Sept. 1, 1931. F. A. KOLSTER 1,821,650

RADIO SYSTEM

Filed June 26, 1928

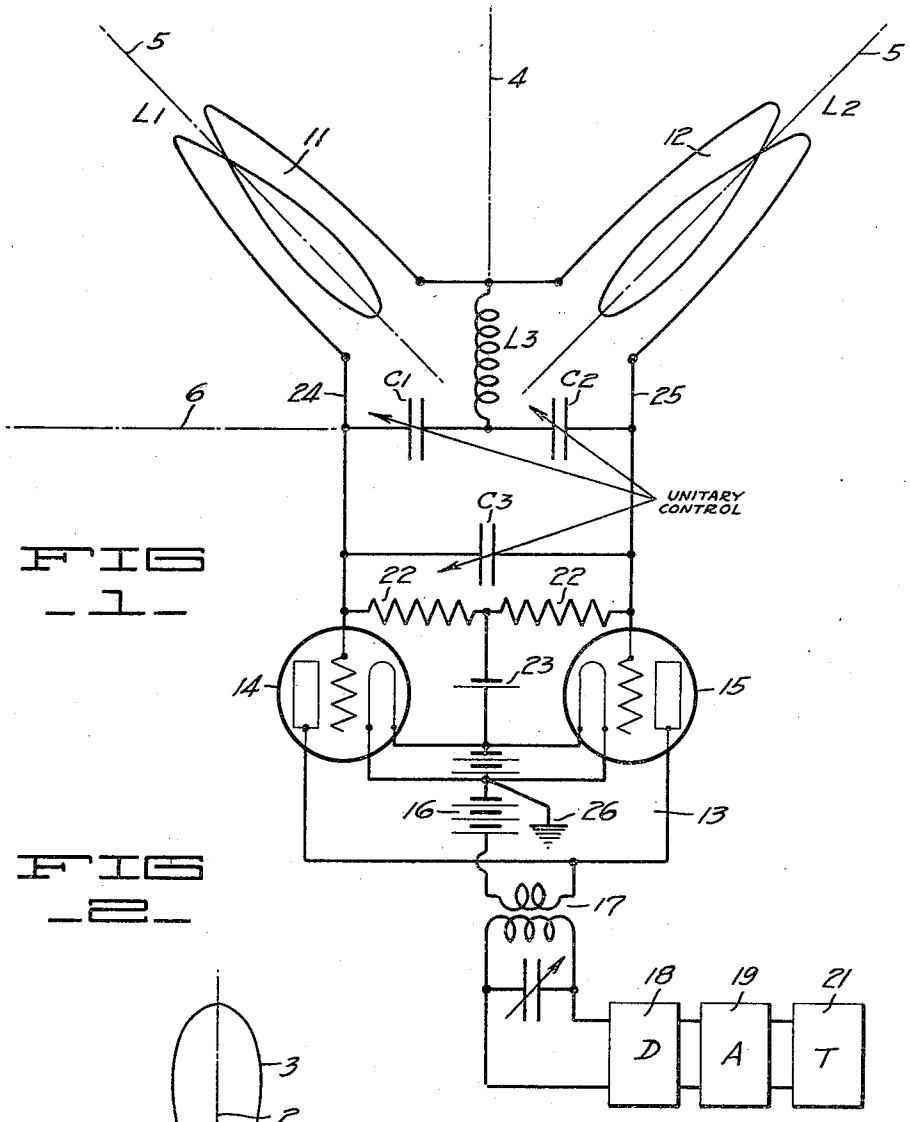



FIG 1

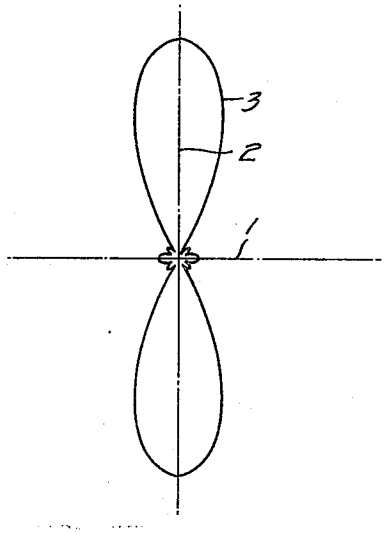



FIG 2

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Patented Sept. 1, 1931 1,821,650

# UNITED STATES PATENT OFFICE

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## RADIO SYSTEM

Application filed June 26, 1928. Serial No. 288,462.

This invention relates to radio signaling systems and particularly to systems for the directive reception of signals.

An object of the invention is to provide radio receiving means having pronounced directional characteristics.

The above object is achieved by so placing two bilaterally directive antennæ that the directions of maximum efficiency of the separate antenna are 90° apart and so associating them in an electric circuit that they produce, on a detecting device, a cumulative signaling effect in response to signals from one direction while producing little or no effect in response to signals from other directions.

Referring to the drawings:—

Figure 1 is a circuit diagram illustrating the preferred form of connecting the apparatus which I utilize in my system and method.

Fig. 2 is a view illustrating diagrammatically the characteristics of my combined system and method.

The system of this invention may be outlined briefly as comprising a pair of directive radio antennæ arranged so as to be directed along intersecting paths, and connected to conjointly effect a radio receiver. The reactance of the several elements and the inductance of the antennæ are proportioned so that the system provides the same resonant period for any one setting of the system irrespective of the direction from which signals are received.

The drawing depicts a pair of directive antennæ 11 and 12, in the form of loops having a relatively small distributed capacitance and high frequency resistance, and comparatively high lumped inductances. The loop antennæ are arranged in planes at an angle to each other, the preferred angle being about 90 degrees as shown. A suitable signaling circuit 13 is connected so as to be jointly influenced by both antennæ.

The system and method of this invention is particularly useful for radio receiving systems and therefore signaling circuit 13 is shown as consisting of suitable means for receiving and detecting radio signals. In this connection it is preferred to employ radio frequency amplifying means utilizing electron relays 14 and 15 of the usual three element type. The grids of relays 14 and 15 are connected to corresponding terminals of loop antennæ 11 and 12, by means of conductors 24 and 25. The plates of relays 14 and 15 are connected together and are energized from a suitable source of potential represented by the "B" battery 16. For coupling the remainder of the receiver with the output circuits of relays 14 and 15, there is shown a coil 17 connected in series with "B" battery 16, and this coil is shown as coupled to the input circuit of a suitable detector 18. The energy in the output circuit of detector 18 is preferably amplified in a suitable audio frequency amplifier 19 before being impressed upon a translator 21. Suitable grid leaks 22 are connected between the grids and filaments of the relays, and a suitable "C" battery 23 is inserted in the cathode-grid path common to the two tubes for maintaining a negative bias upon the grids. The cathodes of relays 14 and 15 preferably have a common energizing circuit provided with a suitable ground connection 26.

It is commonly known that a single loop antenna is bilaterally directive, that is, it is directive in two directions along a linear axis. A curve representing the directional characteristics of such a loop is theoretically a figure 8. It has been found that by properly combining two loop antennæ, the directional characteristics of the resultant system can be made more accentuated than the characteristics of a single loop antenna. To obtain this result, there is employed, in addition to the apparatus described above a pair of variable condensers $C_1$ and $C_2$ which are connected in series across conductors 24 and 25. Likewise connected directly across conductors 24 and 25 and therefore in shunt with series condenser $C_1$ and $C_2$, there is another condenser $C_3$. In addition to these condensers, there is provided an inductance coil $L_3$ having one of its terminals connected to corresponding terminals of loops 11 and 12, and its other terminal connected to the conductor interconnecting series condensers $C_1$ and $C_2$.

The lumped inductance of loop 11 is made substantially the same as the lumped induc-

tance of loop 12, and the inductance of coil $L_3$ is substantially the same as to that of each of loops 11 and 12. Likewise the condensers $C_1$, $C_2$ and $C_3$ have equal capacities. In order to tune the system for different wave lengths, the capacitance of each of the condensers is varied, and for this purpose these condensers are made variable and are preferably mechanically actuated by means of a single unitary control. For any one setting of the unitary control, the condensers each have the same capacity.

The system as explained above has a pronounced directional characteristic, which is represented aproximately by curve 3 of Fig. 2. This curve is plotted along the polar axes 1 and 2, the axis 2 corresponding to the direction of maximum response. Assuming that the output circuits of relays 14 and 15 are connected in parallel as in Fig. 1, then the axis 2 of Fig. 2 corresponds to the direction indicated by the dot-dash line 4 of Fig. 1. Line 4 is drawn to bisect the angle formed by the planes of loops 11 and 12. If the output circuits of relays 14 and 15 are differentially connected then the direction of maximum response is substantially at right angles to line 4, and line 4 represents the direction of minimum response. Loops 11 and 12 have their terminals so connected to the remainder of the apparatus, that when receiving signals from a direction represented by line 4, impulses impressed upon the grids of relays 14 and 15 will be in phase or of the same sign at any one instant.

The manner in which the above system operates may be explained as follows: As previously mentioned, a single loop antenna has theoretically a figure 8 directional characteristic and the direction of maximum reception is parallel to the plane of the loop. The directions of the planes of loops 11 and 12 have been indicated by lines 5, and the direction at right angles to line 4 is represented by line 6. Assuming first that signals are being received from directions parallel to line 4, then it is evident that currents of equal intensity will be induced in loops 11 and 12. Because of the manner in which terminals of these loops are connected with the remainder of the apparatus, potential impulses of the same intensity and of the same phase relationship are impressed upon the grids of relays 14 and 15. Therefore amplified current variations in step with the potential variations impressed upon the grids are caused to flow in the output circuits of relays 14 and 15, which are cumulative with respect to the coil 17, and effect a response in the translator 21. Assuming a second case in which signals are being received along directions parallel to the plane of loop 11, then current is induced in loop 11 but no current is induced in loop 12 since the plane of this loop is at right angles to the direction from which signals are being received. The effect of excitation of loop 11 causes impulses to be impressed upon the grids of relays 14 and 15 which are of opposite sign at any one instant, so that no corresponding current variations are produced in coil 17. Assuming a third case in which signals are being received along directions parallel to line 6, then curents are again induced in both loops 11 and 12, but these currents are 180 degrees out of phase. Therefore at any one instant, the potentials impressed upon the grids of relays 13 and 14 are of opposite sign, hence they produce currents in the output circuits of these relays which are equal but of opposite sign so that they neutralize each other, and therefore produce no corresponding current variations in coil 17.

It can be demonstrated theoretically that for any one setting of the apparatus, the system is resonant to one frequency irrespective of the direction from which energy of that frequency is received. Assuming again the first case in which signals are received from directions parallel to line 4, two separate reactive paths are provided for current flow. Designating loops 11 and 12 as inductance $L_1$ and $L_2$ respectively, then one path is provided by inductance $L_1$, condenser $C_1$ and inductance $L_3$, and another path is provided by inductance $L_2$, condenser $C_2$ and inductance $L_3$. The two circuits are interrelated in that inductance $L_3$ is in common to both. In computing the period of the circuit arrangement for this case, inductance $L_1$ and $L_2$ are to be considered as functioning in parallel and each of these inductances are to be considered as in series with inductance $L_3$. Condensers $C_1$ and $C_2$ are likewise to be considered as in parallel. Since the potentials upon conductors 24 and 25 are equal at any one instant, condenser $C_3$ has no effect upon the circuit. The expression representing the product of inductance and capacitance for this case can therefore be written as follows:

$$\left(\frac{L}{2}+L\right)2C \quad (1)$$

In the above expression L represents the inductance value to which inductances $L_1$, $L_2$ and $L_3$ are each equal, and C represents the capacitance value of any one of condensers $C_1$, $C_2$ and $C_3$, which are equal. The above expression reduces to the following:

$$\frac{3L}{2}\times 2C \text{ which reduces to } 3LC \quad (2)$$

Therefore for the first case considered, the product of inductance and capacities is equal to 3LC.

For the second case, that is for signals received along directions parallel to line 5, current flow is along a path formed by in-

ductance $L_1$, condenser $C_3$, and inductance $L_2$. In shunt with condenser $C_3$ and inductance $L_2$, are the series connected elements $C_1$ and $L_3$. For this case no potential difference will occur across condenser $C_2$ so that this condenser has no effect upon the system. The product of inductance and capacitance for this arrangement can be written:

$$\left(L+\frac{L}{2}\right)2C \text{ which reduces to } 3LC \quad (3)$$

The system is therefore rendered automatically resonant to signals received along directions parallel to line 5, when resonant to the same signals received along directions parallel to line 4.

For the third case, in which signals are received parallel to line 6, a path for current flow is formed by inductance $L_1$, condensers $C_1$ and $C_2$ in series and inductance $L_2$, and a shunt path is formed about series connected condensers $C_1$ and $C_2$ by condenser $C_3$. At any one instant no potential difference occurs across the terminals of inductance $L_3$ and therefore this inductance has no effect upon the circuit. For this condition the product of inductance and capacitance can be written:

$$2L\left(\frac{C}{2}+C\right) \text{ which reduces to } 3LC \quad (4)$$

Expression 4 reduces to the same value of 3LC, thus proving that the system is resonant to the same frequency irrespective of the direction from which the radio energy is received. As explained above however the distribution of energy to the relays 14 and 15 is such that when receiving signals along directions indicated by lines 5 and 6, substantially no current variations are produced in coil 17, while when receiving along the direction indicated by line 4, a maximum response is produced. Although in the above theoretical discussion only three cases have been considered represented by the directions of lines 4, 5 and 6, it is obvious that the system will be resonant to waves of the same frequency received from all other directions. Thus if loop antennæ 11 and 12 are mounted upon a suitable frame rotatable about a vertical axis, then when receiving signals from any one transmitter, the system will remain in resonance with the frequency to which it is tuned as the antennæ are rotated thru 360 degrees.

The described system provides a radio system having pronounced directional characteristics. Such a system is useful for reducing interference when communicating between two stations, or may be employed as a radio compass for taking direction bearings.

I claim:

A radio system comprising conjugate loop antennæ having their planes in angular relation, a coil having an inductance equal to the inductance of each loop, said coil having one terminal connected to a terminal of each of said loops, a pair of series connected condensers connected between the other loop terminals, a condenser connected in shunt to said series connected condensers, said condensers all having equal capacitance values, the other terminal of said coil being connected to the connection between said series connected condensers, and a symmetrical signaling circuit coupled to both said loops.

In testimony whereof, I have hereunto set my hand.

FREDERICK A. KOLSTER.