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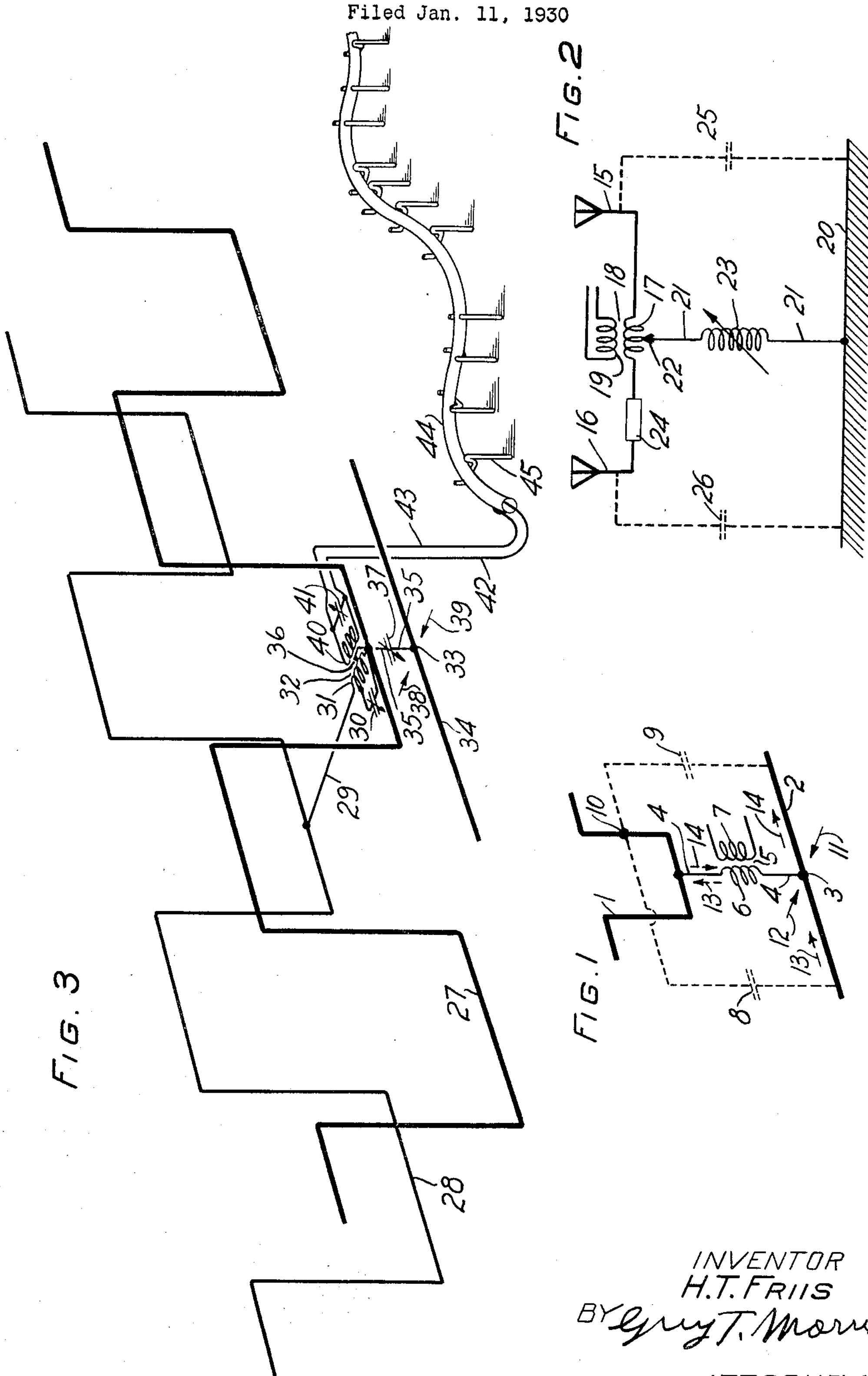

FIG. 1

FIG. 2

FIG. 3

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ANTENNA COUNTERPOISE SYSTEM

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9 Claims. (Cl. 250—33)

This invention relates to antenna systems and more particularly to counterpoise arrangements associated with antenna systems.

As is well known, counterpoise arrangements of the floating and grounded type have been used in the past in transmitting and receiving antenna systems. While in general they perhaps have not proved as effective or satisfactory as the grounded arrangements, and many of them at present in use are employed more as a matter of necessity rather than of preference, in certain systems including systems wherein a good ground is available, they are especially effective as compared with the grounded arrangements. For example, in directional systems employing a plurality of antenna units a counterpoise may be easily arranged to permit adjustment of the impedances between itself and the individual units so that the phase of the currents in the various units may be rendered similar.

One of the inherent disadvantages of practically all counterpoises as at present employed, is that it absorbs energy which opposes that induced in the antenna proper.

It is an object of this invention to improve the operation of transmitting and receiving antennæ.

It is another object of this invention to eliminate the effects of voltages induced in a counterpoise.

It is still another object of this invention to minimize the impedance of the antenna-counterpoise system.

It is an additional object of this invention to improve the directional characteristics of directive systems employing a plurality of antenna elements.

One feature of the invention resides in the use of two quarter wave length open-ended conductors conductively and colinearly joined to form a double counterpoise. This counterpoise by reason of the length of its elements offers a minimum impedance to desired currents and by reason of its direction of extension balances the pick-up of ether waves propagated in a given direction.

Another feature of the invention comprises an adjustable impedance inserted in a common down lead to the counterpoise or ground from two or more antennæ for the primary purpose of securing a desired phase difference between the respective antenna currents.

In one embodiment of the invention a counterpoise comprising a half wave length horizontal conductor such as a copper tube is connected at its midpoint to the exciter and reflector of a directional receiving antenna system by means of a short common down lead containing an adjustable impedance, the impedance between the reflector and the counterpoise being relatively large as compared to the exciter-counterpoise impedance. The counterpoise is horizontally positioned relatively close to the exciter and in a plane perpendicular to the direction of the incoming interfering waves. Undesired counterpoise currents are thus minimized or balanced and, as any change in the value of the impedance in the down lead affects the phase of the two currents a different relative degree, substantially any desired phase difference between the two currents may be obtained.

The nature of this invention will be more fully understood from the following description taken in connection with the drawing, in which:

Fig. 1 represents an antenna-counterpoise system in which the balanced counterpoise is employed;

Fig. 2 represents an antenna system in which a plurality of antenna units are connected to ground through a common phase-varying impedance; and,

Fig. 3 shows a directional antenna system and associated transmission system in which both the balanced counterpoise and the counterpoise impedance are employed.

In Fig. 1 reference numeral 1 designates a portion of a zig-zag antenna, assumed to extend indefinitely in either direction from the portion disclosed and to regularly repeat the conformation so disclosed. The invention is not specific to the use of this type of antenna which was selected as merely typical of present day transmitting or receiving antennæ. Numeral 2 designates a counterpoise conductor. The counterpoise conductor is connected at its midpoint 3 to the antenna by means of down lead 4. Reference numeral 5 represents a transformer having one winding 6 inserted in series with the down lead 4 and the other winding 7 connected to a translation system not shown on the drawing. The translation system may be either a transmitter or a receiver. Condensers 8 and 9, shown dotted, represent the capacities between any infinitesimal segment, such as segment 10, of the antenna 1 and the left and right hand section respectively of the counterpoise 2. There are, of course, corresponding capacities for the remaining segments of the antenna and in consequence thereof the capacities between the antenna, taken as a whole, and both counterpoise sections are in a sense symmetrical and balance each other.

The directions of the incoming desired and undesired waves are shown respectively by arrows 11 and 12. These directions shown are representative only and, as a matter of practice, the direction of the undesired wave varies in a plane perpendicular to the surface of the earth. The angle of propagation of the waves, that is, the angle between the direction of propagation and the earth is, however, between 0 and 80 degrees.

When employed in connection with a receiving system waves coming from the cooperating transmitting station, that is, waves having a direction 11, and waves coming from the opposite direction, as shown by arrow 12, induce electromotive forces along the counterpoise conductor 2. Ordinarily the most annoying waves are those which, in addition to having an undesired direction, as, for example, direction 12, have a wave length equal substantially to the operating wave length of the antenna. Considering waves coming from undesired direction 12 the electromotive forces induced along conductor 2 by the horizontally polarized component are similar in direction in both legs of the counterpoise and, in view of the fact that the counterpoise is perpendicularly positioned with respect to these undesired waves the infinitesimal voltages induced are in phase. Assuming that the resulting current present in the circuit comprising left hand section of counterpoise 2, winding 6, antenna 1, segment 10, and condenser 8 possesses the direction indicated by the dotted arrows 13, the current in the circuit comprising right hand section of counterpoise 2, condenser 9, segment 10, antenna 1, and winding 6 will have the direction indicated by arrows 14; and this latter current will be opposite in direction in transformer winding 6 to the current in the first mentioned circuit. These currents will therefore substantially tend to balance each other in the transformer winding inasmuch as they are in phase and opposite in direction. It should be noted here that a balance would also be obtained if the transformer were associated with the antenna in the manner shown in Fig. 2, that is, if it were included in the horizontal antenna member connecting the two vertical members instead of in the down lead. Moreover, by positioning the counterpoise horizontally similar capacities, and hence similar impedances, are secured between the antenna and each side of the counterpoise so that substantial amplitude balance is also obtained. Consequently very little, if any, undesired current flows through winding 6.

Supplementing the above explanation it is clear that the horizontally polarized component in a plane perpendicular to the direction of propagation of the undesired wave is principally responsible for inducing the undesired electromotive forces in the counterpoise. This is evident because the other polarized component which is perpendicular, in the above mentioned plane, to the horizontal component will not even if tilted, induce electromotive forces in horizontal conductors extending perpendicularly to the direction of propagation. This then constitutes a second reason for placing the counterpoise horizontal. That is, pick-up from the component perpendicular to the above mentioned horizontal component is minimized by utilizing a horizontal counterpoise. The vertical down lead, however, does absorb some energy from this perpendicular component and it is therefore made as short as practicable. With respect to the horizontal component an amplitude and phase balance of the undesired currents are affected, as pointed out above, regardless of the angle of propagation. Regardless of the theory, the optimum position of the counterpoise is horizontal since various experiments have shown that a minimum amount of undesired energy is present in the receiver proper when the counterpoise is horizontally positioned perpendicular to the plane of wave propagation.

Referring to Fig. 2, reference numerals 15 and 16 designate separate antennæ or separate units of the same antenna system which are connected to each other through winding 17 of transformer 18, the other transformer winding 19 being associated with a translation system. Winding 17 is connected to ground 20 by means of down lead 21 having a sliding contact 22 at winding 17 and containing a phase-varying adjustable impedance 23. A suitable counterpoise may be employed in place of the ground, without affecting the result produced by the invention, since, in general, a counterpose is effectively a ground. In fact, the circuit may if preferred be designed to embody all the distinctive features of the system of Fig. 1.

Reference numeral 24 designates a relatively high impedance inserted between the antenna 16 and the winding 17. Condensers 25 and 26 shown dotted represent the impedance between ground 20 and antennæ 15 and 16, respectively.

In operation, waves of the same or different phase are absorbed by antennæ 15 and 16 and the resultant currents are conducted through impedance 23 to ground 20. Every substantial change in the value of impedance 23 affects the phase of both of these currents, but because of the large value of impedance 24 the current flowing in the circuit comprising antenna 15, contact 22, impedance 23, ground 20 and impedance 25 is affected to a much greater degree than that flowing in the circuit comprising antenna 16, high impedance 24, contact 22, impedance 23, ground 20 and impedance 26. Consequently, any desired difference in phase relation between the two antennæ currents may be easily secured by varying impedance 23. A much finer phase adjustment may be obtained by moving contact 22 along winding 17.

Specifically impedance 23 is here represented as an inductance and its function is to variably retard the phase of the current flowing from antenna 15 to ground 20 a much greater amount, relatively, than that flowing from antenna 16 to ground 20. Other phase varying means, such as a condenser, may be substituted, of course, for inductance 23 in which case the current from antenna 15 would be advanced a greater amount relative to that of the current from antenna 16.

Impedance 24 may in general be any suitable high impedance. For example, an impedance transformer, such as that described in a copending application of E. J. Sterba, Serial No. 482,-210, filed September 16, 1930, and assigned to the applicant's assignee may be satisfactorily employed, especially in short wave systems. The impedance transformer comprises a line an odd multiple of a quarter wave length long. By inserting a conductor one quarter wave length long between winding 17 and antenna 16, in the system shown in this figure a suitable impedance transformer is formed since the ground is in effect the other conductor of the line. The surge impedance of the line is high so that the relatively small impedance between the antenna 16 and the ground 20 at the antenna is transformed to a very high impedance at winding 17 looking toward antenna 16. This may be written mathematically $Z_s^2 = Z_a Z_w$, where Z_s equals the surge impedance of the line, Z_a the impedance at the antenna and Z_w the impedance at the winding.

In Fig. 3, reference numerals 27 and 28 designate respectively, an exciter and a reflector of a directional antenna system, such as is disclosed in copending applications Serial Nos. 235,464 and 282,382, filed November 25, 1927 and June 2, 1928, respectively, all interest in which has been assigned to the applicant's assignee. The exciter and reflector are placed a quarter wave length apart and are connected by means of a conductor 29 and a tuned circuit comprising adjustable condenser 30 and primary winding 31 of transformer 32. This tuned circuit is located relatively close to the exciter so that the transmission conductor 29 connecting reflector 28 to the tuned circuit is approximately a quarter wave length long, whereas the length of the conductor from antenna 27 to the said circuit is so small that it may be disregarded. Primary winding 31 is connected to the midpoint 33 of a balanced counterpoise 34 by means of a down lead 35. This down lead is adjustably associated with the primary winding 29 by means of slidable contact 36. Reference numeral 37 designates a variable condenser inserted in the down lead for phase varying purposes.

The counterpoise 34 is a half wave length long and horizontally positioned preferably in the same vertical plane as the exciter. It extends in a direction perpendicular to the direction of the undesired incoming waves as represented by arrow 38 which is a significant fact with respect to the invention. It also extends, incidentally, perpendicular to the direction of the desired waves, which are incident from the opposite direction as indicated by arrow 39.

The antenna system is inductively associated with the receiver by means of secondary winding 40 of transformer 32 which, with adjustable condenser 41, forms a tuned circuit. Numerals 42 and 43 designate the conductors of the line connecting the tuned circuit and the receiver proper and numeral 44 designates a sinusoidal transmission line comprising an outer tubular conductor and an inner conductor supported concentrically within said outer conductor and insulated therefrom. This outer conductor is horizontally supported by brackets 45 approximately one half foot above the ground, and the inner and outer conductors are conductively associated, respectively, with conductors 42 and 43. The outer conductor is grounded. The snake-like design of the line minimizes the straight line expansion of the conductors resulting from atmospheric temperature variations.

In operation, the electromotive forces induced in the exciter and reflector by incoming waves, having the direction shown by arrow 39, are substantially 90° out of phase. This phase relation is necessary in order to insure, in cooperation with the phase retardation effected by conductor 29, a cumulative effect of direct and reflected waves at a receiver connected to secondary winding 40 through transmission line 44, or analogously, at a transmitter. They are not exactly 90° out of phase because, for one reason, the exciter acts as a screen. The desirable quarter cycle phase difference is obtained by the conductor 29 and also by adjusting condenser 37 and then, if necessary, also slidably adjusting contact 36 along primary winding 31. As in the system shown in Fig. 2, the desired phase difference is easily secured in this system since the reflector impedance is considerably higher than that of the exciter. In other words, the quarter wave length conductor 29 connecting the primary winding 31 and the reflector 28 transforms the reflector-to-counterpoise impedance to a maximum value as measured at the primary winding; and any change in capacity of the phase varying condenser 37 affects the phase of the exciter and reflector currents an unequal amount, relatively. Consequently, by properly setting the condenser 37 and adjusting contact 36 an exact quarter cycle out of phase relation is obtained.

Undesired voltages induced in the counterpoise by undesired waves, especially those from direction 38 are effectively balanced in the winding 31 in a manner similar to that described in connection with Fig. 1, by placing the counterpoise 34 in a horizontal plane perpendicular to the direction of the undesired waves and symmetrical to both the exciter and reflector. This may be seen from the fact that the capacities between each side of the counterpoise and the exciter or reflector are similar; and that the undesired current flowing between one side of the counterpoise and a segment of the exciter or reflector opposes that flowing between the other side of the counterpoise and the same segment. Still further, and as again illustrated in Fig. 1, the geometry of the system, especially as affects the counterpoise, is such as to minimize the pick-up of waves by the counterpoise and therefore to reduce greatly the load on the balancing circuits immediately above described. The half wave length counterpoise also serves as a double open-ended quarter wave counterpoise and consequently offers a minimum impedance for the received current. In other words, two parallel paths, each of minimum impedance, are provided for the exciter and reflector currents, so that a maximum desired signal current is obtained.

The sinusoidal transmission system possesses several distinct advantages over the ordinary transmission line. For example, a minimum amount of interfering energy is absorbed and only a relatively small amount of transmitted energy is reradiated in view of the facts that the line is comparatively close to the ground and also, in view of the fact that the line conductors are relatively close to each other. Furthermore, as stated before, the sinusoidal design minimizes the effects produced by temperature and atmospheric changes.

Although the invention has been described in connection with certain specific embodiments, it is to be understood that the various features described are not to be limited to these embodiments. In this respect it is obvious that any type of antenna employed in long or short wave systems, directional or otherwise, which differ in construction from those described, as, for example, open and looped antennæ, may be successively employed in connection with the invention. It is equally clear that phase varying means, other than those shown or described, may be satisfactorily employed in place of the counterpoise impedance.

What is claimed is:

1. In combination, a directional antenna designed for a particular operating wave length, a counterpoise connected thereto and comprising a conductor, a half wave length long, or an odd

multiple thereof, the counterpoise being positioned in a plane perpendicular to the known direction of an incoming undesired wave traversing said counterpoise and having a wave length equal, substantially, to the operating wave length.

2. In combination, a plurality of antenna circuits, the impedance of at least two of which are designed to be substantially different, and an adjustable common impedance included in said last mentioned circuits, said impedance having a small value compared to the remaining impedance of one of the last mentioned circuits and a large value compared to the remaining impedance of the other of said last mentioned circuits.

3. In combination, a plurality of antenna elements, a high impedance and an inductance serially connected between two of the said elements, and phase varying means having one terminal connected effectively to ground and the other terminal connected to said inductance.

4. In combination, a directional system comprising a plurality of antenna elements, a variable impedance having one terminal connected to at least two of the said elements and the other terminal connected to an effective ground, a conductor an odd multiple of a quarter wave length long included between said impedance and one of the elements, and a translation system associated with said system.

5. In combination, a plurality of antenna elements, an inductance, a sliding contact associated with said inductance, said inductance being connected between two of the elements, and a conductor having one terminal connected to an effective ground and the other terminal connected to said sliding contact, and a variable impedance in said conductor.

6. In combination, a directional antenna comprising an exciter and a reflector, an inductance, said exciter and reflector being connected to different points of said inductance, a variable impedance, and a ground lead including said impedance adjustably connected to said inductance.

7. In combination, a directional antenna comprising an exciter unit and a reflector unit, a counterpoise conductor an odd multiple of a half wave length long, a phase varying means connected between said units and the mid-point of the counterpoise, and a relatively high impedance in circuit with the reflector and the counterpoise.

8. In combination, a directional antenna comprising an exciter and a reflector, a counterpoise conductor an odd multiple of a half wave length long, said counterpoise being horizontally positioned relatively close to said exciter in a plane perpendicular to the direction of undesired waves, an impedance having one terminal connected to the exciter and the other terminal to the reflector, phase varying means connected between said impedance and the mid-point of the counterpoise, and a relatively high impedance inserted between the reflector and the first mentioned impedance.

9. In a directional aerial system, an antenna comprising an exciter and a reflector, a transformer winding, an impedance transformer, said transformer winding and impedance transformer being serially connected and included between the exciter and the reflector, a counterpoise comprising one or more conductors at least one of which is an odd multiple of a half wave length long horizontally positioned in the vertical plane of the exciter and relatively close thereto, an adjustable condenser, a relatively short conductor connecting one terminal of the condenser to the mid-point of the counterpoise conductor, and another relatively short conductor having one of its terminals connected to the other terminal of the condenser and its other terminal adjustably connected to the transformer winding, and a translation system inductively associated with said transformer winding.

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