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APERIODIC DIRECTIVE ANTENNA SYSTEM

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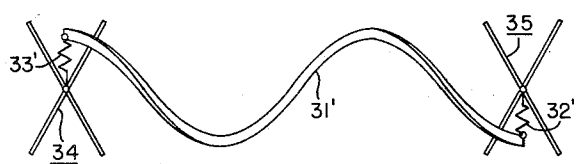
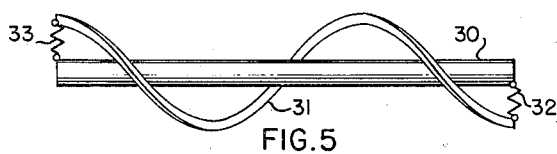
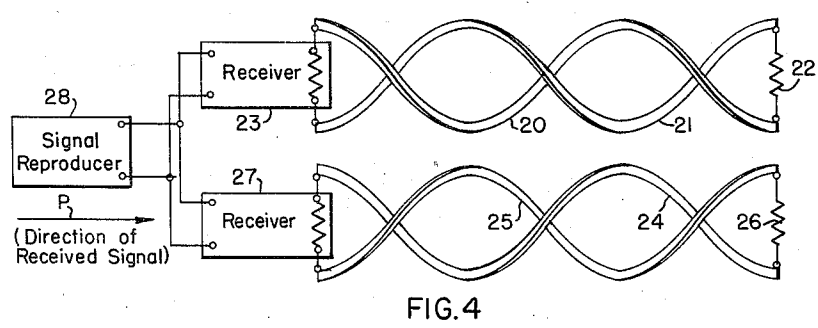
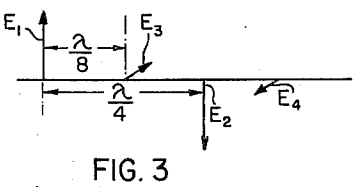
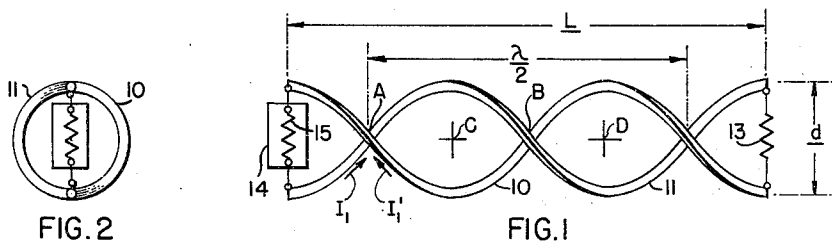


FIG. 6

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APERIODIC DIRECTIVE ANTENNA SYSTEM

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10 Claims. (Cl. 250—33.51)

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This invention is directed to aperiodic antenna systems characterized by radiation with approximately circular polarization and primarily directive toward one end. Such an antenna is frequently designated in the art as of the "end-fire" type and is subject to a wide variety of uses.

Many end-fire antenna constructions have been proposed heretofore. One forms the subject matter of copending application Serial No. 670,081 filed May 16, 1946, in the name of Harold A. Wheeler and assigned to the same assignee as the present invention. The disclosure of the copending application is specifically concerned with directional-coupling arrangements but teaches how such an arrangement may be employed as a directive or end-fire antenna. In its simplest form, it includes a pair of coplanar conductors having a spacing that is small relative to the operating wave length and terminated to achieve a desired directivity. This antenna, however, exhibits plane polarization, whereas it may be desirable in certain installations to have an end-fire antenna characterized by circular polarization. The present invention, which constitutes an extension of the development upon which the above-mentioned copending application is predicated, proposes such an end-fire antenna featuring circular polarization.

It is an object of the invention to provide a new and improved aperiodic antenna system which is predominantly directive toward one end and exhibits the property of radiation with approximately circular polarization.

It is another object of the invention to provide an improved and simplified aperiodic antenna system of the end-fire type which radiates wave signals with substantially circular polarization.

It is a further object of the invention to provide an end-fire antenna system for a diversity receiver, featuring two directive aperiodic antennas individually responsive to received wave signals circularly polarized in one of two directions of rotation.

In accordance with the invention, an aperiodic directive antenna system comprises a helical radiating conductor having a pitch substantially equal to one-half of the operating wave length, a helical diameter much less than one-quarter of the operating wave length and a length of at least substantially one-half a turn. The system has means for terminating one end of the conductor in its characteristic impedance and means for connecting signal-translating apparatus to the antenna system at the opposite end of the conductor, whereby the antenna system is pre-

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dominantly directive in the direction of the aforesaid opposite end and exhibits the property of radiation with substantially circular polarization.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a representation of a two-conductor directive antenna system embodying the invention; Fig. 2 is an end view of the Fig. 1 arrangement; Fig. 3 is a vector diagram utilized in explaining the directive properties of the antenna system of Fig. 1; Fig. 4 is a schematic representation of a diversity receiver employing the present invention; while Figs. 5 and 6 represent modified forms of the invention utilizing a single conductor of helical configuration.

Referring now more particularly to Figs. 1 and 2, the arrangement there represented includes an aperiodic directive antenna system of the end-fire type. The antenna structure comprises a pair of similar radiating conductors 10 and 11. Each conductor is in the form of a helix, both being pitched in the same sense. The helical conductors 10 and 11 are positioned coaxially but are rotationally displaced with reference to one another about their common axis. There is a wide latitude permissible in connection with the relative displacement of the conductors. The displacement affects the total radiation of the system, producing a maximum when radiation from one conductor aids that from the other to the fullest and minimizing radiation where the conductor arrangement causes the components of radiation from the two conductors to cancel. For optimum results one conductor is displaced half a turn relative to the other so that they are positioned symmetrically with respect to their common axis. This symmetrical relationship is indicated in Fig. 1, which is a projection in a vertical plane of the antenna conductor structure. Each of conductors 10 and 11 has a pitch which closely approximates one-half of the operating wave length and the diameter of each helix or the spacing of the wires in a transverse direction is very much less than one-quarter of the operating wave length. This transverse spacing is identified by the dimension line d , Fig. 1. The conductor thickness or cross-sectional diameter is very much less than the diameter d of the helix defined by the conductor. The conductor thickness and conductor spacing

determine the radiation resistance as well as the reactance of the antenna structure, the radiation resistance being primarily a function of spacing and the reactance being a function of spacing as well as thickness. Usually, the thickness is very small in relation to a quarter of the operating wave length as already indicated and its upper limit is approximately determined by one-half of the conductor spacing or one-half a radian length, whichever is the smaller. The dimension "radian length" is the wave length divided by two π .

The length, indicated by dimension line L, of each conductor 10 and 11 is at least approximately one-half a turn of the helix. While a conductor length of only one-half a turn is perfectly feasible, the use of longer conductors improves the directivity, that is, accentuates the end-fire characteristic of the antenna. Also, longer conductors tend to make the directivity of the antenna more selective as to frequency. For the most part, each conductor length is an integral multiple of one-half turn of the helix, but as the length L approaches a large number of half turns, the integral relationship of length to half turns of the helix becomes less critical.

The antenna system under consideration has means for terminating one pair of the adjacent ends of conductors 10 and 11 in the characteristic impedance of these conductors. This means is represented by the terminating impedance 12 of Fig. 1. Additionally, means are provided for connecting signal-translating apparatus to the antenna system at the opposite ends of its conductors, this means being represented by a block diagram 14. The impedance 15 within the unit 14 is intended to signify a terminal impedance applied thereby to conductors 10 and 11 for connecting to the ends thereof, preferably with impedance matching. As is well understood, antenna systems have identical characteristics when employed for wave-signal transmission or reception, and it is for this reason that the block representation of unit 14 is sufficient as a disclosure of either use. While it may designate any wave-signal translating apparatus connected with the antenna system, it will be assumed for the purposes of the present discussion that unit 14 constitutes a wave-signal transmitter.

In considering the operation of the Fig. 1 arrangement and the manner in which it attains a directive radiation characteristic, reference is made to the vector diagram of Fig. 3. The vector E_1 indicates the electric field intensity, or a component of radiation with vertical plane polarization originating at the point A of the conductor system 10, 11. At this point, for the instantaneous current condition indicated by the arrows I_1 and I_1' , the currents in conductors 10 and 11 have vertical components which add and horizontal components which oppose one another. This gives rise to the component E_1 of vertically polarized plane radiation. At the point B, a quarter wave distant from the first reference point A, the currents in conductors 10 and 11 again present vertical components in adding relation and horizontal components which are opposed. However, the transposition of the conductors due to the helical configuration causes the electric field intensity or radiation component E_2 originating at the point B to be in phase opposition with the first-mentioned radiation component E_1 . In similar fashion, it may be demonstrated that at each transposition point of the conductors in a vertical plane similar radiation

components of vertical plane polarization are produced, alternate ones of these having the same phase or polarity.

The directive effect of the antenna, at least so far as the vertical plane polarization is concerned, may be ascertained from a consideration of the influence of the components E_1 and E_2 on one another. As stated above, the current components I_1 and I_1' establish the component E_1 at the point A. The antenna is aperiodic and the conductor spacing provides a transmission time for the traveling wave of current along a given section of the conductors that is substantially the same as the wave-propagation time along a space path of corresponding length. In other words, the time delay of a current component at the point B, related to the reference point A, is substantially the same as the propagation time between these points. Consequently, for radiation in the direction of the excited end of the antenna there is effectively a half-wave delay or half-wave path difference between the points A and B. A delay or path difference of one-quarter of the operating wave length is introduced by the conductor length between the points A and B, and another delay is caused by the propagation time in space from the point B back to the point A. In view of this delay or path difference, the radiation component E_2 from the point B in traveling toward the excited end of the antenna structure arrives in phase with the instant radiation at the point A. Therefore, radiation from the points A and B is additive in the direction of the excited end of the antenna.

Radiation toward the end of the antenna which is terminated by the impedance 13 is quite different. Specifically, by the time the traveling-wave current arrives at the point B to establish the radiation component E_2 , the radiation component E_1 originating at point A also arrives at the point B. These radiations, being of opposite polarity or phase, tend to suppress one another. When the conductors 10 and 11 are symmetrical with reference to their common axis, substantially complete cancellation is obtained and radiation with vertical plane polarization toward the unexcited end of the antenna is effectively nullified.

A projection of the antenna system of Fig. 1 in a horizontal plane would show crossover or transposition points at C and D. At the point C, a component E_3 of electric field radiation with horizontal plane polarization is obtained while a similar component E_4 of opposite phase is established at the point D. It may be shown, in a manner similar to the treatment of the radiation from the points A and B, that the components of radiation with horizontal plane polarization add in the direction of the excitation end of the antenna and cancel in the direction of the opposite end. Thus, it is apparent that the antenna is predominantly directive in the direction of the end at which it is excited.

The points A and C have a separation of approximately one-eighth of the operating wave length. Therefore, radiation from the point C, referred to the point A, has a delay time or a path difference of one-quarter of the operating wave length. This effect causes the components of radiation with horizontal plane polarization to have a phase-quadrature relation in time with reference to the components of radiation with vertical plane polarization. The horizontal and vertical radiations are of the same magnitude so that the antenna system exhibits the property

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of radiation with approximately circular polarization in a direction of rotation determined by the sense of the pitch of its helical conductors 10 and 11.

In a complete communication system of the direct signal type, wherein a signal from a transmitting antenna is directly intercepted by a receiving antenna without any intervening reflection, like antennas are to be employed. That is, the helical conductors of the receiving antenna are to be pitched in the same sense as those of the transmitting antenna. On the other hand, where it is desired to detect reflected signals and to reject direct ones, the conductors of the receiving and transmitting antennas are to have opposite pitches. The discrimination between direct and reflected signals results from the fact that a circularly polarized radiation reverses its direction of rotation upon reflection.

Reception of signals of various origins and over various transmission paths may be accomplished in a diversity receiving system, employing a pair of spaced directive antennas, similar to the arrangement of Fig. 1 but having helical conductors with opposed pitches. Such an arrangement is represented in Fig. 4, where one antenna includes the conductors 20 and 21 having a right-hand pitch. This antenna is terminated at one end in a resistor 22 corresponding to its characteristic impedance and is terminated at the opposite end in a first diversity receiver 23. The second spaced antenna includes the conductors 24 and 25 having an opposite pitch, terminated at the remote end in its characteristic impedance by a resistor 26, and terminated at the near end in a second diversity receiver 27. The pitch, helical diameter, thickness and length of the conductors of each separate antenna are as described in connection with the arrangement of Fig. 1. The receiving units 23 and 27 include the usual signal-translating stages through the wave-signal detector and are paralleled with the input circuit of the common signal reproducer 28 in conventional manner. The overall system is directive in the direction of the ends to which the receiving components are connected and is suited to receiving wave signals approaching as indicated by the arrow P. Since its individual antennas 20, 21 and 24, 25 are reversely pitched, the system may respond to wave signals of circular polarization having either direction of rotation, as well as signals of plane polarization at any angle.

While the arrangements thus far described utilize two rotationally displaced helical conductors, an aperiodic antenna system in accordance with the invention may, if desired, include but a single helical conductor. In Fig. 5, for example, the antenna system has a linear conductor 30 and a helical conductor 31. The latter is coaxially disposed about the former and their projected lengths in the vertical or horizontal plane are equal. An impedance 32 connects one pair of the adjacent ends of the conductors in the characteristic impedance thereof and an impedance 33 of the same value terminates the opposite pair of conductor ends. Connections to the antenna may be made at either pair of the conductor ends. Where a directivity similar to that described for the arrangements of Figs. 1 and 4 is desired, the impedance 33 represents signal-translating apparatus connected to the antenna. The helical conductor 31 has the same pitch, helical diameter, thickness and length re-

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cited in the discussion of conductors 10 and 11 of Fig. 1.

The embodiment of Fig. 6 is generally similar to that of Fig. 5 and corresponding components thereof are designated by the same reference characters primed. In this case, two spiders 34 and 35 provide a space ground for the antenna system, each spider including several radially extending conductors having a length approximately equal to one-quarter of the operating wave length. The spokes are preferably perpendicular to the axis of the helix. The impedances 32', 33' provide critical damping terminations at the opposite ends of radiating conductor 31'. This is the same as terminating the conductor with its characteristic impedance. The characteristic impedance of the conductor 31' is determined by a pseudo-shield or equipotential surface established around the conductor by capacitive currents which leave and enter the conductor along spaced portions of its length. This pseudo-shield, however, does not impede radiation from the conductor. A pair of antennas, constructed in accordance with Fig. 5 or 6, may be utilized in a diversity receiving system of the type represented in Fig. 4.

Each of the described embodiments of the invention comprises an aperiodic directive antenna system of simplified mechanical construction. In each case the antenna is of the end-fire type and exhibits the property of radiation with approximately circular polarization in a sense related to the pitch of its helical conductor or conductors. A very long antenna of this type has a limiting value of directivity because of its attenuation resulting from radiation and dissipation. The cancellation of radiation toward the unexcited end of the antenna is maintained if the attenuation in nepers per radian length of antenna is much less than unity. The power ratio of directive gain is about equal to the number of half-wave lengths in the length of the radiating conductors, if the total attenuation is less than one neper.

For convenience, each embodiment has been considered as excited from the same end, namely, the left-hand end, as represented in the drawing. The directivity may be reversed by exciting the opposite end of the antenna, so a single structure may be used for opposite directions. Also for convenience, the structures of Figs. 1, 5 and 6 have been described principally in connection with wave-signal transmission. As already indicated, the functions of reception and transmission with any such antenna are unavoidably associated by the reciprocity theorem. Therefore, such expressions as "radiating conductor" and "property of radiation" and the like are used in the text and in the appended claims in a generic sense to define an antenna structure in accordance with the invention whether that antenna be utilized for signal transmission or reception.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An aperiodic directive antenna system comprising: a helical radiating conductor having a

pitch substantially equal to one-half of the operating wave length, a helical diameter much less than one-quarter of said wave length, and a length of at least substantially one-half a turn; means for terminating one end of said conductor in its characteristic impedance; and means for connecting signal-translating apparatus to said antenna system at the opposite end of said conductor, whereby said antenna system is predominantly directive in the direction of said opposite end and exhibits the property of radiation with substantially circular polarization.

2. An aperiodic directive antenna system comprising: a helical radiating conductor having a pitch substantially equal to one-half of the operating wave length, a helical diameter much less than one-quarter of said wave length, a conductor thickness much less than said diameter, and a length of at least substantially one-half a turn; means for terminating one end of said conductor in its characteristic impedance; and means for connecting signal-translating apparatus to said antenna system at the opposite end of said conductor, whereby said antenna system is predominantly directive in the direction of said opposite end and exhibits the property of radiation with substantially circular polarization.

3. An aperiodic directive antenna system comprising: a helical radiating conductor having a pitch substantially equal to one-half of the operating wave length, a helical diameter much less than one-quarter of said wave length so that the transmission time along a given section of said conductor is substantially the same as the wave-propagation time along a corresponding space path, and having a length of at least substantially one-half a turn; means for terminating one end of said conductor in its characteristic impedance; and means for connecting signal-translating apparatus to said antenna system at the opposite end of said conductor, whereby said antenna system is predominantly directive in the direction of said opposite end and exhibits the property of radiation with substantially circular polarization.

4. An aperiodic directive antenna system comprising: a helical radiating conductor having a pitch substantially equal to one-half of the operating wave length, a helical diameter much less than one-quarter of said wave length, and a length substantially equal to an integral multiple of one-half a turn; means for terminating one end of said conductor in its characteristic impedance; and means for connecting signal-translating apparatus to said antenna system at the opposite end of said conductor, whereby said antenna system is predominantly directive in the direction of said opposite end and exhibits the property of radiation with substantially circular polarization.

5. An aperiodic directive antenna system comprising: a helical radiating conductor having a pitch substantially equal to one-half of the operating wave length, a helical diameter much less than one-quarter of said wave length, and a length of at least substantially one-half a turn; means for terminating one end of said conductor in its characteristic impedance; and means for connecting signal-translating apparatus to said antenna system with impedance matching at the opposite end of said conductor, whereby said antenna system is predominantly directive in the direction of said opposite end and exhibits

the property of radiation with substantially circular polarization.

6. An aperiodic directive antenna system comprising: a single helical radiating conductor having a pitch substantially equal to one-half of the operating wave length, a helical diameter much less than one-quarter of said wave length, and a length of at least substantially one-half a turn; means for terminating one end of said conductor in its characteristic impedance; and means for connecting signal-translating apparatus to said antenna system at the opposite end of said conductor, whereby said antenna system is predominantly directive in the direction of said opposite end and exhibits the property of radiation with substantially circular polarization.

7. An aperiodic directive antenna system comprising: a linear conductor; a single helical radiating conductor coaxially disposed about said linear conductor, having a pitch substantially equal to one-half of the operating wave length, a helical diameter much less than one-quarter of said wave length, a thickness much less than said helical diameter and a length of at least substantially one-half a turn; means for terminating one pair of the adjacent ends of said conductors in the characteristic impedance thereof; and means for connecting signal-translating apparatus to said antenna system at the opposite ends of said conductors, whereby said antenna system is predominantly directive in the direction of said opposite ends and exhibits the property of radiation with substantially circular polarization.

8. An aperiodic directive antenna system comprising: a single helical radiating conductor having a pitch substantially equal to one-half of the operating wave length, a helical diameter much less than one-quarter of said wave length, and a length of at least substantially one-half a turn; means for providing a space ground for said antenna system; an impedance, having a value equal to the characteristic impedance of said conductor, for connecting one end of said conductor to said space ground; and means, coupled between the opposite end of said conductor and said space ground, for connecting signal-translating apparatus to said antenna system, whereby said antenna system is predominantly directive in the direction of said opposite end and exhibits the property of radiation with substantially circular polarization.

9. An aperiodic directive antenna system comprising: a pair of similar, coaxial helical radiating conductors rotationally displaced with reference to one another about the common axis, having a pitch substantially equal to one-half of the operating wave length, a spacing much less than one-quarter of said wave length, and a length of at least substantially one-half a turn; means for terminating one pair of adjacent ends of said conductors in the characteristic impedance of said pair of conductors; and means for connecting signal-translating apparatus to said antenna system at the opposite ends of said conductors, whereby said antenna system is predominantly directive in the direction of said opposite ends of said conductors and exhibits the property of radiation with substantially circular polarization.

10. An aperiodic directive antenna system comprising: a pair of similar, coaxial helical radiating conductors positioned symmetrically with reference to the common axis, having a pitch substantially equal to one-half of the operating wave length, a spacing much less than one-quarter

ter of said wave length, and a length of at least substantially one-half a turn; means for terminating one pair of adjacent ends of said conductors in the characteristic impedance of said pair of conductors; and means for connecting 5 signal-translating apparatus to said antenna system at the opposite ends of said conductors, whereby said antenna system is predominantly directive in the direction of said opposite ends of said conductors and exhibits the property of 10 radiation with substantially circular polarization.

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