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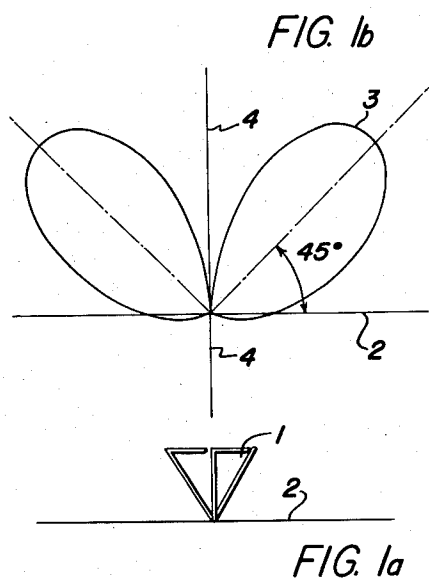
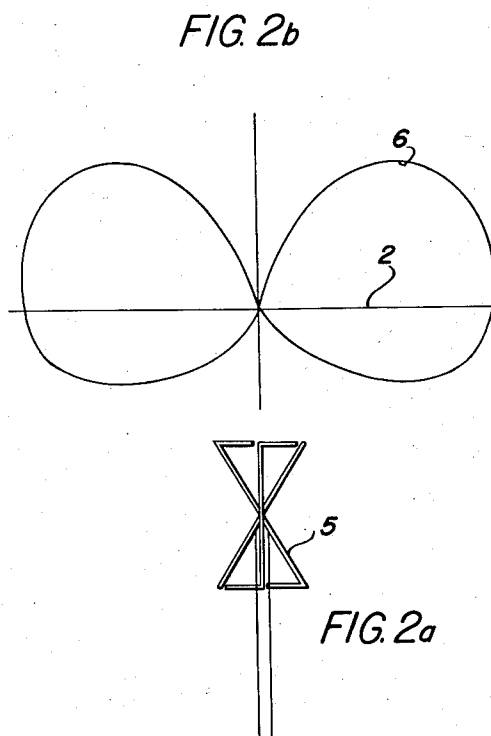
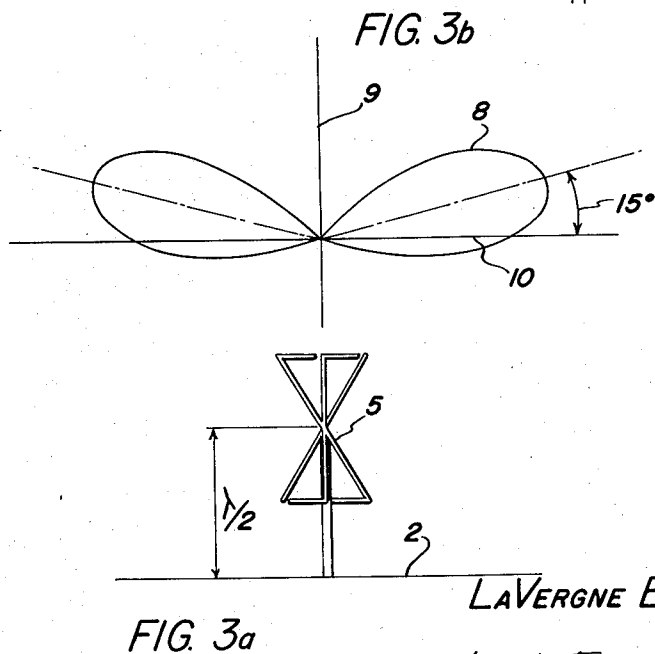
LA VERGNE E. WILLIAMS

2,964,747

VEE ANTENNA

Filed July 21, 1958

2 Sheets-Sheet 1



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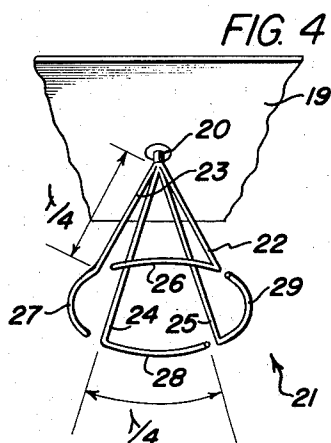
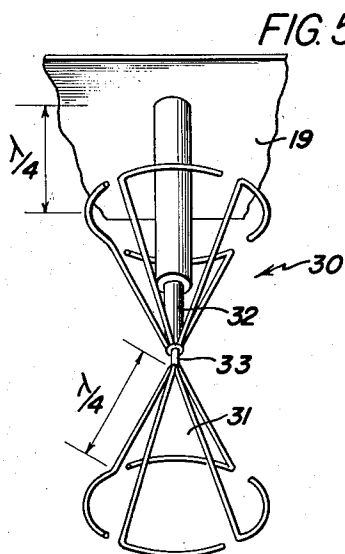
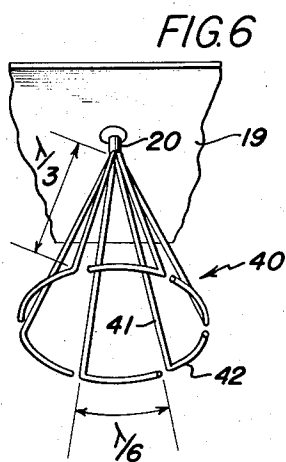
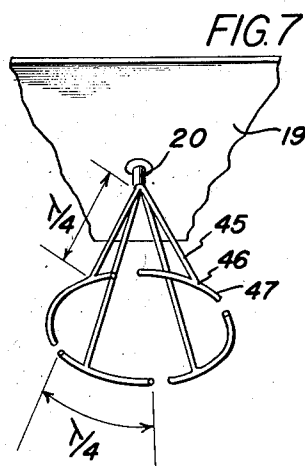
LA VERGNE E. WILLIAMS

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VEE ANTENNA

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2 Sheets-Sheet 2



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2,964,747

VEE ANTENNA

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Filed July 21, 1958, Ser. No. 749,946

11 Claims. (Cl. 343—726)

The present invention relates generally to omnidirectional antennae and more particularly to azimuthally omnidirectional antennae which respond equally to radiation of arbitrary polarization when utilized as receivers, and which may be employed to transmit circularly or elliptically polarized wave energy having either sense of rotation, according to the arrangement of the antenna.

Briefly describing the present invention in its basic embodiments, it comprises a plurality of rod-like first elements diverging from a common apex as elements of a cone, and a further rod-like extension of each first element, the extensions extending generally along the circumference of the base of the cone to form a loop. The first elements and the extensions may be each of length $\lambda/4$ at the operating frequency of the antenna.

The cone-like structure comprising the basic device of the present invention may be duplicated to provide a dipole, or operated with respect to a ground plane, and the dipole may operate in free space or be located with its center a distance $\lambda/2$ above a ground plane.

The theory of operation of the present invention is briefly as follows. The first or cone elements of the basic antenna are driven co-phasally and may be considered, when operated with respect to a ground plane, to define a cone, and therefore to have a relatively wide band response and an omnidirectional radiation pattern in azimuth, the pattern making an angle of about 45° with the ground plane. The field pattern for the circumferential elements is essentially that of a small loop and is accordingly similar to that of the cone elements.

Assuming the axis of the cone antenna to be vertical, voltages for the cone elements and the circumferential elements are approximately 90° out-of-phase. The antenna will therefore receive circular polarization or elliptical polarization of either sense of rotation, and will respond to either vertical polarization, or horizontal polarization, and to any intermediate polarization angle.

The antenna may be arranged as a transmitter of circularly or elliptically polarized waves, rotating in either sense depending on the relative direction of loop currents, i.e., on the sense of extension of the circumferential antenna elements in space with respect to the cone axis.

The antenna may preferably employ four elements to form a cone, but is not limited to four. Each element includes an essentially vertical portion and an essentially horizontal portion, phased by 90° in a preferred embodiment, but one portion may be lengthened at the expense of the other, to change the phasing. Thereby the antenna may be employed to generate elliptically polarized waves. The circumferential or H element, in the preferred embodiment, is an extension of the cone or V element, but operating characteristics may be varied by connecting the ends of the V portions intermediate the ends of the H portions, or the H portions

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intermediate the ends of the V portions. The basic antenna, accordingly, permits of a wide variety of modifications, with concomitant variations of characteristics.

The H elements are arranged to form a circular loop, in the preferred embodiment of the invention. However, triangular or square loops may be employed, or loops following any geometric configuration.

The Vee antenna configuration is known to provide wide bandwidth antenna response, which is variable with the angle of the Vee. In the present antenna the total number of antenna elements employed may also be a function of the angle of the Vee, i.e., for a large vertex angle five or six rather than four, elements may be employed, while for a small vertex angle only two or three may be permitted.

It is, accordingly, a broad object of the present invention to provide a novel omnidirectional antenna which is sensitive to arbitrary polarization.

It is another object of the invention to provide an antenna comprised of rods, each rod having a portion coincident with a generating element of a cone and a portion coincident with the circumference of the base of the cone.

A further object of the present invention resides in the provision of an antenna comprised of plural radiating elements, each radiating element comprising two portions which have voltages in 90° time phase and which are approximately in 90° space phase.

It is a further object of the invention to provide a conical antenna having discrete antenna elements each of length $\lambda/4$, where λ is the operating wave length and wherein first elements extend from the apex to the base circumference of an imaginary cone and certain other elements extend circumferentially of the base of the cone, and are connected to the first elements.

A further object of the invention resides in provision of an antenna having elements responsive simultaneously to two polarizations 90° apart in space and 90° apart in time phase, respectively.

It is another object of the present invention to provide a cone antenna having an omnidirectional radiation pattern in azimuth for an arbitrary polarization.

A further object of the present invention resides in the provision of an antenna capable of transmitting omnidirectional elliptically polarized wave energy having any desired degree of ellipticity.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of several specific embodiments thereof, especially when taken in conjunction with the accompanying drawings, wherein:

Figure 1a is a view in elevation of a cone antenna operating with respect to a ground plane;

Figure 1b is a representation of the radiation pattern of the antenna of Figure 1a, in vertical section;

Figure 2a is a view in elevation of a dipole comprised of two cones, as in Figure 1a;

Figure 2b is a representation in section of the radiation pattern of the antenna of Figure 2a;

Figure 3a is a view in elevation of a dipole antenna according to Figure 2a, but operating with respect to a ground plane;

Figure 3b is a representation of a radiation pattern pertaining to the antenna of Figure 3a;

Figure 4 is a view in perspective of a conical antenna according to the invention;

Figure 5 is a view in perspective of a dipole antenna employing two conical antennae of the type illustrated in Figure 4; and

Figures 6 and 7 are views in perspective of modifications of the antenna of Figure 4.

Referring now more specifically to the accompanying drawings; Figure 1a illustrates a generally conical or Vee antenna identified by the reference numeral 1, which is mounted with its apex adjacent to a ground plane 2. The ground plane 2 may preferably have a diameter of about 3λ , or more, where λ is the operating wave length of the antenna. In a practical application of the present system, the ground plane 2 may be constituted of the metallic fuselage of an aircraft. In such case the radiation pattern of the antenna is illustrated in Figure 1b, and constitutes, when the axis of the cone 1 is vertical, an omni-directional pattern 3 taken about the vertical axis 4 of the cone 1, the pattern making an angle of approximately 45° with the plane of the ground plane 2.

The antenna 1 of Figure 1 may be employed as one element of a dipole 5, which is center fed. In such case, the dipole 5 may subsist in free space, as in Figure 2a, the radiation pattern 6 remaining omni-directional, but the effective angle of the radiation pattern 6 with respect to the horizontal being substantially or approximately zero, as is illustrated at Figure 2b. Referring to Figure 3b, a ground plane 2 may be employed in conjunction with the dipole 5 and the center of the dipole 5 may be located approximately $\lambda/2$ above or below the ground plane 7. In such case the radiation pattern 8 of the antenna is symmetrical about the vertical axis 9, and makes an angle of about 15° with the horizontal plane 10.

The character of the antennae 1 or 5 may be such as to provide response to circularly polarized wave energy having either direction of rotation and in general to wave energy of arbitrary direction. When the antenna is utilized as a transmitting antenna, its transmission characteristics are such as to generate circularly polarized wave energy in space, in a preferred embodiment. The plane of polarization may rotate either clockwise or counter-clockwise, depending upon the arrangement of certain elements of the antenna, to be described hereinafter.

Reference is now made to Figure 4 of the accompanying drawings, wherein is illustrated structural features of the antennae of Figures 1 to 3, inclusive. Figure 4 of the accompanying drawings illustrates a ground plane 19, which may be constituted of the metallic fuselage of an aircraft. A supporting connector 20 for a cone antenna 21 is secured to the ground plane 19 and through this support, which may be or include a conventional coaxial connector, radio frequency energy is supplied to the antenna or is abstracted from the antenna. The antenna itself includes four elements, 22, 23, 24, and 25, which lie on the surface of an imaginary cone, the connector 20 constituting or lying at the apex of the cone. The elements 22-25 may lie on generating elements of the cone 21 or they may make an acute angle with such generating elements. In general, if the axis of the cone is vertical, the elements 22-25 have very large projections on the vertical axis, so that they may respond primarily to vertically polarized radiant energy wave.

The generally vertical or V elements 22-25 each proceeds to a generally horizontal or H extension, the latter being identified, respectively, by the reference numerals 26, 27, 28 and 29, and the extensions subsisting along the circumference of the base of the cone. Each of the elements 22, 23, 24, 25, 26, 27, 28 and 29 is preferably $\lambda/4$ in length, at the operating wave length λ of the antenna. The elements 26, 27, 28 and 29 subsist generally in a horizontal plane or in a plane generally perpendicular to the axis of the cone 21. Accordingly, the elements 26, 27, 28 and 29 of the antenna respond to horizontally polarized wave energy.

The response of the vertical elements 22, 23, 24 and

25 of the antenna is essentially that of a vertically disposed cone, which in turn approximates that of a vertical rod, i.e., has an omni-directional pattern in azimuth, the pattern making generally an angle of about 45° with respect to the ground plane 19, assumed to be horizontal. The radiation pattern of the elements 26, 27, 28 and 29 is essentially that of a horizontal loop and accordingly is essentially the same radiation pattern as the pattern of the vertical elements. The two sets of elements respond, however, to vertical and horizontally polarized waves, respectively, in major part, and in addition since the element 22 is in series with the element 26 electrically, the element 23 is in series with the element 27 electrically, the element 24 is in series electrically with the element 28 and the element 25 is in series with the element 29, respectively, the voltages at these elements have a 90° phase displacement. It follows from the spatial relation of the elements and the electrical phase relation of the elements that the antenna will respond to circularly polarized wave energy regardless of the direction of rotation of the plane of polarization. As respects transmission of wave energy, the antenna of Figure 4 radiates circularly polarized energy, but the direction of rotation of the plane of polarization depends upon the direction in which extend the elements 26, 27, 28 and 29 with respect to the axis of the cone, i.e., whether these extend counterclockwise or clockwise.

It will be realized that while I have illustrated the antenna of Figure 4 of the accompanying drawings as including four radiating devices, that this number is not critical and that either more or fewer radiating elements may be employed. It will further be appreciated that while the elements 22, 23, 24 and 25 may be taken to fall on the surface of a cone, they may similarly be considered to fall on the surface of a pyramid, and that while for four elements the pyramid is rectangular, three elements may be utilized, or five elements may be utilized, changing the nomenclature of the pyramid without essentially changing the broad operating characteristics of the antenna. Similarly, the elements 26, 27, 28 and 29 are shown as elements of the circumference of the base of a cone. These elements may be linear, if desired, constituting elements of the base of a pyramid.

The advantage of the conical antenna configuration is in that the response band of a conical antenna is known to be wider than the response band of a rod antenna. In the limit, nevertheless, the present antenna may consist of a single element 22 coupled with a single element 26, i.e., may be essentially L shaped. In such case, however, the vertical antenna element will provide an omni-directional pattern in azimuth while the horizontal element will not. The necessity for employing plural antenna elements is that the horizontal elements of the antenna are required to simulate a loop, whereby the radiation pattern for horizontally polarized energy will essentially duplicate the radiation pattern for vertically polarized energy. The most effective mode of constructing the antenna to have the desired vertical angle of cone such that substantially identical radiation patterns exist for both vertical and horizontal polarization, is the four element configuration.

In the system of Figure 5 of the accompanying drawings, the antenna of Figure 4 is shown employed as one element of a dipole antenna, comprising oppositely extending cones 30 and 31. The cones 30 and 31 are energized in parallel by means of a transmission line comprising an outer conductor 32 and an inner conductor 33, the elements of the cone 30 being connected all in parallel to the outer conductor and the elements of the cone 31 being connected all in parallel to the inner conductor 33, whereby the cones are driven in phase opposition, as is appropriate to a dipole. The base of the cone 30 is arranged to be approximately $\lambda/4$ in spacing from

the ground plane 19, whereby the drive points for the cones are approximately $\lambda/2$ from the ground plane 20.

The polarization response characteristics of the antenna may be modified so as to produce polarization with any desired degree of ellipticity, by changing the relative lengths of the vertical and horizontal elements of the antenna. Moreover, solely vertical polarizations are obtained, for example, when the vertical antennae elements are connected to the centers of the horizontal antennae elements, and for the specified lengths, i.e., one quarter wave length for both vertical and horizontal elements, the degree of ellipticity may be modified by changing the point of connection to the horizontal elements along the length of the latter.

Referring now more particularly to Figures 6 and 7 of the accompanying drawings, Figure 6 illustrates an antenna in which each rod and its extension has a total length of $\lambda/2$, but in which the H elements are shorter than the V elements. Thereby, the phase relations and relative instensities of the H and V components of the radiation pattern are modified, and the resultant pattern is elliptically polarized. Additionally, five radiators are employed.

In Figure 6 a typical V element is 41 and a typical H element 42, the radiators collectively being identified by the reference numeral 40. For the sake of example, the V element 41 is assumed of length $\lambda/3$, and the H element 42 is assumed of length $\lambda/6$. Thereby, when the antenna is used as a transmitter the V element predominates in current intensity, and the phase relation of voltages in the series antenna elements is no longer 90° . The resultant radiated energy remains omni-directional in azimuth, but is elliptically rather than circularly polarized.

In the limit one of the H or V elements may be reduced to zero length, whereupon the radiation pattern will be plane polarized correspondingly.

In Figure 7 the V elements 45 are connected to an intermediate point, as 46, of the H elements 47. The lengths of the V elements 45 may then be preferably selected to provide a good impedance match to the H elements 47. Since the latter extend in opposite senses from the junction, 46, they radiate effectively as an element of short length, and if equal as an element of zero length, i.e., their net radiation is zero.

Tests on antennae constructed in accordance with the present invention show that directional patterns, and voltage standing wave ratios, remain reasonably constant over a frequency bandwidth of at least 2 to 1.

Patterns may also be modified by increasing or decreasing the V angle, and by increasing or decreasing the relative lengths of the V sections to the loop elements, and by stacking dipoles where it is desired to increase directivity.

While I have described and illustrated several specific embodiments of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. An antenna comprising a conical device consisting of a plurality of linearly extensive elements, each of said elements having a length of approximately $\lambda/2$, where λ is the operating wave length of the antenna, each of said elements comprising two portions, each of length approximately $\lambda/4$, wherein one of said portions extends between apex and circumference of an imaginary cone,

the other portions extending along the circumference of the base of said cone to form a loop, said elements being electrically interconnected only at said apex.

2. The antenna according to claim 1, where said plurality is four.

3. An antenna according to claim 1, wherein the total length of the plurality of other portions extend substantially completely around the circumference of the base of said cone.

4. An antenna according to claim 1, wherein is further provided a ground plane, said ground plane lying generally perpendicular to the axis of said cone and immediately adjacent to the apex of said cone.

5. The combination according to claim 1, wherein is provided a further conical device substantially duplicating the first named device, the apices of said devices being immediately adjacent and the axes of the conical devices being substantially co-linear.

6. The combination according to claim 5, wherein the axes of said first-named device and of said further device are substantially vertical.

7. The combination according to claim 5, wherein is provided a ground plane extending generally perpendicularly of said axis, said apices being spaced from said ground plane by a distance equal to substantially $\lambda/2$.

8. An antenna comprising a device consisting of a plurality of linearly extensive elements, each of said elements composed of two electrically connected portions of which one portion of each element extends along a wall of an imaginary geometric figure having an apex and a base, and extending between the apex and the base, the one portion being substantially symmetrically spaced relative to one another on the surface of said imaginary figure, the remaining portion of each of said elements extending all in the same sense along the perimeter of the base of said geometric figure, the length of each of the above-mentioned elements being approximately $\lambda/2$, where λ is the operating frequency of said antenna, said elements being electrically interconnected only at said apex.

9. The combination according to claim 8, wherein is further provided a transmission line coupled to the apical ends of all the first-mentioned portions.

10. The combination according to claim 9, wherein said portions are each of length $\lambda/4$.

11. A wide band omni-directional antenna comprising a Vee having a plurality of radiating elements of essentially one polarization and a continuation of each of said radiating elements, said continuations arranged to form a loop having its axis approximately parallel to the direction of said one polarization and a phase of voltage substantially displaced from the phase of voltage in the first-mentioned radiating elements, the latter extending each from apex to perimeter of base of an imaginary cone, the radiating elements of said antenna being interconnected only at the apex of said Vee.

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