Dielectric Loaded Colinear Vertical Dipole Antenna

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DIELECTRIC LOADED COLINEAR VERTICAL DIPOLE ANTENNA

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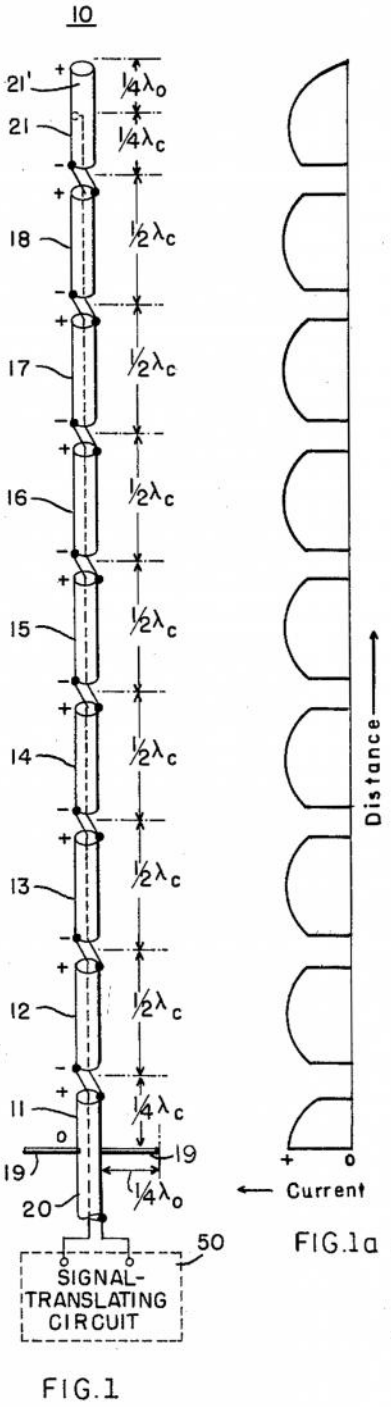

FIG.1

FIG.1a

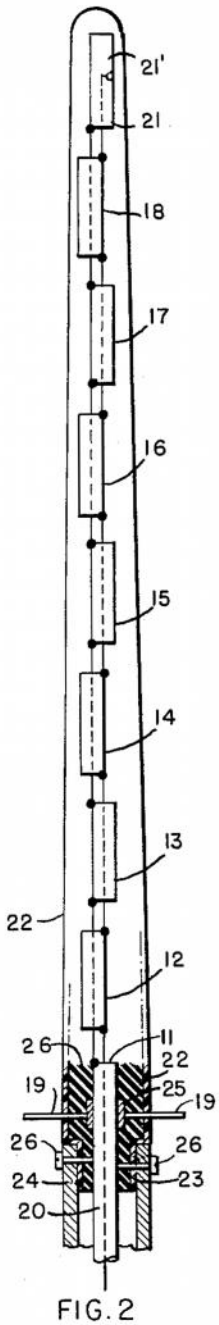

FIG.2

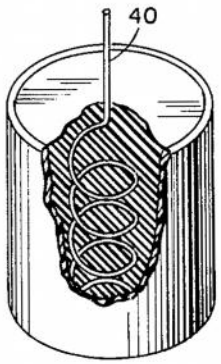

FIG.3

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3,031,668 DIELECTRIC LOADED COLINEAR VERTICAL DIPOLE ANTENNA

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Continuation of applications Ser. No. 606,386, Aug. 27, 1956, and Ser. No. 797,003, Feb. 17, 1959. This application Nov. 21, 1960, Ser. No. 70,904
15 Claims. (Cl. 343—790)

The present invention is directed to antennas and, more particularly, to linear antennas of the type having a length greater than one wave length and having current in the same direction on the outer surface thereof over the entire length. Although such antennas may have a variety of shapes and applications, they are especially useful as vertical antennas and hence will be described in that environment.

This application is a continuation of applicant's abandoned application Serial No. 606,386, filed August 27, 1956, and of applicant's copending application Serial No. 797,003, filed February 17, 1959 for Antenna.

Vertical linear antennas having substantially omnidirectional radiation patterns shaped like a flattened horizontal doughnut have been employed successfully for various purposes. For some applications, however, they have proved to be larger than was desired and have not afforded as high a radiating efficiency as was also desired. One prior such antenna which is subject to the disadvantages just mentioned comprises a series of interconnected half-wave coaxial line sections having air dielectric between conductors. At each junction occuring at intervals of one-half wave from the free end of the antenna, the inner and outer conductors of the coaxial line sections are interposed by a cross connection. This leaves a gap between the adjacent sections and at each gap the voltage developed is of the same polarity and phase. Consequently the radiating current on the outer conductor of each section of the antenna is in the same direction and phase. This is extremely desirable but does not solve the problems of securing a shorter antenna, greater radiation loading thereon, and a convenient and economical means for supporting the various sections of the antenna.

It is an object of the invention, therefore, to provide a new and improved antenna which avoids one or more of the above mentioned disadvantages and limitations of prior linear antennas.

It is another object of the invention to provide a new and improved vertical linear antenna which has a more nearly uniform current along its length and hence greater gain than prior such antennas.

It is a further object of the invention to provide a new and improved antenna which has a substantially omnidirective radiation pattern normal to its conductors.

It is a still further object of the present invention to provide a new and improved vertical linear antenna which has a flattened horizontal doughnut pattern of radiation and affords omnidirective gain.

It is an additional object of the present invention to provide a new and improved antenna which is simple to construct, less expensive to manufacture, and for a smaller antenna affords the same gain as prior such antennas.

In accordance with a particular form of the invention, an antenna comprises a sequence of coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wave length in those sections. The antenna also includes terminal means for the aforesaid sequence providing maximum voltage at the junctions and providing current on the outside of each of the aforesaid outer conductors which flows in the same direction and phase. The coaxial sections include such material between the aforesaid conductors and are of such configuration as to have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof, whereby the value of the current on the outer conductors is substantially greater than zero over their lengths.

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

In the drawing, FIG. 1 is a diagrammatic representation of an antenna in accordance with a particular embodiment of the invention;

FIG. 1*a* illustrates the current distribution along the outer conductors of the antenna of FIG. 1;

FIG. 2 is an elevational view of a practical embodiment of the invention, the lower portion of the antenna being shown in section; and

FIG. 3 is an enlarged perspective view of a detail of a portion of a modified antenna.

DESCRIPTION OF FIG. 1 ANTENNA

Referring now to FIG. 1 of the drawing, there is represented an antenna **10** in accordance with the present invention which is coupled in a conventional manner to a signal-translating circuit **50** which is shown in broken-line construction since it forms no part of the invention. Circuit **50** may be a transmitter or a receiver. While the antenna **10** may be used as an element of a directive array or may be formed in a curve such as a horizontal circle to provide omnidirective gain with horizontal polarization, it is represented diagrammatically as a vertical linear antenna giving omnidirective gain by virtue of a flattened horizontal-doughnut pattern of radiation. Such an antenna is particularly useful in the VHF and UHF bands such as government and mobile bands (148–174 mc.), and mobile and citizens radio (450–470 mc.).

The antenna **10** comprises a sequence of coaxial cable sections **12–18**, inclusive, with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wave length ($\frac{1}{2}\lambda_c$) in the cable sections. These sections are of such material and configuration as to have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof. The sections are filled with insulation having a dielectric constant greater than unity and to that end they are preferably made from a solid-dielectric coaxial line wherein a dielectric such as polyethylene supports the conductors and imparts a measure of mechanical stability. Type RG–8A/U cable having a braided outer conductor and a solid insulation with a dielectric constant k of 2.30 has proved useful in this environment. For such a cable, the ratio of the inside/outside velocity is

$$\frac{1}{\sqrt{k}}$$

or 0.66.

The antenna **10** also comprises terminal means for the sequence of sections which provides maximum voltage at the junctions between those sections and provides current on the outside of each of the outer conductors which flows in the same direction and phase. The bottom section **11** of the antenna has a length of one-quarter wave length in the cable section and, when a reflecting wave shield such as a plurality of radially disposed conductive spokes **19, 19** are employed, section **11** may constitute an extension of the antenna feed cable **20** which is coupled to the signal-translating circuit **50**. Each of the spokes **19, 19** has an effective length which is one-quarter wave

length measured in free space. Alternatively, a metal disk or other known equivalent such as a metal sleeve may be employed to reflect a wave that would travel down on the outside of section 20.

The terminal means at the upper end of the antenna comprises a quarter-wave length of coaxial cable section 21 having its lower end connected to adjacent section 18 as represented and having the upper end of its inner conductor conductively connected to its outer conductor at a point one-quarter wave length in the section from the bottom edge thereof. At the top of radiating section 21 there is preferably mounted a hollow conductive section 21' having a length effectively one-quarter wave length in free space or on the outside of the outer conductors of the antenna 10. This section 21' has a diameter equal to that of the outer conductor of section 21 and provides the desired current pattern, shown at the top of FIG. 1*a*, in the end section 21, 21'. The antenna represented in FIG. 1 has nine sections and eight gaps therebetween. The top section 21, 21' is conductively connected to the outer conductor of the bottom section 11 and, since the lower end of the latter is normally grounded, the entire antenna may be considered a grounded structure. The connection of the inner conductor of the top section to its outer conductor as indicated has little effect on the radiofrequency impedance of the antenna and assures lightning protection for an antenna of the type under consideration having any number of gaps between sections.

The antenna 10 has a voltage polarity as indicated in FIG. 1 by the series of + and − signs at the gaps between the coaxial sections, and the current distribution along the length is represented by the graph of FIG. 1*a*. It will be noted that the value of the current on the outer conductors of the sections is substantially greater than zero over their length. When the solid dielectric of the sections is such that the sections have a wave velocity on the inside which is about two thirds that on the outside, the value of the current at the gaps is substantially one-half the maximum value of the current on the outer conductors. In prior art antennas employing coaxial transmission-line sections having an air dielectric, the current falls to nearly zero at each gap. On the same basis, the antenna of the present invention has about one and one half times as many gaps in the same total length as the prior art antenna, and also about one and one half times the radiation conductance at each gap so that the total radiation conductance is increased approximately by the ratio k or the dielectric constant of the solid dielectric. In the usual case the outer radius of the coaxial line sections is much less than

$$\frac{1}{2\pi}\lambda_0$$

so that the radiation conductance at each gap is much less than the wave conductance in the cable sections. Therefore the solid dielectric cable sections, which provide a greater number of gaps, make possible a closer approach to matching the total conductance outside the sections with the wave conductance inside the sections.

DESCRIPTION OF FIG. 2 ANTENNA

Reference is now made to FIG. 2 of the drawing showing an embodiment of the invention which is relatively easy to construct. The antenna of FIG. 2 is generally similar to that of FIG. 1; accordingly corresponding elements are designated by the same reference numerals. Instead of comprising a collinear series of coaxial cable sections as in FIG. 1, in the FIG. 2 antenna alternate ones of the cable sections extend in two straight lines which are separated by approximately the radius of the sections. By offsetting consecutive coaxial cable sections in the manner represented, it is possible to make reliable connections between the inner conductor of one section

and the outer conductors of adjacent sections and still maintain gap tolerances within close limits. The offset feature makes it unnecessary to spend time-consuming and costly operations in bending the inner conductors to the positions represented in FIG. 1. Since the gaps are quite critical, offsetting the coaxial cable sections assures more uniform characteristics in antennas of the same design.

The sequence of coaxial cable sections of FIG. 2 is encased in a rigid dielectric sheath or housing 22 of a suitable material such as fibreglass. Care must be exercised in introducing the sections into the housing to avoid twisting of the sections which distorts the gaps and may break or set up strains in the soldered connections. To that end removal of the vinyl outer covering of the coaxial cable sections proved to be helpful. The base of the housing 22 has a portion 23 of reduced diameter for insertion in a brass pipe support 24 which facilitates mechanical mounting of the antenna. The housing 22 is provided with suitable apertures to permit the radial spokes 19, 19 to pass through for engagement with a metallic sleeve 25 disposed about a portion of the feed cable 20. Suitable screws 26, 26 with pointed ends anchor the housing 22 to the support 24 and make a conductive engagement with the grounded outer conductor of the feed cable 20.

To provide mechanical rigidity and additional protection, the housing 20 is filled through a hole in the top (not shown) with a suitable material such as a wax 26 which may be seen in the representation near the base of the antenna. The thickness of the dielectric material including the housing and the wax surrounding the sequence of cable sections may be much less than

$$\frac{\lambda_0}{2\pi}$$

where λ_0 is the wave length on the outside of the cable, so that most of the wave energy outside the cable travels in air. A dielectric foam of very low density may be employed in lieu of the wax.

While the antenna has been described as including nine coaxial cable sections, it will be understood that any desired plurality thereof may be employed. To secure in the coaxial cable sections of the antenna an internal velocity which is substantially less than free space, a coiled inner conductor 40 as in FIG. 3 may be employed in a representative section. Its use may be in addition to the use of a solid dielectric and will afford somewhat shorter sections.

While the invention is not limited to any particular dimensions and electrical parameters, the following constants represent one specific embodiment which has been found to have particular utility in a 5 megacycle frequency band centered at 452.5 megacycles:

Length of section 11	4.230 inches.
Length of section 21'	6.080 inches.
Length of sections 12–18	8.460 inches.
Overall diameter of ground plane	13⅛ inches.
Gaps between sections	5/16 inch.
Coaxial cable sections (50 ohm cable filled with solid insulation having a dielectric constant k=2.30 and outer diameter of 8 mm.)	Type RG–8A/U.
Housing 22	Fiberglass.
Dielectric 26	Cochran Chemical Co. Type C88 wax.

Total radiation conductance approximately matches that of the coaxial cable.

Directive gain is about 6 db over a half-wave dipole.

While there have been described what are at present considered to be the preferred embodiments of the inven-

tion, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all changes and modifications as fall within the true spirit and scope of the invention.

What I claim is:

1. An antenna comprising: a sequence of coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; said sections including such material between said conductors and being of such configuration as to have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths.

2. An antenna comprising: a sequence of coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; said sections including such material between said conductors and being of such configuration as to have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths; said sequence of sections affording an even number of gaps between sections so that the outer conductor of one end section is conductively connected through intermediate sections to the outer conductor of the other end section, whereby when said last-mentioned outer conductor is connected to ground said one end section is also at ground potential.

3. An antenna comprising: a sequence of solid-dielectric coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; the solid dielectric of said sections being of such material that said sections have a value of wave velocity on the inside thereof which is about two-thirds that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths and the value of the current at the gaps between sections is substantially one-half the maximum value of said current on said outer conductors; said terminal means at the remote end of said antenna comprising a coaxial cable section having said solid dielectric therein and an effective length which is one-quarter wave length in said section, and further comprising a hollow air-filled conductive section which is an extension of the outer conductor of said last-mentioned coaxial cable section and which has a length that is one-quarter wavelength in free space, the remote end of the inner conductor of said last-mentioned coaxial cable section being conductively connected to its outer conductor at the line of extension.

4. An antenna comprising: a sequence of coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, the top section having an effective length which is one-quarter wavelength in said section and each of the remaining sections having an effective length which is one-half wavelength in said sections; terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; said sections including such material between said conductors and being of such configuration as to have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths; the inner conductor of the top section being conductively connected to the outer conductor thereof at the remote end of said top section; and a conductive element having a diameter equal to that of said outer conductor of said remote end and secured thereto and having a length which is substantially one-quarter wavelength in free space.

5. An antenna comprising: a sequence of dielectric loaded coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; the dielectric between said conductors being of such material as to provide a value of wave velocity on the inside of said sections which is substantially less than that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths.

6. An antenna comprising: a sequence of solid-dielectric coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; the solid dielectric of said sections being of such material that said sections have a value of wave velocity on the inside thereof which is about two-thirds that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths and the value of the current at the gaps between sections is substantially one-half the maximum value of said current on said outer conductors.

7. An antenna comprising: a sequence of solid dielectric coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; and terminal means for said sequence including a reflecting wave shield at one end of said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; the solid dielectric of said sections being of such material that said sections have a value of wave velocity on the inside thereof which is about two-thirds that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths, and the value of the current at the gaps between sections is substantially one-half the maximum value of said current on said outer conductors.

8. An antenna comprising: a sequence of solid-dielectric coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; and terminal means for said sequence including a plurality of conductive spokes at one end of said sequence and each having an effective length which is one-quarter wavelength in said sections for providing maximum voltage at said junctions and providing current on the outside of each of said outer

conductors which flows in the same direction and phase; the solid dielectric of said sections being of such material that said sections have a value of wave velocity on the inside thereof which is about two-thirds that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths and the value of the current at the gaps between sections is substantially one-half the maximum value of said current on said outer conductors.

9. An antenna comprising: a sequence of coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections, and alternate ones of said sections extending in two straight lines which are separated by approximately the radius of said sections; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; said sections including such material between said conductors and being of such configuration as to have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths.

10. An antenna comprising: a sequence of coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; a protective housing encasing said sequence; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; said sections and said housing being of such dielectric material and configuration as to have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths.

11. An antenna comprising: a sequence of coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; a rigid dielectric housing encasing said sequence; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; said sections including such material between said conductors and being of such configuration and the dielectric of said housing being of such material and dimensions that said sections have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths.

12. An antenna comprising: a sequence of coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; a rigid dielectric housing filled with a low dielectric-constant wax encasing said sequence; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; said sections including such material between said conductors and being of such configuration and said housing and wax having such dimensions that said sections have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths.

13. A linear antenna comprising: a sequence of coaxial cable sections with their inner and outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections; a rigid dielectric housing filled with a low dielectric-constant wax encasing said sequence; a conductive pipe support secured to the lower end of said housing and the outer conductor at the lower end of said sequence; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; said sections including such material between said conductors and being of such configuration and said housing and said wax having such dimensions that said sections have a value of wave velocity on the inside thereof which is substantially less than that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths.

14. An antenna comprising: a sequence of solid-dielectric coaxial cable sections with their imbedded inner and surrounding outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections, said inner conductors being formed in a helix having a diameter substantially larger than the diameters of said inner conductors; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; the solid dielectric of said sections being of such material that said sections have a value of wave velocity on the inside thereof which is about two-thirds that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths and the value of the current at the gaps between sections is substantially one-half the maximum value of said current on said outer conductors.

15. An antenna comprising: a sequence of solid-dielectric coaxial cable sections with their imbedded inner and surrounding outer conductors cross-connected at each junction between sections, each of the latter having an effective length which is one-half wavelength in said sections, the inner conductor of at least one of said sections being formed in a helix having a diameter substantially larger than the diameter of that inner conductor; and terminal means for said sequence providing maximum voltage at said junctions and providing current on the outside of each of said outer conductors which flows in the same direction and phase; the solid dielectric of said sections being of such material that said sections have a value of wave velocity on the inside thereof which is about two-thirds that on the outside thereof, whereby the value of said current on said outer conductors is substantially greater than zero over their lengths and the value of the current at the gaps between sections is substantially one-half the maximum value of said current on said outer conductors.

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