March 8, 1938. V. D. LANDON ET AL 2,110,159

ANTENNA SYSTEM

Filed April 28, 1934 2 Sheets-Sheet 1

Fig. 1.

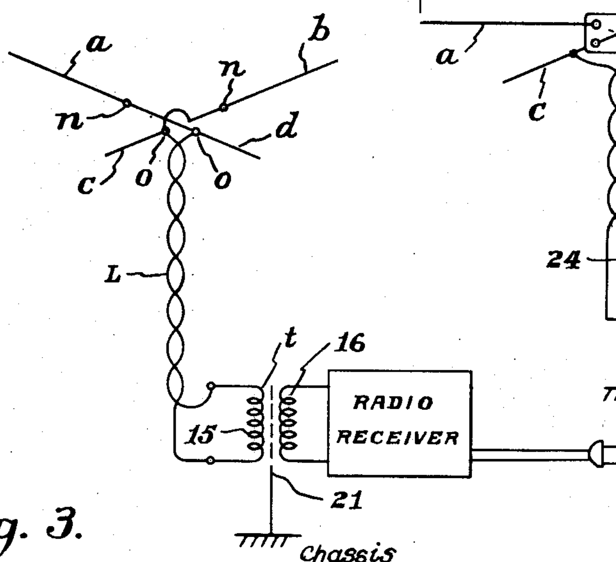


Fig. 4.

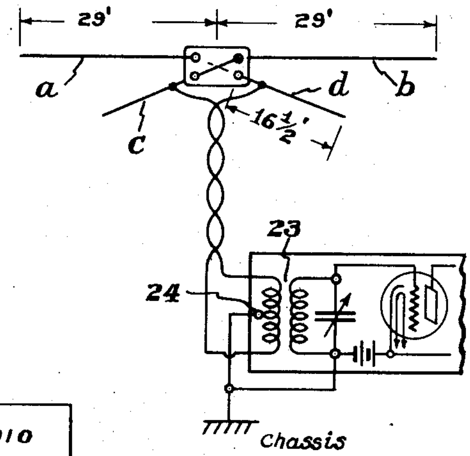


Fig. 3.

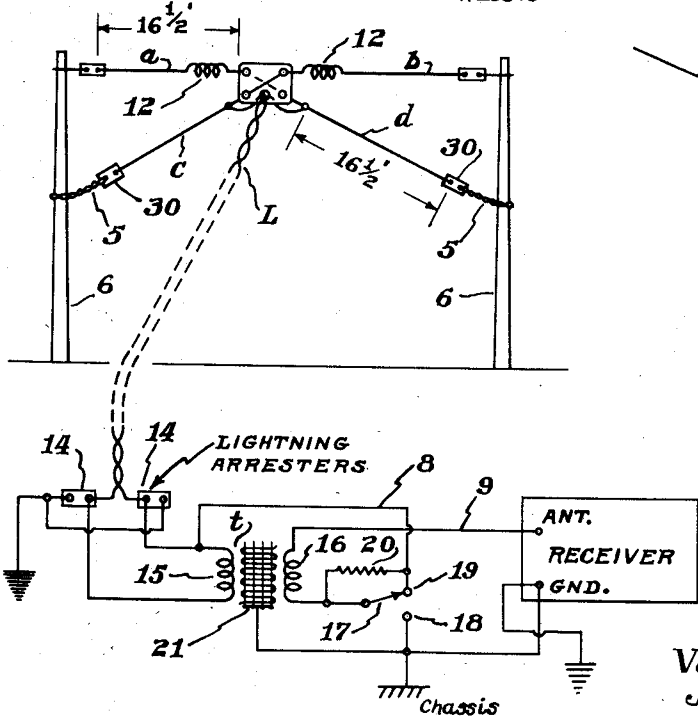
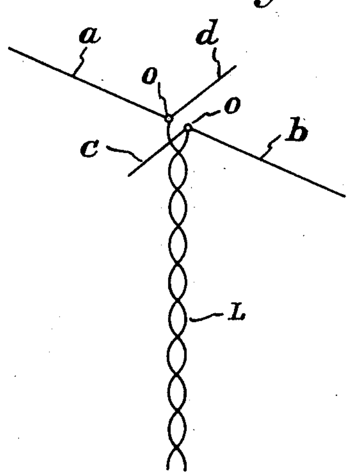


Fig. 2.



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March 8, 1938. V. D. LANDON ET AL 2,110,159

ANTENNA SYSTEM

Filed April 28, 1934 2 Sheets-Sheet 2

Fig. 5.

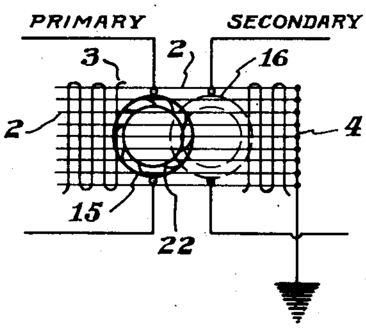


Fig. 6.

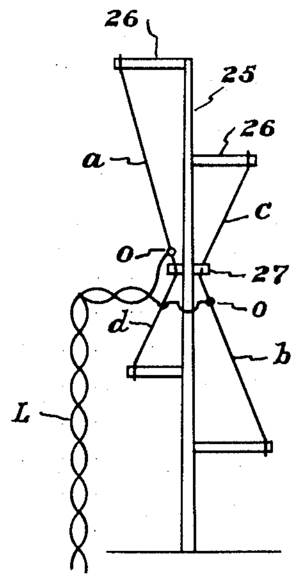


Fig. 7.

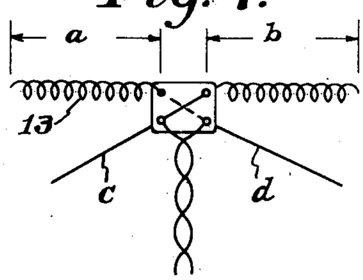


Fig. 8.

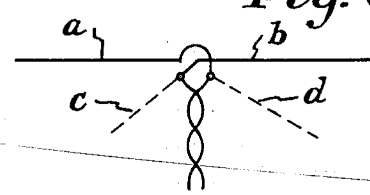


Fig. 9.

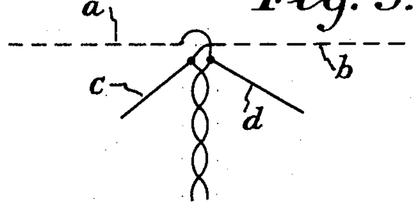
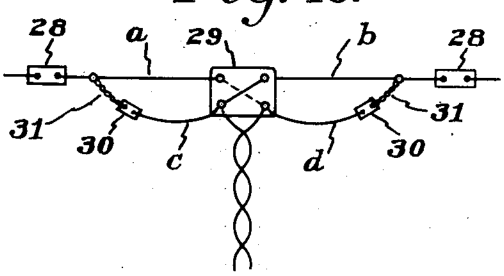


Fig. 10.



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Patented Mar. 8, 1938

2,110,159

UNITED STATES PATENT OFFICE

2,110,159

ANTENNA SYSTEM

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Application April 28, 1934, Serial No. 722,842

27 Claims. (Cl. 250—33)

This invention relates to antenna systems for radio communication and has particular reference to the adaptation of such systems for reception of signals over a very broad range of frequencies including short-wave frequencies.

One of the difficulties encountered in the past in providing a suitable antenna system for short-wave reception is that the portion of the antenna which is to collect the signalling energy should, if possible, be at a remote point from the radio receiver, but to do this a transmission line interconnecting the energy collecting portion with the receiver was liable to absorb a considerable amount of the energy so collected. Furthermore, this interconnecting transmission line was also liable to pick up unwanted signals and interfering waves.

It has been customary, therefore, to provide a rather critical tuning arrangement in connection with a high-frequency antenna system. Much thought has been given to the matching of impedances as between the energy collecting conductors on the one hand and the transmission line to the receiver on the other hand.

It is an object of our invention to provide an antenna system suitable for short-wave and for the usual broadcast wave reception.

Another object of our invention is to provide an antenna system which is highly efficient over a wide range of frequencies.

Another object of our invention is to provide an antenna system which will permit of locating the energy collecting portion remote from the receiver.

Another object of our invention is to so coordinate the impedances of an antenna system as to make it broadly responsive over a very wide range of frequencies and at the same time to minimize its response to interfering waves.

Another object of our invention is to minimize the noise level in the reception of signals.

Another object of our invention is to provide an antenna system for efficient reception of short-wave and broadcast bands of frequencies which shall be easy to install at low cost and which entails a minimum of upkeep expense.

The novel features considered characteristic of our invention are set forth with particularity in the appended claims. The invention in its entirety, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of certain specific embodiments when read in connection with the accompanying drawings, in which

Fig. 1 represents diagrammatically a preferred disposition of our energy collecting conductors and their connection through a transmission line to a radio receiver;

Fig. 2 represents diagrammatically a modified arrangement of the energy collecting conductors;

Fig. 3 represents diagrammatically certain details of structure and circuit connections of an antenna system suitable for receiving short-wave signals and signals within the usual broadcast frequency spectrum;

Fig. 4 shows diagrammatically a modified arrangement of the transmission line connections between a radio receiver and the energy collecting portions of an antenna system according to our invention;

Fig. 5 represents diagrammatically one form of electrostatic shielding between inductance coils such as might be used in the antenna system represented in Fig. 3;

Fig. 6 shows diagrammatically how the energy collecting portions of our antenna system may be supported from a single antenna pole;

Fig. 7 shows diagrammatically how certain arms of an antenna system according to our invention may be provided with distributed inductance so as to have a greater effective length than would otherwise be permitted within certain space limitations;

Figs. 8 and 9 represent diagrammatically how different arms of our antenna system are made effective for picking up signals at different frequencies; and

Fig. 10 shows diagrammatically a modified arrangement of suspending the several arms of our antenna system.

Referring to Fig. 1, we show an energy collecting system comprising a pair of antenna conductors diverging longitudinally in four directions from a given point *o*. The four arms of the antenna conductors are designated *a*, *b*, *c* and *d* respectively. It will be noted that the arms *a* and *b* are of equal length and diverge at an obtuse angle from the position *o*. The arm *c* in this instance is coaxial with the arm *b*, while the arm *d* is coaxial with *a*. The two arms *c* and *d* are preferably of equal length and may be considerably shorter than *a* or *b*.

We have found that where the conductors *a* and *b* form a dipole of approximately a half-wave length at a frequency near the low end of the tuning range to be covered, and that where the arms *c* and *d* form another dipole of approximately a half-wave length of a frequency near the high end of the tuning range, that a very satisfactory response characteristic may be had. At or near the resonance condition of either arm of a dipole the other arm appears to be a high impedance and can be neglected. Thus for certain frequencies the arms *a* and *b* will be responsive and at other frequencies the arms *c* and *d* will be responsive.

Considering the theory of operation in another light, the arms *a* and *d* form a half-wave antenna while the arms *b* and *c* form a similar antenna. The system is rendered effective by connecting the line L at some distance from the voltage nodes *n* on the half wave antennae.

In order to obtain a practically flat response characteristic over a reasonably wide frequency spectrum the distance between the position of line connection *o* and either of the nodal points *n* should be only slightly greater than the distance required for an impedance match to the line L. If, however, the distance is increased by increasing the difference between the lengths *a* and *d* this mis-match of impedances results in only a moderate sacrifice of mid-range transmission.

Referring to Fig. 2, we show a modification of the antenna conductors in which the arms *a* and *d* are disposed at an obtuse angle to one another, while the arms *b* and *c* are similarly disposed with respect to one another. In this modification, however, arms *a* and *b* are coaxial and arms *c* and *d* are coaxial with one another. The angle subtended between *a* and *d* as in Fig. 2, or the angle subtended between *a* and *b* as in Fig. 1, may be varied considerably to meet different conditions of the directional effect that is desired.

If the antenna arms *a* and *d* as shown in Fig. 2 are disposed at an acute angle a sacrifice of mid-range efficiency will result. For this reason the angle between *a* and *d*, or between *b* and *c*, is preferably made obtuse. It will be seen that electrically long and short arms *a* and *c*, respectively, that may be termed as coextensive in relation, are connected to opposite sides of the transmission line L. The same is true of arms *b* and *d*.

If desired, a third pair of dipoles may be added in which the effective lengths of the long arms and of the short arms are of themselves unique but bear the same relationship to one another as in the two dipoles shown in Fig. 2. The frequency range of the antenna system may, in fact, be increased to any desired extent by the addition of further pairs of dipoles having different effective lengths. While it is possible that the multiple resonance conditions of the long arms might affect the performance of the short arms, it will in general be found that the response is increased rather than decreased. When the additional dipoles are included, however, we find that it is of great advantage to observe the general rule that any long arm thereof should form an obtuse angle to a short arm with which it is connected.

The transmission line L as shown in Figs. 1 and 2 consists preferably of a pair of twisted conductors leading to the primary terminals of a transformer *t* which may be adjacent a radio receiver, or, if preferred, it may be one of the radio frequency transformers of the receiver itself. It is desirable that the line impedance be somewhat higher than the impedance of the antenna at resonance since a broad response characteristic can be obtained by this combination.

In Fig. 3 we show an embodiment of our antenna system in which for economy of space the respective energy collecting arms are of substantially the same physical length (for example 16½ feet) but the effective length of the horizontal arms is increased by the addition of inductances 12, resulting in electrically long arms *a* and *b*. The inductances 12 may be disposed at any convenient part of the pick-up arms or may be distributed thereover as shown at 13 in Fig. 7. Such impedances may, if desired, produce the same effect on an antenna arm of 16½ feet length as would be produced by an antenna arm 29 feet in length as shown in Fig. 4.

In several of the embodiments of our invention we have found it desirable to employ a cross-over insulator having substantially flat sides and having holes therein for anchoring the several arms of the antenna system in spaced relation to one another. Such an insulator is shown in Figures 3, 4, 7 and 10. It may be composed of any suitable material which will not deteriorate from exposure to the weather. In addition to the four corner holes which are useful for anchoring the antenna arms thereto, a fifth hole may be provided as shown in Figure 3 for anchoring the lead-in cable. The arrangement is such that two wires may be stretched each between diagonally opposite holes in the insulator, the latter serving as a spacer to separate the wires by at least its own thickness. If, then, one of two conductors of a lead-in cable is connected to one of the antenna wires on one side of the insulator, a similar connection may be made on the other side of the insulator between the remaining antenna wire and the remaining lead-in conductor.

Referring again to Fig. 3, it should be noted that it is preferable to provide non-metallic cords 5, such as braided clothesline, for spanning the distance between the poles 6, and the insulators 30, since if wire were used an undesirable coupling would take place across the insulators 30. The transmission line L consists of a twisted pair of conductors leading to a convenient point of anchorage at the terminals of two lightning arresters 14. The primary winding 15 of transformer *t* connects across the ends of the twisted conductors of the transmission line L. A secondary winding 16 of transformer *t* has one terminal of its coil connected to the antenna post of a receiver and the other terminal of its coil is preferably connected with the switch arm 17 of a single-pole double-throw switch for either balanced or unbalanced reception. One of the poles 18 of this switch is grounded, while the other of the poles 19 connects both with one end of the primary coil 15 and also preferably with a high resistance 20, the other terminal of which is connected with the switch arm 17. The switch in the position shown short-circuits the high resistance 20 and provides an antenna system suitable for unbalanced reception. In effect, for broadcast waves, the transformer windings 15 and 16 (which have very few turns) offer a negligible impedance path or are effectively bypassed. Hence it will be seen that the two conductors of the transmission line L act as one, i. e., are unbalanced, and all four arms of the energy collecting system and the line cooperate as a single antenna rather than as two dipoles.

Fig. 3 makes merely a conventional showing of a radio receiver, since it will be understood that various types of receivers may be used. In general, however, a receiver suitable for both broadcast, or long wave, reception and for short-wave reception as herein contemplated will preferably be provided with interchangeable transformer coils the primaries of which are connectible between the antenna and ground posts such as shown and the secondary terminals of which, respectively, are connected to the grid and cathode of the first tube therein.

When noise reducing reception is desired in the short-wave frequency spectrum, the switch arm 17 is thrown in contact with its pole 18 thereby grounding one side of the transformer secondary 16 for balanced operation and rejection of in-phase currents. The energy collecting arms then cooperate as dipoles and the energy picked up is transferred over the balanced line as out-of-phase currents to the receiver through the magnetic coupling between the coils 15 and 16. Interposed between these coils we preferably employ a shield 21 grounded to the radio chassis for eliminating capacity coupling. This shield may, if desired, be made integral with the coils of the transformer as diagrammatically shown in Fig. 5. In carrying out the details of this construction we prefer to employ the principles of the disclosure in Patent 1,942,575, granted to L. Shapiro on January 9, 1934. Shapiro showed the use of a fabric in which either warp strands or weft strands are made of wire woven together with insulating yarn or thread. The wires 2 at one end are interconnected as by the common conductor 4, and the yarn 3 by which the fabric is held together is of such size that the wires 2 cannot come in contact with one another to produce eddy currents, though they are maintained at a common potential due to their interconnection by the wire 4 along one edge of the fabric.

As an improvement over Shapiro's disclosure we have found it advantageous to employ the shielding fabric as a support for the coils 15 and 16, which coils may, if desired, be sewed onto the fabric by threads 22. In practice the primaries and secondaries will, of course, be disposed coaxially, although they have not been shown in that manner in Fig. 5 simply because the coil 16 would have been concealed by the coil 15.

Fig. 4 shows an alternate form of transformer 23 in which the shielding is replaced by a balanced arrangement in the primary winding. It is essential that the two halves of the primary be accurately adjusted to have substantially the same value of coupling to the secondary. One preferred method of obtaining this result is to inter-weave the two halves of the winding turn for turn. A cylindrical form of insulating material may be used, if desired, for disposing the primary and secondary winding coaxially to one another.

When the shielded transformer *t* is used as shown in Fig. 1, currents arriving on the two sides of the transmission line in phase, as when picked up by the transmission line itself, cause no primary current in the winding 15. If, however, in Fig. 4 the transformer 23 is used, the currents which are in phase because picked up on the transmission line will cancel out in the magnetic fields of the two halves of the primary and will also be conducted to ground by the center-tap 24. In each case the result is to effectively eliminate the transmission line as a collector of signal and noise energy. This provides an improvement in the ratio of signal response to noise response, and the antenna may be located well away from the noise source.

It should be noted that a further advantage to be derived from our invention is that the pick-up of interfering waves on the ground lead and on the power cord may also be eliminated, since the shield 21, and likewise the center-tap 24, may preferably be grounded to the receiver chassis, thereby rendering employment of a real ground immaterial for balanced operation.

Referring now to Fig. 6, we show an antenna pole 25 on which are mounted a number of cross-arms 26 and an anchorage 27 for conveniently supporting the antenna arms *a*, *b*, *c* and *d*. The connections of these antenna arms to the transmission line L may be made at the points *o*, the same as shown in Fig. 2.

Referring to Figs. 8 and 9, we show the antenna arms of our system in such manner as to explain the theory of operation. When receiving waves to which the arms *a* and *b* are of such length as to be at or near the resonance point they alone will be effective in picking up the energy and for this reason they are shown by full lines in Fig. 8, while the arms *c* and *d* would in this case offer so high an impedance to the received energy as to be negligible in their effect. They have therefore been shown in Fig. 8 by dotted lines.

In Fig. 9 it is assumed that the received energy is of such wave length that the arms *c* and *d* alone would be effective because their length is such as to make them nearly resonant to such waves. In this instance the arms *a* and *b* would offer high impedances to the received energy and for this reason they have been shown by dotted lines.

Assuming now that signals are to be received of a frequency intermediate the wave lengths just previously mentioned, then all four arms of the two dipoles will become effective in picking up the energy, and each in proportion to the proximity of its resonant point to the frequency of the received wave.

It is not absolutely essential that the energy collecting arms of our antenna system should be disposed along straight lines. Fig. 10, for example, shows how two of the arms *a* and *b* may be stretched between convenient points such as the insulators 28, while the arms *c* and *d* are suspended from the centrally disposed insulator 29 and the insulators 30. The insulators 30 may be hung by non-metallic cords 31 attached to the arms *a* and *b* respectively.

In a particular embodiment of our invention which has been constructed and put into operation it was found that very satisfactory results could be obtained in making the antenna system responsive to signals picked up throughout the range from six megacycles to upwards of eighteen megacycles. In this case the arms *a* and *b* were each 29 feet long and the arms *c* and *d* were each 16½ feet long. Considering the operation of a single 29 foot dipole it will be recognized that the weakest point would be for the second harmonic of the frequency. For example, if the longer dipole should be tuned to 6 megacycles the response would be very poor at 12 megacycles. This difficulty may be overcome, however, by making the shorter dipole of such length that it will produce a response curve having high efficiency at 12 megacycles and odd multiples of that frequency.

As heretofore indicated, our antenna system may be used for receiving signals within the broadcast range and reception of other long-wave signals by the throwing of the switch 17 into the position shown. In this position, incidentally, the high resistance 20 is short-circuited. The antenna is thus converted into one which works as a unit against ground. The effect of this arrangement is to cut off the use of the transformer t and to connect the antenna directly to the antenna post of the receiver.

For short-wave reception it is desirable to minimize the capacity coupling from the line to the secondary 16 in order to derive the benefit of balanced transmission or noise reduction as previously mentioned. The switching arrangement shown in Fig. 3 has, therefore, been found preferable to other arrangements that have been tried. When the switch arm 17 makes circuit with contact 18 it is at ground potential and the capacity coupling between contact 19 and ground is not detrimental. Further advantages of structural arrangement are also to be had by disposing the conductor 8 in a position well removed both from the secondary coil 16 and from the conductor 9 so as to minimize capacity coupling therewith.

When the switch 17 is thrown over to the grounded pole 18, a high impedance leakage path is afforded by the resistor 20 to thereby dissipate static charges set up on the antenna arms. Such a resistor 20 may be of the order of 100,000 ohms, if desired.

Although we have shown and described herein a number of specific embodiments of our invention, it is to be understood that these are merely illustrative. Modifications may be made without departing from the spirit and scope of our invention as defined in the accompanying claims.

We claim as our invention:

1. A radiant energy collecting system comprising two dipole antennae disposed substantially in a plane and having intersecting axes, radio apparatus, and a twisted pair of conductors connected between said radio apparatus and points on said antennae near their intersection, each conductor being individually connected to its respective dipole and said intersection being such that the system is resonant to two frequencies bearing a ratio to one another of approximately 33 to 58.

2. An antenna system comprising two electrically different and differently oriented dipoles, each dipole having energy-collecting arms of substantially equal length, a radio receiver, means including a twisted pair of conductors and a coupling transformer for transmitting the energy collected by said dipoles to said receiver, a connection between one of the conductors of said twisted pair and two of said arms which are disposed at no less than a right angle to one another, said arms being of different dipoles, a corresponding connection between the other conductor of said twisted pair and the remaining arms, and means including a high resistance path from ground to the primary of said coupling transformer for dissipating static charges on the antenna system.

3. An antenna system in accordance with claim 2 and having further means including a single-pole double-throw switch for disconnecting the path from said high resistance to ground and for short-circuiting said high resistance in a path from the primary of said transformer through the secondary thereof and to the antenna post of said receiver.

4. An antenna system comprising a plurality of energy-collecting arms of at least two different lengths directionally radiating from a common position, a transformer having a primary and a secondary winding, means whereby said secondary winding may be switched alternatively between a radio receiver and either ground or the primary of said transformer, and a plurality of lead-in conductors twisted about one another and connecting the primary of said transformer with different arms of said antenna system at the position from which they radiate.

5. An antenna system in accordance with claim 4 in which, when the secondary winding of said transformer is grounded, the primary winding thereof is provided with a high resistance path to ground.

6. An antenna system comprising a plurality of energy-collecting dipoles disposed in electrically symmetrical arrangement, a twisted pair of lead-in conductors connecting at one end with the center of electrical symmetry of said system, each conductor connecting respectively with a symmetrical half thereof, a transformer the primary of which is connected across said conductors at the other end thereof, means interposed between and supporting the two windings of said transformer for electrostatically shielding said windings from one another, said means being constituted by a fabric of parallel wires interwoven with non-metallic strands and the wires being electrically interconnected and grounded at one end only thereof, and means for connecting the secondary of said transformer at times between a radio receiver and ground and at times between said radio receiver and one of the conductors of said twisted pair.

7. An antenna system comprising a plurality of energy-collecting arms each directionally radiating from a point constituting the electrical center of symmetry between two electrically different halves of said system, said arms of either one electrical half being of unequal length and disposed at greater-than-right angles to one another, a radio receiver remotely located with respect to said center of symmetry, and means for transferring to said radio receiver signalling energy which is collected by said arms substantially free from contamination by interfering and unwanted energy picked up in the space intervening between said arms and said receiver, said means comprising a twisted pair of conductors, each conductor connecting with its respective half of the antenna system at the point from which the arms radiate, and comprising further an inductive coupling device the primary winding of which has a grounded center-tap and is disposed in circuit between the two ends of said conductors of the twisted pair adjacent the receiver.

8. An antenna system comprising two differently oriented dipoles, a radio receiver, means including a twisted pair of conductors and a coupling transformer for collecting oppositely phased currents from different arms of said dipoles and for transferring said currents to said radio receiver and means independent of said transformer for at times utilizing said dipoles and said twisted pair of conductors as a single antenna for broadcast wave reception and the like, the last said means including a conductor and switch so disposed with respect to, and interconnecting, the primary and secondary windings of said transformer as to minimize the deleterious effects of capacity coupling between ground and the various elements of said system.

9. In a device of the class described, a plurality of energy collecting arms of at least two different lengths directionally radiating from a common position, a transformer having an electrostatic shield disposed between its primary and

secondary, said shield being formed of parallel wire strands grounded at one end and interwoven with parallel non-metallic strands, a plurality of lead-in conductors twisted about one another and connecting the primary of said transformer with different energy collecting arms, a radio receiver, and means including a connection from said radio receiver through said secondary and alternatively to ground or to said primary, for transferring to said receiver, in one case, short waves induced in said secondary winding and, in another case, long waves fed through said plurality of lead-in conductors as though they were a single conductor.

10. In a radio receiving system for long and short wave signal bands, a long and short wave receiver having antenna and ground terminals, a remote antenna, a two conductor transmission line connected at one end to said antenna, a coupling transformer having a primary connected to said line and a secondary connected at one side to said antenna terminal, a switch for connecting the other side of said secondary either to said ground terminal for the reception of short waves, or to said line for the reception of long waves.

11. An all-wave antenna system comprising a plural dipole antenna connected to a two wire type transmission line, said antenna including a pair of electrically long arms and a pair of electrically short arms co-extending in substantially the same direction as said long arms respectively, means for supporting said antenna arms in extended relation, each pair forming a dipole responsive to a frequency band substantially different from the other, said co-extending arms being connected to opposite sides of said line as to produce additive complementary response characteristics between their resonance points for effectively covering a wide range of frequencies.

12. The invention as set forth in claim 11 wherein one long arm and one short arm are connected to the same side of said line and extend in substantially opposite directions.

13. The invention as set forth in claim 11 wherein each long arm is a continuation of each short arm connected to the same side of said line.

14. The invention as set forth in claim 11 wherein a long arm and a short arm, connected to opposite sides respectively of said line, extend in directions forming an acute angle.

15. The invention as set forth in claim 11 wherein one long arm and one short arm extend in substantially the same horizontal direction and are spaced vertically an amount sufficient to minimize interference between their fields.

16. The invention as set forth in claim 11 wherein said arms are disposed in substantially a common vertical plane.

17. The invention as set forth in claim 11 wherein one long arm and one short arm extend in substantially the same vertical direction and are spaced horizontally an amount sufficient to minimize interference between fields.

18. The invention as set forth in claim 11 wherein said dipoles are constituted by conductors supported in intersecting cross-over relation.

19. The invention as set forth in claim 11 wherein said dipoles are constituted by a pair of conductors supported in intersecting cross-over relation and in a substantially vertical plane and forming acute angles between adjacent long and short arms respectively connected to opposite sides of said transmission line, an obtuse angle between said long arms and an obtuse angle between said short arms.

20. The invention as set forth in claim 11 wherein means are provided for suspending said dipole arms solely from two points of support.

21. The invention as set forth in claim 11 wherein means are provided for suspending said dipole arms and transmission line solely from two points of support.

22. A radio receiving system for long and short wave signal bands, comprising an antenna, a long and short wave radio receiver, a transmission line connected at its remote end to said antenna, a transformer coupling the receiver end to said receiver for receiving short wave signals, and switch means for by-passing said transformer to effectively connect said receiver end to said receiver for receiving long wave signals.

23. A radio receiving system for long and short wave signal bands comprising a dipole type antenna, a long and short wave receiver, a balanced transmission line connected to said antenna, a transformer coupling said line to an input terminal of said receiver for receiving short wave signals from the antenna acting as a dipole, and switch means for by-passing said transformer for long wave signals from said antenna, acting as a capacity type, to said terminal.

24. In a radio receiving system; an all-wave antenna; a receiver selectively responsive to long and short wave bands; a transmission line, balanced for short waves and unbalanced for long waves, connecting said antenna with said receiver; means coupling the receiver to said line; said means comprising a path selective to out-of-phase short wave currents in said line and rejecting in-phase currents in said line; and means for providing a path, selective to long wave signals, between said line and said receiver.

25. The invention as set forth in claim 24 wherein said short wave path comprises a transformer having a grounded electro-static shield disposed between windings thereof.

26. The invention as set forth in claim 24 wherein said antenna operates as a dipole for short waves and as a capacity type antenna for long waves.

27. The invention as set forth in claim 24 wherein said second named means includes a switch for changing over from short wave reception to long wave reception.

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