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METHOD OF AND ARRANGEMENT FOR STRAY ELIMINATION IN RADIO COMMUNICATION
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Fig. 1

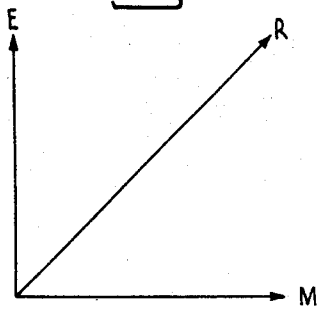
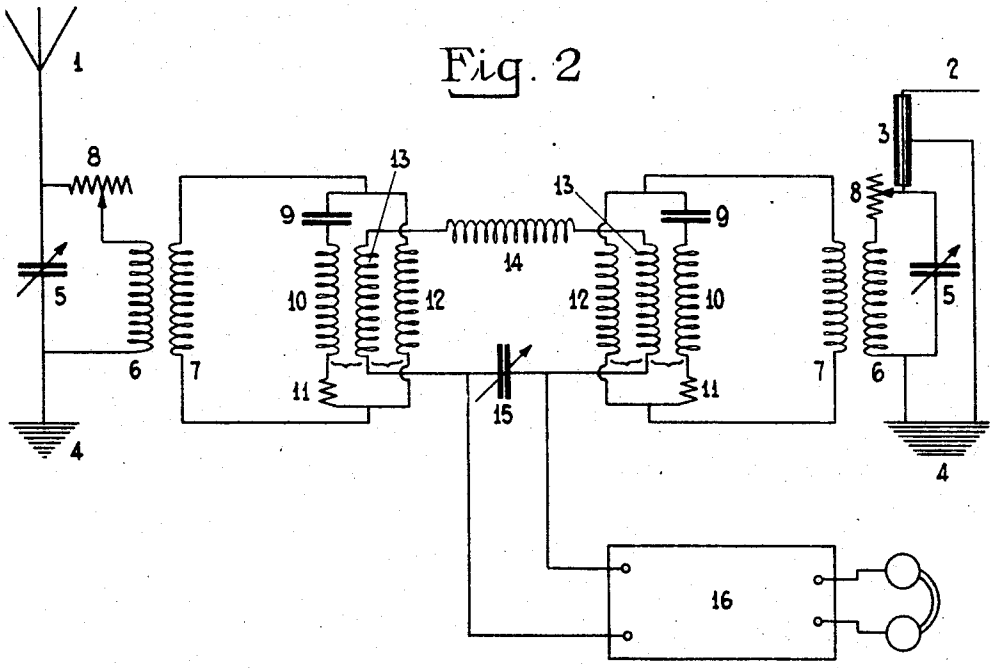


Fig. 2



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METHOD OF AND ARRANGEMENT FOR STRAY ELIMINATION IN RADIO COMMUNICATION.

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In radio communication it is well known that a great deal of disturbance is occasioned in receiving equipment by so-called "strays" or "static"; these are generally supposed to be due to atmospheric electricity, which in some manner affects the receiving antennas and finally causes currents to flow through the telegraphic indicating apparatus of considerable magnitude relative to the signalling currents ordinarily induced by the travelling electromagnetic waves of a distant transmitting station.

Up to the present stray eliminating systems have been based upon one of the following methods:

(*a*) *Directional antenna methods.*—In these, receiving antenna systems are set up which are directional in their receiving capabilities; the supposition being that the signalling waves come from one direction, and that the strays are waves similar to the signalling waves, but travelling in towards the receiving station from all, or a number of directions. The receiving antennas are then so oriented, or their associated circuits so adjusted as to give most favorable reception in the direction of the signalling waves. It has been experimentally determined that when this is done, the strays received are markedly fewer in number, and this has been taken as indicating the correctness of the theory involved, namely, the similarity of strays and signal waves in character, but difference in direction of propagation.

(*b*) *Receiving circuit methods.*—In these, circuit systems are employed in which impulses (which are assumed to be the general form of the electromotive forces due to the fields of the strays) are discriminated against, in favor of the sustained alternating currents due to the signalling waves. Such discrimination is supposed to be obtainable by means of certain types of filter circuits.

Applications of the above general principles have not solved the stray problem in radio communication. Considering the principle of directional reception, it is obvious that it can only be operative if the strays are truly electromagnetic waves and if these come, in general, from directions considerably differing from that of the signal. For example, on the North Atlantic coast, of the United States, when one of these directional receiving systems is set up, it shows a maximum reduction of strays when oriented so as to receive signal waves coming from the northeast (that is, the direction of Europe). When it becomes necessary to receive signals from the quadrant between the directions of south and west, these systems fail to give appreciable stray reduction.

As regards the principle of discrimination against impulses by circuit systems, this has not been found to be of marked advantage; indeed the mathematical theory of such systems as have been proposed (e. g., filters) shows that the attainable discrimination is not large.

In the following specification which should be read in connection with the accompanying drawing, a method of elimination embodying the principles of my invention, is described. In the drawing,

Figure 1 is a vector diagram illustrating the phase relation of the voltages of the magnetic and electric fields, and

Figure 2 is a circuit illustrating an approved form of my invention.

This method of elimination is based upon assumptions regarding the principles of operation of receiving systems, and of the character of strays, which differ from those described above. Briefly, the assumption on which this method is based is that strays differ radically in their type of field, from the field of the electromagnetic signal waves. In order to make this clearer, let us consider the various types of fields which may exist in space, due to electrical charges or currents:

In the space around a charged condenser, consisting for example of two flat plates, there exists a type of field which we call electrostatic. If the charges on these plates are alternating, for example if the plates are charged by means of an alternating E. M. F., the field becomes an alternating electric field; and if a condenser similar to the first is placed in this field, its plates acquire charges by so-called electric induction. The characteristic of this type of induction is that at the same moment as the voltage on the first condenser is at a maximum, the field has its maximum strength and the induced voltage on the second condenser is also a maximum. That is, the induced E. M. F. is in phase with the inducing field. Were the second condenser replaced by a straight wire,

equal in length to the distance between its plates and placed so as to be perpendicular to the planes of the plates, the same alternating voltage would be induced in the wire as in the condenser.

In addition to the alternating electric field around the first condenser, there exists also an alternating magnetic field. This is due to the displacement current flowing in the ether between the condenser plates. However, this magnetic field is in general very small compared to the electric field, and plays little part in inducing voltages in a conductor placed in the field.

Now consider a coil of wire through which alternating currents are flowing: The field surrounding such a coil is mainly magnetic in nature, and if a wire is placed so that it may be cut by the magnetic lines of force, voltages will be induced in it. However, there is an important difference between this kind of induction and that due to an alternating electric field, viz, the maximum of induced E. M. F. occurs when the magnetic field is at its minimum, or zero; i. e. when the rate of variation of the field is greatest, and not when the field strength is greatest, as in the case of the electric field. That is, the induced E. M. F. is 90° out of phase with the inducing field.

Finally, consider an electromagnetic wave, such as that employed in radio communication. This, as is well known consists of an alternating electric field travelling together with an alternating magnetic field. The maxima of the two fields occur at the same time in space, and they are equal in magnitude (when the wave is at a considerable distance from the transmitting station). The lines of force of the electric field are perpendicular to the ground (over a perfectly conducting earth), while those of the magnetic field are parallel to the ground, perpendicular to the lines of the electric field, and also perpendicular to the direction of propagation of the wave.

If a wire is placed in the path of such a wave, parallel to the lines of electric force, then voltages are induced in it. This constitutes the usual method of receiving radio signals. The voltage which is induced I take to be the vector sum of the separate voltages induced by the electric and magnetic fields. The voltage due to the electric field is in phase with the latter; the voltage due to the magnetic field is equal to that induced by the electric field, but 90° out of phase with it. For the magnetic field is in phase with the electric field, but the voltage it induces in the wire is 90° out of phase with itself, and therefore 90° out of phase with the voltage due to the electric field. This is illustrated in Figure 1, where E represents the voltage due to the electric, and M the voltage due to the magnetic field, while R represents the resultant voltage in the wire; it is 1.4 times as great as E or M, and lagging 45 degrees in phase with respect to the wave (i. e. with respect to the maxima of the electric and magnetic fields which compose the wave).

It will be observed that a vertical wire is affected by both the electric and magnetic fields of an electromagnetic wave. Now let this wire be turned so as to be horizontal, at some distance from the ground, and let a connection be made through suitable receiving apparatus, between the horizontal wire and earth. The wire is assumed to be very short compared to the wave length. It is possible to eliminate any induction (either electric or magnetic) in the connecting wires, (to the receiving apparatus) which are of course vertical, by surrounding them with a shield of well-conducting material, e. g. copper gauze, and earthing this shield. The horizonal wire extending out into the wave field will be affected by the electric component of this field, but not by the magnetic component; for, a potential gradient will exist between the level occupied by the horizontal wire and the earth which will cause electric charges to be induced on the wire, but since the magnetic lines of force do not cut the wire no magnetically induced E. M. F.'s can arise.

We can thus differentiate between a field which is mainly electric, one which is mainly magnetic, or one which comprises both namely, an electromagnetic wave-by utilizing the properties of a vertical antenna and a horizontal antenna (or condenser antenna) with any vertical connecting wires suitably shielded as described above. For, if we connect a vertical antenna and this special type of horizontal antenna differentially to a common receiver we can balance out any response due to electric fields and retain responses due to electromagnetic waves. Now it is reasonable to assume that a great many types of strays, if not the majority, are fields largely electric in nature. This would be the case if they were merely rapid fluctuations in the earth's electric field in the neighborhood of the receiving antennas, or were due to the fluctuations of electric charges on clouds within possibly 10 or 15 miles of the receiving station, or in fact, fields due to fluctuations of atmospheric electricity originating within moderate distances of the receiving stations. For, all atmospheric electrical phenomena are predominantly electric or electrostatic in nature; currents, which may give rise to powerful magnetic fields flow only during actual lightning discharges. But powerful strays are heard even during the clearest weather, and, in fact, are exceedingly strong just before storms, when atmospheric convection and electrical cloud-charging is pro-

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ceeding most rapidly, but lightning rarely occurs.

The above assumption has been quite well borne out by the actual operation of a receiving system using the vertical and special horizontal antenna as previously described, connections being arranged so as to balance out electric fields and retain responses due to electromagnetic waves. The arrangement used, which constitutes one of the elements of this invention, is shown in Figure 2.

Here 1 is a vertical wire, and 2 a horizontal wire. The vertical lead-in of 2 is shielded by a conducting shield 3, connected to earth, 4. The antennas are tuned by condensers 5 and inductances 6. The latter are coupled, in an adjustable fashion, to secondary inductances 7. Resistances 8 are included in the tuning circuits so as to make the logarithmic decrements of the two antenna circuits equal.

The inductances 7 are connected to phase-shifting devices which consist of the branched circuits composed of condensers 9 inductances 10, and resistances 11, and inductances 12, with inductances 13 arranged so as to be rotatable and coupled simultaneously to inductances 10 and 12. By suitable construction as is well known, the voltage induced in coil 13, as this is rotated, can be made sensibly constant in magnitude but adjustable in phase with respect to the current flowing through coil 7. The voltages induced in the two coils 13 are then applied to the tuned circuit composed of inductance 14 and condenser 15, while to the terminals of the latter suitable detecting amplifying and indicating apparatus, 16, may be connected.

By means of the above circuits it will be clear that the intensity and phase of currents tending to flow in circuit 13—14—15, in response to voltages induced by fields affecting antennas 1 and 2, may be adjusted; the intensity, by varying the coupling between coils 6 and 7, and the phase, by suitable adjustment of the phase-shifting devices.

Now, antenna 1 is responsive to both electric or magnetic fields. Thus it will respond to both components in the electromagnetic waves, and the electric fields constituting the strays. On the other hand, antenna 2 is responsive only to the electric component of the electromagnetic waves, but just as responsive as antenna 1 to the electric field of the strays. As a result, it will be seen that adjustments may be made which will cause currents in circuit 13—14—15 due to electric fields striking the antennas to balance out; but when this is done, current due to the magnetic field of the waves striking antenna 1 will still remain. Hence in so far as strays are electric fields, their effect on the system will cancel—as will the effect due to the electric component of the signalling waves. But effects due to magnetic fields, or the magnetic component of the signalling waves, will remain.

In the practical setting-up of this system, it is not always necessary to shield vertical portions of the horizontal antenna 2; for example, the receiving apparatus may be housed in a shielded building, and the horizontal antenna terminate on the roof of the building. The down leads may then be run through the roof to the inside of the building, in which case the shielding of the building is sufficient to prevent magnetic fields from affecting them. Both vertical and horizontal wires may, compared to the wave lengths, be very short; for example, I have used wires only about 50 feet long, in working with waves of the order of magnitude of 14000 meters in length.

The system described in the foregoing is only one application of the general principle of this invention, namely the construction of receiving collector systems on which either electric or magnetic fileds may be received, or both, and the adjustment of such systems such that responses due to electric fields are eliminated. The particular forms of collectors described herein need not necessarily be used; other equivalent forms may be employed provided they are constructed so that discriminatory response to electric or magnetic fields is utilized.

Having described my invention what I claim is as follows:

1. In combination, an antenna adapted to receive electromagnetic and electrostatic waves, means for tuning said antenna, phase adjusting means associated with said antenna, a second antenna adapted to receive electrostatic waves only, means for tuning said second antenna, phase adjusting means associated with said second antenna and a receiving circuit coupled to each of said phase adjusting means.

2. A static eliminator comprising an antenna adapted to receive electromagnetic and electrostatic waves, a circuit coupled to said antenna for adjusting the phase of the received waves, a second antenna adapted to receive electrostatic waves only, a circuit coupled to said second antenna for adjusting the phase of the received waves and a receiving circuit coupled to both of the phase adjusting circuits.

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