -- measurement of the harmonic coefficient of the amplitude of the modulated oscillation of the high-frequency channels and pickup of the frequency characteristics with respect to the envelope. In this case the KK is included and the pass band of the receiver is 50-10000 hertz. In order to measure the harmonic coefficient, the harmonic analyzer or coefficient of nonlinear distortion meter is connected to the output terminals.

2. In the "background" position -- measurement of the background voltage of the high-frequency channels. In this case the $FNCh_2$ filter is included, and the pass band is limited to frequencies of 50-100 hertz.

3. In the "noise" position -- measurement of the high-frequency channel noise. In this case the FVCh high-frequency filter is included, and the band is 400-10000 hertz.

4. In positions 1 and 2 kilohertz -- the measurement of the crosstalk in each high-frequency channel. In this case the narrow band filters K_1 and K_2 are included respectively, and only the voltages at frequencies of 1 and 2 kilohertz are measured. The presence of noise interfering with the measurement is determined by using the acoustic monitoring channel in the "loud" position of the volume switch. The outside of the instrument is shown in Fig 6.14.

[Photo illegible]

Figure 6.14. Outside of the KPU

6.9. Channel Monitoring Device (UKT)

The UKT channel monitoring device is a portable instrument which can be used for checking and tuning the channels of the TPV network, to check the fitness of the GT at the subscribers and the GPTV. The 1000-hertz oscillator in the UKT can be connected to the UPTV-200 transmitter and it is possible to check the correctness of the regulation in it of the suppression of the carrier and depth of modulation. Rigid requirements are imposed on the portable device with respect to weight and economy when fed from a battery. Therefore the UKT circuit is appreciably simpler than, for example, the VIG-3 oscillator, but the simplifications are achieved at the expense of some loss of precision and stability of the instrument.

The structural diagram of the UKT [35] is presented in Fig 6.15. The device is made up of the master oscillator (ZG), the low-frequency 1000-hertz oscillator (GNCh), the power amplifier (UM), multivibrator (MV), the meter that measures the modulus of the input impedance on carrier frequencies, the Z-meter, rectifier, and stabilizer of the DC feed voltage. The oscillation frequency of the master oscillator ZG (&8 or 120 kilohertz) can be switched both manually and automatically using the MV multivibrator. The multivibrator controls the relay which, in turn, connects (or disconnects) the capacitors to the oscillatory circuits of the ZG and UM. The frequency is switched every 6 to 9 seconds. This time is entirely sufficient to measure the level on the line using the lineman's indicator.

The amplitude modulation of the carrier frequencies is realized directly in the master oscillator itself without an additional modulator by feeding a voltage from the output of the GNCh low-frequency oscillator to the emitter circuit of the transistor. The AM mode is used to check, without measuring the quality indexes, fitness of the GT and GPTV. The voltage of the GNCh can be used also for other purposes. For example, on connecting its output to the transmitter it is possible to check and adjust the depth of modulation, the degree of suppression of the carrier. The modulus of the input impedance of the feeders is measured in the usual way: a current or defined magnitude (calibration) is fed to the line, and then the voltage drop on the Z_{inp} line is measured. The two-limit scale of the meter is calibrated directly in ohms from 0 to 100 and from 100 to 1000 ohms. In the UKT, the M24 microammeter for 100 microamps is used. The device is connected to the line in parallel, but so that the band-elimination filters ZFR separate the UKT from the low-frequency station amplifiers.

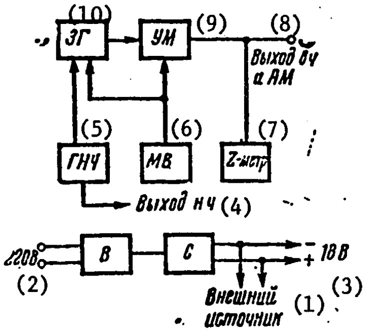


Figure 6.15. Device for monitoring channels

Key:

1. Outside power supply
2. 220 volts
3. 18 volts
4. Low-frequency output
5. GNCh
6. MV
7. Z-meter
8. High-frequency and AM output
9. UM power amplifier
10. ZG master oscillator

The parameters of the device are as follows: the output power on the carrier frequencies on a resistance of 300 ohms is 1 watt; the voltage of the GNCh is 2 volts, the high-frequency on a load of 1500 ohms is 2 volts. The operating frequencies are as follows: 78 and 120 kilohertz with precision of ±1.5%, 1 kilohertz ±20%. The continuous adjustment of the high-frequency signal level is no less than 20 decibels. The measurements of the modulus of the input impedance of the RF distributing feeder on carrier frequencies are within the limits of 10-1000 ohms±15%.

The instrument is powered from the AC, 220 volt network or 3 to 4 KBS batteries with a voltage of no more than 18 volts.

6.10. Test Signal Pickup (G-78/120)

In order to tune the individual and group receivers and intermediate amplifiers, a special AM oscillator is required with higher quality indexes. The

G-78/120 pickup is a source of AM signals made up of two independent carrier frequency oscillators identical with respect to circuitry and a common power pack. The structural diagram of the sensor is shown in Fig 6.16. The amplitude modulation of the carrier frequencies can be realized either by an external low-frequency oscillator or internal with modulation frequencies of 1000 hertz and rated modulation depth of 70%. Each oscillator is made up of the master oscillator with quartz stabilization of the frequency and a modulator executed by the circuitry of the two-cycle amplifying stage with modulation in the emitter circuit. At the output the oscillator has a continuous amplification regulator which provides for regulation of the output voltage within the limits of 15 decibels and a step voltage regulation switch for 0.1, 0.3, 1.0 and 3.0 volts (for the DPU). The power supply for the pickup is from the 220 volt AC network. This voltage is rectified and stabilized with respect to the DC voltage by a parametric stabilizer. As the source of the low-frequency signals it is possible to use any sound frequency oscillator with output impedance of 600 ohms. The basic parameters of the pickup are as follows: modulating frequency band 20 to 15000 hertz with nonuniformity on the higher frequency of 3 decibels, harmonic coefficient of 0.5% in the 20-6000 hertz band, background level 65 decibels, signal/noise ratio with mutual connection of the outputs of the two oscillators to the common load of 70 decibels, power intake from the network 3.5 watts, mass of the instrument 2.5 kg.

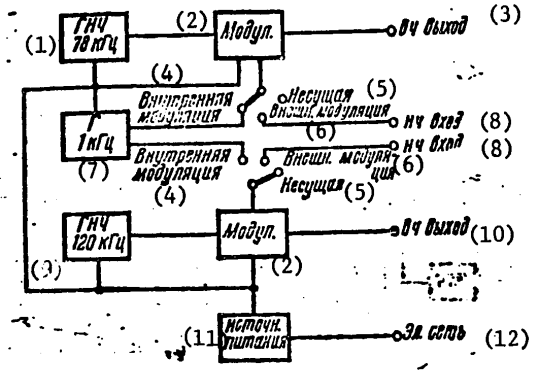


Figure 6.16. Test signal pickup

Key:

1. Low-frequency oscillator 78 kilohertz
2. Modulator
3. High-frequency output
4. Internal modulation
5. Carrier
6. External modulation
7. 1 kilohertz oscillator
8. Low-frequency input
9. Low-frequency oscillator 120 kilohertz
10. High-frequency output
11. Power supply
12. Electrical network

6.11. Measurement Panel of the Distributing Feeder Frame (PI-STR)

The measurement panel is built into the STR-5 distributing feeder frame installed on transformer substations for remote control and monitoring of the operation of the transformer substations of large cities with triple-program wire broadcasting. The measurement panel provides for the following: measurement of the signal level of all three programs, measurement of the modulus of the input impedance of each feeder (to 10) on the signal frequencies of the three programs, measurement of the quasipeak value of the envelope of the modulated signal of the second and third programs.

All of the measurements are performed without interrupting broadcasting over the distributing feeders. The levels are measured simultaneously with respect to three programs. This is achieved as a result of doing away with the pointing indicators and using a cathode ray tube as the indicator. Another characteristic of the PI-STR panel is the fact that the modulus of the input impedance of the feeder is measured not by using special oscillators, but on the broadcast transmission currents of the low-frequency programs and the carrier frequencies of the second and third programs. The structural diagram of the panel when measuring the program levels is presented in Fig 6.17. The voltage from the STR-5 buses goes to the input device which insures the possibility of connecting three filters to the buses: low frequency transmitting the signal of I and two band filters at 78 and 120 kilohertz. The voltage from the output of the filters goes through the preset regulators to the integrators (IU). Their purpose is to insure measurement of the level by the procedure established by MRTU-1029-66 specifications. According to this procedure the integration time (the minimum signal duration, the level of which is reckoned with 90%±10% fidelity) is equal to 10 milliseconds, and the capacitive discharge time is from 3 to 4 seconds. The integrator satisfies these requirements. It includes two amplification stages (emitter repeaters), detector and integrating circuit. All three devices are identical. From the output of the integrator the voltage goes through an electron switch to the vertical deflection amplifier (UVO) but only in the case where the switch is not closed. The switches are controlled by an electronic commutator and pass the signal from the IU [integrator] alternately. The switching speed is 100 times per second (twice the electrical network voltage frequency). The UVO [vertical deflection amplifier] amplifies the signals arriving from any IU and transmit them to the vertical deflection plates of the cathode ray tube beam. With respect to horizontal the beam is deflected by pulses obtained from the same electronic commutator which controls the switches. The deflection (scanning) is realized so that if the first program switch is opened, the beam is not deflected, but remains on the left side of the screen. When the second switch is opened (the first one is blocked), the beam deflects jumpwise to the middle of the screen, and on blocking the third switch, farther than the middle. In addition to the pulses, an AC voltage (from the network) is fed to the horizontal deflection plates, deflecting the beam so that instead of points from the beam on the screen dashes 5 to 10 mm long appear. This facilitates reading and increases the service life of the cathode ray tube. A transparent mask is fitted to the cathode ray tube screen with three scales plotted on it calibrated in effective volts. By these scales and the maximum beam deflection the program levels on the STR-5 buses are reckoned. When the electronic switches operate the transient processes influencing the degree of deflection of the beam occur. These spurious beam deflections can be perceived by an observer as a variation in the signal voltage. However, even if the observer, knowing the origin of this interference, does not notice them, they still complicate proper reading of the level with respect to the beam position. In order to facilitate reading, the beam is extinguished during the switching time of the measured channels. In order to extinguish the beam pulses are fed to the modulator of the cathode ray tube. These pulses are obtained in the electronic commutator. The integrators, electronic switches and commutator are made of transistors, and the vertical deflection amplifier is made from the 6N2P tube (the magnitude of the voltage required for the beam deflection reaches 200 volts, and industry still does not produce the corresponding transistor).

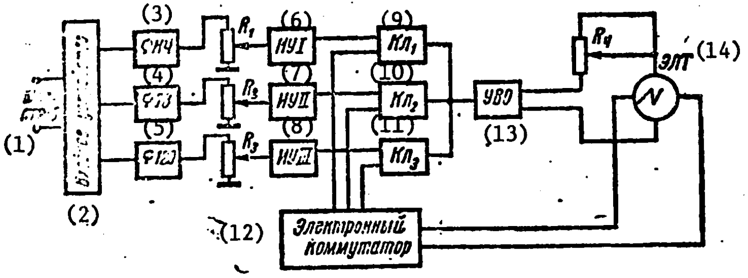


Figure 6.17. Structural diagram when measuring program levels

Key:
1. STR-5 buses
2. Input unit
3. Low-frequency filter
4. Band filter 78 kilohertz
5. Band filter 120 kilohertz
6. Integrator I
7. Integrator II
8. Integrator III
9. Switch 1
10. Switch 2
11. Switch 3
12. Electronic commutator
13. UVO [vertical deflection amplifier]
14. Cathode ray tube

The structural diagram of the PI-STR when measuring the quasipeak values of the envelope of the modulated signal is presented in Fig 6.18. In contrast to measuring the signal levels, the measurement of the level of the envelope is made not simultaneously with respect to two (II and III) programs, but in turn. The program is selected manually by the switch B. The electronic commutator does not operate in this case, and the magnitude of the corresponding DC voltage deflecting the beam horizontally is established by the variation in position of the switch B. The high-frequency voltage from the STR-5 buses goes through the input device, the 78 and 120 kilohertz filters and the switch B to the input of the amplitude detector. At the output of the detector a low-frequency voltage is obtained, that is, the same envelope, the voltage of which must be measured. Then the low-frequency voltage is fed to the integrator, and from its output thew pulsating voltage is fed to the vertical deflection amplifier and then to the deflecting plates.

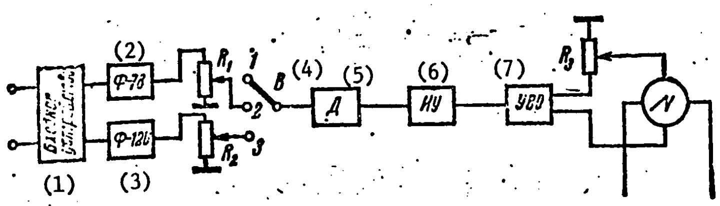


Figure 6.18. Structural diagram of measuring the envelope level

Key:

1. Input device	5. Detector
2. F-78 band filter	6. Integrator
3. F-120 band filter	7. Vertical deflection amplifier
4. Switch	

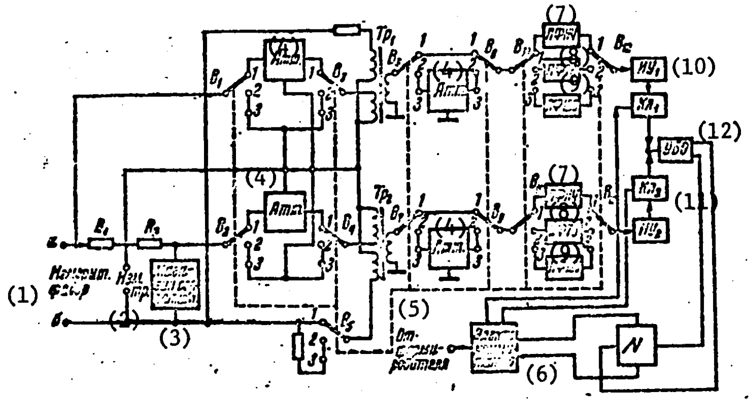


Figure 6.19. Structural diagram of monitoring the constancy of the input resistance modules of the feeder lines

Key:

1. Measuring feeder	10. Integrator
2. Measuring transformer	11. Switch
3. Resistance box	12. UVO vertical deflection amplifier
4. Att	
5. From the shaper	
6. Electronic commutator	
7. PFNCh low-frequency band filter	
8. 78 kilohertz band filter	
9. 120 kilohertz band filer	

The modulus of the input impedance of the feeders is measured by the structural diagram in Fig 6.19. In this case the voltage goes to the feeder from the buses of the transformer substation through the measuring transformer and the resistor R_1. A circuit made up of the resistor R_2 and the resistance box is connected in parallel to the output of the measuring transformer. The magnitude of the resistance R_2 is 20 times that of R_1. If the resistance is set on the resistance box so that the drops on both resistors will be identical, this means that the resistance of the box is 20 times greater than the input impedance of the feeder. Thus, in order to measure the modulus of the input impedance it is necessary, switching the resistances of the box, to equalize the voltage drops on R_1 and R_2 and reckon Z_{inp} of the feeder by the box scales (a difference of 20 times is considered during calibration). The voltages are measured on the resistors just as the program levels are measured. The voltage is fed through the switches and the transformer to the filters which pass the currents of the program, on the frequency of which the measurements are made. On the programs II and III, measurement is made on carrier frequencies, and on program I, in the frequency band of 400 to 800 hertz. Although the operating rules require performance of the measurements of Z_{inp} only on a frequency of 400 hertz, if the filter band of program I is made very narrow, the voltage at the filter output will be small, and the greater part of the time it will not exist at all, for the voltage components with a frequency of 4-0 hertz in the spectrum of the broadcast program occur rarely. Therefore in order to facilitate the measurements the filter band is made relatively wide.

From the filter output the voltage goes to the integrator, and then through the electronic switch and the vertical deflection amplifier, to the cathode ray tube plates. The electronic commutator alternately includes the switches and simultaneously shifts the beam horizontally. In this case two strips will be obvious on the screen of the cathode ray tube which move vertically in accordance with the broadcast transmission level. Turning the switch of the resistance box, it is necessary to set it to the position in which both strips will be at the same height, and then read the modulus of the input resistance of the feeder by the box scale.

The PI-STR is a highly accurate instrument; its error in the mode of simultaneous monitoring of the dynamic levels of all three programs does not exceed ±10%, and the additional error as a result of the presence of the voltage of additional programs does not exceed ±4%. The values of the moduli of the input resistances can be measured with an accuracy of ±10% in the range from 100 to 1000 ohms and with an accuracy of ±10 ohms in the range from 30 to 100 ohms.

The structural design of the PI-STR provides for the installation of the panel on the STR-5 frame without any adjustments. If the modules for monitoring the programs, measuring the input impedance and the pulse meter are installed in advance on the frame, it is necessary to remove them and install the PI-STR panel in their place. The panel feed is from the STR-5 feed module, but since the cathode ray tube and the transistorized stages require additional rated values of the stabilized voltage, an additional feed module is installed on the PI-STR.

6.12. Problems of Introducing Meters

The above-enumerated instruments do not completely correspond at the present time to the operating needs. One of the main peculiarities of the triple-program wire broadcasting is the use of a variable carrier. This factor gives rise to significant difficulties in measuring the voltage distribution on the wire broadcast networks. The instruments used quite precisely measure the voltage if the carrier is tone modulated, that is, when the carrier remains constant. The tone line measurement can be made when the TPV networks in the given region have only just been created. However, when the network has already begun to operate, it is inadmissible to carry out the current tone measurements for entirely understandable causes (preventive, operational or operative). It is possible to say the same thing about the measurements when searching for damage and determining the degree of influence on the voltage distribution along the feeder of the newly connected leads. The readings of the voltmeters -- the lineman's indicator and RTPV-2 -- essentially depend on the nature of the broadcast transmission (voice, music), and they can lead to invalid conclusions. This leads to the necessity for making individual measurements. The creation of an instrument, the readings of which will not depend on the level and nature of the broadcast program appears to be difficult. Therefore it is more expedient periodically to change the operating conditions of the transmitter: to convert it for some time to operating conditions with nonregulatable carrier. Then during this time the carrier will be constant, and by the readings of the instrument reacting to the existing voltages it is possible quite precisely to determine the transmission coefficient of the various elements and the level distribution on the network. The disconnection of the carrier regulation, however, is connected with an increase by 20 decibels of the crosstalk interference on the high-frequency channels from program I which can turn out to be noticeable for the subscribers. The noticeability of the crosstalk can be reduced to the minimum by reducing the time during which the transmitter conditions change. It is obvious that this variation must be of a periodic (pulse) nature. The pulse duration, the buildup and decay fronts, the repetition periodicity are to be determined by theoreticaly and experimental work. It is also necessary to develop and install the corresponding automatic devices in the transmitters that have already been produced and newly developed.

There is a theoretical possibility of determining the transmission coefficient of the lines and the devices by measuring not the maximum values of the signal, but the residue of the carrier frequency voltage in the intervals (it does not depend on the level of the broadcast programs). This measurement procedure does not require introduction of an automatic device into the transmitter, periodic disconnection of the regulationof the carrier, and it does not lead to an increase in the crosstalk interference.

At the present time the problems connected with the development of the AM signal generator to measure the high quality indexes of the individual channels and the TPV devices have been basically solved. There is a necessity for oscillators of three types:

a) High quality (standard) oscillators for checking the KPU;

b) Oscillators required to organize the production of the receivers and amplifiers;

c) Oscillators designed to check out the fitness and simple repair of the receivers and the DPU at the point of their installation. These instruments have been developed.

The first type includes the modulated attachment, the second type includes the generator and the test signal sensor and the third type, the device for monitoring the UKT channels.

The KPU monitoring device which permits measurement of the quality indexes of the transmitter and subscriber point channel will satisfy the operating needs.

In order to measure the complex resistances of the lines and the devices, the PI-STR, IKS, VIG-3 and UKT instruments are used. The PI-STR and the VIG-3 instruments are stationary. A deficiency of them is the fact that they measure the input impedances only on the carrier frequencies. There is a necessity for developing a stationary instrument which will permit measurement of the resistance in the entire frequency band of the high-frequency channels, which will permit more exact and complete estimation of the quality of processing the TPV networks. A similar goal is being fulfilled by the IKS instrument, but the measurement of the resistances with this help is inconvenient, and errors are possible in the recalculations. The measurement of the resistances by the VIG-3 instrument is much more convenient and more precise. It is expedient to develop a new instrument in which the advantages of the both instruments will be combined. The operative measurements that do not require high precision when processing the lines, when searching for and eliminating failures on the networks are realized by the portable UKT instrument.

The manufactured IPTV-1 fault finder, although basically satisfying the operating needs, still has a deficiency: when finding short circuit points using the search coil, the sensitivity increases with an increase in frequency. This complicates the search for the short circuit points. It is necessary to develop an instrument which will be free of this deficiency. In addition, usually the lineman carries the IPTV-1 instrument and the lineman's indicator with him when searching for the damaged points. It is expedient to combine the functions of a detector and an indicator in the new instrument.

CHAPTER 7. HIGH-FREQUENCY PROCESSING OF THE LINE PART OF A CHANNEL AND HIGH-FREQUENCY LINE DEVICES

7.1. High-Frequency Processing of Lines

In order to create traveling wave conditions in the lines for high-frequency signals and match the individual channel elements (MF [main feeder]-TP [transformer substation], overhead wires and cable, and so on), it is necessary to carry out high-frequency processing of the lines and channel devices from the transmitting station to the subscriber units. It reduces to inclusion of the devices which provide for transmission of all three programs without nonlinear and frequency distortions and with sufficient level at various points of the lines, and which lower the mutual effect between the channels. The quality of processing the lines using high-frequency devices depends on the parameters of the devices themselves and the precision of matching the various sections of the channel. This quality can be determined by measuring the distribution of the voltage levels and the harmonic coefficient on the higher modulating frequencies along the line. This type of operation is difficult; therefore it is possible to determine with sufficient accuracy the degree of matching, measuring the input impedance of the line in the frequency band of each channel, and with respect to the input resistance, the nonlinear distortions. The theoretical calculations and practical measurements have demonstrated that if the modulus of the input impedance on frequencies that are ±4 kilohertz away from the carrier differs from the modulus of the input impedance on the carrier itself by no more than 1.4 times, the phase angle will not exceed 15°, then the harmonic coefficient will be no more than 3%. When these conditions are not satisfied, the matching must be carried out more exactly.

In order to process the distributing and main feeders with leads and cable inserts, passive devices are used which are basically made up of LC-elements. The short feeder leads $\ell_{lead}<\lambda/12\simeq 200$ meters not having oscillatory processes can be connected to the feeder line without matching. When processing the cable inserts two forms of them are distinguished: short and long. The length of the short insert is appreciably less than the wave length $\ell_B\leqslant\lambda/12$. The limiting lengths of the short inserts depend on the type of cabl-. These data are presented in Table 7.1 together with the capacitance on the carrier frequency of 120 kilohertz. For the long cable insert $\ell_B \geq \lambda/12$.

Table 7.1

Type of cable	ℓ_B, meters	C_B, picofarads
PRVPM-1,2	79	7300
PRPPM-1,2	91	6350
MRM-1,2	139	3100

In order to process short inserts, compensation devices of the KU-1 and KU-2 type are used; for processing the longer inserts, the SU type matching devices are used. In order to process the leads, the matching resistance SS and the automatic transformers ATO are used; in order to process the subscriber transformers, bypass devices of the OUA type are used; for processing feeder transformers, a bypass of the OUTP type and also the band-elimination filters ZFR and ZFM; for processing the signal damping monitoring device KRF, the band-elimination filter ZFK; for processing the transformer substation, the UPTP and SUTP devices; in order to connect the transmitters, UPP devices are used. A more detailed description of each device is presented below.

It must be noted that the AM signals, passing through the high-frequency channels, vary both with respect to magnitude and with respect to depth of modulation as a result of nonuniformity of the frequency characteristic of the transmission coefficients of the various devices and sections of the channels. The variation of the depth of modulation leads to the appearance of frequency distortions. The measurements of the frequency distortions on the real channels made up of the transmitter input and the subscriber output demonstrated that they exceed the norms even for exact matching of individual elements. These distortions basically occur in the high-frequency devices for processing the RT network. Thus, for example, the compensation device established for compensating the capacitance of the cable insert at the transformer substation has the input impedance appreciably below the wave impedance in the MF [main feeder] on the side frequencies, which leads to mismatch on these frequencies and to worsening of the nonuniformity of the frequency characteristic of transmission coefficient which in practice can reach 1-2 decibels. The frequency distortions also increase even when using the matching devices as a result of dependence on the frequency of the input resistances of the distributing feeders.

7.2. Bypasses

The low-frequency feeder and subscriber transformers have low resistance load for the high-frequency currents and can introduce the damping for which the high-frequency voltage on the receivers turns out to be below rated. In these cases the bypasses OUA for AT and the OUTP for the feeder are included in parallel to the transformers. The electric circuits of these devices are identical and are distinguished only by the given elements. The OUA circuit is presented in Fig 7.1. This is a step-down high-frequency transformer which jointly with the capacitors C_1-C_4 forms the high-frequency filter with cutoff frequency of 60 kilohertz blocking the path of the sound frequency current. The rated input impedance of the device on frequencies of 68, 88, 110 and 130 kilohertz is no less than 2000 ohms. The measurements demonstrated that the input impedance for high-frequency currents is sufficiently high for resistances of the house networks and subscriber lines equal to 20-100 ohms. The crosstalk between the signals of the different programs at the subscriber transformer is very small and can be neglected. In the majority of cases the rated levels of high-frequency programs at the receiver inputs can be insured also without including the OU [bypass].

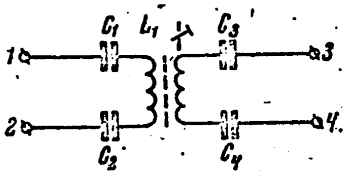


Figure 7.1 OUA bypass

Only for very low input impedance of the house networks where the transmission coefficient of the AT [subscriber transformer] for high-frequency currents drops sharply is the OUA used. The experience in introducing the TPV demonstrated that the number of required OUA-1 (with transformation coefficient 10) does not exceed 20% of the total number of AT. In order to insure high-frequency levels on relatively long subscriber lines, the OUA-2 device with n=3 is used. With a smaller transformation coefficient the damping introduced into the OUA-2 feeder increases and can reach 10 decibels.

The OUTP device enters into the device for connecting the transformer substation and insures transmission of low-frequency current to the distributing network.

Since the resistance of the distributing network is less than the wave impedance of the main feeder, the OUTP must perform the role of the high-frequency matching transformer. The load resistance for which OUTP is calculated is equal to 60 ohms. The transformation coefficient is selected equal to 3 from the condition that the transformer substation supplies 10 distributing feeders with input impedance of each of them equal to 600 ohms. In practice good matching is very difficult to obtain, for the number of feeders can differ from 10 and also as a result of the fact that parallel to the input impedance of each feeder a capacitance of the cable input is connected, and the input impedance of the transformer substation is not purely active. This means that nonlinear distortions appear on the OSh. The measurements demonstrated that on a modulation frequency of 3 kilohertz they can in several cases reach 3%. It must be noted that having only one type of OUTP it is theoretically impossible to obtain constancy of the modulus of the input impedance of the transformer substation, the phase angle of this impedance and the transmission coefficient of the bypass with variation of the modulus of resistance of the load and its phase angle on the carrier frequencies. In order to keep the input impedance constant with a load resistance more than 60 ohms it is necessary to connect the shunting RC-circuit, the resistance of which must be determined by the load resistance.

7.3. Compensators

When crossing highways, railroad lines, electric power transmission lines and in other cases the necessity arises for using cable inserts which create mismatch, and therefore require special processing. A relatively short insert can be considered as a concentrated capacitance between the wires, and on inclusion of the line it can cause reflection of the electromagnetic wave. In order to eliminate the influence of this capacitance, compensation of it is carried out using special devices of the KU type. The capacitance of the insert enters into the composition of the KU. On the carrier frequencies in the KU there is resonance of the currents; its resistance on these frequencies is high, and the effect of the capacitance is decreased significantly. On the side frequencies the resistance of the KU decreases to a value which depends on the value of the L and C circuits. The less the inductance, the worse the quality of compensation in the frequency band of the channel.

The magnitudes of the capacitances of the various types of cable with a length of the cable insert of 50 meters are indicated in Table 7.2.

Table 7.2

Type of cable	MRM-2000-2x1,2	PRPPM-1,2	VTSP-1x4x1,2	PRVPM-1,2
C_k, picofarads	1130	3500	3000	4650

As follows from the table, in the overwhelming majority of cases (excluding the application of PRVPM-1,2) the capacitance of the cable insert 50 meters long does not exceed 4000 picofarads; therefore the parameters of the devices are selected so that it will be possible to compensate for this capacitance. In practice three types of devices are used.

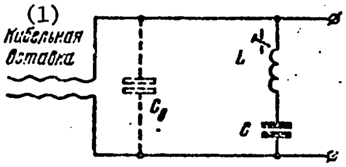


Figure 7.2. KU-1 compensation circuit

Key:

1. cable insert

The KU-1 (the inductance is included with respect to the parallel circuit) is presented in Fig 7.2. The magnitude of the inductance L is selected so that with a capacitance of the insert (C_B) it makes up a circuit tuned to the average frequency of 95 kilohertz between the two carrier frequencies. The resistance at the point of connecting the coil increases, which is equivalent to a decrease in the effect of the insert. The KU-1 can compensate the capacitance to 2000 picofarads; therefore its application is limited. The KU-2 device (inductance included by a series circuit) is presented in Fig 7.3. It is used to compensate the capacitance of the cable input by a value to 3000 picofarads at the transformer substation. In this case the inductance together with the capacitance of the insert and the same value of the additional capacitance form a low-frequency filter with a cutoff frequency of no less than 130 kilohertz. The capacitance of the insert becomes an element of the filter decreasing the effect of the insert. The KU-3 device is presented in Fig 7.3. The KU-3 for the main feeder and the distributing feeder are identical with respect to circuitry and they are distinguished by the operating voltage of the capacitors: in the KU-3M it is 2500 volts, in the KU-3R, 500 volts. The KU-3 together with the compensating capacitance forms a 5-element reactive two-terminal network. The elements of its circuit are calculated so that they can compensate for 78 and 120 kilohertz capacitance of the cable if it is 4000 picofarads. If the capacitance is less, in order to avoid tuning the circuit, an additional capacitance is connected parallel to the insert which together with the capacitance of the cable gives a total of 4000 picofarads. This capacitance is selected on location when processing the cable insert. For compensation of a capacitance of greater magnitude, for example, to 8000 picofarads, the resistance of KU-3 on the side frequencies will become commensurate with the wave impedance of the overhead line, that is, on side frequencies there will be no traveling wave mode. This leads to nonlinear distortions of the envelope of the AM signal. It is impossible to compensate for greater capacitance by using a device of this type.

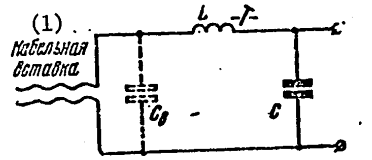


Figure 7.3. KU-2 compensator

Key:
1. cable insert

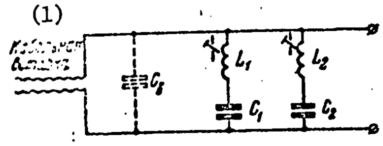


Figure 7.4. KU-3 compensator

Key:
1. cable insert

Inasmuch as according to the norms the harmonic coefficient of the envelope of the AM signal caused by the frequency distortions in the line must not exceed 3% in the distributing feeder and 1% in the main feeder, the device itself must not introduce distortions of more than 1%. The current resonances in the KU coincide with the value of the carrier frequencies. The resistances on the side frequencies must be no less than the value for which the distortions will be within the limits of the given norms. Practice has demonstrated that they do not exceed the admissible values for the following normalized resistances: on the carrier frequency the input impedance of the KU must be no less than 5000 ohms; on frequencies of 83 and 115 kilohertz, 1100 ohms; on a frequency of 125 kilohertz, no less than 1600 ohms.

The crosstalk from the low-frequency program on the low-frequency channel created by the device must be no more than -70 decibels.

7.4. Matching Devices

The cable inserts more than 50 meters long cannot be considered as concentrated capacitances: they are segments of a long line with distributed parameters. In order to eliminate the reflection of the electromagnetic wave at the joints of the overhead and cable sections of the line matching devices are installed SU.

The matching of the cable insert to the overhead line in the broad frequency spectrum causes difficulties inasmuch as the wave impedance of the cable in the sound frequency spectrum is appreciably higher than on high frequency; the matching transformer must be designed for a low-frequency signal power and to transmit frequencies from 50 hertz to 13 kilohertz, and no spurious modulation of the current frequencies by the low-frequency program currents must occur in it. It is in practice inexpedient to manufacture such a transformer, and the matching must be done using matching devices. The cable inserts of greater extent are processed by including the SU on both sides. The sonic frequency currents run through the device without transformation, and the transformation coefficient with respect to high frequency is selected depending on the input impedance of the cable insert:

$$n = \sqrt{\frac{Z_{\text{МФ}}}{Z_{\text{кл}}}}.$$

The inserts can be made of cable of different types having different wave impedances. Table 7.3 gives the parameters of the cables in the range of 78-120 kilohertz.

Considering the fact that the inserts can be made of cable of four (basic) types and the overhead lines of wires made of bimetal and steel and also the fact that for the main feeder and the distributing feeders the SU devices must be different as a result of different values of the rated voltages, the number of SU must be equal to 16. However, it is inexpedient to produce this number of types; it is admissible to limit ourselves to four: SU-1 for the main feeder and distributing feeder and SU-2 also for two types of feeders. The SU-1 device is presented in Fig 7.5.

Table 7.3

Type of cable	MRM	VTSP	PRPPM	MPVG-1000	ORG-3000
Z, ohms	207	150	105	108	54

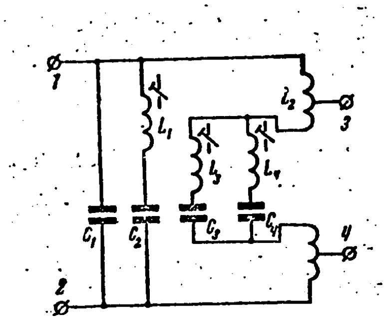


Figure 7.5. SU-1 matching device

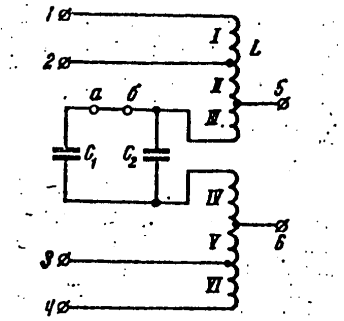


Figure 7.6. SU-2 matching device

The matching element here is an overhead automatic transformer L_2. In order that the automatic transformer be able to operate normally, its high frequency circuit must be closed. However, it is impossible to short the center leads of the ends of the coil, for in this case it will be closed with respect to frequency. Therefore two series resonances L_3C_3 and L_4C_4 circuits are connected to the central leads of the coil having low resistance and carrier frequencies. The coil L_2 together with the C_1, C_2 and L_1 elements is tuned to frequencies of 78 and 120 kilohertz. The device simultaneously compensates for the capacitance of the cable insert. The SU-1 also, just as the KU, has reduced resistance on the side frequencies. If we consider that the SU must be included at the input and the output of the insert, then the shunting effect of it on the side frequencies will double. This leads to the appearance of nonlinear distortions (K_Γ). If in the transformer L_2 we make four pairs of symmetric leads at 50, 100, 150 and 200 ohms, in this case better matching is achieved and the harmonic coefficient K_Γ decreases. The SU-2 device (Fig 7.6) must not be universal, just as the SU-1 with leads, for on variation of the resistance of the inserts not only must the transformation coefficient vary, but also values of L and C. Therefore SU-2 is a wide band device and is designed only for matching the main feeder or the distributing feeder made of steel or bimetal and the cable inserts, made of the MRM type cable.

A steel overhead line is connected to the terminals 1-4; a bimetal line is connected to the terminals 2-3; the MRM cable is connected to the terminals 5-6. The matched rated wave impedances are as follows: for the steel overhead line 750 ohms; for the bimetal 500 ohms; for the MRM cable, 210 ohms.

When matching the wave impedances of 500 and 210 ohms, only the capacitor C_2 is included; when matching 750 and 210 ohms, the jumper a-b is installed and both capacitors C_1 and C_2 are used. The rated input impedance of the device in the "steel" mode at frequencies of 68, 88, 110 and 130 kilohertz is 770±70 ohms; the transmission coefficient is 0.53. Correspondingly, in the bimetal mode we have 560±70 ohms and 0.61. The nonlinear distortions with respect to the envelope in the SU amount to no more than 0.8%, and the cross-talk from the direction of the low frequency program on the high-frequency channels, no more than 70 decibels.

The feeder leads more than 250 meters long are connected to the autotransformer of the ATO type lead. In accordance with the transmission coefficient of the ATO, the voltage at the lead is somewhat reduced; therefore it is possible to use it only in the case where the voltage of the end of the lead remains sufficient with respect to magnitude. If the voltage is small, it is necessary either to increase it at the input of the distributing feeder or to use the DPU. The traveling wave mode must be insured both in the basic direction of the distributing feeder and at each lead connected to it. For this purpose at the end of the feeder leads a matching impedance is included equal to the mean arithmetic equivalent wave impedances:

$$R = \frac{Z_{\text{эв}\,78} + Z_{\text{эв}\,120}}{2}.$$

In order that the low-frequency currents not flow through this resistance a capacitor is included in series with it (Fig 7.7). The dissipation power of the resistance is determined by the maximum possible voltages of the two carrier frequencies at the end of the line, and the operating voltage of the capacitor, by the peak value of the rated low-frequency voltage in the distributing feeder, that is, with a low-frequency voltage equal to 240 volts, the operating voltage is 340 volts; with a voltage equal to 120 volts, the capacitor must be selected for a voltage of 170 volts.

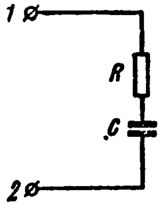


Figure 7.7. Matching resistance

With direct connection of the matching feeder lead to the basic direction of the distributing feeder, the matching is disturbed in the basic direction. Therefore the lead must be connected through the ATO which steps up its input impedance to the value, the shunting effect of which in the low-frequency band can be neglected. The connection of several leads to the distributing feeders can create a high load which leads to a reduction in the levels of the high-frequency signals in the RF [distributing feeder] section at the points of connecting leads and after them. If the feeder lead has its own lead, it connection to the first lead is inadmissible even through the ATO, for between the distributing feeder and the second lead the high-frequency signals will pass through two devices stepping down the high-frequency voltage. In such cases it is necessary to redesign this section of the network. The ATO circuit is presented in Fig 7.8. The automatic lead transformer was made in accordance with the resonance circuit and in practice has no influence on the transmission of the sound frequency currents. This is a four-terminal network which is an autotransformer on high frequencies. The transmission coefficient of the ATO on frequencies of 68, 88, 110 and 130 kilohertz is 0.44; the input impedance is 2000 ohms. In practice for an input impedance of the feeder lead equal to 600 ohms, the input impedance of the ATO with the lead is about 2500 ohms, which corresponds to the minimum input impedance of the loaded subscriber transformer. The transformation coefficient with respect to high frequency is selected calculating that at the end of the lead the voltage level will be no less than 3 volts. The crosstalk interference from the low-frequency program on the high-frequency channels in the ATO is negligibly small.

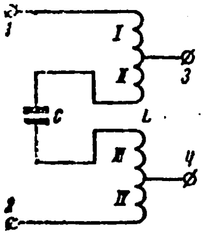


Figure 7.8. Automatic lead transformer

7.5. Band-Elimination Devices

The band-elimination devices include the band-elimination filters which prevent the transmission of the currents of high-frequency programs to the TPV network elements in which crosstalk interference could be formed between programs. The ZFM filters enter into the composition of the devices for connecting the transformer substations from the main feeder side and the ZFR filters, from the distributing network side. They prevent the penetration of the high-frequency signals into the windings of the feeder transformer. The filter diagram is presented in Fig 7.9. In order to eliminate the effect of the KRF device, the ZFK filter is included in front of it. In the KRF boxes there are detecting circuits which can create significant crosstalk. The ZFK does not transmit the high-frequency signals to the input of the box. The ZFZ filter is installed at the transformer substation at the input of the outdoor public address feeder; its load is the powerful loudspeakers fed by the currents of the low-frequency program. In order that the public address feeder not create additional load for the high-frequency currents, it is connected to the common buses of the transformer substations through a filter.

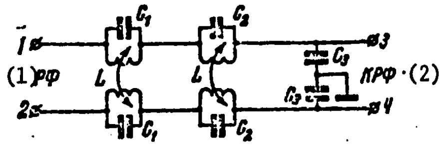


Figure 7.9. Band-elimination filters

Key:
1. Distributing feeder
2. KRF

In order to limit the range of the low-frequency programs, the ZFO restriction filters are installed on the distributing feeders. This is necessary in cases where the damping at the end of the feeder exceeds the admissible norm, and the installation of an intermediate amplifier is inexpedient. The inclusion of this filter makes it possible to increase the voltage of the high-frequency programs before the filter and, therefore, the effective operating length of the line increases.

All of the indicated filters are identical with respect to electric circuitry.

The normalized resistance at the input terminals of the band-elimination filters is as follows: on carrier frequencies 8000 ohms; on side frequencies 72, 84, 114 and 126 kilohertz, 2500 ohms.

7.6. Devices for Connecting Transmitters

The outputs of the low-frequency amplifier and the two high-frequency transmitters must be connected to a common load -- the wire broadcast network. The addition of low frequency and high-frequency signals on a common load must be realized so that the energy losses of the signals of each channel will be minimal. In addition, mutual influence between the channels must be excluded. These functions are performed by the UPP transmitter connection circuits. The UPP-1 circuit diagram is presented in Fig 7.10. It is used for connecting one main feeder. In the case of supplying several main feeders the inputs of the UPP are connected to the signal source in parallel. The UPP has three inputs: 1-2 for supplying program I; 3-7 for supplying program II; and 4-7 for supplying program III; 5-6 -- the output of the device, to which the PV [wire broadcast] is connected. The high-frequency programs are fed to the feeder lines through a common high-frequency transformer L_1, L_2 with transformation coefficient n=1:1 or n=1:3. The inductance L_1 enters into the circuit tuned to the carrier frequencies of 78 and 120 kilohertz, which is insured by the circuit having resonance on both carriers for each transmitter. Inasmuch as the output impedance of the transmitter is small for the currents of another program and the resistance of the capacitors C_4 and C_5 is small, the program II transmitter turns out to be loaded on the $L_1C_3C_6$ circuit tuned to its carrier. The transmitter of

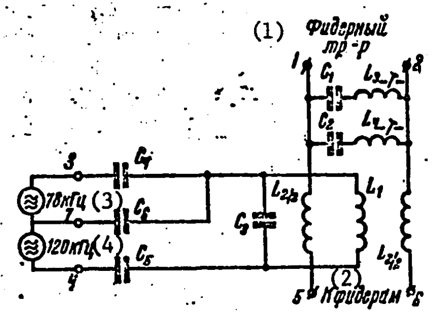


Figure 7.10. UPP-1 transmitter connecting device

Key:
1. Feeder transformer
2. to the feeders
3. 78 kilohertz
4. 120 kilohertz

program III is loaded on the L_1C_3 circuit tuned to its carrier. The inductance L_2 is divided into two equal parts included in the wires of the output circuit. If the load of the UPP is connected through the cable input, then its capacitance can be compensated by a decrease in capacitor C_3. The series resonance circuits L_3C_1 and L_4C_2 tuned to 78 and 120 kilohertz prevent the occurrence of crosstalk in the low-frequency amplifier and energy losses of the signals of the high-frequency programs in the winding of the feeder transformer. In order to decrease the mutual modulation the transmitters are specially connected. The output transformer of each transmitter has two secondary windings, to each of which the load is connected. The windings are connected in counterseries to each other so that the current of the other transmitter on passing through these windings will create mutually compensating magnetic fields in the tape recorder of the output transformer, that is, no voltage drop summed for these windings will occur, and the transmitters will not influence each other. The UPP device with transformation coefficient of n=1:1 has the following parameters: resistance on the carriers of 480 ohms; on the side frequencies it is reduced to 370 ohms; the transmission coefficient is equal to 0.95, the output voltage is 120 volts. Only one feeder can be connected to the device. The damping introduced by the UPP is 1.5 decibels. The UPP with n=3:1 has the following parameters: resistance on the carrier frequencies of 400 ohms; on the side frequencies, 280 ohms. The transmission coefficient 0.37, output voltage 35 volts, that is, up to 10 feeders can be connected to it.

In practice with joint operation of the UPTV-200 transmitters on common load there is mutual influence and the harmonic coefficient of the envelope can reach 3 to 5%, and the crosstalk interference will increase to -50 decibels.

The mutual effect is caused basically by the transmission of part of the circuit current of the UPP through the transmitter of the adjacent channel.

In addition, the device increases the amount of high-frequency radiation as a result of asymmetry with respect to voltage relative to ground. It has a relatively low efficiency, insufficient amount of suppression of the high order harmonics occurring in the powerful low-frequency amplifier and falling in the frequency band of the high-frequency channels.

The UPP-2 device has higher quality indexes and will permit more efficient use of the transmitter power. It is a six-terminal network in which the addition of the signals of the low-frequency amplifier and the transmitters takes place by the scheme in Fig 7.11. The overhead lines are connected to the UPP-2 by the cable input, the capacitive resistance of which is compensated by the elements of the device. The electric circuit diagram of the UPP-2 is presented in Fig 7.12. The main element of the circuit is the four-element loop with resonance frequencies of 78 and 120 kilohertz which does not load the transmitter with the reactive component of the current on the carriers. The resonances are determined by the inductance of the winding 3-6 of the transformer Tp_1 and the elements C_{44}-C_{53}, L_6, C_{54}-C_{56}. The capacitance of the cable input recalculated for this winding Tp_1 is compensated by the loop. The parallel capacitance of the loop is made in the form of a battery of capacitors, which makes it possible to compensate for any capacitance from 0 to 5600 picofarads. The four-terminal network included between the points 2-7 of the Tp_1 and the terminals 1-2 to which the feeder transformer is connected (FT), eliminates its influence, prevents nonlinear interaction of the signals of the three programs in the FT and suppresses the products of nonlinearity of the powerful low-frequency amplifier.

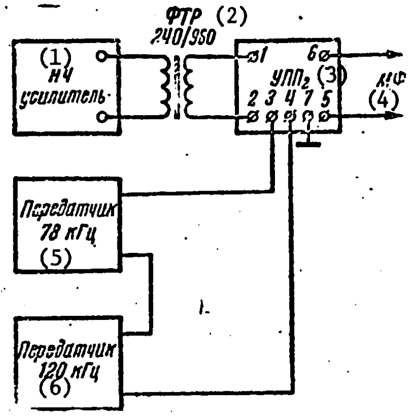


Figure 7.11. Circuit diagram of the transmitters and low-frequency amplifier

Key:

1. Low-frequency amplifier	5. 78 kilohertz transmitter
2. FTR 240/960 transformer	6. 120 kilohertz transmitter
3. UPP_2 transmitter connection device	
4. Main feeder	

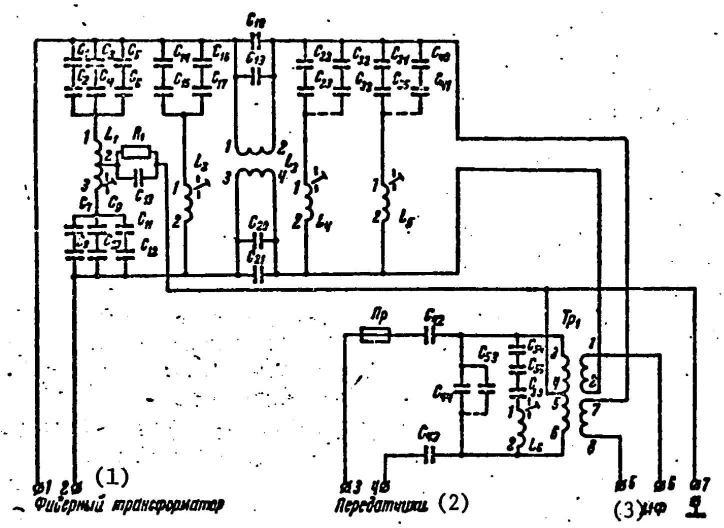


Figure 7.12. Schematic circuit diagram of the UPP-2

Key:
1. Feeder transformer
2. Transmitter
3. Main feeder

The series $L_4C_{22}-C_{33}$ and $L_5C_{34}-C_{41}$ circuits have very low resistance on the frequencies of the high-frequency channels; the high-frequency currents of the useful signal flow through them and the load. The dissipation inductance of the Tp_1 is compensated by tuning these circuits to frequencies of 84 and 124 kilohertz. In order to suppress the harmonics from the low-frequency amplifiers in the frequency bands of 68-88 and 110-130 kilohertz, the parallel $L_3C_{18}-C_{21}$ circuit and series $L_1C_1-C_{12}$ and $L_2C_{14}-C_{17}$ circuits are used.

As a result of the spurious capacitances of the windings of the feeder transformer FT, asymmetry of the circuit occurs. The grounding of the midpoints of the coil L_1 through the capacitor C_{13} and the windings 3-6 of Tp_1 made it possible significantly to decrease the asymmetry of the circuit from the direction of the terminal 5-6 on frequencies of 150-600 kilohertz and to reduce the emission of the carrier frequency harmonics. The capacitors $C_{42}C_{43}$ decrease the magnitude of the current of the low-frequency channel flowing through the transmitters.

The parameters of the device are the following: input impedance on carrier frequencies 500 ohms, input impedance under complex load in the frequency band of 68-88 and 110-130 kilohertz, 250 ohms, asymmetry with respect to "ground" on the carrier frequencies 5%; in the frequency band of 150-600 kilohertz 20%; the harmonic coefficient of the envelope 0.5%, the suppression of the nonlinearity products of the low-frequency amplifier 38 decibels, the crosstalk from the low-frequency channel 74 decibels.

7.7. Transformer Substation Switching Devices

The carrier voltages on the common buses of the transformer substations must be 20 to 30 volts. Great attenuation on these frequencies in the feeder transformer does not permit us to obtain the required voltage. In addition, in the feeder transformer between the high-frequency and low-frequency programs crosstalk occurs. Therefore, for transmission of high-frequency programs from the main feeder to the distributing network to the bypass of the feeder transformer special connection devices are included which match the input impedance of the distributing network to the wave impedance of the main feeder. The application of several types of connecting devices is possible: UPTP-1, SUTP-2, SUTP-3, UPTP-3.

A diagram of the UPTP-1 is presented in Fig 7.13. The high-frequency currents do not run to the feeder transformer as a result of inclusion of the ZFM and ZFR band-elimination filters in the circuit. These themselves partially exclude the spurious modulation of the carrier frequencies by the low-frequency program currents. The circuit includes the OUTP bypass, but it does not insure complete matching inasmuch as it is loaded on the inconstant magnitude of the resistance between the TP [transformer substation] buses. Distortions of the envelope occur at the OSh which can reach 4%. When installing a device of this type significant level gradient of the high-frequency programs is possible, and also its properties depend on the polarity of the inclusion of the feeder transformer. The indicated deficiencies limit the application of the UPTP-1.

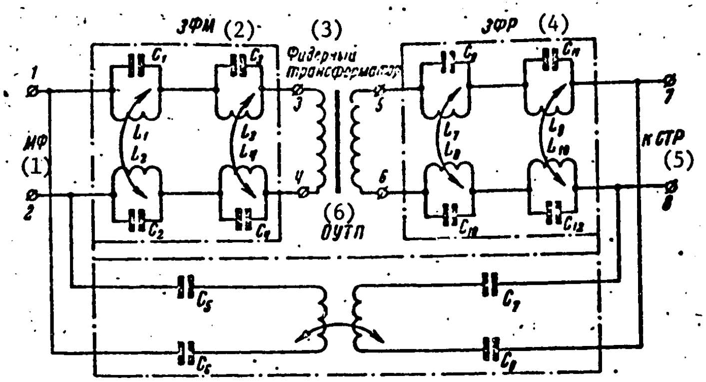


Figure 7.13. UPTP-1 device for connecting the transformer substation

Key:
1. Main feeder
2. ZFM
3. Feeder transformer
4. ZFR
5. To the STR
6. OUTP

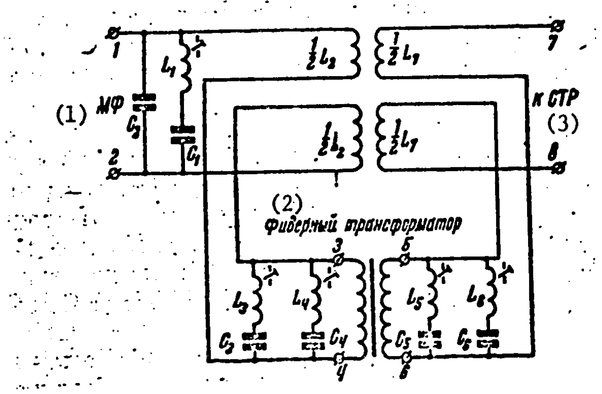


Figure 7.14. SUTP-2 transformer substation matching circuit

Key:
1. Main feeder
2. Feeder transformer
3. To the STR

The circuit diagram of the second SUTP-2 device is presented in Fig 7.14.

In order to transmit high-frequency voltages a resonance high-frequency transformer is used, the windings of which are included in series with the windings of the feeder transformer. The latter turns out to be shunted by the LC circuits tuned to the carrier frequencies. As a result of this, more complete matching of the main feeder regime is insured. The inclusion of the SUTP-2 makes it possible also to compensate for the capacitance of the cable input to a value of 4000 picofarads. However, the transmission coefficient and input impedance of the device also depend on the load. The SUTP-3 device presented in the circuit in Fig 7.15 is recommended for use in the case of feeding the main feeder of several transformer substations. The operation of the circuit is analogous to the above-described device and has the same advantages and disadvantages. If each of the several transformer substations fed from one main feeder is connected to it through the UPTP-1 or the SUTP-2 devices, disturbance of the matched regime of the feeder takes place, for each section of it, in addition to the latter, turns out to be loaded on two parallel connected loads: the transformer substation and the subsequent section of the main feeder. This common load differs from the wave impedance, which leads to the appearance of standing waves in the main feeder. As a result of the application of the SUTP-3 device the section of the main feeder turns out to be matched.

The UPTP-3, the circuit diagram of which is presented in Fig 7.16 is more improved. Here the feeder transformer is included in series with the high-frequency transformers L_2L_7. The primary winding of the transformer L_2 together with the C_2, L_1 and C_1 elements forms a circuit having current resonances on the carrier frequencies. The magnitude of the capacitance C_2 is selected equal to 4000 picofarads. Since it includes the capacitance of the feeder $C_{\text{main feeder}}$ and the recalculated total capacitance of the inputs of the distributing feeders $C_{\text{distributing feeder}}$, the capacitor C_k included between the terminals 1-2 must have a capacitance of $C_k=4000-(C_{\text{main feeder}}+C_{\text{distributing feeder}})$, that is, this device solves the problem of compensating the capacitance of the inputs. For equality of the capacitance of the main feeder and the distributing feeder the maximum capacitance of the input which can be compensated is 2000 picofarads.

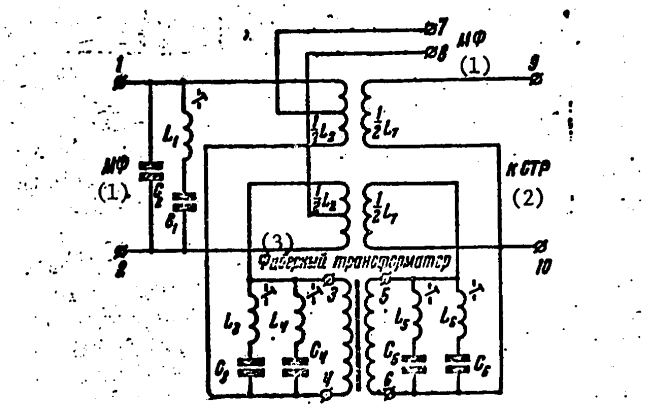


Figure 7.15. SUTP-3 transformer substation matching circuit

Key:

1. Main feeder
2. To the STR
3. Feeder transformer

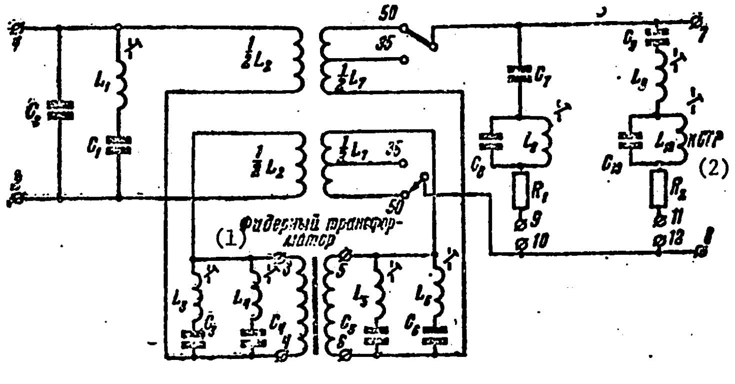


Figure 7.16. UPTP-3 device for connecting the transformer substation

Key:

1. Feeder transformer
2. To STR

The ST [feeder transformer] bypass is insured by resonance shunting circuits for the main L_3C_3 element; L_4C_4 and for the distributing element L_5C_5; L_6C_6. For reduction of the high-frequency transformer to some constant value, the circuits are used for reduction of the TsPN78 load (R_1, L_8, C_7, C_8) and TsPN120 load (R_2, L_9, L_{10}, C_9, C_{10}). In the frequency band of its own channel each of them has a resistance of about 50 ohms, and in the band of the adjacent channel, the very high resistance. The load of the high-frequency transformer for the carriers is determined by three parallel-included resistances: the common resistance of the RF, the total capacitive resistance of the cable inputs of the RF and the series-connected resistance of the reduction circuit and some calculated resistance Z_x. The capacitive resistance is compensated by the corresponding decrease in the capacitance C_2. The remaining resistances taken together must equal a defined value in order that the input impedance of the loaded UPTP be 600 ohms. The total resistance of the RF [distributing feeder] depends on the number and the input impedance of each of them. It is different for 78 and 120 kilohertz. The total resistance of the reduction circuit and Z_x for each TP [transformer substation] and each carrier is calculated so that it together with the complex resistance of the actual load will make up an active resistance of 50 or 35 ohms. For this purpose, the resistances Z_x are included between the terminals 9-10 and 11-12, the magnitude of which is calculated by formulas. For reduction to 50 ohms $Z_x=2500/(Z_{osh}-50)$. For reduction to 35 ohms, $Z_x=(117-Z_{osh})/(Z_{osh}-35)$ times 15, where Z_{osh} is the total load resistance on the common buses of the transformer substation. The reduction to a value of 35 ohms is used in the case of a large number of distributing feeders and low input impedances (as a result of high density of the distributed load) where the reduction to a value of 50 ohms turns out to be insufficient. In order to insure constancy of the input impedance of the loaded UPTP in both cases the secondary winding of the transformer L7 has leads.

The device has the following parameters: the input impedance on carrier frequencies of 600 ohms, on side 68 and 110 kilohertz no less than 460 ohms; on 88 and 130 kilohertz no more than 820 ohms; the transmission coefficient under load at 50 ohms of 3.6 with load at 35 ohms, 4.55; the harmonic coefficient caused by the envelope distortions does not exceed 1.0% when operating on the rigid load of 50 ohms and on the complex load reduced to rated by means of the TsPN circuit.

CHAPTER 8. TUNING AND MEASURING THE PARAMETERS OF THE DEVICES, THE LINES AND THE CHANNELS FOR THREE-PROGRAM WIRE BROADCASTING

8.1. General Information

All of the TPV station devices come from the plant tuned. Before putting them into operation they must be checked for correspondence to the technical specifications, that is, it is necessary to carry out the acceptance testing. In addition, in the operating process it is necessary to perform the measurements after repairing the equipment, periodic, operative (monitoring), emergency, when processing the lines, when detecting the damage points, and so on. The periodic operating measurements of the basic quality indexes of the high-frequency channels and all the devices (except the GT) must be made no less than once a year. It is mandatory to perform the measurements after repairing the equipment and line structures. The basic quality indexes to be measured must include the following: sensitivity, output power, frequency characteristics, harmonic coefficient, crosstalk between channels, ratio of the signal voltage to the background and noise voltage.

The measurements on the linear part of the channel include also measurement of the carrier frequency voltages in different sections, the recording of the level diagram on the distributing feeders, measurement of the total input resistances on the main feeder, at the transformer substation, the distributing feeders and the three-pair GPTP networks. Such indexes as the input impedances of the devices and improvement of the output level of the voltage on disconnecting the load in the transmitters, the DPU and GPTV must not be measured, for they are caused by an electric circuit.

Measurements are taken when processing the lines: voltages at various points of the channel, wave impedances and capacitances of the cable inserts and inputs. The high-frequency devices are tuned directly under actual operating conditions.

When checking the correspondence of the electrical variables of the devices and channels to the norms at the given time, periodic tests are run. They include the following: measurements of electric variables of the transmitters, the DPU, GT, GPTV, measurements of the quality indexes of parts of the channel made up of the transmitter input and the actual transmitter load (UPP input), the transmitter input and the transformer substation (the common STR buses), the transmitter input and the subscriber radio point of the network fed from the GPTV.

The operative measurements are taken by the operating personnel in order to check the operating conditions of the devices and the channels of the TPV system. They included the following: monitoring the transmitter loads, monitoring the voltages of the high-frequency programs at the transformer substations, monitoring the modules of input resistances of the main feeder and the distributing feeders on the carrier frequencies.

The emergency measurements are taken in order to determine the nature and the place of the damage in the devices and the channels of the system.

A procedure is presented below for taking the measurements and methods are given to eliminate some of the failures of the TPV equipment. Inasmuch as the tuning of the transmitters, receivers and DPU is carried out by the instructions presented for them, it is inexpedient to present the tuning procedure here. At the same time, a series of high-frequency devices can be made locally and tuned directly during processing of the networks; therefore, a brief procedure for tuning them is presented. In the book methods are given for taking electrical measurements on the line part of the TPV channels and also measurements of the quality indexes of the high-frequency channels and sections of them. For the measurements on the TPV networks introduced into operation, it is necessary to reduce as much as possible the level and feed time of the measurement signals inasmuch as they can be heard by the subscriber. It is necessary to check out the tested section in advance on a frequency of 100 hertz weakly perceptible here and with low signal level.

It must be noted that none of the industrially manufactured generators of standard signals can be used during the measurements as the source of AM signals, for they have increased harmonic coefficient, increased frequency distortions, AC current background and insufficient accuracy of setting the frequency. Therefore it is necessary to use the TPV transmitter, modulation attachment or tested signal pickup as the signal source.

In order to decrease the errors in measuring the voltages of the high-frequency channels it is necessary to read the measured variables by the voltmeters and level indicators in the righthand side of the scale.

8.2. Electrical Measurements of the Transmitters

The procedure for tuning the UPTV-200 is indicated in the "instructions for tuning and adjusting the UPTV-200" [20], but the acquired experience makes it possible to present it in improved form.

1. Before feeding a signal to the input, the RU regulator must be set to the maximum position, and the "depth of modulation" and "control signal"

regulators, to the middle position. The "carrier suppression" regulator is used to take the carrier suppression and the "high-frequency level" regulator to set the output voltage $U_{out\ 1}$=105 volts. Then the "carrier suppression" regulator is used to set the output voltage of the carrier frequency $U_{out\ 2}$=12 v.

2. The signal with a frequency of 1000 hertz and voltage of $U_{inp\ 1}$=0.78 is fed to the input. The "control signal" regulator is set to the position close to maximum. The "stepped modulation" regulator is used to set the modulation coefficient m=70%. Here the output voltage of the carrier frequency must be equal to $U_{out\ 3}$=120 volts.

For more accurate tuning after item 1 of this section it is necessary to send the signal to the input of the transmitter with a frequency of 1000 hertz and a voltage of $U_{inp\ 2}$=0.4 volts (-6 decibels). The "controlling signal" and "stepped modulation" regulators are used to set the output voltage of $U_{out\ 4}$=105 volts with a modulation depth of m=40%. Then it is necessary to perform the measurements in accordance with item 2.

The output voltage of the carrier frequency can be measured also in the "high-frequency monitoring" jack of the powerful module.

The methods of measuring the electrical characteristics are presented for the UPTV-200 transmitter, but in the majority of cases they are also applicable to the UPTV-60 and UPTV-400 transmitters.

The transmitter measurements are taken by the circuit presented in Fig 8.1 at one of two outputs (points 1-2, 3-4). The load resistors R_1 and R_2 of 144 ohms each are made of wire or tape with high resistance.

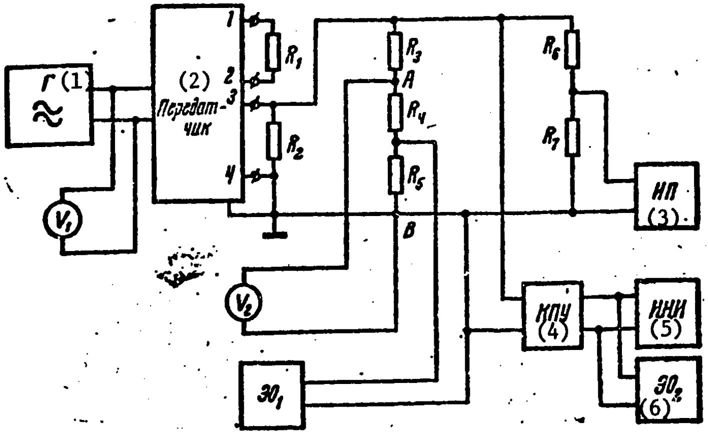


Figure 8.1. UPTV-200 transmitter measurement circuit

Key:
1. oscillator; 2. transmitter; 3. IP; 4. KPU; 5. INI; 6. oscillograph

The voltmeter V_2 which controls the output voltage is connected through a divider to the points A and B to obtain the reading in the righthand side of the scale. The potential end of the voltmeter is connected to the point A; the screen is connected to the point B. The data from the divider resistors are as follows: R_3=6470 ohms, wattage 6 watts; R_4=430 ohms, 0.5 watts; R_5=100 ohms, 0.5 watts.

The resistors R_6=20 kilohms, 2 watts and R_7=150 ohms, 0.25 watts form the divider for connecting the interference meter.

The depth of modulation is established using the EO-1 oscillograph connected to the voltage divider $R_3R_4R_5$. A voltmeter which reacts to the mean value of the measured voltage (or KPU) must be used as the instrument V_2. When measuring the voltage of the AM oscillations, the voltmeter readings depend on the nature of the measured voltage. The mean peak and operating values of the AM voltages are equal to the following respectively:

$$V_{\underset{(1)}{\text{ср}}} = V_{\underset{(2)}{\text{ср. нес}}}; \quad V_{\underset{(3)}{\text{а}}} = V_{\underset{(4)}{\text{а. нес}}}(1+m);$$
$$V_{\underset{(5)}{\text{д}}} = V_{\underset{(6)}{\text{д. нес}}}\sqrt{1+m^2/2}.$$

Key: 1. mean; 2. mean carrier; 3. peak; 4. peak carrier; 5. effective; 6. effective carrier

From the formulas it follows that in order to determine the voltage of the carrier by the voltmeter readings it is necessary to know the depth of modulation exactly. This fact excludes the application of the voltmeters of peak and effective values for measuring the effective value of the carrier frequency voltage with variable level, for there are no instruments for exact measurement of the depth of modulation in the TPV system. The mean value of the AM voltage is equal to the mean value of the carrier frequency and does not depend on the depth of modulation (for $m<1$). The voltmeter which reacts to the mean value of the measured voltage and is calibrated in effective values of the sinusoidal voltage, indicates the effective value of the carrier frequency voltage on feeding the AM voltage to its input. The most widespread voltages, for example, V3-13, are close to the mean value voltmeters, although this is not stipulated in the technical specifications. Therefore, before using the electronic voltmeter in the transmitter measurements it is necessary to be convinced that the given voltmeter does not react to the presence of modulation and its depth. The voltmeter tests are run using the modulation attachment MP. The effective value of the carrier voltage at the output of the MP does not depend on the presence or depth of modulation. The carrier frequency is selected equal to 120 kilohertz, the modulating frequency is selected at 6 kilohertz, m=70%. The voltmeter connected to the measurement scale 3V, is connected to the output of the MP. The output voltage switch of the attachment is set to the position 4 B. The continuous output voltage regulator of the MP is used to set a voltage equal to 2.9 volts according to the voltmeter scale. Then the step attenuator of the low-frequency oscillator is used to reduce its output voltage by 30 decibels and the voltage U_1 is read according to the tested voltmeter. If the condition

$((2.9-U_1)/2.9)100 \leqslant 3\%$ is satisfied, the voltmeter is suitable for measuring the effective value of the carrier voltage of the AM oscillations. The analogous tests are performed when setting voltages of 1.0 and 1.5 volts on the same scale of the voltmeter. The output voltage of the transmitter $U_{out}=KU_2$, where $K=\frac{R_3+R_4+R_5}{R_4+R_5}=13{,}2,$

that is, $U_{out}=13.2\ U_2$.

During the test process it is necessary to monitor the anode current of the output stage of the transmitter, comparing it with the rated value. For all of the measurements, with the exception of checking for the output power and sensitivity, the operative level regulator RU must be in the 0 decibel position, and the "depth of modulation" regulator in the position corresponding to the rated output voltage of the transmitter at 120 volts with output of a rated voltage of 0.775 volts with a frequency of 1000 hertz to its input.

In order to measure the regulating characteristic, the signal with a frequency of 1000 hertz is fed to the transmitter input and the values of 0, 0.01, 0.05, 0.1, 0.2 and so on to 1.1 of the rated value of the input voltage are set successively. The readings of the voltmeter V_2 are picked up in this case. It is expedient to construct the adjustment characteristic on a logarithmic scale, taking the rated value of the input and output voltages as 0 decibels.

The magnitude of the output voltage of the carrier in the absence of a signal at the transmitter input determines the depth of regulation of the carrier:

$$\underset{(1)}{\Pi_{\text{рег}}}=20\lg\frac{U_{1\text{вых}}^{(2)}}{U_{\text{п}\,(3)}},\ \text{decibels,}$$

Key: 1. reg; 2. 1 out; 3. interval

where $U_{1\ out}$ is the output voltage corresponding to the rated voltage; $U_{transmitter}$ is the output voltage in the absence of a modulating signal at the transmitter input, that is, in the transmission interval.

If the regulation characteristic does not correspond to the normalized values, then it is necessary to correct it using the "carrier suppression" and "control signal" regulators. For this purpose in the absence of a low-frequency voltage at the transmitter input it is necessary to set the "carrier suppression" regulator to the position in which the carrier voltage is 0.1 of the rated value. Then a 1000 hertz voltage equal to half the rated value, that is, about 0.4 volts, is fed to the transmitter input, and the "control signal" regulator is fed to the position in which the rated value of the carrier frequency voltage will appear at the output of the transmitter.

In order to determine the sensitivity and the output power, the operative level regulator RU must be set to the 0 decibel position, and the "depth of modulation" regular, to the position corresponding to the maximum sensitivity.

A signal with a frequency of 1000 hertz, m=70% of the value such that the rated output voltage will be set at its output, is fed to the input of the transmitter. Using the input attenuator and the sensitivity regulator of the KVU instrument, a rated voltage is set at its output, and the harmonic coefficient is measured. The magnitude of the input voltage for this measurement corresponds to the sensitivity with respect to the low-frequency input of the transmitter. If the sensitivity is below the norm, it must be regulated using the adjustable regulator, and if necessary, the tubes in the modulator must be replaced.

If the output power does not correspond to the norm, then it is necessary to check the operating conditions of the tubes and replace them if necessary.

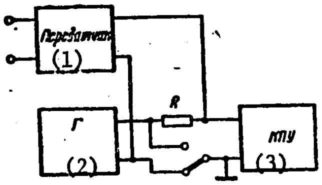


Figure 8.2. Measuring the modulus of output impedance of the transmitter

Key:
1. transmitter
2. oscillator
3. KPU

The modulus of the total output resistance of the transmitter for the signals of the adjacent high-frequencing channel is measured in accordance with the schematic in Fig 8.2. When measuring, the master oscillator is disconnected. The measuring frequencies for the transmitter of channel II are as follows: 114, 117, 120, 123 and 126 kilohertz; for the transmitter of channel III they are: 72, 75, 78, 81 and 84 kilohertz. The output impedance is

$$Z = \frac{U_Z R}{U_R},$$

where U_Z is the voltage drop on the output resistance of the transmitter measured by the KPU in the "voltmeter" mode; U_R is the voltage dropped on the standard resistor in the amount of 10-30 ohms. This resistor must be nonreactive, and its resistance is measured by the DC bridge with an error of no more than 1%.

In order to measure the frequency characteristic, a voltage of 0.1 of the rated value is fed to the transmitter input; the measuring frequencies are as follows: 50, 100, 200, 400, 1000, 2000, 4000, 6000, 8000 and 10000 hertz. Using the KPU voltmeter the voltage is measured at the transmitter output.

The frequency characteristic of the transmitter usually does not vary during the entire operating time with the exception of the case of damage to the parts or the mounting (breaks, closures, and so on). If the characteristic nevertheless turns out not to be at the norm, then for improvement of it it is necessary first of all to replace the tube L_1 in the UNCh [low-frequency amplifier], and then check the correctness of tuning of the circuit connected to the cathode circuit of the left side of the tube. The resonance frequency of this circuit must be equal to 8 kilohertz. The harmonic coefficient with respect to envelope is measured on a frequency of 1000 hertz with a voltage of the input of 0.1 of the rated value, and on frequencies of 120, 200, 400 and 1000 hertz, for values of the input voltage of 0.3 and 1.0 of rated; at frequencies of 2000, 3000 and 4000 hertz, at the rated output voltage of the transmitter. For subsequent measurement, the input voltage is decreased by the amount corresponding to the predictions in the transmitter channel. Initially a voltage with a frequency of 1000 hertz is fed to the input of the transmitter, and the rated levels are set at its output and the output of the KPU. The measurements for a value of 0.1 of the rated input voltage are made in the "noise" position. With an increase in the nonlinear distortions with respect to the envelope above the norm, it is difficult to recommend any defined measures for reducing distortions, for the reasons causing an increase in $K_Г$ can be different. The distortions can arise in all stages of the transmitter, including the master oscillator. Therefore when finding the failures it is necessary to be guided by some general principles. First it is necessary to disconnect the carrier suppression using the "carrier suppression" regulator, and the "control signal" regulator is set to the position for which the low-frequency voltage will not reach the right half of the tube L_2. If the distortions are eliminated, this means poor filtering at the output of the rectifiers (tubes 112 and 116). If the distortions do not diminish and predominance of even harmonics is observed, it is necessary to give attention to the nature of the increase in distortions with an increase in depth of modulation. If the distortions increase smoothly, beginning with 30 to 40% depth of modulation, it is necessary to replace the first tube in the low-frequency amplifier, check the state of repair of the filter parts 51, 52 and 53 and the stabilovolt 37. If the distortions increase sharply with modulation above 60%, and the distortions appear in the form of truncation of the envelope at the top, then it is necessary to check the operating conditions of the tubes 66, 80 and 83 and if necessary, replace them. If a sharp increase in distortions is connected with rounding of the sine curve at the bottom of the envelope (in the depression of the modulated signal), these distortions occur either in the modulator or in the terminal stage. Of course, other causes of the occurrence of nonlinear distortions are possible, but the above-enumerated ones are encountered most frequently.

In order to measure the background and noise voltages it is necessary to calibrate the sensitivity of the KPU with respect to the carrier level in the transmission interval. The depth of regulation of the carrier must correspond to the norm. In order to increase the accuracy of the measurement it is possible to use the effective value voltmeter (for example, type V3-5), connecting it to the output of the KPU. It is necessary to feed a signal with a frequency of 1000 hertz to the input of the transmitter and set the rated level with m=70% at its output, and also to set the rated output level at the output of the KPU with respect to the V3-5 voltmeter. Then it is necessary to pick up the signal and connect the resistor with the resistance equal to the resistance of the signal source to the output of the transmitter. Including the corresponding filters in the KPU, the background and noise voltage are measured by the V3-5 voltmeter. The signal/background ratio and the signal/noise ratio in decibels are defined by the formula

$$D_{\text{background (noise)}}=20\ \lg \frac{U_{\text{rated}}}{U_{\text{background (noise)}}}.$$

The increase in background level can be caused by failure of parts of the filters 51, 52, 53, 65, and 71 or failure of the tube L_1. However, more frequently the norm with respect to the background level is not met as a result of damage to the shielding of the input circuits of the transmitter. It is possible to detect the location of poor shielding only by practical methods, disconnecting circuit after circuit in series, beginning with the primary winding of the input transformer 8.

In order to measure the harmonic voltages (second, third, fourth, fifth, seventh and ninth) of the carrier frequency it is necessary to use an interference meter with battery power supply. The rated signal level with a frequency of 1000 hertz, m=70% is set at the output of the transmitter. The relative level of each harmonic is

$$\underset{(1)}{A_{\text{г}}} = 20 \lg \frac{10^6 U_{\text{вых. ном}}{}^{(2)}}{K U_{\text{г}}{}_{(3)}},\ \text{decibels},$$

Key: 1. harmonic; 2. output rated; 3. harmonic

where $U_{\text{output rated}}$ is the rated voltage of the transmitter; U_{harmonic} is the harmonic voltage, microvolts measured by the interference meter; K is the division factor of the divider:

$$\dot{K} = \frac{(R_8 + R_7)(R_7 + R_{\text{изм. помех}}^{(1)})}{R_7 R_{\text{изм. помех}}\ (1)},$$

Key: 1. mes. interference

where $R_{\text{mes interference}}$ is the input impedance of the interference meter. When measuring the harmonic voltages at the output of the transmitters in operation, it was established that the voltages of the fourth, fifth, seventh and ninth harmonics are 10 times less than the voltages of the second and third harmonics. Therefore, if for the measurements the level of the second and third harmonics correspond to the norm, it is not necessary to take the measurements on other harmonics. If the harmonic level does not correspond to the norm, it is necessary to check the symmetry of the arms of the output stage of the transmitter.

8.3. Electrical Measurements of the Group Receivers

The GPTV measurements are made for each channel individually with connection as the resistance load of 36 ohms and a power of 25 watts to the corresponding output of the receiver. It is necessary to consider the measurements correct which are taken directly from the transmitter which will feed the programs to the GPTV. Here the transmitter and the receiver must be in the "work areas" connected by the real processed line. In this case the quality indexes measured at the output of the receiver must correspond to the norms for the channel. If it is impossible to use the transmitter, it is necessary to perform the measurements with the MP attachment or test signal sensor.

Before measuring the qualitative indexes the receiver must be in the on state for 30 minutes with actual broadcast transmission or with feeding of the signal modulated by a frequency of 1000 hertz to its input for which the output voltage reaches 7 volts.

In order to avoid failure of the GPTV the voltage of the measuring signal at its input must not be more than 8 volts.

With the exception of the crosstalk the quality indexes are measured by the scheme in Fig 8.3. The sensitivity of the receiver is determined (with the automatic gain control on) by the input voltage of the carrier frequency with frequency modulation of 1000 hertz and depth of modulation of m=70%, with rated output power and position of the level regulator corresponding to the maximum output level. If the receiver has lowered sensitivity, this is caused by explicit failure of it inasmuch as usually the GPTV has significant reserve with respect to sensitivity. It is necessary to check the DC conditions of the high-frequency amplifier and also the state of repair of the filters.

The output power is checked with feeding of the AM signal to the input with frequency modulation of 1000 hertz and m=70%. The rated output power corresponds to an output voltage of 30 volts with harmonic coefficient exceeding 3.6%. If the receiver does not give a power of 25 watts, it is necessary to check the conditions with respect to DC and AC current of the stages of the low-frequency amplifier.

When picking up the frequency characteristic the depth of modulation is established within the limits of 30-50% and it is kept constant on all measurement frequencies. The measurements are performed with the automatic gain control off. On a modulating frequency of 1000 hertz a voltage of 7.75 volts is set at the output of the GPTV, which corresponds to the 0 decibel division with respect to the voltmeter scale. The frequency characteristic is picked up by the decibel scale. In the high-frequency range the characteristic can vary as a result of failure of the filters. It is possible to restore it either by tuning the filters or by some decrease in blocking capacitance at the detector output. The low-frequency trough can be caused by a decrease in the amplification coefficient with respect to the current of stage I of the low-frequency amplifier (Fig 5.7). It is necessary either to replace the transistor in the stage or increase the separating capacitance C_{14}. The harmonic coefficient is measured with the automatic gain control off on modulation frequencies of 100, 200, 1000 and 4000 hertz. Here a carrier frequency of 100 millivolts is fed to the input, and the rated output voltage of 30 volts is established by the level regulator at a frequency of 1000 hertz. On a frequency of 1000 hertz $K_{harmonic}$ is also checked with the automatic gain control on and with the carrier voltage down by 6 times (m=45%).

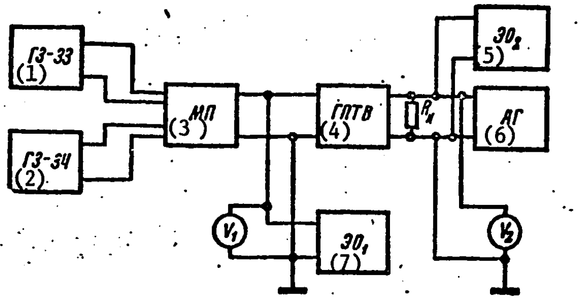


Figure 8.3. GPTV-3 measurement circuit

Key:

1. G3-33
2. G3-34
3. MP
4. GPTV
5. EO_2 oscillograph
6. AG
7. EO_1 oscillograph

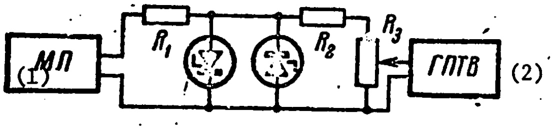


Figure 8.4. Measuring the background and noise in the GPTV

Key:

1. ML
2. GPTV

The nonlinear distortions on the low and middle frequencies occur, as a rule, only in the low-frequency amplifier, and this is connected with disturbance of the operating conditions of the preliminary stages (a reduction in the amplification coefficient of the transistors) or with overload of the terminal stage. It is necessary to be convinced of the good repair of all transistors of the powerful low-frequency amplifier. It is not recommended that the depth of feedback be changed with the exception of the case where generation on high frequencies occurs with the load disconnected. Then it is necessary to decrease the feedback somewhat. The distortions on the higher frequencies can occur as a result of bias of the frequency characteristic of the filter.

In order to measure the DC background and the natural noise of the receiver, the circuit depicted in Fig 8.4 is assembled. The amplitude limiter suppresses the AM modulation caused by the background. The resistor R_1 of several kilohms increases the internal resistance of the source and improves the operation of the limiter. The resistors R_2, R_3 establish the required input voltage of the GPTV equal to 0.1 of the rated voltage of the carrier frequency. The KPU is connected parallel to the R_H load of the receiver and in the "voltmeter" mode, with "background" and "noise" positions of the filter switch, the background and noise voltages are measured with the "low-frequency" position of the channel switch.

The background and noise components are estimated by the ratio to the rated output voltage of 30 volts.

In the case of increased background voltage it is necessary to check the state of repair of the filtering capacitors and check whether there is a short circuit in the choke.

The noiseproofness with respect to high-frequency channels is measured by the circuitry in Fig 8.5. It is necessary to establish a sensitivity of 100 millivolts before the measurement using the adjustable regulator.

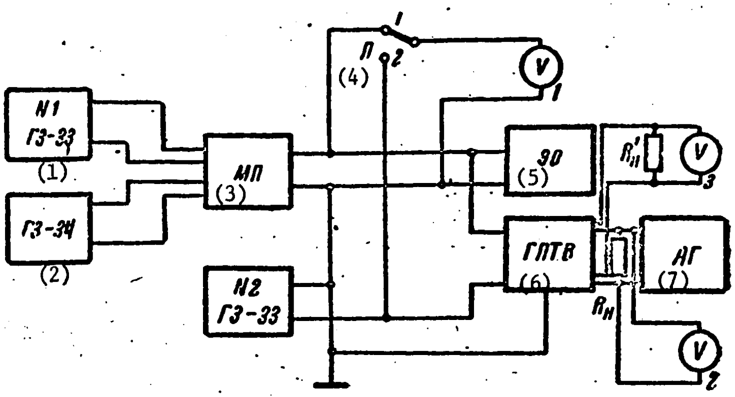


Figure 8.5. Measuring the noiseproofness of the GPTV with respect to the high-frequency channel

Key:

1. G3-33
2. GS-34
3. MP
4. П switch
5. EO oscillograph
6. GPTV
7. AG

The measurement is taken at the output of one channel when feeding an unmodulated carrier frequency at this channel with a voltage of 10 millivolts and simultaneously rated carrier frequency voltage of the other channel modulated by a frequency of 1000 hertz with m=70% to its input. The ratio of the measured voltage to the rated (30 volts) expressed in decibels characterizes the crosstalk attenuation between the high-frequency channels. The harmonic analyzer or KPU is used to measure the interference voltage components U_1 on a frequency of 2000 and U_2 on a frequency of 3000 hertz. The signal/crosstalk interference ratio is determined by the formula

$$\underset{(1)}{A_{\text{п}}} = 20\lg\frac{30}{U_1^2+U_2^2}, \text{ decibels}$$

Key: 1. interference

The attenuation of the low-frequency program signal in the high-frequency channels is measured by the circuitry in Fig 8.6 using the harmonic analyzer on frequencies of 1000 and 10000 hertz. One of these frequencies with a voltage of 30 volts and simultaneously the unmodulated carrier frequency of the given channel with a voltage of 10 millivolts are fed to the input of the measured channel. The ratio of the measured output voltage to the rated (30 volts) expressed in decibels characterizes the crosstalk attenuation of the low-frequency program on the low-frequency channels. On occurrence of increased crosstalk between channels it is necessary to check the attenuation of each filter at the frequency of the other channel and the correctness of the tuning of the high-frequency amplifier circuit. If the filters and circuits are tuned correctly, this means that the interference is created between the measuring instruments, and it is necessary to check the correctness of their connection (especially the ends connected to the housing). Insofar as possible these wires from all of the measuring instruments must converge at one point.

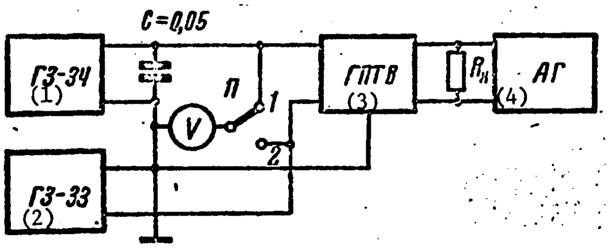


Figure 8.6. Measuring the noiseproofness of the GPTV from the low-frequency program

Key:

1.	G3-34	3.	GPTV
2.	G3-33	4.	AG

In order to measure the range of regulation of the input voltage it is necessary to set the adjustable regulator R_3 (Fig 5.7) to the maximum amplification position, to set a voltage of 30 volts at the output and measure the input voltage of $U_{inp\ 1}$. Then it is necessary to set the regulator to the minimum amplification position (but not to zero) and increase the input voltage until 30 volts is obtained at the output. The ratio of the measured $U_{inp\ 2}$ to $U_{inp\ 1}$ expressed in decibels characterizes the regulation range. These measurements are taken with the automatic gain control off.

The range of automatic control is measured with the automatic gain control on and it is determined by the ratio of input voltages corresponding to the output voltages $U_{out\ 1}$=22-23 volts and $U_{out\ 2}$=31-32 volts. If the range of regulation of the automatic gain control is less than 14 decibels, it is necessary to decrease the resistor R_7. If the automatic gain control does not operate at all, then it is necessary to use the tester to check the state of repair of the diodes and circuits of the automatic gain control. If switching the automatic gain control on causes the appearance of nonlinear distortions (the second harmonic), this indicates significant reduction of the capacitance of the capacitor C_9.

One of the standard failures of the GPTV is breakdown of the transistors in the DC stabilizer. This breakdown is caused by overheating of the transistors T_4 and T_6 with prolonged operation from the network with increased voltage (more than 242 volts). In this case, in order to decrease the probability of breakdown it is necessary to decrease the number of turns of the secondary winding of the power transformer by 10-15%. It is necessary to consider that with a reduction in the network voltage to 176 volts the receiver must give the rated output power.

8.4. Tuning and Electrical Measurements of the High-Frequency Devices

The tuning of any high-frequency device begins with tuning of its circuits. In order to tune the series and parallel circuits it is necessary to assemble the circuits in Fig 8.7. A series circuit is tuned with respect to minimum voltage on it. For more exact tuning the magnitude of the current flowing through the circuit must not depend on its tuning, that is, the oscillator Γ must be a current generator. This condition is easily satisfied: it is sufficient to include a resistance, the magnitude of which will be 2 to 3 times greater than the reactive resistance of the inductance (or capacitance) on resonance frequency in series in the circuit between the oscillator and the loop. Usually this resistance is selected equal to 2-5 kilohms. This circuit is convenient in that the capacitance of the voltmeter in practice has no influence on the accuracy of tuning the circuit.

The parallel circuit is tuned with respect to minimum current in the generator circuit. For tuning it is more convenient to measure not the current itself, but the voltage drop created by it on the resistance included in series with the oscillator. Its magnitude must be several times less than the resonance resistance of the loop. As a rule, the voltmeter used has high sensitivity, and therefore the magnitude of the resistance is selected equal to several hundreds of ohms. In this circuit the capacitance of the voltmeter also has no influence on the accuracy of tuning the circuit. All of the circuits are tuned to the resonance frequencies with tolerance of +0.5%. Inasmuch as the high-frequency devices have symmetric input and outputs, for the measurement oscillators are used with symmetric output. As the voltage meter it is possible to use either the KPU instrument or the tube voltmeter included through the symmetrizing transformer (EST-1, SET-10, SET-13).

The basic indexes characterizing the operation of the devices for processing the IT network are the moduli of total input resistances and the transmission coefficient. The first indexes measured by the IKS instrument, the VIG-3 or a bridge, for example, MPP-300 type.

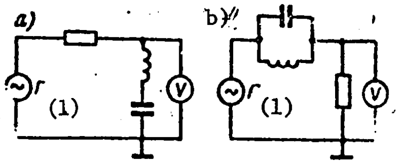


Figure 8.7. Loop tuning circuits
Key: 1. Oscillator

The transmission coefficient is calculated by the formula

$$K = \frac{U_{\text{output device}}}{U_{\text{inp device a}}}$$

The circuits for measuring Z_{inp} and K are presented in Fig 8.8.

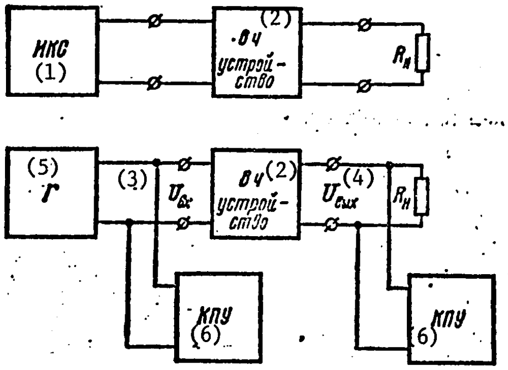


Figure 8.8. Circuit for measuring high-frequency devices

Key:

1. IKS
2. High-frequency device
3. U_{inp}
4. U_{out}
5. Oscillator
6. KPU

When installing several high-frequency devices in the TPV system channel, the frequency distortions introduced by them can reach 2 decibels altogether. These distortions must be taken into account when designing the RT network although they are not normalized for each device individually. The nonlinear distortions and the crosstalk interference introduced by the high-frequency devices are small; therefore they also are not normalized and, as a rule, are not measured. If the devices are made under workshop conditions, they must be subjected to tuning and testing. The electric strength and the magnitude of the insulation resistance are important indexes for the devices. The electric strength is checked on the all-purpose UPU-1M breakdown devices after tuning the high-frequency device. The insulation between the terminals must withstand voltages at a frequency of 50 hertz for 1 minute corresponding to the technical specifications without breakdown. The resistance of the insulation of the electrical wiring is measured by a megommeter. Its magnitude must be no less than the normalized value indicated in Table 8.1 with feeding of the test voltage between the terminals, the magnitude of which is also indicated in this table.

Let us consider the tuning of several high-frequency devices.

Table 8.1

Terminals subjected to testing	Test voltage, kv	Resistance and insulation, Mohms
From the connection to the MF [main feeder]:		
Between the terminals	1.5	50
Between each terminal and housing of the high-frequency device	5.0	100
From the direction of connection to the distributing feeder:		
Between the terminals	0.35	50
Between each terminal and housing of the high-frequency device	2.0	50
Between one end of the secondary winding of the OUA and the housing	2.0	50
Between one end of the primary winding and one end of one half of the secondary winding of the high-frequency transformer of the UPP	5.0	100
Between one end of the primary winding and one end of the second half of the secondary winding of the high-frequency transformer of the UPP	5.0	100

Bypasses

Each loop of the OUA device (Fig 7.1) is tuned to a frequency of 40±3 kilohertz. The $C_1L_1C_2$ loop is tuned by the core of the coil; the $C_3L_2C_4$ loop is tuned by selecting the capacitors. The measurements of the modulus of the input impedance are made on terminals 1-2 on inclusion of the equivalent load resistance to the terminals 3-4. For the OUA-1 device it is 20 ohms; for the OUA-2 device it is 220 ohms. The modulus of the input impedance is measured on frequencies of 68, 88, 110 and 130 kilohertz. It must be no less than 2000 ohms; the transmission coefficient must be no less than 0.086. In order that the voltage of the high-frequency signals at the output of the device and the subscriber transformer be summed, it is necessary to observe correct polarity of connecting the OUA and the AT. For this purpose it is necessary to assemble the circuit in Fig 8.9. From the oscillator it is necessary to feed a voltage of several volts at a frequency of 100 kilohertz. This connection for which the voltage gives a larger reading is considered correct.

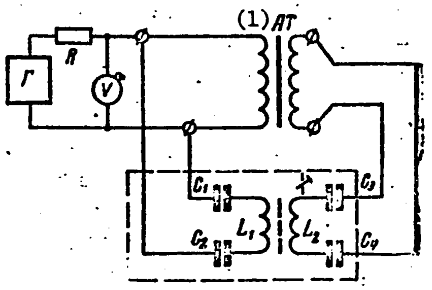


Figure 8.9. Bypass measurement circuit

Key:
1. AT subscriber transformer

Compensation Devices

Inasmuch as the capacitance of the capacitor C_B is selected as a function of the compensated capacitance of the cable insert or input, when adjusting the compensators (Fig 7.4) this capacitance is disconnected. The L_1C_1 loop is tuned to a frequency of 37.8 kilohertz; the L_2C_2 loop, to a frequency of 101 kilohertz. These loops connected in parallel are tuned to the frequency which is within the limits of 89 to 92.5 kilohertz. When connecting the capacitactor C_B=4000 picofarads, the moduli of the input impedances are measured which must be no less than 5000 ohms on the carrier frequencies, 1100 ohms on side frequencies and 73, 83 and 115 kilohertz, and 1600 ohms on 125 kilohertz.

Matching Devices

The state of repair of the autotransformer (Fig 7.6) can be checked by measuring its inductance using the low-frequency bridge. For this purpose the capacitors must be excluded, connecting the ends of the windings to each other. The total inductance L_{1-4} must be 8.76 millihenries. For short circuit leads 5-6 it must be no more than 0.125 millihenries. The resonance frequency of the circuit formed by all of the series connected windings and capacitors C_1+C_2, must be 15.3 kilohertz. The frequency of the loop formed by the windings II, III, IV and V and the capacitor C_2 must be 26.4 kilohertz.

The moduli of the input impedances and the transmission coefficient are measured in two modes: in the "steel" mode on the terminals 1-2 with short circuit terminals a-b and in the "bimetal" mode on terminals 2-3 on inclusion of only the capacitor C_2 in the circuit. The load resistance is 210 ohms. These variables are measured on frequencies of 68, 88, 110 and 130 kilohertz. In the "steel" mode Z_{inp} must be 770+70 ohms, K is 0.53±0.04. In the "bimetal" mode Z_{inp} is 560+70 ohms and K is 0.61±0.05 respectively.

The inductance of the autotransformer of the ATO lead in Fig 7.8 is also checked without a capacitor. It must be 16.6 millihenries on terminals 1-2. For the short circuit leads 3-4 this inductance must be no more than 1.7 millihenries. Then the capacitor is connected, and the tuning of the series circuit to a frequency of 19.1 kilohertz is checked. The modulus of the input impedance is measured on frequencies of 68, 88, 110 and 130 kilohertz. The terminals 3-4 are loaded to an active resistance of 480 ohms. Z_{inp} must be equal to 2000 ohms. The transmission coefficient is measured on connection of a load resistance of 600 ohms, and it must be equal to 0.44±0.03.

Band-Elimination Filters

The tuning of the band-elimination filter circuits (Fig 7.9) is checked according to the circuitry in Fig 8.10 for short circuit terminals of 3-4. The LC_1 loop is tuned to a frequency of 120 kilohertz; the LC_2 loop is tuned to a frequency of 78 kilohertz. The modulus of the input impedance is also measured for short circuit terminals of 3-4. It must be equal to the following: 8000 ohms on the carrier frequency; 2500 ohms on the side frequency.

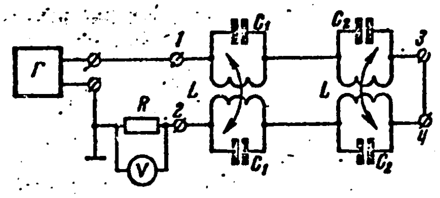


Figure 8.10. Band-elimination filter measurement circuit

UPTP-1 Devices for Connecting the Transformer Substation (Fig 7.13). Initially it is necessary to tune the band-elimination filters by the above-indicated procedure and the OUTP bypass. Each of the loops of the OUTP bypass is tuned to a frequency of 58±3 kilohertz. Then the modulus of the input resistance of the entire device is measured in three modes: from the direction of the terminals 3-4 with short circuit terminals of 1-2; from the direction of the terminals 5-6 for short circuit terminals 7-8; from the direction of the terminals 1-2 for short circuit terminals of 3-4 and 5-6 and with the resistor of 60 ohms connected to the terminals 7-8 (for the UPTP-1 device). The transmission coefficient is measured on the input terminals 1-2 with the resistor of 60 ohms connected to the terminals 7-8. The results of the measurements must correspond to the values in Table 8.2.

Table 8.2

	Frequency, kilohertz					
Name of indexes	68	78	88	110	120	130
Z_{3-4}, ohms	2000	7000	1200	1200	7000	2000
K_{5-6}, ohms	200	450	150	150	450	200
Z_{1-2}, ohms	480 to 600					
K	0.28±0.03					

UPTP-3 Tuning (Fig 7.16). The state of repair of the high-frequency transformer is checked by measuring its inductance which must be equal to 0.8 millihenries. Here the L_3C_3 and L_4C_4 circuits must be short-circuited. When measuring the scattering inductance the L_5C_5, L_6C_6 circuits and the L_7 winding are enclosed by a jumper. The inductance must be no more than 0.125 millihenries. Then the tuning of the circuits is tested: L_1C_1 to a frequency of 100 kilohertz, L_3C_3, L_5C_5 to 78 kilohertz, L_4C_4, L_6C_6 to 120 kilohertz.

The $C_7L_8C_8$ two-terminal network has voltage resonance on a frequency of 78 kilohertz and current resonance at 120 kilohertz. The two-terminal network $C_9L_9C_{10}L_{10}$ is tuned as follows: initially the $C_{10}L_{10}$ circuit is tuned to 78 kilohertz. Then the entire circuit is tuned by the core of the coil L_9 with respect to the voltage resonance to 120 kilohertz. The transmission coefficient and input impedances of the entire device are measured in two modes: jumpers on the secondary winding L_7 are set to the 35 ohm position. The terminals 3-4, 5-6, 9-10 and 11-12 are open. The 35-ohm resistor is connected to the terminals 7-8. The parameters of the device must in this case correspond to the values in Table 8.3. In the second mode the jumpers in L_7 are set through the 50-ohm position. The terminals 3-4, 5-6, 7-8 are open. The terminals 9-10 and 11-12 are closed. The load of the device is the TsPN network.

Table 8.3

	Frequency, kilohertz					
Name of index	68	78	88	110	120	130
Z, ohms	460±60	600±60	820±60	580±60	600±60	770±60
K		4.55			4.55	

The parameters of the device must correspond to the values in Table 8.4.

Table 8.4

Name of index	Frequency, kilohertz 78	120
Z, ohms	600±60	600±60
K	3.56	3.56

UPP-1 Transmitter Connection Circuit (Fig 7.10). The circuits of this device must be tuned to resonance on the following frequencies: L_3C_1 at 78 kilohertz, L_4C_2 at 120 kilohertz, L_1C_3 at 120 kilohertz and $L_1C_3C_6$ at 78 kilohertz. For measuring the device with transformation coefficient 1:1 for processing the main feeder the capacitor C_3 must be transferred to the terminals 5-6 to which the load resistance of 600 ohms is connected. In the given case the capacitor C_3 simulates the capacitance of the cable insert equal to 5600 picofarads. The capacitance of the insert is transformed through the transformer L_1L_2 and it detunes the L_2C_3 circuit. The connection of the capacitance to the load makes it possible to check the scattering inductance in the transformer and the capacity of the device to compensate the capacitance of the insert or the input. During measurement of the UPP for the distributing feeder with transformation coefficient of 3:1 a load of 60 ohms and a capacitor with a capacitance of 5600 picofarads are connected to the terminals 5-6. The capacitance C_3 is disconnected from the circuit. When measuring the input impedance on frequencies of 68, 78 and 88 kilohertz the measuring device is connected to the terminals 3-7, and the terminals 4-7 are connected by a jumper. In order to measure the transmission coefficient on these frequencies the oscillator and the device for measuring the input voltage are connected to the terminals 3-7. The output voltage is measured on the terminals 5-6. When measuring the input impedance and the transmission coefficient on frequencies of 110, 120 and 130 kilohertz, the oscillator and the instrument are connected to the terminals 4-7, and the terminals 3-7 are connected by a jumper. The measured parameters must correspond to values in Table 8.5. The accuracy of measuring the wave impedance on carrier frequencies must be ±50 ohms, and on the remaining frequencies, ±70 ohms. The accuracy of measuring the phase angle on all frequencies must be ±10°.

Table 8.5

Наименование показателей (1)	(2) УПП для фидеров магистрального (3)						распределительного (4)					
	(5) и частот, кГц											
	68	78	88	110	120	130	68	78	88	110	120	130
(6) Z, Ом	310	420	410	430	480	430	30	400	300	400	350	280
φ°	+50	+10	−5	+40	0	−15	−40	0	−30	+20	−10	−30
K	0,95±0,15						0,37±0,05					

Key: 1 -- name of indexes; 2 -- UPP for feeder; 3 -- main; 4 -- distributing
5 -- and frequencies, kilohertz; 6 -- Z, ohms

8.5. Electrical Measurements of Intermediate Amplifiers

The quality indexes of the DPU are measured by the circuit in Fig 8.11. In order to avoid failure of the circuit elements, the voltage of the measured signals at the input of the DPU with the position of the double regulators corresponding to the maximum amplification must not exceed twice the value of the actual sensitivity.

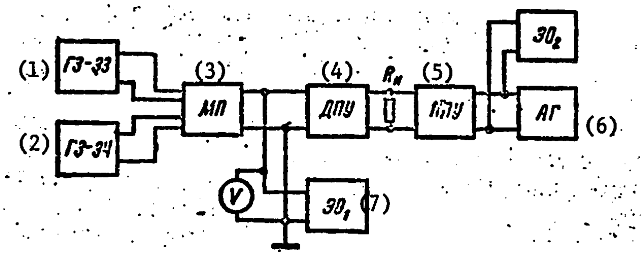


Figure 8.11. DPU measurement circuit

Key:

1. G3-33
2. G3-34
3. MP
4. DPU
5. KPU
6. AG
7. EO_1 oscillograph

The measurements are taken on connection of a load resistance of 400 ohms to the input of the high-frequency channel: $P_{scatter}$=4 watts. The DPU is tested in the rated mode (U_{out}=20 volts) and maximum mode (U_{out}=28 volts).

In order to determine the sensitivity a carrier frequency is fed to the DPU input modulated by a frequency of 1000 hertz, and m=70%. The rated output voltage is set at the output of the amplifier. It is measured by the KPU in the "voltmeter" mode. In this case $K_Г$ [$K_{harmonic}$] must correspond to the normalized value. The magnitude of the input voltage corresponds to the sensitivity of the DPU. The output power is calculated for rated and maximum modes.

The frequency characteristic is measured for the rated mode using the KPU (in the "receiver" mode) on frequencies of 1000, 4000, 5000 and 6000 hertz.

If the output power or the frequency characteristic turn out to be not in the norm, then it is necessary initially to construct the high-frequency circuit of the first stage of the amplifier and then tune the input and output band-elimination filters.

The harmonic coefficient is measured in the maximum mode on modulation frequencies of 1000, 3000 and 4000 hertz. The rated voltage is established at the output of the KPU, and the harmonic analyzer performs the measurements.

It is also necessary to make the measurement on a frequency of 1000 hertz with a modulation depth of 45% and carrier voltage decreased by 10 times with respect to the maximum mode. In the case of noncorrespondence to the norm of the harmonic coefficient it is necessary to check the operating conditions of the transistors with respect to direct current. In order to measure the background of the alternating current and the natural noise of the amplifier, the circuit in Fig 8.4 was assembled. By using the resistor R_3 at the input of the DPU a voltage is fed equal to 0.1 of the value of the actual sensitivity of the amplifier. The KPU is connected parallel to the load of the DPU, and the background and noise voltages are measured in the "voltmeter" mode in the "background" and "noise" positions.

The noiseproofness from the adjacent high-frequency channel is measured by the circuit in Fig 8.12 on a modulating frequency of 1000 hertz with a modulation depth of 70%. The "frequency" switch of the oscillator No 2 is set to the position x1000; the output resistance switch is set to the 5 ohm position. The voltmeter is switched to position 2, and the voltage at the frequency of the tested channel equal to 0.1 of the value of the actual sensitivity is established at the output of oscillator No 2. Then the voltmeter is set to position 1, and by its readings the signal voltage equal to 3 times the value of the actual sensitivity of the measured channel of the DPU is set at the output of the modulated oscillation source. By the readings of the KPU in the "voltmeter" mode the level regulator of the influencing channel at the output of the DPU is used to set a voltage of 20 to 28 volts. Then the KPU is switched to the "receiver" mode and the crosstalk noise level is measured. In the case of increased crosstalk it is necessary to check the tuning of the output band filter.

The frequency characteristic is measured in the low-frequency channel frequency band by the circuit in Fig 8.13 on frequencies of 400, 1000, 2000, 4000, 6000, 8000 and 10000 hertz.

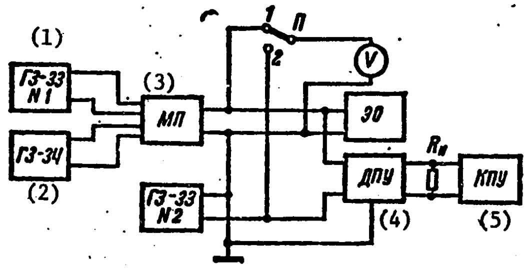


Figure 8.12. Circuit for measuring the noiseproofness of the DPU.

Key: (1) GA-33 master oscillator
(2) GZ-34 master oscillator
(3) MP
(4) DPU
(5) KPU

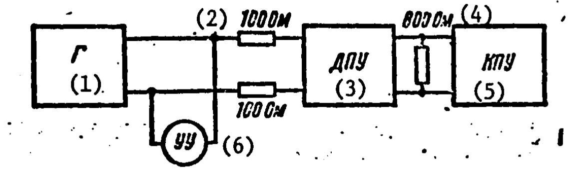


Figure 8.13. Circuit for measuring the frequency characteristic of the DPU

Key:
1. Oscillator
2. 100 ohms
3. DPU
4. 800 ohms
5. KPU
6. UU

The output voltage of the oscillator must be monitored using the IU-600 or UUP-600 type level indicators. When using the GZ-34 oscillator the constancy of the output voltage on the indicated frequencies can be monitored using the voltmeter of this oscillator with included internal load and the 5-ohm position of the output resistance switch. The voltage of the amplifier load is measured using the KPU in the "voltmeter" mode. The resistances of the resistors are indicated in the circuit for the case where the DPU is designed for installation of the lines made of steel. If the DPU is installed on the bimetal line, then the resistors simulating the output resistance of the source must have a value of 50 ohms each, and the load resistor, 200 ohms. For deviations of the frequency characteristic from the norm it is necessary to check the tuning of the low-frequency filter.

8.6. Electrical Measurements of the Lines

The voltages of the carrier frequencies on the line part of the channels are measured by the lineman's indicator or the KPU instrument in the absence of transmission. The presence of a broadcast transmission with respect to any other program does not interfere with the measurement. The carrier voltage at the inputs of the UPP is measured on buses connecting like terminals 3-4 of each of two groups (Fig 7.12) on connection of a real load to the outputs of the UPP. A signal is fed to the input of the transmitter from the measuring oscillator on a frequency of 1000 hertz, a rated level of 0 decibels and duration to 10 seconds. The voltage of the carrier at the inputs of the distributive feeder is measured, connecting the instrument to the contacts of the holders of the discharges of any feeder on the face of the STR bay. Before the measurements it is necessary to set the rated depth of regulation of the carrier on the transmitter. The measurements are taken in the interval, that is, with output voltage of the transmitter 10 times less than rated. The measured voltage is multiplied by 10, and the result obtained must be the normalized value. The voltage of the carrier on the distributive feeders and their leads is measured approximately every 300 meters, reckoning from the end of the feeder (or the end of the lead). It is necessary to take the measurements at the points of inclusion of the high-frequency devices: compensating, matching and other and also at the input and output of the intermediate amplifiers. Before the measurements the "carrier suppression" regulator of the transmitter is set to the position corresponding to the carrier voltage equal to half the value of the rated voltage. The voltage is measured on the RF [distributing feeder] and multiplied by 2. The result obtained corresponds to the rated transmitter mode and can be compared with the normalized values of the voltages. The measurements of the voltages on the distributing lines reflect the true level diagram only under the condition that the carrier voltage at the transformer substation during the measurement remains unchanged, that is, if the lines are disconnected at the OUS or TP. In order to construct the level diagram on the RF the voltages obtained are converted to absolute levels and decibels. The total resistances and their moduli are measured during the break in broadcasting by the IKS instrument. The element, the input impedance of which is measured is disconnected from the output of the preceding element. The measurements are taken on frequencies of 74, 78, 82, 116, 120 and 124 kilohertz. When measuring the input impedances of the distributing feeder (Fig 8.14) the fuses of the measured feeder on the STR bay are removed, and the feeder input is connected to the Z_x terminals of the instrument. The measured value is the total input impedance of the distributing feeder Z_{inp} and the capacitance C_k of the cable lead-in parallel to the input. The magnitude of this capacitance is measured by the IKS instrument with the lead-in disconnected from the overhead line and common buses. It is sufficient to measure C_k of one lead-in, for with identical structural execution the capacitances are equal for all lead-ins.

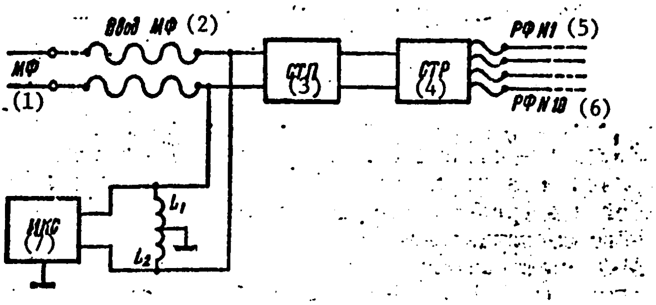


Figure 8.14. Circuits for measuring the input impedance of lines at the transformer substation

Key:
1. MF [main feeder]
2. MF input
3. STP
4. STR
5. Distributing feeder N1
6. Distributing feeder N10
7. IKS

The input impedance is calculated by the formula

$$\underset{(1)}{Z_{\text{вх}}} = \frac{1}{\frac{1}{\underset{(2)}{Z_{\text{изм}}}} - i\omega C_{\text{к}}}, \ \underset{(3)}{\text{Ом.}}$$

Key: 1. inp; 2. meas; 3. ohms.

When measuring the load resistance of the transformer substation the instrument is connected to the contacts of the discharger holders of any distributing feeder. The doors of both cells of the STP bay, just as in the preceding case, must be open. The common buses of the distributing feeder are disconnected from the UPTP output in this case.

When feeding the transformer substation with reserve with respect to the high-frequency programs this is obtained automatically for the armatures of both contactors in the released state. In the absence of a reserve it is necessary to disconnect the outputs of the UPTP filters from the common buses of the distributing feeders before the measurements. The measured value is the total impedance of all distributing feeders and capacitances of the cable lead-ins Z_Σ. In order to determine the total resistance of the parallel connection Z_{osh} of all of the distributing feeders without the capacitances of lead-ins, for example, in the case of using the UPTP-3 device where the value of Z_x is found by the value of Z_{osh}, it is necessary to use the formula

$$\underset{(1)}{Z_{\text{ош}}} = \frac{1}{\frac{1}{Z_\Sigma} - i n \omega C_{\text{к}}}, \underset{(2)}{\text{Ом}}$$

Key: 1. Z_{osh}; 2. ohms

Here n is the number of distributing feeders at the given transformer substation (excluding the feeder for the outdoor public address system FUZ, which must be processed by a band-elimination filter). When measuring the input impedance of the transformer substation from the high-voltage side the lead-in of the main feeder is first disconnected from the overhead wires (Fig 8.14). All of the distributing feeders must be connected to common buses. If the transformer substation has reserve feed with respect to all programs, the measurement is repeated twice: once with the lead-in and the UPTP of the feeder A (basic), another time with the input and UPTP of the feeder B (reserve). When measuring the basic complex, the contactor of cell B of the STP scale must be in the nonoperating position and the door of this cell is open. The IKS instrument together with the Z_x terminals connected to it by two identical inductance coil L_1 and L_2, the connection point of which is grounded, are connected to wires running to the UPTP input (in cell A of the STP bay). The IKS housing must be grounded. Then the armature of the contactor in cell A is mechanically fixed in the pulled position, the door of this cell is closed and measurements are taken. When measuring the complex B the procedure is analogous. The induction coils are designed to protect the operator and the instrument in the case of random contact of the wires of the distributing feeder and the electrical network wires. Their resistance to currents of measuring frequencies of the IKS is several kilohms and has no influence on the measurement result. These coils are made locally using a ferrite core of the NM-2B30 type with magnetic permeability M=2000, 75 turns and an inductance of no less than 9 millihenries.

The moduli of the total input impedances of the main feeders on frequencies of 78 and 120 kilohertz are measures of the input terminals of the UPP through which the given line is fed. The transmitters and other UPP are disconnected from the terminals. The terminal 7 is grounded by the requirements of safety engineering. During the measurements on a frequency of 78 kilohertz the IKS is connected to the terminals 3-7 of the UPP; the terminals 4-7 are connected by jumper. For measurements on a frequency of 120 kilohertz the instrument is connected to terminals 4-7, and terminals 3-7 are closed.

The moduli of the input impedances of the pairs of 3-pair house networks are measured on a frequency of 400 hertz. The input of the measured pair is disconnected from the corresponding terminals of the GPTV and are connected to the Z_x terminals of the IKS instrument.

8.7. Electrical Measurements of Quality Indexes of High-Frequency Channels and Parts of Them

On the parts of the "transmitter input and actual transmitter load (UPP input)" channel and the "transmitter input and transformer substation (common buses of the STR)" channels the frequency characteristics, the harmonic coefficient with respect to the envelope and the magnitude of the crosstalk interference from the adjacent transmitter are measured.

On the "transmitter input and subscriber radio point of a single pair house network" channel the frequency characteristics, the harmonic coefficient, the magnitude of the crosstalk interference from the low-frequency channel and from the adjacent high-frequency channel are measured. The measurements must be taken with respect to every high-frequency channel at two subscriber points of each transformer substation fed from different distributing feeders. During periodic measurements the number of subscriber points subject to measurement is selected from the calculation of H=N/2000, where N is the total number of subscribers fed from the given OUS, including the single program radio point. The points fed from different transformer substations are selected for the measurement.

On the "transmitter input and subscriber radio point of the three-pair house network" channel the amplitude characteristics, frequency characteristics, harmonic coefficient, background and noise voltages and magnitude of crosstalk interference from the adjacent high-frequency channel are measured. The measurements are performed with respect to each high-frequency channel at one subscriber point of the three-pair house network fed by the GPTV.

During periodic measurements, one radio point each out of M three-pair networks of each OUS is selected for measurements, where M=m/5; m equals the number of GPTV in the given OUS.

The part of the high-frequency channel "transmitter input and actual load" is measured by the circuit in Fig 8.15. The remaining parts of the high-frequency channels beginning with the transmitter input are measured by the same circuit, but the KPU and the nonlinear distortion meter, depending on which channel is measured, are connected to the output of the transformer substation or to the subscriber point.

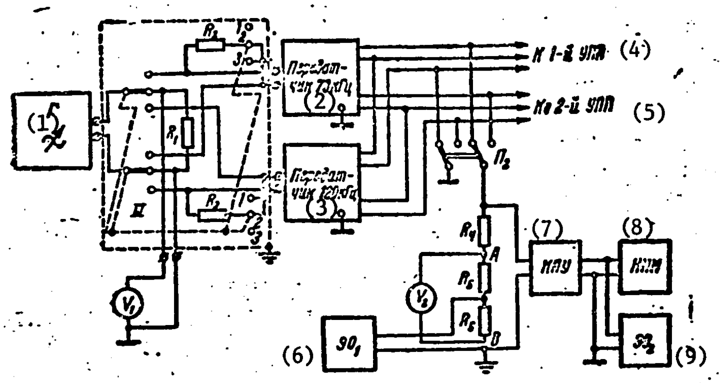


Figure 8.15. Circuit for measuring the parts of the high-frequency channel

Key:

1. Oscillator
2. 78 kilohertz transmitter
3. 120 kilohertz transmitter
4. to the 1st UPP
5. to the 2d UPP
6. EO_1 oscillograph
7. KPU
8. NNM
9. EO_2 oscillograph

The parameters of the resistors R_4, R_5, R_6 in the given circuit correspond to the parameters of the resistors R_3, R_4, R_5 of the circuit in Fig 8.1. The indexes are measured at the inputs of the first and second groups of UPP connected to the corresponding outputs of the transmitter. The UPP groups are replaced using the П2 switch. When measuring the remaining high-frequency sections of the channel the depth of modulation and the carrier frequency voltage are monitored using the EO_1 oscillograph and the V_2 voltmeter at the output of the UPP group to which the main feeder feeding the transformer substation and the distributing network where the measurements are taken is connected.

The duration of the sendings of the measuring signal in the sound frequency spectrum must be minimal. The checking is done by feeding the signal with a frequency of 50-100 hertz and with a level of 30 decibels below rated to the input of the transmitter. The presence of the signal at its connection point is checked using the KPU.

The oscillator frequency tuning and setting of the required levels of measuring signals must be carried out when loading the oscillator for the resistor with a resistance equal to the rated input impedance of the transmitter, that is, for position 2 of the switch Π_1. In order to obtain a stable value of the output voltage of the oscillator in the frequency band when connecting it to the input of the transmitter (position 1 or 3 of the switch Π_1) the output impedance of this oscillator must be an order less than the input impedance of the transmitter.

When measuring the sections of the channel it is necessary first to measure the background and noise level, the crosstalk and then the frequency characteristic and the harmonic coefficient.

Before the measurements the sensitivity of the KPU instrument is calibrated by the carrier level in the interval. This replaces feeding a signal with a frequency of 1000 hertz to the input of the transmitter to establish the rated level at the measurement point. For measuring the background and noise levels the signal source is disconnected from the input of the transmitter of the tested channel and together with it a resistor is connected in the screen with the resistance equal to the modulus of the output impedance of the signal source. When taking the readings of the KPU in decibels the calculation formula for calculating the signal/background and signal/noise ratio has the form: $D=20-(x+y)$, where D is the signal/background and signal/noise ratio, decibels; 20 is the depth of adjustment of the carrier, decibels; x is the value of the reading with respect to the output attenuator, decibels; y is the instrument readings, decibels.

When measuring the crosstalk interference level, the measuring signal with a frequency of 1000 hertz, rated level and duration of 5-10 seconds is fed to the input of the influencing channel. Here the output voltage of the terminal modules of the equipment is monitored, and if the high-frequency channel is influencing, then also the modulation depth is monitored. If the low-frequency channel is influencing, then the low-frequency signal with rated level is fed only to the transformer substation on the lines of which the measurements are taken. All of the distributing feeders of this substation must be connected. On the two-element network the measuring signal is fed only to the distributing feeder on which the measurements are taken.

The crosstalk interference level measurements are taken with the "noise" position of the filter switch in the KPU. If the interference level exceeds by less than 6 decibels the noise level and if it is below the noise level, then the measurement is taken in the 1 and 2 kilohertz positions. In this case the level of the crosstalk interference is determined by the formula

$$A_{п} = 20 + 20\lg\frac{0,775}{\sqrt{U_1^2+U_2^2}},$$

U_1 and U_2 are the crosstalk interference voltages, volts, on frequencies of 1 and 2 kilohertz.

When measuring the interference level in the "noise" position and taking the readings of the KPU instrument in decibels the interference level is determined by the formula $A_{\pi}=20-(x+y)$, decibels.

In order to measure the frequency characteristic, a voltage of 0.25 volts is fed to the input of the transmitter on a frequency of 110, 160, 1000, 3000, 4000 and 6000 hertz. Initially a measuring signal is fed with a frequency of 1000 hertz for 10 to 15 seconds. The input attenuator and calibration regulator K are used to set the pointer of the KPU instrument to the -4 decibel position, with a position of the output attenuator at 0 decibels and the "measurement" position of the calibration switch. Then the instrument is read successively on all frequencies.

The harmonic coefficient is measured on frequencies of 2000 and 4000 hertz for the rated output voltage of the transmitter and modulation depth M=70% and signal duration of no more than 60 seconds. Measurements are taken in the "noise" position of the regulator by the KPU using the nonlinear distortion meter.

When measuring the quality indexes of the channel with the group receiver, initially the harmonic coefficient is measured, then the background voltage, the noise of the crosstalk interference and then the frequency characteristic. The harmonic coefficient is measured on a frequency of 1000 hertz with rated voltage at the transmitter output. For the measurements it is possible to use the nonlinear distortion meter of the S6-1 type connected by the symmetric input to the house network. The voltage of the measuring signal can be monitored by the KPU in the "voltmeter" mode.

Before the measurements of the background, the noise of the crosstalk interference and the frequency characteristic it is necessary to feed a preset signal to the input of the transmitter with rated frequency level of 1000 hertz to maintain a value of the amplification coefficient of the GPTV having automatic gain control. Directly after feeding the preset signal the KPU instrument is used to take measurements in the "voltmeter" mode with the channel switch position at low frequency. The duration of the preset signal is 3 to 5 seconds. The background and noise voltages can be read for 20 seconds; otherwise the amplification coefficient of the GPTV varies and distorts the measurement result. The signal/background and signal/noise ratios are determined by the formula

$$\text{Д} = 20\lg \frac{U_{\text{у}}(2)}{U_{\text{ф}(\text{ш})}}, \quad (1)$$

Key: 1. background (noise); 2. preset signal

where U_y is the preset signal voltage measured by the KPU; $U_{\text{background}}$ and U_{noise} are the background and noise voltages measured by the KPU in the corresponding positions of the filter switch.

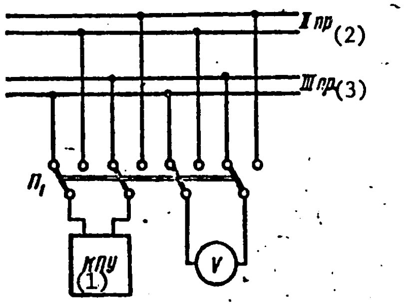


Figure 8.16. Circuit diagram of the measuring instrument connection to the three-pair GPTV network

Key: 1. KPU; 2. program II; 3. program III

In order to measure the crosstalk interference from the signals of the adjacent high-frequency channel, the preset signal lasting 1 second is fed to the input of the transmitter subjected to the effect. By using the switch Π_1 a measuring signal lasting 8 seconds is fed directly to the input of the transmitter of the influencing channel. By using the KPU in the "voltmeter" mode the interference voltage $U_{1\pi}$ is measured, and any voltmeter with symmetric input or a lineman's indicator is used to measure the voltage U_2 of the influencing signal on the same pair of the three-pair network which belongs to the influencing channel. Then the points of connecting the KPU and the voltmeter to the three-pair network change places (see Fig 8.16) and by using the switch Π_1, the measuring signal is fed to the input of the transmitter to which the preset signal was fed. The KPU is used to measure the interference voltage $U_{2\pi}$ (for 8 seconds), and the voltmeter is used to measure the voltage of the influencing signal U_1. The signal/crosstalk ratio in the two high-frequency channels is defined by the formulas:

$$A_{1\text{п}} = 20\lg\frac{U_1}{U_{1\text{п}}},\ \text{дБ}_{(1)};\quad A_{2\text{п}} = 20\lg\frac{U_2}{U_{2\text{п}}},\ \text{дБ}._{(1)}$$

Key: 1. decibels

The time diagrams of the voltages at the outputs of the transmitters (in the measurement process) are presented in Fig 8.17.

In order to measure the crosstalk interference from the low-frequency signals the preset signal lasting 1 second is sent to the input of the transmitter subjected to the effect; then the measuring signal is fed for 3 to 5 seconds. The interference voltage is measured using the KPU. The same method is used to measure the interference in the second high-frequency channel. The signal/interference ratio is determined by the above-indicated formulas. When measuring the interference voltage in the "noise" position the interference voltage is read directly by the instrument scale. If the measurements

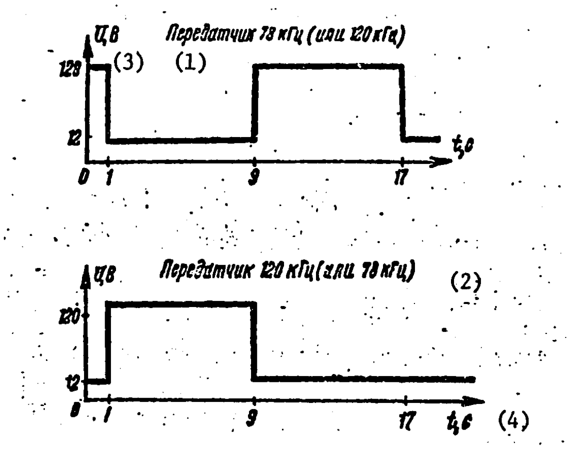


Figure 8.17. Time diagrams of the voltages at the output of the transmitters

Key:
1. 78 kilohertz (or 120 kilohertz) transmitter
2. 120 kilohertz (or 78 kilohertz) transmitter
3. U, volts
4. t, seconds

are taken in the positions 1 and 2 kilohertz, the magnitude of the interference voltage is defined by the formula

$$U_{\underset{(1)}{\text{пнч}}} = \sqrt{U_1^2 + U_2^2},$$

Key: 1. interference, low frequency

where U_1 and U_2 are the voltages of the crosstalk (in volts) on frequencies of 1 and 2 kilohertz.

The preset signal lasting 1 second is fed to the input of the transmitter to measure the frequency characteristic, then after 15 seconds, during which the level is measured, the measuring signal with a frequency of 1000 hertz and a level of 0.25 volts lasting 5 seconds is fed. The time diagram of the voltages at the input of the transmitter in the measurement process for one measuring frequency is represented in Fig 8.18. Using the KPU in the "voltmeter" mode and in the low-frequency position the signal level is measured. The measurements are repeated on frequencies of 110 and 6000 hertz with feed of the preset signal at the rated level before each sending of the measuring signal.

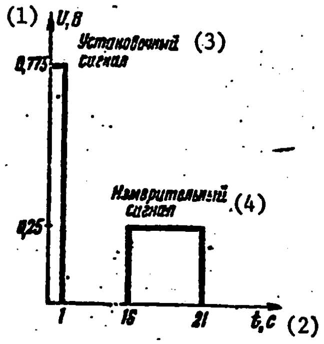


Figure 8.18. Time diagram of the voltages at the input of the transmitter

Key:

1. U, volts
2. t, seconds
3. Preset signal
4. Measuring signal

APPENDIX 1. QUALITY INDEXES OF THE HIGH-FREQUENCY CHANNELS (FROM THE DRAFT OF OST "CHANNELS OF THE THREE-PROGRAM WIRE BROADCAST HIGH-FREQUENCY SYSTEMS. BASIC PARAMETERS")

Table П 1.1. Quality Indexes of the Through Channel

Names of indexes	Norms
Reproducible frequency band, hertz	100-6000
Nonuniformity of the frequency characteristic, decibels, no more than	in accordance with Fig 3.4
Harmonic coefficient, %, no more than, on frequencies of:	
above 100 to 200 hertz	8/4
above 200 to 2000 hertz	4/2
above 2000 to 4000 hertz	5/2, 5
Signal/background ratio, decibels, no less than	40
Signal/noise ratio, decibels, no less than	55
Signal/intelligible crosstalk ratio, decibels, no less than	50

Notes:

1. The indexes of the through channel are normalized with the three-program speaker corresponding to class II of the through channel.

2. The unaltered value of the nonuniformity of the frequency characteristic ΔS_2 can be shifted within the limits of ΔS_1 (Fig 3.4).

3. The norms for the harmonic coefficient indicated in the numerator must be withstood for the rated signal level at the end of the through channel, and in the denominator for all levels reduced with respect to rated from 6 to 20 decibels, for channels with devices having two-cycle low-frequency stages.

4. Signal/background ratio; signal/noise ratio; signal/intelligible crosstalk ratio are normalized in the interval.

5. Signal/background ratio is given for the channel with three-program speaker corresponding to class II of the through channel. For the channel with group receivers the norm in decibels is no less than 50.

Table П1.2. Quality Indexes of the Operating Channel and Parts of It

Name of Indexes	Norms for the quality indexes of the operating channel and parts of it			
	Input-output of transmitter	Input of the transmitter -- output of the transformer substation	Input of the transmitter -- subscriber rosette of the three-program speaker	Input of the transmitter -- subscriber rosette of group receiver
Reproducible frequency band, hertz	100-6000	-	100-6000	100-6000
Nonuniformity of the frequency characteristic, decibels, no more than	In accordance with Fig 3.6	-	In accordance with Fig 3.5	In accordance with Fig 3.4
Harmonic coefficient, %, no more than, at frequencies:				
more than 100 to 200 hertz	4.0/2.0	-	-	8.0/4.0
more than 200 to 2000 hertz	2.5/1.3	-	-	4.0/2.0
more than 2000 to 4000 hertz	2.5/1.3	2.8/1.4	4.0/2.0	5.0/2.5
Signal/background ratio, decibels, no less than	60	-	-	50
Signal/noise ratio, decibels, no less than	60	-	-	55
Signal/intelligible cross-talk ratio, decibels, no less than:				
from the low-frequency channel	60	55	53	50
from the high-frequency channel	60	-	57	50

APPENDIX 2. EQUIVALENT PARAMETERS OF THE DISTRIBUTING FEEDER LINES

Table П2.1. Equivalent Parameters of the Bimetal (BSM) Circuit with Wire Diameter of 3 mm

Load -- subscriber transformer TAG-10

S, тр/км (1)	(2) Параметры на частоте 78 кГц				(8) Параметры на частоте 120 кГц			
	$z_{вэ}$ (3)		$\alpha_э$	$\beta_э$	$z_{вэ}$ (3)		$\alpha_э$	$\beta_э$
	модуль Ом (4)	угол (5)	дБ/км (6)	рад/км (7)	модуль, Ом (4)	угол (5)	дБ/км (6)	рад/км (7)
5	633	2°20′	0,76	1,59	602	—0°36′	0,45	2,54
10	645	4°36′	1,30	1,55	596	—1°12′	0,65	2,57
15	656	7°24′	1,90	1,52	588	—1°42′	0,86	2,51
20	664	9°48′	2,50	1,49	576	—1°42′	1,06	2,64
25	670	13°12′	3,1	1,46	568	—2°18′	1,25	2,68
30	672	16°	3,7	1,43	556	—[illegible]°24′	1,43	2,71
35	671	18°54′	4,40	1,41	544	—3°24′	1,61	2,74
40	665	21°48′	5,0	1,39	534	—3°24′	1,8	2,78
(9) Нагрузка—абонентские трансформаторы ТАГ-25								
5	658	14°24′	3,7	1,44	624	4°	1,65	2,47
10	633	29°12′	7,5	1,37	623	8°	3,10	2,44
15	537	39°38′	10,8	1,40	622	11°30′	4,5	2,43
20	472	45°18′	13,7	1,46	612	15°30′	6,0	2,43
25	417	48°56′	16,2	1,54	599	18°18′	7,4	2,44
30	378	51°	18,4	1,62	583	21°48′	8,7	2,45

Key:

1. S, tr/km
2. Parameter on a frequency of 78 kilohertz
3. z_{Be}
4. Modulus, ohms
5. Angle
6. Decibels/km
7. Rad/km
8. Parameters on a frequency of 120 kilohertz
9. Load -- subscriber transformer TAG-25

Table П2.2. Equivalent Parameters of a Steel Network with Wire Diameter of 3 mm

Load -- subscriber transformers TAG-10

S тр/км (1)	(2) Параметры на частотах 78 кГц				(8) Параметры на частоте 120 кГц			
	$z_{вэ}$ (3)		$\alpha_э$	$\beta_э$	$z_{вэ}$ (3)		$\alpha_э$	$\beta_э$
	модуль Ом (4)	угол (5)	дБ/км (6)	рад/км (7)	модуль Ом (4)	угол (5)	дБ/км (6)	рад/км (7)
5	820	—6°10′	3,5	1,96	762	—6°40′	3,8	3,07
10	237	—3°35′	4,1	1,91	750	—6°	4,2	3,10
15	850	—0°43′	4,8	1,85	740	—5°30′	4,5	3,13
20	860	2°	5,5	1,80	730	—5°	4,8	3,17
25	866	5°	6,3	1,76	719	—4°40′	5,0	3,21
30	867	7°40′	7,1	1,72	710	—4°10′	5,4	3,25
35	862	10°30′	7,8	1,67	700	—3°25′	5,6	3,39
40	855	14°20′	8,7	1,62	690	—3°25′	5,8	3,33
(9) Нагрузка—абонентские трансформаторы ТАГ-25								
5	860	7°35′	7,0	1,72	787	—3°15′	5,21	2,93
10	790	23°10′	11,7	1,58	787	0°50′	7,0	2,89
15	675	32°10′	16,0	1,56	775	4°50′	8,75	2,85
20	594	37°45′	19,7	1,59	760	8°25′	10,7	2,84
25	550	40°30′	23,2	1,64	742	12°	12,3	2,84
30	515	42°30′	26,6	1,70	720	15°	14,1	2,83

Key:

1. S, tr/km
2. Parameters on a frequency of 78 kilohertz
3. z_{Be}
4. Modulus, ohms
5. Angle
6. Decibels/km
7. Rad/km
8. Parameters on a frequency of 120 kilohertz
9. Load -- subscriber transformer TAG-25

APPENDIX 3. MAXIMUM ADMISSIBLE LOADS OF A STORY (IN POINTS) OF THE STAIRCASE WIRING LINES

Table П3.1

Длина линии лестничной проводки, м (1)	Число точек на этаже, подключенных к одной линии лестничной проводки, при длине квартирной проводки, м (2)							
	15				30			
	длина чердачной проводки, м (3)							
	0	(4) до 10	(4) >10 до 15	(4) >15 до 25	0	до 10	(4) >10 до 15	>15 до 25 (4)
Провод ПТВЖ-2×1,2 (5)								
(4) до 15	6	6	6	6	6	6	6	4
>15 до 27	6	5	4	2	6	2	2	—
>27 » 36	6	4	3	2	4	—	—	—
>36 » 48	4	2	2	—	2	—	—	—
>48 » 60 (4)	2	—	—	—	—	—	—	—
Провод ПВЖ-2,5 (6)								
(4) до 15	6	6	6	6	6	6	6	6
>15 до 27	6	6	6	4	6	4	3	2
>27 » 36	6	6	5	3	5	3	3	2
>36 » 48	6	4	3	2	3	2	2	—
>48 » 60	3	2	2	—	2	—	—	—
Провод ПВ-1,5 (ППВ-2×1,5) (7)								
>15 до (4) 27	6	6	6	6	6	6	6	4
>27 » 36	6	6	6	6	6	6	6	3
>36 » 48	6	6	6	6	6	6	5	3
>48 » 60	5	5	5	5	5	4	3	2
>60 » 80	4	4	4	3	3	2	2	—

Key:
1. Length of the staircase wiring line, meters
2. No of points in a story connected to one staircase wiring line; with a length of the residence line, meters
3. Length of attic wiring, meters
4. to
5. PTVZh-2x1,2 wire
6. PVZh-2,5 wire
7. PV-1,5 (PPV-2x1,5) wire

APPENDIX 4. CALCULATION OF THE INDUCTANCE AND CAPACITANCE OF THE RESIDENCE CIRCUIT L_{res}, C_{res} AND THE REACTANCES X_C AND X_L ON CARRIER FREQUENCIES OF 78 AND 120 KILOHERTZ

Table П4.1

f_0=78 kilohertz	f_0=120 kilohertz
$L_{res} = 4170 \frac{1}{C_{[picofarads]}}$, millihenries	$L_{res} = 1750 \frac{1}{C_{[picofarads]}}$, millihenries
$C_{res} = 4170 \frac{1}{L_{[millihenries]}}$, picofarads	$C_{res} = 1750 \frac{1}{L_{[millihenries]}}$, picofarads
$X_L = 0.49\ L_{[millihenries]}$, kilohms	$X_L = 0.75\ L_{[millihenries]}$, kilohms
$X_C = 1.95 \cdot 10^3 \frac{1}{C_{[picofarads]}}$, kilohms	$X_C = 1.33 \cdot 10^3 \frac{1}{C_{[picofarads]}}$, kilohms

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