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DIRECTION-FINDING ADAPTER

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[Figures referred to are appended.]

Among the assignments which can be carried out by radio amateurs during the observation of signals from the artificial Earth satellite is the determination of the instant when the satellite will pass over an observation point. The instant of transit can be determined by various methods, in particular, by the shift of the received frequency due to Doppler effect, or else by the method of equisignal zone (widely used in radar for determination of angle coordinates). This article describes the equisignal-zone method and a simple adapter for observations of the satellite by this method.

The Equisignal Zone Method

What an equisignal zone is can be seen from Figure 1. This figure shows schematically two identical antennas, A_1 and A_2, which are located some distance from each other.

Radiation patterns of the antennas in the vertical plane are shown here by a solid line. For observations by this method, the radiation patterns of the antennas are formed in such a manner that the direction of best reception of the antennas is somewhat displaced in space. Let us assume that the satellite is passing over the antennas in such a way as to occupy positions one and two successively. Let us observe the changes of the signal strength in the antennas during the movement of the satellite. As is seen from Figure one, when the satellite is located at position one, the signal in antenna A_1 will be at its maximum and will considerably exceed the amplitude of the signal in antenna A_2. As the satellite moves to the right from point I, the signal level increases in antenna A_2 and decreases in antenna A_1. Therefore, in position two, which the satellite will occupy several instants later, the signal amplitude in the antennas will not differ as much as it did in position one.

In its further movement, the satellite will occupy position three, when the signal becomes equal in both antennas. In this case we can say that the satellite is located in the equisignal zone.

In space, this zone comprises a vertical plane between the antennas, which the satellite should necessarily intersect when passing over the point of observation, except when the trajectory of the satellite is parallel to the equisignal plane. Registering the instant of transit of the satellite over the equisignal plane can serve for the precise determination of its orbit. For a determination of this instant both antennas (A_1 and A_2) are connected to the receiver through a special direction-finding adapter, the basic element of which is an electronic switch. The switch alternately connects the antennas to the receiver at a rate of several hundred times per second (Figure 2), which affords opportunity to observe the oscillations at the output of the receiver (Figure 3) to determine the ratio of the signals induced in antennas A_1 and A_2.

If the satellite is outside the equisignal zone, then the signal strength in the two antennas is different; therefore, the amplitude of the oscillations at the input of the receiver changes with the frequency of the

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antenna switching (Figure 3). Detection of these oscillations will produce square pulses, reproducing the signal envelope at the input of the receiver. These pulses can be heard as a tone with a frequency equal to that of the antenna switching (with local oscillator disconnected). In the course of the movement of the satellite, the signal in antenna A_1 will decrease and will increase in antenna A_2; as a result tone loudness at the output will decrease. At the instant the satellite transits the equisignal zone, the signals in antennas A_1 and A_2 will be equal, and the tone of the switching frequency will not be heard (Figure 3). To secure an equisignal plane, the antennas should be completely identical and have symmetrical (with respect to the vertical axis) radiation patterns. The required shift of the direction of best reception with respect to the vertical axis can be attained by a proper positioning of the antennas.

The basic element of the described direction-finding adapter (Figure 4) is a symmetrical multivibrator (L_4,L_5) which controls two identical high-frequency amplifiers (L_1,L_2) with a common plate load (circuits L_2, C_5,C_6). The signal from each antenna is transmitted to the corresponding input (A_1 A_2) of the amplifier by means of a coaxial cable.

To the screen grids of tubes L_1 and L_2 is supplied a voltage in the form of square pulses, which change the potential of the screen grids in steps from 0 to +120 volts. In accordance with this, there occurs an alternate connection of the high-frequency amplification stages, and from the common plate load to the output stage of the adapter (L_3), the amplified signals alternate from each of the antennas.

The multivibrator, built with an electron coupled circuit, generates pulses which are almost square. The switching frequency is determined by the capacitance of the capacitors C_7, C_8 and resistance of resistors R_9, R_{10}. For the magnitudes of these elements in this circuit, the switching frequency is 270 cycles. For the complete cutoff of tubes L_1, L_2, a small positive (with respect to the cathodes of tubes L_4, L_5) voltage of about 10 volts is applied to the cathodes of tubes L_1 and L_2, which is built up by the current in the circuits of the cathodes of tubes L_1, L_2, L_3 across the resistor R_5.

Autotransformers are used to match the characteristic impedance of the cable (75 ohms) at the input circuits.

The cathode circuit of the output stage, which comprises a common cathode follower, is closed on the direct current through the incoming circuit of the receiver.

For observations by the equisignal zone method, it is necessary that both high-frequency stages have the same amplification. Adjustment of amplification is accomplished by changing the bias at the grids of tubes L_1, L_2 with the aid of resistor R_3.

The capacitors C_3 and C_{10}, each 100 micromicrofarads, decouple the screen grids of the high-frequency amplifier tubes and do not affect the form of switching voltage. The adapter is installed close to the antennas; therefore, a low voltage of 12.6 volts is selected for its power supply. This voltage is supplied directly to the heating circuits of the tubes, divided into two series-connected groups.

The middle point of the primary winding of the power transformer is grounded and serves to equalize the heater voltage (6.3 volts) in both groups. For power supply to plate circuits, a common Kenotron rectifier

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6Zh5S (16) is used. A potential of 12.6 volts is obtained from a special transformer installed in the vicinity of the receiver; this transformer actually has to be designed for a potential of 13-14 volts to compensate for the potential drop in the connecting wire.

Structurally, this direction-finding adapter is built on a separate chassis having the dimensions 190 by 150 by 60 mm. The location of the basic components on the chassis is seen in Figure 5. To reduce the mutual effect of stages, copper, brass, or aluminum screening sections (tube shields) are placed between tubes L_1, L_2 and L_3. On the side of the chassis are three terminal blocks for coaxial cable (two for antennas A_1 and A_2 and one for the connection to the receiver).

Wiring of both stages of high frequency amplification should be carried out according to the same wiring system. The grounding of all components belonging to the same stage is done at one point near the corresponding tube.

Trimming capacitors C_1, C_5 and C_{12} are mounted in such a manner that the tuning of the circuits can be achieved without removing the lower lid of the direction-finding adapter.

High-frequency coils L_1, L_2, L_3 are mounted at the output of the corresponding trimming capacitors. These coils are made with silvered wire with a diameter from one to 1-1/2 mm, wound on an 8-mm mandrel, and containing seven turns. After winding, the coil is stretched to a length of 18 mm. Coils L_1 and L_3 have taps from the second turn, counting from the grounded end.

Tr_1 has a core of plates Sh-19 (thickness of the assembly, 20 mm). Winding one has 2 by 110 turns of PEL-1 wire, 0.74, three secondary- II- 2 by 4.900 turns of PEL-1, wire, 0.12.

The choke of filter Dr_1 has a core of Sh-15 plates, having an assembly thickness of 25 mm. The winding is done with PEL-1 wire, 0.15, covering the whole form. A step-down transformer for the power supply to the adapter (not indicated in the figure) is built with a core of Sh-19 plates; the thickness of the assembly is 50 mm. The primary winding of this transformer is designed for connection to a power line of 110, 127, and 220 volts and contains, accordingly, 550 turns plus 83 turns of PEL-1 wire, 0.44, + 470 turns of PEL-1, wire 0.33. The step-down winding consists of 87 turns of PEL-1 wire, 1.2, and has taps from the 72d, 77th, and 82d turns for selection to the adapter of a normal voltage of 12.6 volts. Between the primary and the secondary winding is a screen made of a single layer of PEL-1 wires, 0.15 to 0.2.

Adjusting to the direction finding adapter is usually begun by checking tube performance. The operation of the multivibrator is checked with the aid of an oscillograph; the pulses should be practically square at the plates of tubes L_4, L_5. When there is a considerable difference in the duration of the two half-periods of the generated oscillations, it is necessary to change somewhat the value of leak resistance or the capacitance of the separation capacitor in the circuit of the control grid of one of the tubes. It is desirable to check the frequency of the multivibrator-generated oscillations with the aid of an audiogenerator (with respect to Lissajous figures on the screen of the oscillograph). If it is necessary, the frequency can be changed by the selection of capacitors C_7, C_8 or the resistors R_9, R_{10}.

For tuning the high-frequency amplifier, generator BG-1 and voltmeter DKS-7 can be used. For this purpose, a 75-ohm resistance is connected temporarily at an output of a cathode follower.

The tuning of each stage of the high-frequency amplifier is repeated several times.

The final tuning stage is balanced through a balancing and equalizing of the amplification of both arms of the amplifier (with the aid of R_3).

Antennas

Half-wave split dipoles, similar to those which are used for the reception of TV programs, can be used as the antennas. To secure the desired direction for the best reception, the antennas should be placed at a height of a quarter of a wave above the earth's surface. In contrast to television reception, the diameter of the dipoles can be selected only on the basis of constructional considerations; the antenna band-width is of no significance. The antenna structure should be sufficiently rigid so that it will not be swayed by a strong wind.

For measurements by the equisignal zone method, two identical dipoles are used, placed exactly parallel to each other at a distance of the order of half a wave length. (In the future, this distance will be more accurately defined.)

The dipoles are oriented (see Figure 8) so that the line connecting their centers will coincide with the east-west direction and so that the equisignal plane is in the direction of the meridian. The direction-finding adapter is installed on the ground between the antennas, is covered with a protecting jacket, and is connected to the antennas by cables of equal length (with an accuracy up to one to 2 cm).

Because the earth's surface participates forming the antenna radiation pattern, the antenna should be located on a level site; any considerable unevenness of the relief at the site of the antenna will distort the equisignal zone and will cause errors in observations. For the same reason, for a distance of up to ten wavelengths, there should not be any large metallic masses and other shielding objects. It is also objectionable to use metal guy rods for fastening the antennas. As already mentioned, using the equisignal method is impractical in cities. The construction of one of the possible antenna variants for a wave length of 7.5 meters (40 megacycles) is shown in Figure 7. Coupling the antenna to an unbalanced 75-ohm coaxial cable is done with the aid of a balancing U-shaped bend. The dipoles are located at a height of 18.75 meters above the earth's surface, and the distance between them is 3.75 meters. The radiation pattern of a single antenna for this particular case is shown in Figure 9.

For operations without the switch, one of the antennas is directly connected to the input of the receiver.

[Appended figures follow.]

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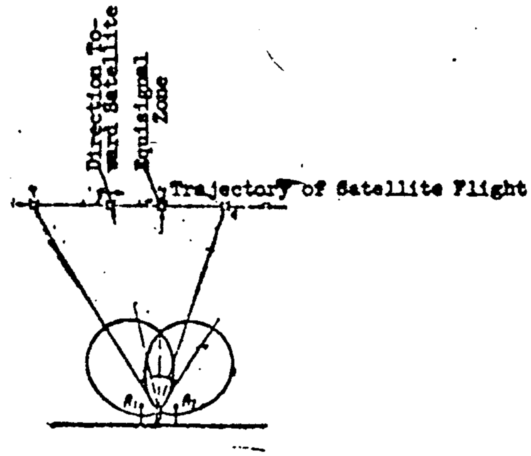

Figure 1

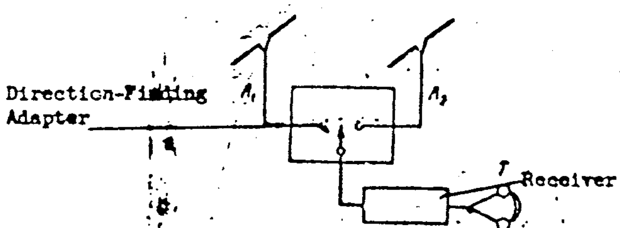

Figure 2

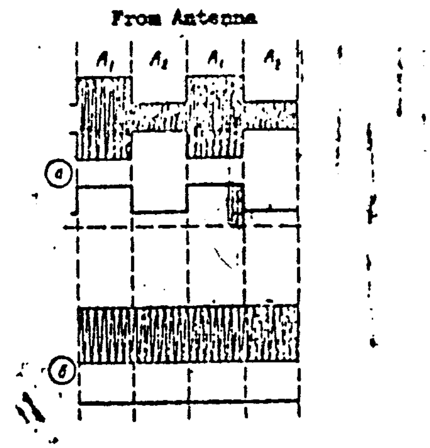

Figure 3

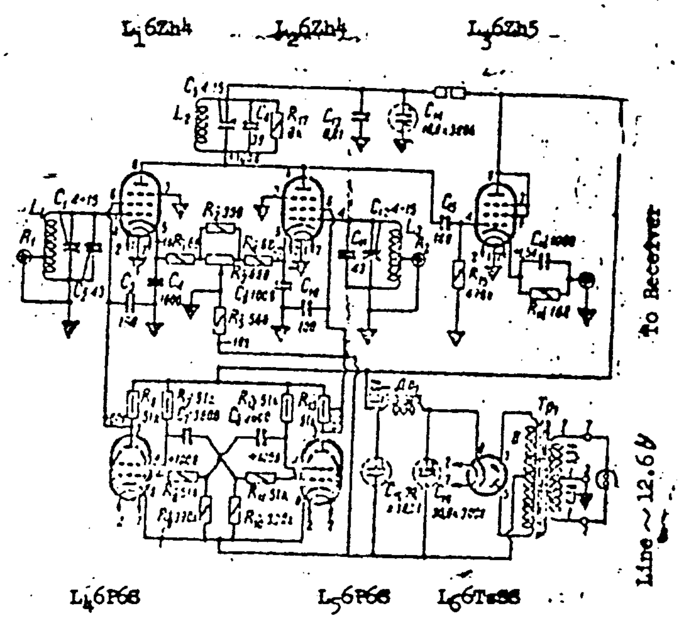

Figure 4

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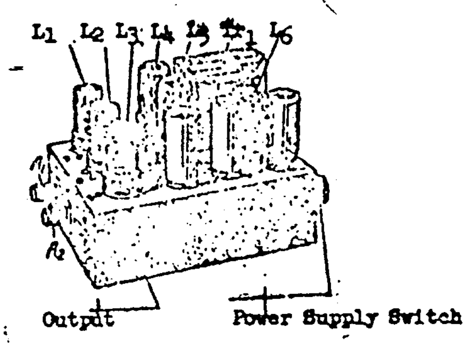

Figure 5

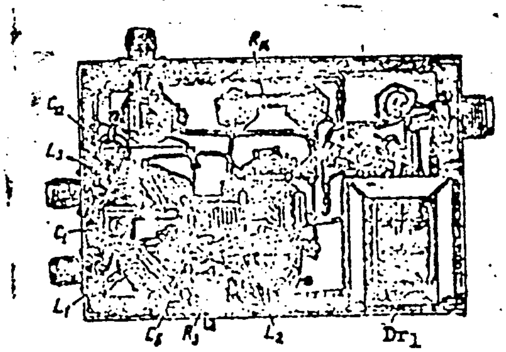

Figure 6

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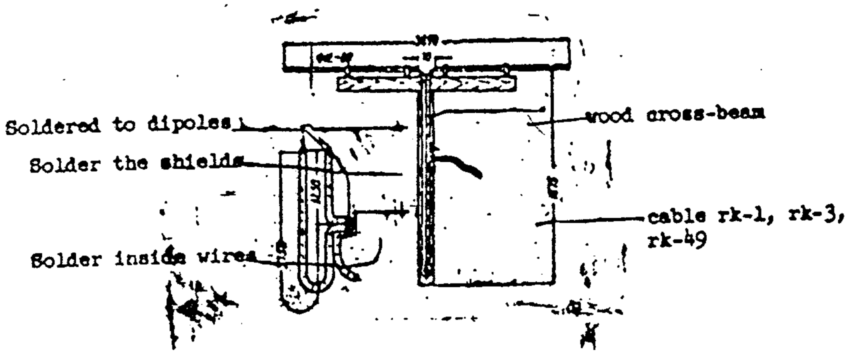

Figure 7

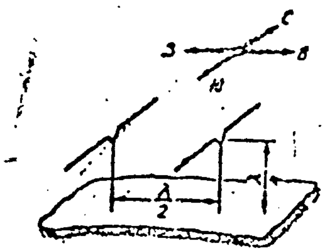

Figure 8

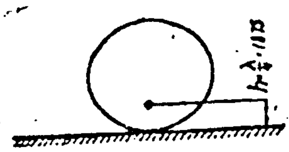

Figure 9

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