May 31, 1949. G. H. BROWN ET AL 2,471,515

ANTENNA

Filed July 25, 1944

Fig. 1.

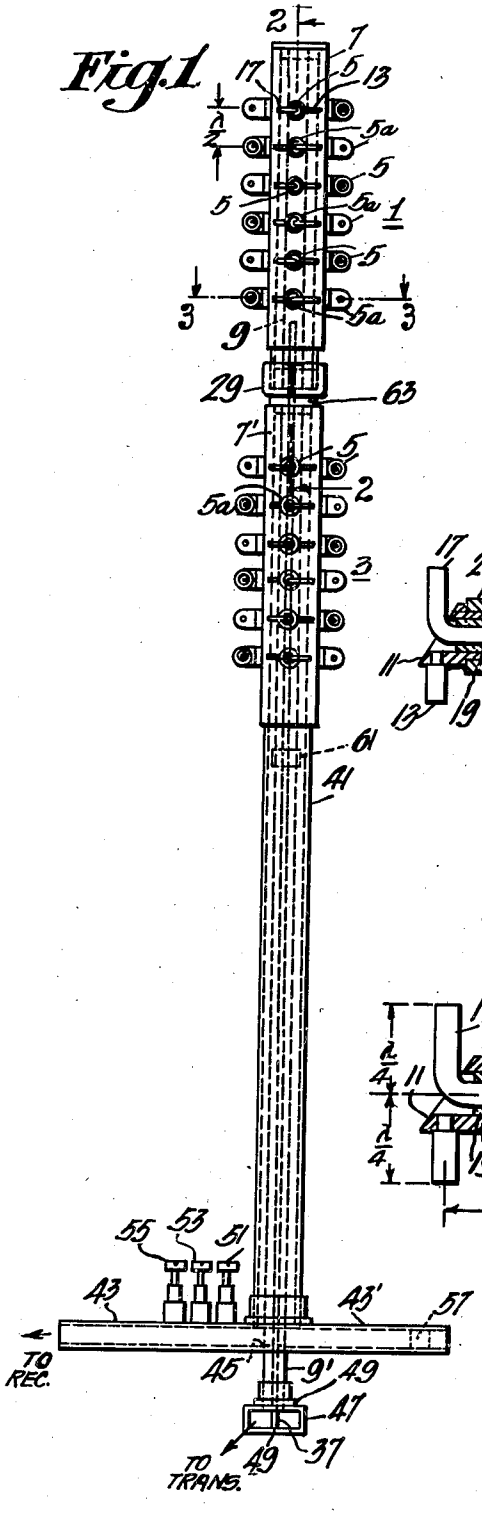


Fig. 2.

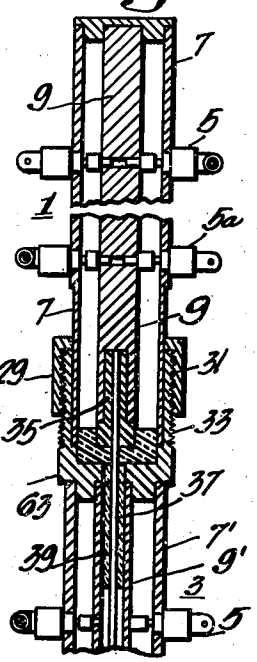


Fig. 4.

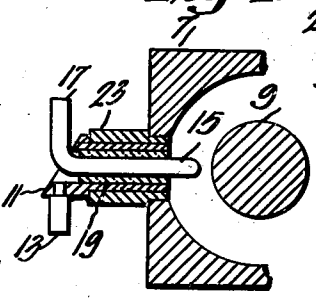
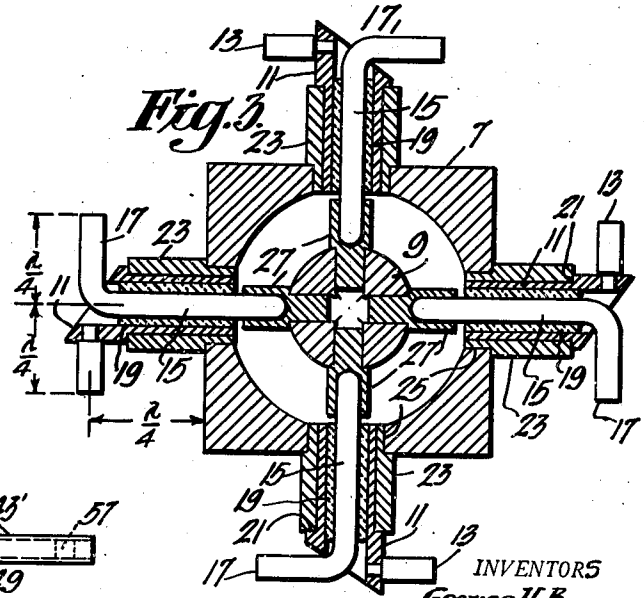


Fig. 3.



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8 Claims. (Cl. 250—33)

1

This invention relates to ultra high frequency radio antennas, and more particularly to antenna systems for providing horizontally uniform omnidirectional field patterns, with horizontally polarized energy. In certain radio beacon systems for aircraft and the like, it is desirable to receive, independently of azimuth, signals of frequencies of the order of 10,000 megacycles per second, and to transmit, in response to said signals, other signals of approximately the same frequency, with field strength also independent of azimuth. The field patterns should be limited in elevation, so that energy is transmitted and received only within a relatively low angle to the horizontal.

The principal object of the present invention is to provide an improved type of antenna system, which will, with suitable design, exhibit a field pattern with horizontal polarization which is substantially uniform in azimuth.

Another object is to provide a system of the described type which may be designed to provide any desired degree of elevational directivity.

A further object is to provide an antenna system including receiving and transmitting sections assembled in a unitary structure, and particularly adapted for independent operation at ultra high frequencies.

These and other objects will become apparent to those skilled in the art upon consideration of the following description, with reference to the accompanying drawing, of which Figure 1 is a view in elevation of a structure embodying the instant invention; Figure 2 is a sectional view, along the vertical plane 2—2 of a portion of the structure of Figure 1; Figure 3 is a sectional view, along the horizontal plane 3—3 of Figure 1; and Figure 4 is a view, similar to Figure 3, of a modification of Figure 1.

Referring to Figure 1, a preferred embodiment of the invention comprises two substantially identical groups 1 and 3 of radiator elements. For the purpose of this description, it will be assumed that the upper group 1 will be used for transmission and the lower group 3 for reception, although either group may be used for either purpose.

Each radiator group includes four orthogonally disposed panels of, in this instance, six horizontal dipoles 5 and 5a. Each panel of the upper group of radiators is supported on one of the faces of a conductive supporting member 7 of rectangular cross section, substantially 0.6 wavelength square. See Figure 3. The member 7 is provided with a cylindrical longitudinal bore through which a conductor 9 extends coaxially. It is important that the diameter of the bore not

2

be made too large, to avoid excitation in undesirable modes of the wave guide formed by the conductor 9 and the wall of the bore. Denoting the diameter of the conductor 9 as A, and the diameter of the bore in member 7 as B,

$$\frac{\pi}{2}(A+B)$$

must be less than one wavelength at the frequency of operation of the system. The member 7 is provided also with a plurality of transverse bores, at the points of support of the dipoles 5 and 5a.

Each dipole is a unitary structure, comprising a tubular conductor 11 to which a radiator element 13 is secured, and an inner conductor 15, bent over at its outer end to form a radiator 17. The conductor 15 is supported within the tubular conductor 11 by a sleeve 19 of insulating material, which preferably is bonded to the members 11 and 15. The outer end of the tubular conductor 11 is provided with an external shoulder 21, and is cut away at a 45° angle as shown to provide clearance for the curved portion of the conductor 15 forming the connection to the radiator 17. A conductive sleeve 23 extends over the outer surface of the member 11, engaging the shoulder 21. The sleeve 23 is provided with a reduced portion 25 which extends through and is secured to the wall of the member 7. The sleeve 23 functions as a spacing member, positioning the radiator elements 13 and 17 one-quarter wavelength from the surface of the member 7. Each of the elements 13 and 17 extends one-quarter wavelength from the axis of the conductor 15.

The conductors 15 extend radially inward toward the inner conductor 9, and are connected thereto by members 27, provided with a cup at one end for engaging the conductors 15, and provided with a tail at the other end for engaging radial openings in the inner conductor 9. The connectors 27 may be omitted, if desired, and coupling to the inner conductor 9 may be effected capacitively. This structure is diagrammatically illustrated by Figure 4.

All of the dipoles 5 and 5a are identical, with the exception that the dipoles 5a are reversed with respect to the dipoles 5. Referring again to Figure 1, the upper layer of dipoles 5 is arranged so that the radiators 17 extend to the left in each case, while the second layer of dipoles 5a has the radiators 17 extending to the right. This arrangement is followed throughout the entire stack, with alternate layers connected in opposite polarities. The adjacent layers are spaced apart vertically by one-half wavelength. Thus, all dipoles are energized in time phase.

The support 7 of the upper radiator system terminates at its lower end in a coupling 29, shown more clearly in Figure 2. The coupling 29 includes threaded members 31 and 33 arranged to connect the member 7 to a corresponding member 7' of the lower radiator system. The inner conductor 9 is coupled by means of a pin and socket connector 35 to a conductor 37. The inner conductor 9' of the lower radiator system is tubular. The conductor 37 extends downward coaxially through the tubular member 9', and is supported therein by tubular spacers 39 of insulating material.

The spacers 39 are made one-half wavelength long, at the velocity of propagation through the insulating material. Thus, assuming $\lambda=3$ cm. and the dielectric constant of the insulating material is 2.54, the spacers are

$$\frac{3}{2\sqrt{2.54}}=.975 \text{ cm.}$$

long. This presents reflection in the line 9', 37 as a result of the impedance discontinuities caused by the presence of the insulators 39, since each line section including one of the insulators acts in the manner characteristic of resonant half wave lines, presenting an impedance at one end equal to that presented to its other end.

The lower radiator system is identical in construction with the upper system, with the exception of the tubular inner conductor 9'. Similar reference numerals are employed to designate corresponding parts of the upper and lower systems. The lower end of the supporting member 7' is secured to a tubular conductor 41, which is connected at its lower end to a waveguide 43. The inner conductor 9' extends through the waveguide and is connected thereto at the point 45 on the lower surface. The conductor 9' is connected also to the upper surface of a second waveguide 47, at the point 49. The innermost conductor 37 extends across the waveguide 47, and is connected to the lower surface thereof at the point 49. The waveguide 47 is coupled to a radio receiver, not shown, and the waveguide 43 is similarly coupled to a transmitter, not shown. The waveguide 43 is provided with three adjustable reactance stubs 51, 53 and 55 spaced at one-quarter wavelength intervals from the point of connection to the conductors 41 and 9'. The waveguide 43 is also provided with a portion 43' extending on the opposite side of the points of connection and provided with an adjustable plug 57. The waveguide 47 is similarly provided with adjustable reactance stubs and a short circuited extension, which are not illustrated for the sake of clarity.

A conductive sleeve 61, one-quarter wavelength long, engages the outside surface of the conductor 9', and cooperates with the conductor 41 to function as a quarter wave line section having an impedance less than that of the line 9', 41. Owing to the well known impedance inversion characteristics of quarter wave lines, this section operates as a transformer, presenting an impedance

$$Z_2=Z_c^2/Z_1$$

at its lower end where Z_c is the characteristic impedance of the quarter wave section and Z_1 is the impedance presented to its upper end. The conductor 9' is short-circuited at its upper end to the bore in the member 7' by a plug 63 to provide a shunt inductive reactance. The dipoles 5 and 5a, being connected effectively in parallel, present a relatively low impedance to the line 9', 41. The sleeve 61 and the plug 63 are placed at positions such that this is transformed at the lower end of the sleeve 61 to a resistive impedance equal to the characteristic impedance of the line 9', 41. Thus the radiator group 3 is substantially matched to its feed line, enabling efficient operation over a relatively wide band of frequencies. The upper group 1 may be matched in similar manner if desired, by means of a quarter wave sleeve on the conductor 37.

The adjustment and operation of the above-described system is as follows: An oscillator or transmitter, tuned to the frequency in which the lower section 3 is to operate, is coupled to the waveguide 43 through a standing wave indicator, which may include a section of waveguide provided with a longitudinal slot for insertion of a probe connected to a vacuum tube voltmeter. The standing wave ratio is then determined in a conventional manner, by locating the points of maximum voltage and minimum voltage in the slotted waveguide. The plug 57 is adjusted to provide approximate equality of voltage at various points along the guide. The stubs 51, 53 and 55 are then adjusted in accordance with conventional practice to provide a substantially perfect impedance match between the waveguide 43 and the radiator section 3. The above-described operation is then repeated with the waveguide 47, tuning the oscillator to the frequency at which the receiver section 1 is to operate.

The directivities of the upper and lower sections 1 and 3 are respectively substantially identical, both in plan and elevation. Owing to the rectangular structure of the supporting members 7 and 7', which also act as reflectors, and the excitation of all of the dipoles in phase, the horizontal directive pattern is substantially circular. The vertical directive pattern is determined by the number of stacks, in accordance with principles well known to those skilled in the art. With the structure of Figure 1, having the described dimensions, the vertical directive pattern comprises a lobe having its maximum intensity along a horizontal axis, with a width of approximately 30° at the points of 50 percent field strength.

The invention has been described as an improved antenna system for use with horizontal wave polarization providing substantial uniform response in the horizontal plane. The described system comprises a plurality of stacks of orthogonally disposed horizontal dipoles. Two electrically separate systems are combined in a single mechanical structure, with one forming a support for the other, and a double coaxial line structure arranged to provide individual electrically isolated connections to the two systems. A novel type of dipole structure is described, comprising a unitary arrangement adapted to be plugged in to the antenna supporting structure.

We claim as our invention:

1. A radio antenna comprising a plurality of stacked groups of four orthogonally disposed horizontal dipoles, spaced vertically at half wave intervals to form four orthogonally related panels; a vertical conductive member of square cross section, mechanically connected to and acting as a support and reflector for one of said panels respectively on each of its vertical surfaces, said member including an axial bore, a conduc-

tor disposed coaxially within said bore and cooperating with said member to function as a coaxial transmission line, and means for coupling respectively one element of each of said dipoles to said coaxial conductor and means for connecting respectively the other element of each of said dipoles to said supporting member, with the mechanical arrangements of adjacent stacked groups reversed with respect to each other whereby all of said dipoles are electrically cophasal.

2. The invention as set forth in claim 1, wherein each of said means for coupling one of said dipole elements to said supporting member comprises a tubular conductor substantially of one-quarter wavelength, constituting a support for said element, and each of said means for coupling to said coaxial conductor comprises a further conductor supported coaxially within said tubular conductor and terminating adjacent the surface of said first mentioned inner coaxial conductor.

3. The invention as set forth in claim 1, wherein each of said dipoles is a unitary structure comprising a tubular conductive sleeve, a quarter wave radiator element secured to one end of said sleeve and extending at right angles to the axis thereof, said sleeve constituting said means for connecting said element to said vertical conductive supporting member, a sleeve of insulating material disposed coaxially within said conductive sleeve, a conductor supported coaxially within said insulating sleeve, and a second quarter wave radiator element integral with said conductor and extending at right angles thereto, said last mentioned conductor constituting said means for coupling said second radiator element to said first mentioned coaxial conductor.

4. An antenna system comprising a pair of antennas of the type set forth in claim 1, with the respective square vertical conductive supporting members connected end to end, the lower acting as a support for the upper, and the coaxial conductor of said lower antenna provided with an axial bore, and a conductor extending coaxially through said bore, and connection between the upper end of said last mentioned conductor and the lower end of the coaxial conductor of said upper antenna, said last mentioned coaxial conductor constituting a feed line for said upper antenna.

5. The invention as set forth in claim 1, wherein said vertical supporting member is substantially 0.6 wavelength square in section.

6. The invention as set forth in claim 1, wherein

$$\frac{\pi(A+B)}{2}<\lambda$$

where B is the diameter of said axial bore, A is the diameter of said coaxial conductor within said bore, and λ is substantially twice the length of each of said dipoles.

7. A dipole structure for radio antenna arrays comprising a rod radiator element, a conductive sleeve connected at its end to one end of said rod and extending at right angles thereto, said sleeve constituting a support and an electrical connector for said rod, a second rod radiator element extending collinearly with said first rod element, and a conductor integral with said second rod extending at right angles thereto and coaxially within said sleeve, said conductor constituting a support and electrical connector for said second rod; a shoulder formed near the outer end of said sleeve, a second sleeve supported outside said first sleeve and in engagement with said shoulder, and a shoulder formed on said second sleeve and a support for said dipole structure, said support including a surface engaged by said last-mentioned shoulder, whereby said second sleeve functions as a spacer fixing the distance of said radiators from said surface.

8. The invention as set forth in claim 7, wherein said first-mentioned sleeve terminates at its outer end in a surface lying at an angle of approximately 45° to its axis to provide clearance for said second rod element.

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