Oct. 13, 1942.

A. B. BAILEY

2,298,449

ANTENNA

Filed Nov. 8, 1941

3 Sheets-Sheet 1

FIG. 1

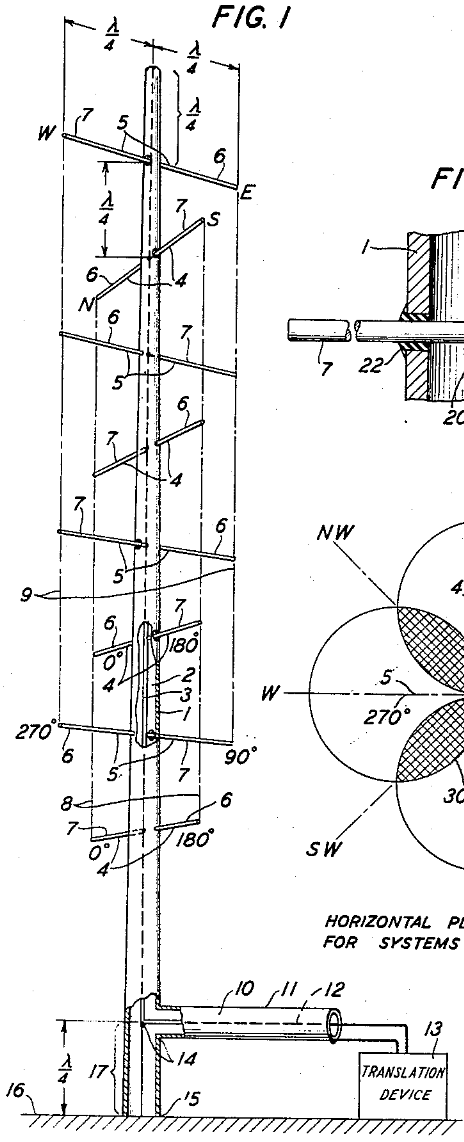


FIG. 2

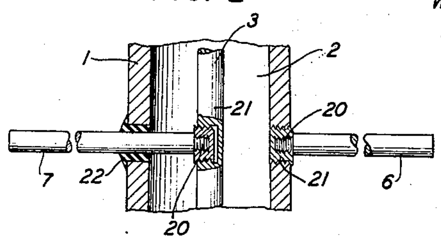
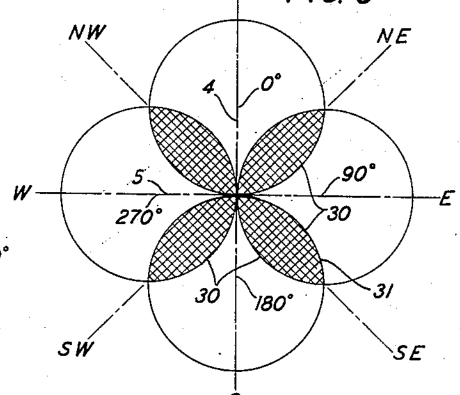
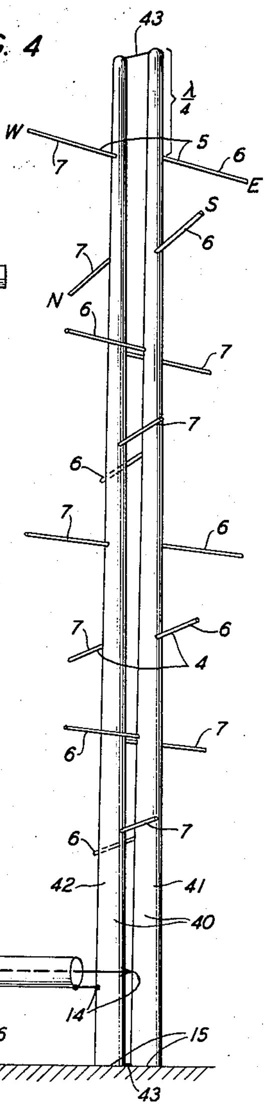


FIG. 3



HORIZONTAL PLANE CHARACTERISTIC FOR SYSTEMS OF FIGS. 1, 4, AND 5.

FIG. 4



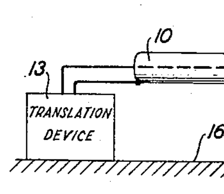


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FIG. 5

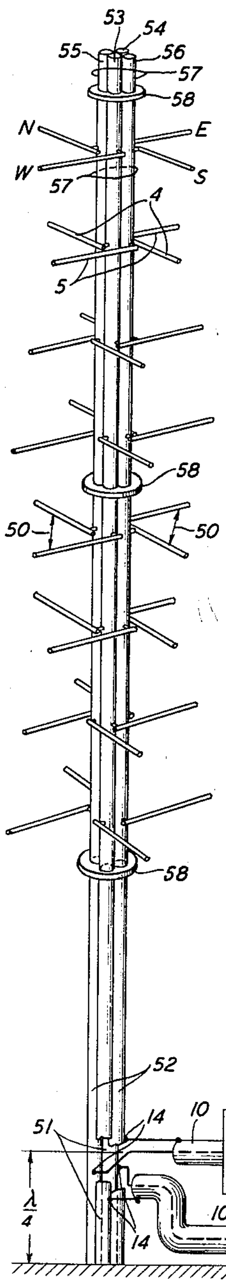
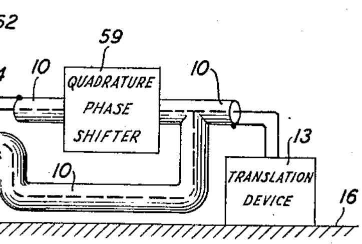



FIG. 7

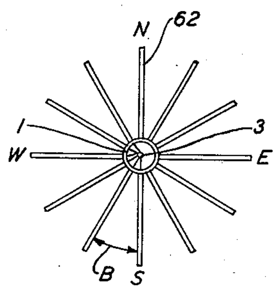
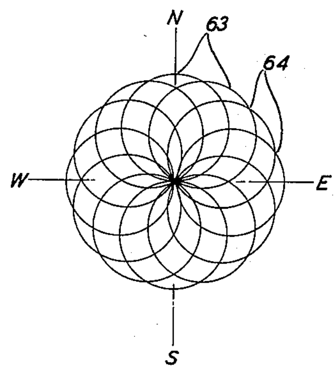


FIG. 8



HORIZONTAL PLANE CHARACTERISTIC FOR SYSTEM OF FIG. 6

FIG. 6

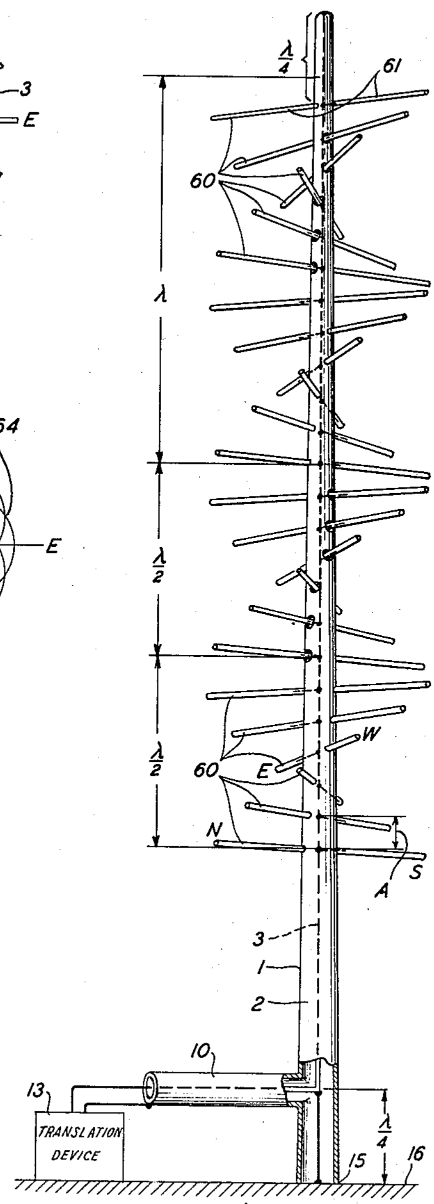


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FIG. 9

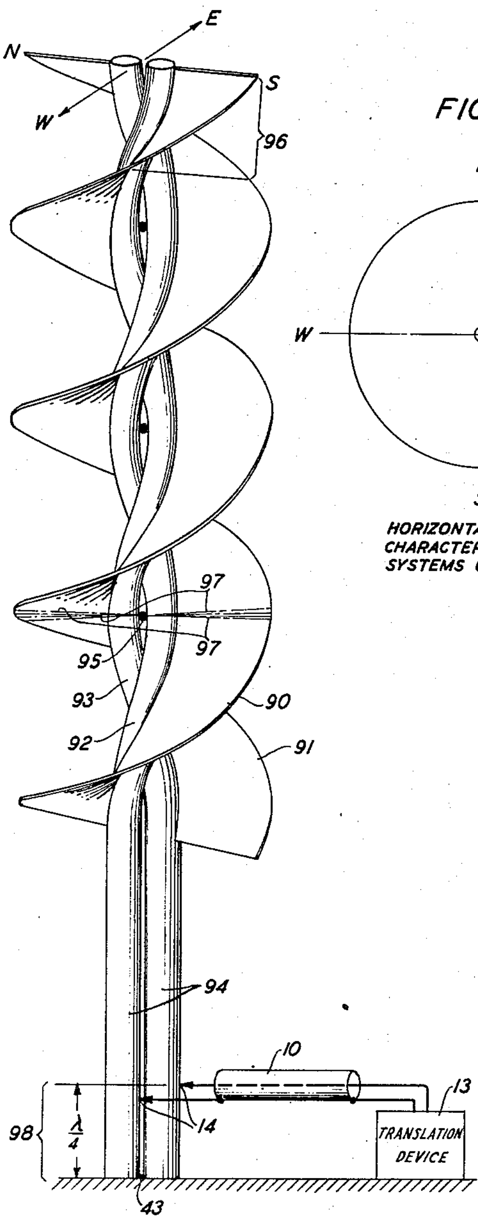
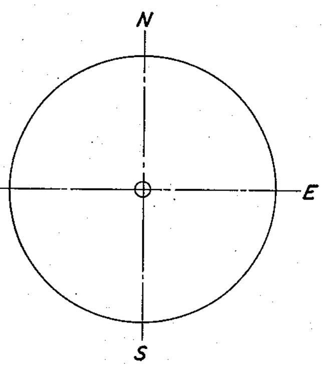
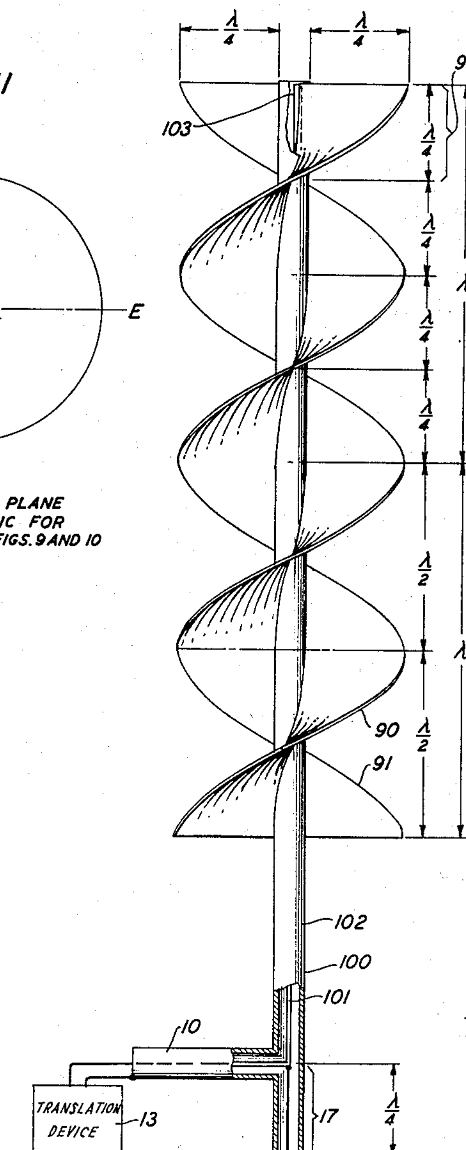


FIG. 11



HORIZONTAL PLANE CHARACTERISTIC FOR SYSTEMS OF FIGS. 9 AND 10

FIG. 10



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2,298,449

UNITED STATES PATENT OFFICE

2,298,449

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Application November 8, 1941, Serial No. 418,363

12 Claims. (Cl. 250—11)

This invention relates to antenna arrays and more particularly to omnidirectional short wave and ultra-short wave antenna arrays.

As is known, in the short and ultra-short wave fields including the frequency modulation broadcast field, arrays comprising two sets or vertical panels of horizontal doublets, the doublets in each panel being vertically spaced and the panels being included in quadrature vertical planes, have been suggested for achieving radiation in substantially all directions in the horizontal or azimuthal plane. Patents 1,937,748, H. R. Darbord, December 5, 1933, and 2,234,744, H. P. Thomas, March 11, 1941, each disclose a staggered or semi-turnstile array in which the horizontal tiers each include a single series-excited doublet and in which the doublets in the adjacent tiers are positioned in space quadrature and energized in time quadrature. Patents 2,086,976, G. H. Brown, July 13, 1937, and the copending application of J. F. Morrison, Serial No. 335,663, filed May 17, 1940, and assigned to applicant's assignee, illustrate respectively, a shunt-excited and a series-excited turnstile array, in which each horizontal tier contains two doublets positioned in space quadrature and energized in time quadrature, the adjacent tiers being substantially identical. As is apparent, the radiations for all of the substantially infinite number of horizontal directions are not always the same in these prior art systems, since each doublet has a figure-of-eight directive diagram and the overall directive characteristic of the two adjacent quadrature doublets is a four-leaved clover similar to that utilized in the well-known A–N Beacon system. It now appears desirable to obtain in a system employing, as in the above-mentioned systems, horizontal polarized waves, a more uniform radio emission and response in the azimuthal plane than heretofore realized and, at the same time, to employ antenna structure having distinct mechanical and electrical advantages not found in the prior art systems.

It is one object of this invention to obtain in a radio system utilizing waves polarized in a given plane, uniform transmission and reception in said plane.

It is another object of this invention to secure an omnidirectional, and substantially circular, horizontal plane directive characteristic for a horizontally polarized antenna.

It is still another object of this invention to employ relatively simple self-supporting antenna structure, for securing azimuthal omnidirectional radio action, which structure is connected to the earth through a path having zero impedance, substantially, for lightning current and a high impedance at the operating frequency and which is easily assembled or dismantled and readily altered for the purpose of effecting a change in its operating quality.

In accordance with one embodiment of the invention, the antenna structure comprises discrete horizontal collecting or emitting members attached to a metallic flagpole type mast at points vertically spaced a quarter wave-length, these members being energized in time quadrature and positioned in space quadrature. The flagpole mast is grounded at its base and constitutes one line conductor, the mast being connected to the main transmission line from the transmitter or receiver at a point a quarter wave-length above its base. The quarter wave line section at the base has a negligible impedance for lightning and a high impedance at the operating frequency. In accordance with a different embodiment one or more additional discrete horizontal members are attached to the mast, each at a point located between the above-mentioned vertically spaced quadrature members. The direction of extension and the phase of the current supplied to each intermediate element are related to the distance along the mast between the added intermediate member and either of the first-mentioned quadrature members.

In accordance with a preferred embodiment of the invention, the antenna structure comprises a grounded metallic vertical mast constituting one line conductor and enclosing the other line conductor and a pair of vertical spiral radiating or collecting sheet conductors each having a suitable horizontal width as, for example, a half or a quarter wave-length. Each sheet is joined along a longitudinal edge to a different line conductor, the path or junction line between each sheet conductor and the associated line conductor being spiral in contour. The pitch, that is, the length of each portion having a complete twist or spiral, as measured along the vertical line conductor, is one wave-length. Every horizontal plane intercepting the mast or vertical line and the attached spiral sheet conductors includes an effective dipole antenna and, similarly, every vertical plane containing the line conductor includes a dipole antenna, the spirality being so dimensioned relative to the vertical line or mast that the effective dipoles vertically spaced a quarter wave-length are in space quadrature and energized in time quadrature. In a sense, whereas the prior art structures comprise discrete dipoles, the spiraliform antenna of the invention is a continuous or expanded turnstile structure or spiraloid analogous to a double circular ramp or an Archimedean screw and comprising non-discrete doublets of infinitesimal vertical thickness, the non-discrete adjacent doublets in contiguous vertical planes and the doublets in adjacent horizontal planes being energized with currents having an infinitesimal phase difference, whereby the array has, in each horizontal plane or tier, a figure-of-eight diagram and by virtue of the juxtaposition of the differently oriented doublets, the effective azimuthal diagram is a true circle.

The invention will be more fully understood from a perusal of the following specification taken in conjunction with the drawings on which like reference characters denote elements of similar function and on which:

Fig. 1 illustrates a semiturnstile or staggered antenna array comprising a single mast; Fig. 2 is a partial detail view of the system of Fig. 1 and Fig. 3 is a directive diagram for the system of Fig. 1; Fig. 4 illustrates a semiturnstile array comprising two masts which constitute the transmission line; Fig. 5 illustrates a turnstile array comprising four vertical masts; Fig. 6 is a perspective view and Fig. 7 a plan view of a circular ladder type array comprising expanded turnstile sections and discrete dipole members and Fig. 8 is a directive diagram for the array of Fig. 6, and Figs. 9 and 10 illustrate spiral arrays comprising respectively, a single flagpole mast and two flagpole masts; Figure 11 shows the horizontal plane characteristic for systems of Figures 9 and 10.

Referring to Fig. 1, reference numeral 1 designates a hollow flagpole type mast constituting the outer conductor of a coaxial line 2 and reference numeral 3 denotes the inner conductor of the line, the mast 1 being tapered as illustrated and the inner conductor being preferably of tapered pipe construction as shown by the exposed view in Fig. 1. Insulators (not shown) are utilized to maintain the inner and outer conductors of line 2 spaced from each other. Numerals 4 and 5 designate, respectively, half wave-length north-south and east-west dipoles or doublets each of which comprises a quarter wave-length member 6 electrically connected to the mast 1 and a quarter wave-length member 7 connected to the inner conductor 3. The adjacent doublets 4 and 5 are perpendicularly related so that the four quarter wave-length members included therein extend in quadrature directions preferably, but not necessarily, coinciding with the cardinal compass points, N, E, S and W. The N—S doublets are included in the same vertical plane and constitute one aerial panel 8 and the E—W doublets are included in a vertical plane perpendicularly related to the above-mentioned plane and constitute another aerial panel 9. The adjacent dipoles in each of panels 8 and 9 are vertically spaced a half wave-length apart along the vertical transmission line 2 and are transposed. Thus, considering any two adjacent dipoles 4 of panel 8, the member 6 of one dipole and the member 7 of the other dipole have the same point-direction but are connected to different line conductors at points spaced a half wave-length along the line; and the quarter wave-length members connected to the same line conductor at points spaced a half wave-length extend from the mast in opposite point-directions. Considering the two panels 8 and 9 together, the adjacent dipoles 4 and 5 are positioned in space quadrature and connected to the line 2 at points spaced a quarter wave-length apart. Hence, the four quarter wave-length members constituting each pair of adjacent dipoles 4 and 5 are connected to the line 2 for energization in phase quadrature. For convenience, the respective phases of the N, E, S and W quarter wave-length members are assumed to be 0°, 90°, 180° and 270°; and each pair of adjacent dipoles 4 and 5 is designated an antenna section. Reference numeral 10 denotes a coaxial line having an outer conductor 11 and an inner conductor 12, and connected between device 13 and the line 2 at a point 14 a quarter wave-length above the mast base 15. The line 2 is short-circuited at the base 15 by the ground conductor 16 and the quarter wave-length line section 17 constitutes a high impedance at the mean operating frequency and substantially zero impedance at other frequencies as, for example, lightning frequency. Also the line 2 extends a quarter wave-length above the top dipole and is short-circuited at the top extremity. The ground 16 may be actual earth or the metallic top of a building or other structure.

As shown in Fig. 2 which illustrates certain mechanical features of the system of Fig. 1, the half dipole members 6 are preferably of light weight tubular construction and are each equipped with a threaded plug 20 which is adapted to fit into a properly located threaded socket 21 on the mast 1, whereby a solid electrical connection is established between each radiating member and the mast and a relatively strong mechanical junction is effected. Similarly, properly spaced threaded sockets 21 are provided in the inner pipe conductor 3 and each half dipole member 7 is equipped with a threaded plug 20 adapted to fit into one of the aforementioned sockets. The members 7 are inserted each through a separate aperture in the mast 1 and fitted to their respective sockets 21 in the inner conductor, annular insulating elements 22 being utilized for insulating the mast 1 from the dipole member 7. As is obvious, other mechanical connections as, for example, plug and jack assemblies, may be satisfactorily utilized in place of the above-described connecting assembly. The mechanical arrangement is such that the projecting quarter wave-length members may easily be removed for the purpose of facilitating transportation to the place of assembly and erection. Also, sections comprising a pair of adjacent dipoles 4 and 5 may be readily removed or added for the purpose of altering the receiving quality or radiating power capacity of the system.

Referring to Fig. 3, the operation of the system of Fig. 1 and Fig. 2 will now be explained. Assuming the translation device 13 is a transmitter, radio energy of the given operating frequency is supplied over line 10 to the line 2 and in proper phase to the four quarter wave-length radiating members 6, 7 constituting each antenna section. As already indicated, at the junction point 14 of lines 10 and 2, the short-circuited wave-length transformer 17 effectively prevents energy of the operating frequency from flowing to the ground 16 but does not impede other frequencies as, for example, lightning. The doublets 4 and 5 each have a figure-of-eight directive diagram 30 and the two diagrams 30 for each antenna section combine to form a four-leaved rose overall diagram having adjacent leaves overlapping, as indicated by the shaded portion 31. Single fields of equal intensity are propagated only in the N, S, E and W directions, the fields propagated along the NE, SE, SW and NW directions being composed of two component quadrature-phased fields. Consequently, each of the NE, SE, SW and NW fields has an intensity substantially different from that propagated in the N, S, E and W directions, whereby the overall directional diagram is not circular but scalloped; and, while the array radiates in all horizontal directions, the radiations in all directions are not equal.

Fig. 4 illustrates a hat-tree array which is similar to the array of Fig. 1 from an electrical and radiant standpoint but which includes certain mechanical features not present in the system of Fig. 1. Numeral 40 designates an open conductor line comprising vertical masts 41 and 42 held, if desired or necessary, in spaced relation by the short-circuiting block member 43 positioned at the top extremity of line 40 which point is a quarter wave-length removed from the uppermost dipole. As in Fig. 1, numerals 4 and 5 designate dipoles included in the N—S panel and the E—W panel, respectively, the quarter wave-length half-dipole members 6 being connected to the same pole or line conductor 41 corresponding to the outside conductor 1 in the system of Fig. 1 and the members 7 being connected to the other dipole conductor 42 corresponding to the inner conductor 3 of Fig. 1. Considering each of pole conductors or masts 41 and 42, the half-dipole members are vertically spaced a quarter wave-length and the adjacent quarter members are in spaced quadrature. The transmission line 10 from device 13 is connected to the line 40 at a point 14 which is a quarter wave-length above the base 15 of each mast. As in the system of Fig. 1, the quarter wave-length dipole members 6, 7 are equipped with threaded plugs for attachment to threaded sockets in the mast conductors 41 and 42.

In operation, Fig. 4, energy is supplied from device 13 to the various dipole members in proper phase relation and the resulting directive diagram is substantially the same as that of the system of Fig. 1. From a mechanical standpoint the system of Fig. 4 may be preferred for certain, but not necessarily all, usages since the coaxial line insulators and the aperture insulators 22 used in the system of Fig. 1 are not required, the poles 41 and 42 are not mechanically weakened by reason of apertures and the vertical open type line is more easily maintained in an operative condition. On the other hand, the embodiment of Fig. 1 possesses certain advantages from the standpoint of sleet formation and ease of transportation.

Fig. 5 illustrates a stack array comprising eight turnstile tiers or sections 50 vertically spaced a quarter wave-length and a pair of transmission lines 51 and 52, the sections 50 each comprising a pair of doublets 4, 5 and the lines 51 and 52 each comprising two tubular or pipe-type conductors designated 53, 54 and 55, 56, respectively. The vertical mast conductors form a columnar structure 57, which extends to the ground 16 and the four vertical conductors constituting the column are held in spaced relation by insulators 58. At point 14 a quarter wave-length above ground 16 lines 51 and 52 are connected through separate branch lines 10 to a main line 10 and associated translation device 13, a quadrature phase shifter 59 being included in the branch line 10 connected to the vertical line 52. The corresponding N, S, E or W half dipoles in alternate turnstile sections 50 are connected to different conductors of the same vertical line and hence are arranged for in-phase energization. The corresponding half-dipole members in adjacent sections 50 are connected to conductors of different lines and, since these lines, 51 and 52, are connected to device 13 for quadrature energization and the lengths of the two lines from device 13 to the adjacent sections differ a quarter of a wave-length, these corresponding members are connected for in-phase energization.

In operation, Fig. 5, assuming device 13 is a transmitter, energy of the operating frequency is supplied over main line 10 and the branch lines 10 to the vertical lines 51 and 52 and to the turnstile sections 50. The phase of the energy delivered to line 52 is shifted 90° relative to the energy of line 51 by means of the quadrature phase shifter 59. Considering each turnstile section 50, the energies supplied to the two halves of each dipole are oppositely phased and the currents delivered to the two dipoles are in phase quadrature whereby the four half dipoles are, as in the systems of Figs. 1 and 4, energized in quadrature and the corresponding half-dipole members in the array are energized in phase. Also, as in the systems illustrated by Figs. 1 and 4, the currents of the operating frequency supplied to lines 51 and 52 are prevented from leaking to ground 16 by means of the separate quarter wave-length short-circuited transformers 17 connected between the ground 16 and point 14 on each of lines 51 and 52; and each line conductor 53, 54, 55, 56 is grounded for lighting and other frequencies differing from the operating frequency as, for example, even harmonic currents. The resulting horizontal plane array characteristic for the system of Fig. 5 is the same as that of the semiturnstile array of Figs. 1 or 4, as illustrated by Fig. 3. The array of Fig. 5, however, has a more desirable vertical plane characteristic since the additional radiators produce a more concentrated beam and a lower angle of fire. If desired, complete turnstile sections 50 may be added to or removed from the system of Fig. 5 in order to conform with particular power or height requirements.

Fig. 6 illustrates a stack array each comprising four expanded-turnstile sections 60 and each section comprising six discrete doublets 61. The doublets are connected in series with the coaxial line 2 which comprises mast 1 and inner conductor 3. Line 1 is connected at a point a quarter wave-length above ground 16 to the main line 10 and the device 13. Considering any two adjacent doublets 62 in the array, the doublets are positioned in parallel horizontal planes and in angularly related vertical planes, and the spacing A in electrical degrees between the above-mentioned horizontal planes as shown in Fig. 6 is the same as the dihedral angle B in angular degrees between the aforementioned vertical planes, as shown in Fig. 7, the value of A and B being $\lambda/12$ for the system illustrated by Fig. 6. More generally, while in the system of Fig. 6 each staggered turnstile section 60 contains six dipoles, it should be understood that in accordance with the invention a complete turnstile section 60 may comprise n dipoles 61, n being any number greater than 2. The equation given below gives the relation between the value of the angle B (and spacing A) and the number n of dipoles in a section 60:

$$A=B=\frac{360^\circ}{2n}$$

where n is greater than 2. It may be noted that with n equal to 2 the above equation applies to the simple staggered arrays of Figs. 1 and 4, since each semiturnstile section in these systems comprises two dipoles in space quadrature. While, ordinarily, the angle B is less than 90°, it may be increased by a multiple, including the integer 1, of a wave-length. Also, while the dipoles, as viewed from the base 15, are successively displaced to the right, that is, in a counterclockwise manner, they may be displaced if desired in a clockwise manner. As in the system of Fig. 1, plug and socket connections are preferably used for attaching the quarter wave-length dipole elements to the vertical line conductors 1 and 3.

In operation, referring to Figs. 6, 7 and 8, device 13 supplies oppositely phased energies to the two halves of each dipole 61. Since the adjacent dipoles are connected to points spaced $\lambda/12$ on the line 2, the currents in these dipoles have a phase difference equal to $\lambda/12$ and, since the adjacent dipoles are positioned at an angle of $\lambda/12$, their figure-of-eight diagrams greatly overlap. Fig. 8 illustrates the horizontal twelve-leaved rose directive characteristic of each turnstile section 61. As may be seen by comparing the four-leaved rose of Fig. 3 with the twelve-leaved rose diagram of Fig. 8, the expanded array of Fig. 6 produces more uniform radiation in a horizontal plane than is produced by the systems of Figs. 1, 4 or 5, the system of Fig. 1 having only four points of equal radiation whereas the system of Fig. 6 has twelve. Moreover, the difference in intensity between any of the maximum fields 63 and any of the minimum fields 64 is less in the case of the system of Fig. 6 than the difference, Fig. 3, between any of the maximum N, E, S and W fields and any of the minimum NE, SE, SW and NW fields for the systems of Figs. 1, 4 and 5. If desired, additional dipoles may be attached to the line 2, Fig. 6, between any pair of adjacent dipoles, the compass or point directions and the points of attachment to the transmission line 2 of the added doublets being selected in accordance with the above equation. For example, an additional dipole may be added to the line at a point midway between the two bottom doublets 61 of Fig. 6, the additional doublet being included in a vertical plane making an angle of 15° with each of the two dihedral vertical planes containing the aforementioned bottom doublets.

Fig. 9 is a perspective view and Fig. 10 is an elevational view of an array comprising two spiral radiating metallic sheet conductors 90 and 91, the array of Fig. 9 being connected to, and supported by, an open mast type line and the array of Fig. 10 to a coaxial mast type line. In appearance the spiraloid of these figures resemble a double circular ramp or an Archimedean screw. Referring to Fig. 9, the sheet conductors 90 and 91 are attached to line conductors 92 and 93 which constitute a vertical self-supporting line 94. Reference numeral 95 designates suitable insulators for maintaining the line conductors 92 and 93 insulated from each other. At a point 14 a quarter wave-length above the ground or other conducting surface 16, the line 94 is connected to line 10 and device 13, the lower portion 17 of line 94 constituting a short-circuited quarter wave-length line. Each of radiating sheets 90 and 91 makes two complete spirals around line 94, each complete spiral or subarray having, as shown in Fig. 10, a vertical height of one wave-length and a horizontal width of a quarter wave-length. Each sheet contains an infinite number of horizontal, non-discrete, adjacent elemental doublets 97, which have an infinitesimal thickness in the vertical and horizontal planes. The segmental or elemental doublets in each sheet located at and between points vertically spaced a quarter wave-length along the line form a turnstile section 96. Considered from another standpoint, the array of Fig. 9 corresponds to the surface of revolution generated by revolving a dipole about its center point and simultaneously moving the dipole along a linear path or axis, and is a structure which may be approximated by adding a sufficient number of intermediate properly spaced and properly oriented discrete doublets to the system of Fig. 6 so as to secure a substantially solid wash-board radiating surface analogous to a spiral or double circular ramp. Again, considering each turnstile section 96, Fig. 9, the every vertical plane passing through the transmission line 94 includes a separate elemental doublet, and each horizontal plane passing through the section 96 contains a separate elemental doublet.

Referring to Fig. 10 the double ramp array 90, 91 is associated with a coaxial self-supporting flagpole type line 100 which comprises inner conductor 101 and outer conductor 102. One longitudinal edge of metallic sheet 90 is attached to the outer conductor 102 along a spiral junction line; and a longitudinal edge of metallic sheet 91 is similarly attached to the inner conductor 101. A spiral slot 103 is provided in the outer conductor for permitting attachment of the sheet 91 to the inner conductor 101, the sheet 91 being maintained spaced from the outer conductor 102 by insulators (not shown). As in the systems previously described, the transmission line 10 from device 13 is connected to line 100 at a point a quarter wave-length above the ground 16.

In operation, energy is supplied by device 13 and line 10 to the line 94, Fig. 9, and to the line 100, Fig. 10, and thence radially to the sheet conductors 90 and 91, the phases of the currents supplied to the contiguous, infinitesimally spaced, horizontal elemental doublets 97 in each sheet conductor having a substantially infinitesimal difference. The doublets are progressively phased and the elemental doublets having a quadrature space relation are energized in quadrature. Considering each turnstile section 96, since the contiguous doublets are displaced successively an infinitesimal amount, the overall directive diagram for each of the systems of Figs. 9 and 10 comprises a large number, approaching infinity, of overlapping figure-of-eight diagrams and is circular, as shown by Fig. 11. Radiation of equal intensity occurs in all horizontal directions and, as compared to the prior art systems and to the systems illustrated by Figs. 1, 4, 5 and 6, more desirable characteristics, horizontal and vertical, are obtained. All parts of the structures of Figs. 9 and 10 are grounded for lightning and the self-supporting structures are rugged and advantageous from a mechanical standpoint.

Although the invention has been explained in connection with certain embodiments, it is to be understood that it is not to be limited to the apparatus illustrated, inasmuch as other equipment and apparatus may be satisfactorily employed in practicing the invention. The antenna of the invention is equally well suited for receiving and transmitting and while the embodiments described produce equalized horizontal radio action of horizontally polarized waves, the invention may be utilized for achieving equalized radio action in any plane of polarization. If, as in airport landing systems, equal radiation in the vertical plane of vertically polarized waves is desired only one spiral sheet conductor is required since the ground image may be employed in place of the other sheet conductor.

I claim:

1. An antenna for securing equi-intensity radio action in all directions in a given plane comprising a pair of sheet conductors each spirally twisted about one of its longitudinal edges and having both faces or surfaces exposed to the ether medium, the corresponding transverse segmental portions of said sheet conductors being included in a plane perpendicular to said first-mentioned plane and containing said edges substantially.

2. An antenna comprising two exposed spiral sheet conductors vertically positioned and connected in series through a translation device, each conductor having a uniform horizontal width and a pitch of a wave-length.

3. An antenna system for securing equal radio actions in all directions in a desired plane of wave travel for waves polarized in said plane comprising a spiral sheet conductor connected along one edge to a line conductor extending substantially in a direction perpendicular to said plane, said sheet conductor being spiralled once about a section of said line conductor having a length of one wave-length.

4. An antenna system for securing equal radio actions in all directions in a desired plane of wave travel for waves polarized in said plane, comprising a pair of line conductors insulated from each other and extending substantially in a direction perpendicular to said plane, and a pair of spiral sheet conductors connected each along one edge to corresponding portions of different conductors.

5. A system in accordance with claim 4, said sheet conductors each having one complete spiral for each line section a wave-length long and extending at corresponding points of connection with said line conductors in opposite point-directions perpendicularly related to the line conductors.

6. In combination, a substantially linear transmission line comprising a pair of conductors, a pair of sheet conductors each having a transverse dimension equal to a quarter wave-length and spirally connected along a longitudinal edge to a different conductor, whereby each plane perpendicularly intercepting said line and said sheet conductors includes a linear antenna.

7. In combination, a substantially linear transmission line comprising a pair of conductors connected to a translation device, a pair of spiral sheet conductors each having a width of a quarter wave-length, said sheet conductors being connected continuously and spirally along one edge to corresponding portions of said line and each complete spiral extending a wave-length along said line.

8. In combination, a vertical transmission line, an antenna array comprising a plurality of vertically spaced doublets connected to said line and positioned in different vertical planes, the spacing betwen adjacent doublets being less than a quarter wave-length and electricaly equal to the angle between the vertical planes containing said adjacent doublet.

9. In combination, a transmission line, a plurality of linear antenna members connected thereto and spaced less than a quarter wave-length, said members being angularly displaced an amount equal to said space.

10. An antenna array comprising a pair of linear members connected to a line and positioned in angularly related vertical planes and in different horizontal planes, the spacing in electrical degrees between said horizontal planes being less than 90 degrees and equal to the dihedral angle formed by said vertical plane.

11. In combination, a translation device, a self-supporting coaxial line comprising a vertical mast conductor and an enclosed conductor, a plurality of perpendicularly related half wave-length horizontal doublets each comprising two one-quarter wave-length members, the members of each doublet being connected in series with each other only through said conductors and device.

12. In combination, a self-supporting coaxial line comprising a pair of rigid conductors, a translating device, an antenna comprising a pair of perpendicularly related doublets, said doublets being removably connected in series with said conductors and said device and each of said line conductors being connected to earth through a path having a substantially infinite impedance at the operating frequency and zero impedance at other frequencies.

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