Oct. 16, 1956 J. F. BYRNE 2,767,397

ANTENNA

Filed March 31, 1951

FIG. 5

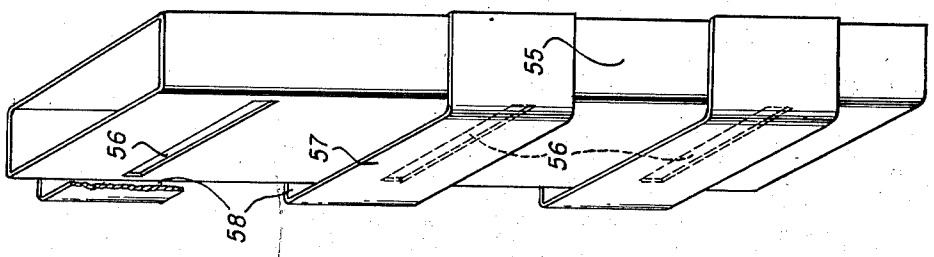


FIG. 4

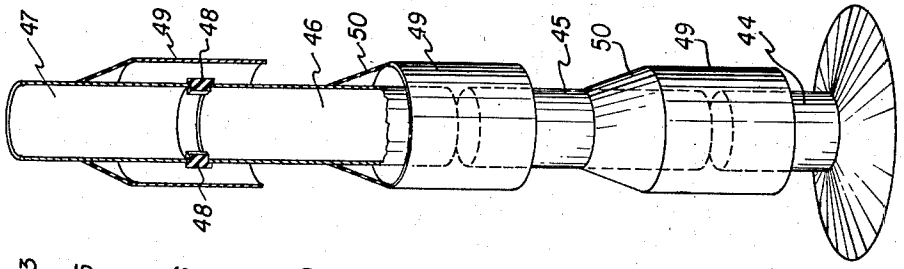


FIG. 3

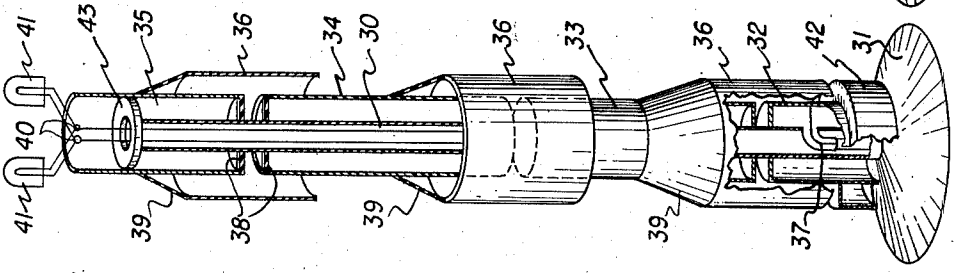


FIG 2

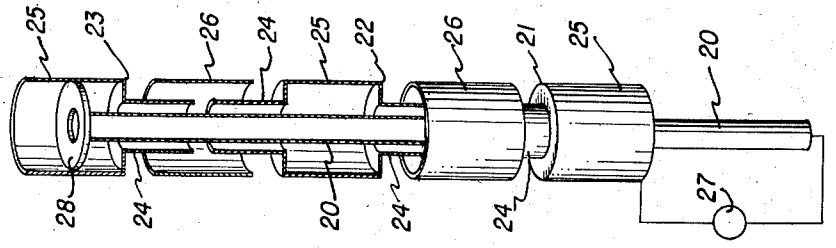
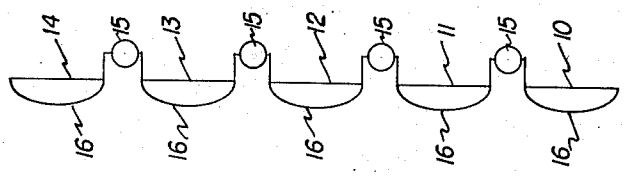


FIG 1



INVENTOR.
John F. Byrne

BY
Foorman L. Mueller
Atty.

United States Patent Office 2,767,397
Patented Oct. 16, 1956

2,767,397

ANTENNA

John F. Byrne, Elmhurst, Ill., assignor to Motorola, Inc., Chicago, Ill., a corporation of Illinois

Application March 31, 1951, Serial No. 218,658

12 Claims. (Cl. 343—790)

This invention relates generally to antenna systems for use with radio signalling waves and more particularly to vertically polarized, omnidirectional high gain antennas for use at very high frequencies.

There is continuing need for simple antenna structures which produce high power gain so that the power output of a transmitter may be reduced, or the sensitivity of a receiver may be reduced, to thereby simplify the construction of the transmitter or receiver and accordingly reduce the cost thereof. High gain antennas, of the vertically polarized type which are omnidirectional in the horizontal plane, have been objectionably expensive and have not been subject to precise electromechanical design. The high cost results from the complex structures previously used and the fact that such antennas must be quite long and extend vertically relatively high in the air. Because of the height of the antenna, and the possibility of ice forming thereon and also the possibility of high winds, the structure must be made quite strong. Also, for such large antennas it may be necessary to provide obstruction lighting at the top of the antenna further increasing the load carried by the antenna and increasing the cost of the antenna structure. It will be apparent that the cost of installing such an antenna is also a major item.

Another problem encountered in the design of such an antenna is in providing satisfactory coupling thereto so that the effect of the various antenna elements are additive. It is to be preferred that such coupling be provided by connection to the antenna at only one point, thereby simplifying the antenna structure itself and the means for making connections thereto.

Due to the above difficulties with presently available high gain vertically polarized omnidirectional antennas, it has, in many cases, been found preferable to use simpler antennas which produce less gain and attempt to provide the required communication by the use of high transmitter power and high receiver sensitivity. However, this may be particularly objectionable in mobile systems where a plurality of mobile units are used since the increased cost applies to all the mobile units and therefore the total cost of the system becomes quite high.

It is therefore one object of the present invention to provide an improved vertically polarized, high gain antenna which has omnidirectional characteristics in the horizontal plane.

A further object of this invention is to provide an improved omnidirectional antenna for use in the very high frequency range which is of simple construction and is subject to precise electromechanical design.

A still further object of this invention is to provide an improved system for coupling the various elements in an antenna array to provide a cophase relation between half-wave elements whereby high gain is produced and omnidirectional characteristics are achieved.

A feature of this invention is the provision of an antenna system including a plurality of vertically stacked sections, each having a length equal to a wave length

at the frequency involved, with conducting members positioned to overlap the adjacent sections for providing a low impedance interconnection therebetween.

A further feature of this invention is the provision of an antenna system including a plurality of tubular conductors positioned one above the other and spaced from each other with a cylindrical conductor positioned over the spaces and overlapping the adjacent tubular conductors. Signals are fed to the tubular sections either by the use of a center conductor which forms a transmission line with the tubular sections, or by using the tubular sections as a wave guide.

Another feature of this invention is the provision of a vertical coaxial antenna array in which the elements are interconnected by insulating means to provide a self-supporting antenna. The antenna includes outer cylindrical members secured to other elements of the array by insulating skirts which both support the cylindrical members and form a protecting member for preventing the entrance of rain and snow and the like into the antenna structure. The innermost conductor may be of tubular configuration to receive conductors for providing obstruction lighting or the like at the top of the antenna.

Further objects, features and the attending advantages of the invention will be apparent from a consideration of the following description when taken in connection with the accompanying drawings in which:

Fig. 1 illustrates the current and voltage distribution in an antenna array which is necessary to provide the desired characteristics;

Fig. 2 illustrates one embodiment of the antenna in accordance with the invention;

Fig. 3 illustrates a modified structural form of the invention;

Fig. 4 illustrates an embodiment of the invention utilizing cylindrical wave guides; and

Fig. 5 illustrates an embodiment of the invention utilizing rectangular wave guides.

In practicing the invention there is provided an antenna array including a plurality of sections which are a wave length long. The sections may be formed as coaxial transmission lines or wave guides, whichever may be more suitable for use with the frequency involved. The various sections of the antenna are connected by conducting members which overlap adjacent sections and form with the antenna sections, two quarter-wave open lines connected in series. This provides a low impedance connection between the sections of the antenna array. The conducting members together with portions of the sections form a plurality of half-wave antenna elements, with the various elements being cophased to thereby provide high gain. Such an antenna may be of simple construction and the electromechanical design may be quite accurate. When the antenna is provided as a circular structure, the pattern thereof is almost completely uniform in all directions in the horizontal plane. The antenna may be of such construction that it is substantially entirely self-supporting, and also so that it is substantially protected from damage due to the weather.

Referring now to the drawings, in Fig. 1 there is illustrated in schematic form the current and voltage distribution which is required to provide a vertical array having an omnidirectional pattern and providing high gain. The various half-wave sections **10**, **11**, **12**, **13** and **14** are illustrated as being fed by sources **15** so that the current and voltage therein are in phase, as illustrated by the curves **16**, whereby the effect of the various sections are added in phase to provide maximum overall effectiveness.

In Fig. 2 there is illustrated a structural embodiment which provides the characteristics illustrated in Fig. 1. This structure is formed basically by a transmission line

including the inner conductor 20 which is illustrated as a tubular member and an outer conductor formed by sections 21, 22 and 23 which have portions of different diameters. The sections 21, 22 and 23 include end portions 24 which are spaced relatively close to the tubular inner conductor 20 and portions 25 which are spaced a substantial distance about the inner tubular conductor. Positioned about the reduced end portions are conducting cylinders 26 which have substantially the same diameter as the enlarged portions 25 of the sections. The signal is applied to or derived from the antenna system by connections to the center conductor 20 and the bottom section 21 as indicated by the connection of the device 27. The inner conductor 20 is electrically connected to the upper section 23 of the outer conductor by an annular member 28.

The antenna structures as shown in Fig. 2 may be of various lengths depending upon the gain required and a plurality of intermediate sections 22 may be provided in the outer conductor to provide increased length. Each of these intermediate sections is substantially a wave lengh long at the frequency involved. The conducting cylinders 26 are one-half wave length long and since they are symmetrically positioned with respect to the sections of the outer conductor, they overlap the sections of the outer conductor by substantially one-quarter of a wave length. It is therefore apparent that the cylinders 26 together with the end portions 24 of the outer conductor form two quarter wave open lines which are connected in series across the ends of the adjacent sections of the outer conductor. This provides a very low impedance connection between the adjacent ends of the outer conductor sections. As the outer conductor sections are a wave length long, the voltage and current distribution across these are cophased. Further, the voltage and current distribution across the conducting cylinders 26 will also be of such phase relationship that the enlarged portions 25 of the outer conductor sections and the conducting cylinders 26 are all cophased and the signals therefore add to provide very high gain in the antenna system. The annular member 28 connecting the inner conductor 20 to the top-most outer conductor section 23 is spaced one-half of a wave length from the bottom edge of this section. This top-most section 23 is preferably three-quarters of a wave length long so that it extends one-quarter of a wave length above the annular member 28.

In Fig. 3 there is illustrated an embodiment of the invention which may be preferable as a commercial unit. In this structure, the inner tubular conductor 30 forms the main supporting element of the antenna and is provided on a suitable base structure 31. The outer conductor of the transmission line is formed by sections 32, 33, 34 and 35 of constant diameter, which surround the inner tubular conductor 30. In such a structure the intermediate sections of the outer conductor, identified as 33 and 34, are a wave length long, with the bottom section 32 being one-half of a wave length long, and the top section 35 being three-quarters of a wave length long. Positioned over the gaps in the outer conductor are cylindrical conductors 36 which are one-half of a wave length long. As in the structure of Fig. 2, these cylindrical conductors, together with the ends of the sections of the outer conductor, form two series connected quarter wave open lines to provide a very low impedance between the adjacent sections of the outer conductor. The transmission line 37 which makes connection to the antenna may be provided within the inner tubular conductor 30 with the outer shield conductor thereof being connected to the inner tubular conductor 30 and the center conductor thereof being connected to the lower section 32 of the outer conductor. A quarter-wave choke 42 may be connected to the bottom section 32 of the outer conductor for providing the desired impedance matching characteristics. The inner tubular conductor 30 is connected to the top section 35 of the outer conductor by an annular ring 43 which is positioned a quarter of a wave length below the top of the section 35 so that the portion of the upper section below the annular ring 43 forms a half-wave closed line.

As previously stated, the inner tubular conductor 30 forms the main supporting member for the antenna system and the sections of the outer conductor may be supported thereon by insulating members 38 extending between the inner conductor 30 and the outer conductor sections 32, 33, 34 and 35. The cylindrical conductors 36 may be secured to the outer conductor sections by insulating skirts 39 which may be made by fiber glass or other suitable insulating material. These insulating skirts extend from the outer conductor downwardly and outwardly to the cylindrical conductors in the form of a cone and may serve as protectors to prevent rain or snow from falling between the antenna elements and affecting the operation thereof. The tubular inner conductor 30 may also serve as a conduit for leads 40 connected to obstruction lights 41 mounted on the top of the antenna so that such obstruction lights can be provided with a minimum of extra equipment.

In Fig. 4 there is illustrated a structure very similar to that of Fig. 3, except the inner conductor of the transmission line is removed. The structure of Fig. 4 may be used for operation at very high frequencies in which the sections forming the outer conductor in the transmission line construction of Fig. 3, serve as wave guide sections. These sections are designated 44, 45, 46 and 47, with the intermediate sections 45 and 46 being a wave length long. These sections may be made to be self-supporting by providing insulating members 48 therebetween so that the various sections are connected into a rigid assembly. Conducting sleeves 49 are placed over the junctures and may be supported by insulating skirts 50 as described with reference to Fig. 3. The system of Fig. 4 will operate in the same manner as the systems previously described with the conducting cylinder 49 forming a low impedance connection between the adjacent wave guide sections. The apertures formed between the conducting cylinders 49 and the wave guide sections are spaced by a half wave length and the waves passing therethrough reinforce each other to provide high gain response.

In Fig. 5 there is illustrated a further wave guide structure and in this case a rectangular guide 55 is provided having slots 56 therein across which are placed conducting plates 57. The waves are radiated through the apertures between the plates 57 and the adjacent wave guide as indicated at 58 with the various radiations being cophased to provide high gain.

It will be apparent from the above that there is provided a relatively simple vertically polarized antenna structure in the form of a vertically stacked array having a substantially omnidirectional pattern in a horizontal plane. The entire array is fed by a single connection at one end, with the various sections being coupled together to provide a cophase relationship. This results since the conductor sections are a wave length long and are interconnected by a pair of series connected open ended transmission lines having a length of a quarter-wave. The various antenna elements so formed are therefore phased to provide an additive relation so that high gain is produced. The construction disclosed is such that the electromechanical design may be precise so that the operating characteristics may be made optimum.

While various embodiments of the invention have been disclosed which are illustrative thereof, it is recognized that various changes and modifications can be made in these structures without departing from the intended scope of the invention as defined in the appended claims.

I claim:

1. An antenna system for use with radio signalling waves of a predetermined high frequency including in combination, a plurality of elongated wave conducting

sections each having a length substantially equal to a wave length at said predetermined frequency, said elongated sections being vertically positioned one above the other in end to end relation and having adjacent portions spaced from each other, a conducting member having a length substantially equal to one half a wave length at said predetermined frequency, said conducting member being spaced from said wave conducting section and being positioned to overlap end portions of a pair of adjacent sections by substantially equal amounts to form therewith two quarter-wave open lines connected in series between said adjacent spaced portions of said sections and providing a low impedance series interconnection therebetween, and means for coupling signal waves of said predetermined frequency to the section at one end of said system so that said waves are applied in series to said wave conducting sections, with said conducting member and said conducting sections forming cophased antenna elements having a spacing of one-half of a wave length.

2. An antenna system in accordance with claim 1 wherein said elongated wave conducting sections form wave guides and said signal waves are conducted therethrough in series from one section to the next.

3. An antenna system for use with radio signalling waves of a predetermined high frequency including in combination, a plurality of wave conducting sections each including a tubular conducting portion having a length substantially equal to a wave length at said predetermined frequency, said sections being vertically positioned one above the other in end to end relation and with the adjacent ends of said tubular portions being spaced from each other, a conducting cylinder having a length substantially equal to one half a wave length at said predetermined frequency, said conducting cylinder being positioned about said tubular portions and overlapping adjacent tubular portions by substantially equal amounts, said conducting cylinder being spaced from said tubular portions to provide therewith two quarter-wave open coaxial lines connected in series between said adjacent tubular portions to provide a low impedance series connection therebetween, and means for coupling signal waves of said predetermined frequency to the section at one end of said system so that said waves are applied in series to said tubular portions, with said conducting member and said tubular portions forming cophased half-wave spaced antenna elements.

4. An antenna system in accordance with claim 3 wherein said wave conducting sections form wave guides and said signal waves are conducted therethrough from one tubular conducting portion to the next.

5. An antenna system for use with radio signalling waves of a predetermined high frequency including in combination, a plurality of wave conducting sections each including a tubular conducting portion having a length substantially equal to a wave length at said predetermined frequency, said sections being vertically positioned one above the other in end to end relation and with the adjacent ends of said tubular portions being spaced from each other, a conducting cylinder having a length substantially equal to one half a wave length at said predetermined frequency, said conducting cylinder being positioned in spaced relationship about said tubular portions and overlapping adjacent tubular portions by substantially equal amounts to provide in effect two quarter-wave open coaxial lines connected in series between said adjacent tubular portions to provide a low impedance series connection therebetween, insulating means mechanically interconnecting said tubular portions and said conducting cylinder so that said antenna system forms a self supporting unit, and means for coupling signal waves of said predetermined frequency to the section at one end of said system so that said waves are applied in series to said tubular portions. with said conducting member and said tubular portions forming cophased half-wave spaced antenna elements.

6. An antenna system for use with signal waves of a predetermined high frequency including, a coaxial transmission line having a continuous inner conductor and an outer conductor including a plurality of spaced sections, each of said outer conductor sections having a length substantially equal to a wave length at said predetermined frequency, a plurality of conducting cylinders spaced about said transmission line each having a length substantially equal to one half a wave length, said conducting cylinders being positioned to symmetrically overlap adjacent sections of said outer conductor to form therewith two quarter-wave lines connected in series between adjacent ends of said sections, means for coupling signal waves of said predetermined frequency between said conductors of said transmission line at one end thereof, and means interconnecting said conductors of said transmission line at the other end thereof so that the signal waves are applied in series across said spaced sections of said outer conductor, whereby said conducting cylinders and the exposed portions of said outer conductor sections form cophased, half-wave antenna elements.

7. An antenna system for use with signal waves of a predetermined high frequency including a coaxial transmission line having a continuous inner conductor and an outer conductor including a plurality of spaced sections, the section at one end of said transmission line having a length substantially equal to one-half of a wave length at said predetermined frequency, the section at the other end of said transmission line having a length substantially equal to three-quarters of a wave length at said predetermined frequency, and the sections intermediate said end sections each having a length substantially equal to a wave length at said predetermined frequency, a plurality of conducting cylinders spaced about said transmission line each having a length substantially equal to one-half a wave length, said conducting cylinders being positioned to symmetrically overlap adjacent sections of said outer conductor to form therewith two quarter-wave lines connected in series between adjacent ends of said sections, means for coupling signal waves of said predetermined frequency to said inner conductor and the section of said outer conductor at said one end of said transmission line, and means for interconnecting said inner conductor and the section of said outer conductor at the other end of said transmission line at a point spaced substantially one-quarter wave from said other end of said transmission line, whereby said conducting cylinders and the exposed portions of said outer conductor sections form cophased, half-wave antenna elements.

8. An antenna system for use with signal waves of a predetermined high frequency including a coaxial transmission line having a continuous inner conductor and an outer conductor including a plurality of spaced sections, the section at one end of said transmission line having a length substantially equal to one-half of a wave length at said predetermined frequency, means for coupling signal waves of said predetermined frequency to said inner conductor and said section of said outer conductor at said one end of said transmission line, means connected to said section at said one end of said transmission line forming a quarter-wave choke, the section at the other end of said transmission line having a length substantially equal to three-quarter of a wave length at said predetermined frequency, and means for interconnecting said inner conductor and the section of said outer conductor at the other end of said transmission line at a point spaced substantially one-quarter wave from said other end of said transmission line, the sections of said outer conductor intermediate said end sections each having a length substantially equal to a wave length at said predetermined frequency, a plurality of conducting cylinders spaced about said transmission line each having a length substantially equal to one-half a wave length, said con-

ducting cylinders being positioned to symmetrically overlap adjacent sections of said outer conductor to form therewith two quarter-wave lines connected in series between adjacent ends of said sections, whereby said conducting cylinders and the exposed portions of said outer conductor sections form cophased, half-wave antenna elements.

9. An antenna system for use with radio signalling waves of a predetermined high frequency including, a coaxial transmission line having a continuous inner tubular conductor and an outer tubular conductor including a plurality of spaced sections, at least a portion of said sections having a length substantially equal to a wave length at said predetermined frequency, a plurality of conducting cylinders spaced about said transmission line each having a length substantially equal to one-half a wave length, said conducting cylinders being positioned to symmetrically overlap adjacent sections of said outer conductor to provide in effect two quarter-wave open coaxial lines connected in series between adjacent ends of said sections, means extending within said inner tubular conductor connected to said inner conductor and the section of said outer conductor at one end of said transmission line for coupling signal waves of said predetermined frequency thereto, and means interconnecting said conductors of said transmission line at the end thereof opposite to said one end so that signals coupled to said transmission line are applied in series across said sections of said outer tubular conductor, whereby said conducting cylinders and the exposed portions of said outer conductor sections form cophased, half-wave antenna elements.

10. An antenna system for use with radio signalling waves of a predetermined high frequency including, a coaxial transmission line having a continuous inner tubular conductor and an outer tubular conductor including a plurality of spaced sections, means for supporting said inner conductor in a vertical position whereby said inner conductor forms the main supporting member of said antenna system, insulating means mechanically connecting said inner tubular conductor and said outer conductor sections for supporting said sections from said inner conductor, at least a portion of said outer conductor sections having a length substantially equal to a wave length at said predetermined frequency, a plurality of conducting cylinders spaced about said transmission line each having a length substantially equal to one-half a wave length, conical insulating skirts extending downward and outward from said outer conducting sections for supporting said conducting cylinders and closing the space between said outer conductor sections and said conducting cylinders, said outer conductor sections being positioned to symmetrically overlap adjacent sections of said outer conductor to provide in effect two quarter-wave lines connected in series between adjacent ends of said sections, and coupling means connected to said inner conductor and to the section of said outer conductor at one end of said transmission line, whereby said conducting cylinders and the exposed portions of said outer conductor sections form cophased, half-wave antenna elements.

11. An antenna system for use with radio signalling waves of a predetermined high frequency including a coaxial transmission line having a continuous inner tubular conductor and an outer tubular conductor including a plurality of spaced sections, means for supporting said inner conductor in a vertical position whereby said inner conductor forms the main supporting member of said antenna system, insulating members mechanically mounting said outer conductor sections on said inner tubular conductor, at least a portion of said sections having a length substantially equal to a wave length at said predetermined frequency, a plurality of conducting cylinders spaced about said transmission line each having a length substantially equal to one-half a wave length, insulating skirt means supporting said conducting cylinders from said outer conductor sections in positions symmetrically overlapping adjacent sections of said outer conductor to provide in effect two quarter-wave lines connected in series between adjacent ends of said sections, whereby said conducting cylinders and the exposed portions of said outer conductor sections form cophased, half-wave antenna elements, signal means at the top of said transmission line, and means extending within said inner tubular conductor for making connection to said signal means and to said inner and outer conductors of said transmission line.

12. An antenna system for use with radio signalling waves of a predetermined high frequency including in combination, a plurality of elongated wave conducting sections each having a radiating portion extending for substantially one half wave length at said predetermined frequency, said elongated sections being vertically positioned with said radiating portions extending one above the other in end to end relation, said adjacent conducting sections having portions spaced from each other and positioned to overlap each other for a length substantially equal to a quarter wave length at said predetermined frequency to form a quarter-wave open line connected in series between said adjacent sections providing low impedance series connections therebetween, and means for coupling signal waves of said predetermined frequency to the section at one end of said system so that said waves are applied in series to said conducting sections, with said radiating portions of said conducting sections forming cophased antenna elements having a spacing of substantially one-half wave length.

References Cited in the file of this patent

UNITED STATES PATENTS

1,957,949	Franklin et al.	May 8, 1934
2,113,136	Hansell et al.	Apr. 5, 1938
2,122,893	Roosenstein	July 5, 1938
2,199,375	Lindenblad	Apr. 30, 1940
2,201,857	Dome	May 21, 1940
2,234,234	Cork	Mar. 11, 1941
2,321,454	Brown	June 8, 1943
2,486,597	Greene	Nov. 1, 1949
2,509,253	Schriefer	May 30, 1950
2,605,412	Riblet	July 29, 1952