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Development of the "Brommy" and the "Wullenwever" Apparatuses [redacted]

Method of Operation

1. The "Wullenwever" apparatus was developed in Germany during the war as a direction finder. By connecting two similar antenna halves in opposition and in proper phase relation, it became possible to obtain a minimum bearing of ±0.5°; however, it was necessary to listen-in on the transmitter for a considerable time. Enemy submarines subsequently changed to sending messages and position by impulses not longer than 50 ms, remaining silent for hours and even days. An instrument had to be developed, therefore, which would be able to receive such an impulse and immediately use it to get bearings. The "Brommy" apparatus was able to do this but the accuracy of the bearing changed at least ± 1°. The instrument described below answered both needs. A switch changed the antennae to audible reception("Wullenwever") or visual direction finding. It became desirable, however, to have the two methods work simultaneously and, if possible, with respect to the same direction of search. This was achieved by simultaneously connecting to the antenna four receiver stations, one of the stations working on audible, and the others, or all four, on visual bearing. (See attached sketch for a circuit diagram of the "Brommy" apparatus.)

Antenna Amplifier

2. An amplifier is located directly behind each of the 40 antenna grids (arrays). First is an input transformer followed by an 6AC7 tube. Next there is another transformer, four amplifier tubes (6AC7) connected in parallel, with four output transformers. Thus, a total of 200 tubes are needed for these antenna amplifiers. A switch is located behind each output to make connection either to one of the four receivers and directly to the "Brommy" apparatus (visual), or to the compensator for audible bearings.

50X1-HUM

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Transit Time Circuit

3. Six adjacent arrays were connected to the input of each receiver. They were arranged in a circle and transit-time-circuits had to be used to compensate for the path difference so that the distance between any group of six antennas and the receiver would be a constant, as would the distance between any group and the transmitter.

Highpass Filter

4. Since the instrument was intended only for a frequency range between two and twenty mc, it became necessary to eliminate the lower frequencies. A highpass filter was, therefore, installed behind each six-antenna cluster which would pass only frequencies above 1.7 mc.

Input Circuits

5. Behind the input transformer in each of the two receiving branches (A and B on sketch) there followed one 6AC7 amplifier, a tuning circuit, another type 6SK7 amplifier tube, and another tuning circuit. The four variable condensers were mounted on one shaft together with the variable condenser for the oscillator and had to be exactly synchronized.

Oscillator I

6. The frequency of this oscillator was 1,640 megacycles (sic) higher than the receiver.

Mixer Stage I

7. The oscillator frequency entered the mixer stages, each of which contained one 6SA7 tube. The intermediate frequency was 1640 kc.

Dividing Filter

8. The dividing filters come next, consisting of four stages in each channel with a variation of ± 4 kc in each. Behind the first four steps a tube was provided to furnish a part of the voltage for another purpose (see below).

Oscillator II, Mixer Stage II, and Dividing Filter II

9. A second oscillator, the so-called "wobble oscillator", produced 25 kc for the two mixer stages II which resulted in frequencies of 1615 and 1665 kc. Each mixer stage II was followed by a dividing filter. The 1615 kc frequency was filtered out for amplifier A, and the 1665 kc for amplifier II B.

Amplifier C

10. Initially, a third amplifier was added parallel to the receivers A and B, coming directly from the antenna and having the same intermediate stages. Instead of the mixer stage II, however, it had a phantom stage, because it was to furnish the first intermediate frequency of 1640 kc following the dividing filter II. Later, however, the first stages (antenna to highpass filter, to input circuit, to mixer stage I, to dividing filter I) were left off and voltage was taken from the two divider tubes in the divider filters I (see above). These two voltages were brought together at a junction point where the strongest channel could be selected, and from there to a divider filter for 1640 kc, which consisted of the four missing second filter stages, so that the same selection could be obtained as in the receivers. The phantom stage which followed was in turn followed by a second dividing filter for 1640 kc. From here the second dividing filter as well as outputs from divider filters II of A and B came together at the input of the intermediate-frequency amplifier.

Phases

11. Calculation will show that the phase of the receiver frequency, which differs in A and B, can be the same in the intermediate frequency. The phase of the middle channel C must remain constant, although the phase itself is not important. What is important is that the group-transit-time of all three frequencies be kept constant to avoid distortions. In order to keep any error during direction finding low, the change in the group-transit-time must not be more than five percent. The phantom phase in Channel C, therefore, is needed to bring about the same phase shift as in mixer stages II in A and B.

Intermediate Frequency Amplifier

12. In order to assure the necessary bandwidth for all three channels for the IF amplifier which comes next, Lt. Col. Khazin suggested that an RC-amplifier be used. This amplifier consisted of six stages with 6SK7 tubes. In order to prevent oscillations it was divided into two parts by a band filter. Its output voltage was 200 mv.

Dividing Filter III, Mixer Stage III

13. In the dividing filter which now followed, the three channels were again separated. While channel C with 1640 kc went through a buffer stage for further use (and through a phase shifter), the channels A and B went directly to the mixer stage III where they again joined channel C, which at this point has been shifted into the correct phase relationship.

25 kc Amplifier

14. The next step was from the mixer stage III to the two 25 kc amplifiers, each with one 6AC7 tube. Their output was approximately 50 v for the two pairs of deflecting plates of the visual instrument.

Visual Indicator

15. The indicator used a cathode-ray tube, type OSW 2068 (Oberspreewerke), with a diameter of approximately 120 mm. Together with the fader (beam-brightness control?) and the horizontal signal, the two deflecting voltages gave a radial beam with a normal direction from the center of the tube vertically upward. Its lateral deviation was nearly 180° to both sides, corresponding to the DF angle. However, the deviation depended on the frequency. The same bearing deviation furnished ten times greater beam deviation at 20 mc than at 2 mc.

Audible Direction Finding

16. The HF voltage of each array, furnished by the antenna amplifier, went through a transformer to three condenser plates. Thus, there were 120 condenser plates serving as stator plates of a cylindrical compensator. At the same time the rotor of this compensator took off the voltages from 18 stator plates. A second rotor collected from the adjoining 18 stators. The compensator had to be constructed with extreme care. The rotor diameter was 800 mm. The next step was from the two rotor plates, past transformers, to the so-called sum-and-difference bridge and from there to channels A and B. The summation voltage from the bridge was used for synchronization and searching, while the difference voltage enabled (the operator) to find the exact bearing at voltage 0. The direction was read from an inclined instrument dial.

Difficulties and Shortcomings of the "Brommy"

17. Lt. Col. Khazin especially wanted quartz filters for the dividing filters. The crystals which were furnished, however, did not prove satisfactory or suitable for the purpose, although several weeks were used in testing them. They were of Soviet manufacture, but where the quartz originally came from is not known. It finally became necessary to use the eight-stage filter circuit.

50X1-HUM

18. When the antennas were first installed, a mismatching factor of m= 1.7 was discovered at the receiver input. This was too high for our purpose since it resulted in multiply-reflected pulses which caused errors in direction finding.

19. The Soviet supervisors were greatly incensed, but they would only allow Dr. Erich Schuettloeffel one attempt to trace the error on the spot. Following Dr. Schuettloeffel's directions, the crew had to go through a tedious process of checking and measuring the distances of the reflectors and the ratio of diameter to height of the arrays. These measurements were done by the Soviets and turned over to Dr. Schuettloeffel for checking. When finally the mismatch had been lowered to m = 1.1, it was discovered that the cement foundations had to be replaced to fit the 40 arrays. The Soviets considered this a serious shortcoming in Dr. Schuettloeffel's work.

"Brommy" Apparatus for Ultra High Frequency (Ultra Short Wave)

20. Drawings for the "Brommy" apparatus for frequencies of 20 to 40 mc were quite rough. No blueprints were made. It was found theoretically that an additional intermediate frequency would be needed at about ten mc. This reduced the number of bands to about five to six. The oscillator for the old intermediate frequency of 1640 mc (sic) had to remain constant. The rest of the receiver design was the same as in the first plan. The error in the direction-finding proved to be greater in the higher frequency: for audible operation it was ± 1° and for visual operation it was ± 2°. By using smaller antenna arrays it became possible to use smaller foundations for the antennas. It was planned to use a dielectric for the compensator.

21. The question of tubes proved to be the greatest difficulty. Types 6AG5 and 6SA7 had to be tested for their suitability. For this purpose the German specialists developed a phase measuring instrument and a tangent meter (Steilheitsmessgeraet). The tubes were tested elsewhere with the phase meter. The 6AG5 proved to have a sufficient electron-transit-time, but the 6SA7 was unsuitable for higher frequencies.

22. Only very rough plans have been made for a "Brommy" installation suitable for frequencies of 40 to 60 mc because it will be necessary, of course, to see how the 20 to 40 mc installation work out.

Development of the PMD-1

23. The PMD-1 is an instrument which is designed for direction finding of enemy transmitters in a wavelength range of 40 to 110 cm. It is divided into two bands: 39 to 67 cm and 65 to 110 cm.

24. The antenna is an H-Adcock. Two parallel dipoles are inclined at a 45 degree angle to the horizontal. They are arranged side by side in front of a reflector and at a distance of 1.20 m from each other. The reflector consists of a flat wire net which is installed vertically at a distance of approximately 15 cm behind the dipoles. The dipoles are approximately 40 cm long, and because of the broadness of the band, have a U-profile open to the front. At their ends they are triangular and pointed. The antenna rests on an adjustable base so that it can be elevated two to five m above the ground. The antenna angle (direction-finding angle) is read from a goniometer divided into 360 degrees with an accuracy of ±1°. A 70-ohm cable, with a maximum 1.1 mismatching, leads from each dipole at the point where they join. A "slide trombone" (Posaune)(Telescoping arrangement) is inserted in one of the branches and must be adjusted to a predetermined length for each frequency. The signals are combined in such a way that the phases of the two antennas differ by 180° so that a direction-finding minimum can be obtained.

25. The receiver is a superheterodyne with cavity resonators. Two LDI tubes are used as input tubes, one of which serves as the oscillator. The two tank-circuits are synchronized and furnish an intermediate frequency of two mc. The bandwidth is 120 kd. This type of circuit provides a reception sensitivity of 3.6 kt_o in the center of the band, 9 kt_o at 40 cm, and 5 kt_o at 110 cm.

50X1-HUM

26. The IF amplifier has three stages and contains a band filter and three 6AC7 tubes. One 6AC7 tube works as a peak limiter or as a modulator on the grid-cathode-path, or as a rectifier in the diode path. Following this there is a 6H6 as FM-detector and a 6SI7 low-frequency amplifier. Finally there is a 1KIP pentode (a Soviet type with 1.4 v filament) which works as a telegraph modulator at 800 cycles. The LD1 input tube was chosen because the unit is to be operated either from the line or from a battery.

27. The main operating switch can be set for the following:

    a. Telephone AM

    b. Telephone FM

    c. Telegraph with modulator

    d. Grid current control

    e. Plate voltage control

    f. Filament voltage control

28. The low frequency potential is read from an output instrument. This instrument serves for direction finding.

29. The amplifier can be controlled by hand or automatically. The receiver uses 1.4 amp at 12.6 v, and 65 ma at 150 v. A plate voltage of 130 to 200 v can be developed by a special power pack. No stabilization is needed for the oscillator because its operation is independent of voltage. Since the oscillator needs only 30 seconds to warm up and its frequency is practically constant after two minutes, and since the temperature coefficient amounts to only f= 2×10^{-5}/°C, the instrument is very suitable for this kind of work. 50X1-HUM

Attachment: Circuit diagram of the "Brommy" apparatus. (Army 4, Navy 2, Air 3,

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Attachment

Circuit Diagram of the "Brommy" Apparatus