343-872 CROSS REFERENCE SEARCH ROOM

Jan. 1, 1963 M. W. SCHELDORF 3,071,771

SUPPRESSED-RADIATION ANTENNA

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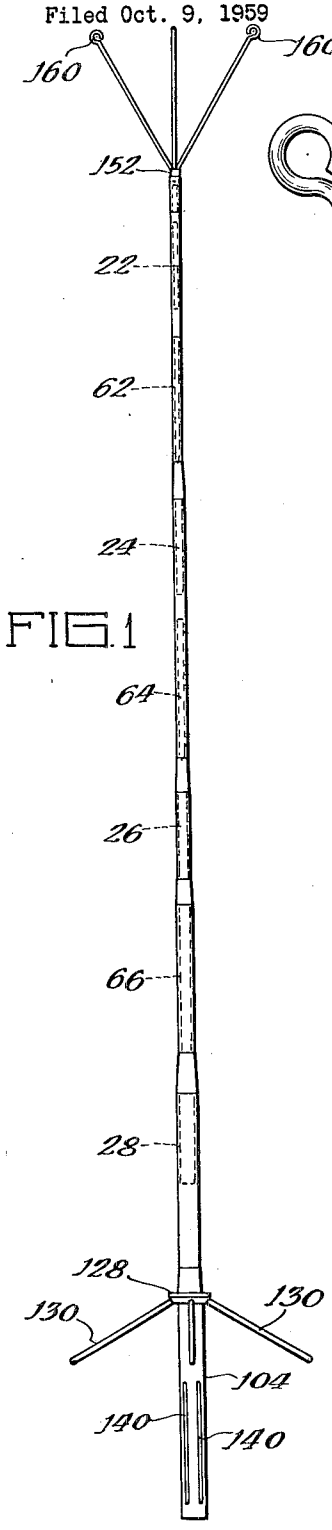


FIG. 1

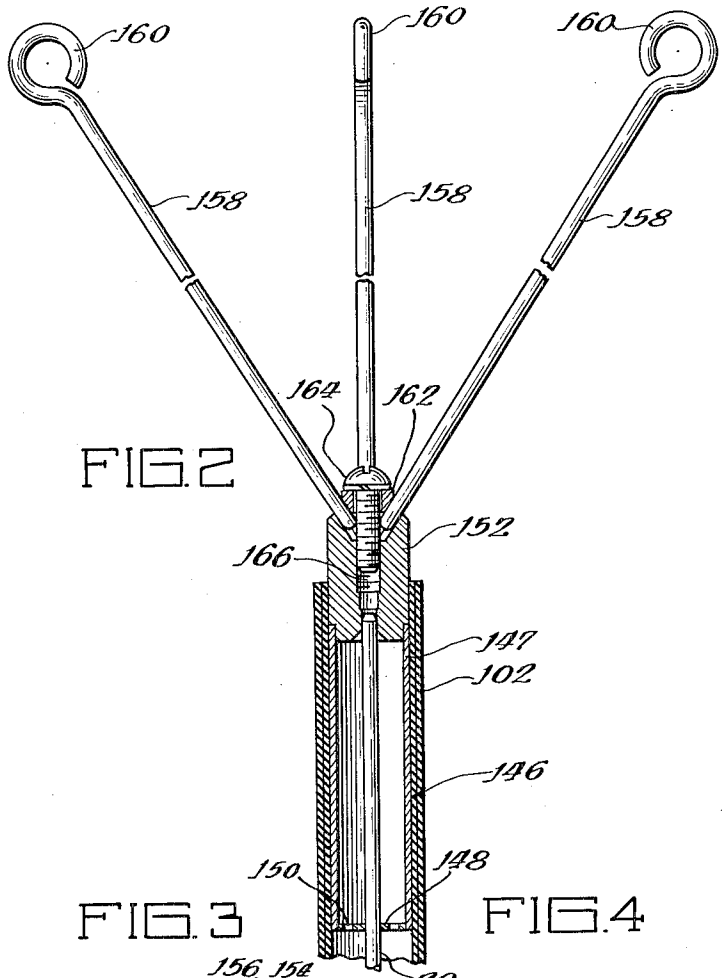


FIG. 2

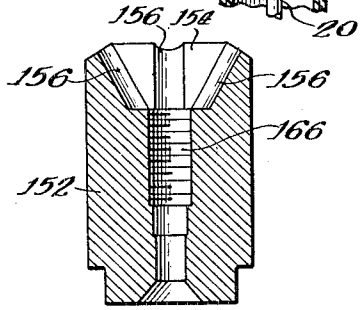


FIG. 3

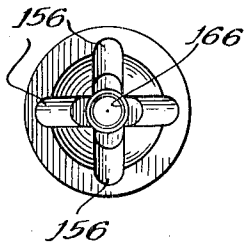


FIG. 4

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FIG. 5

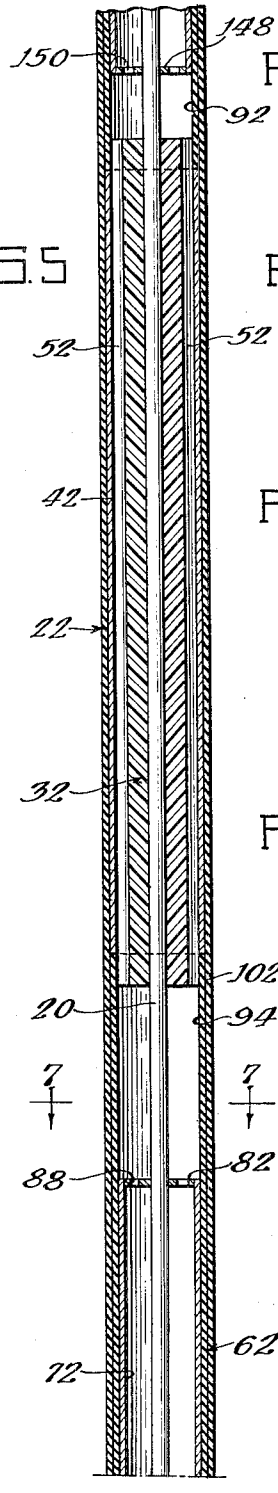


FIG. 7

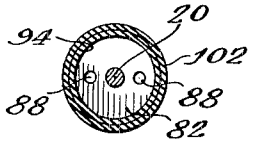


FIG. 8

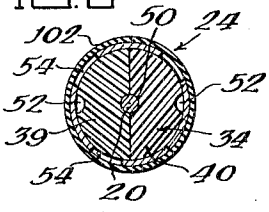


FIG. 9

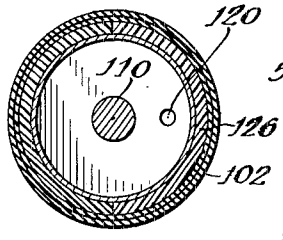


FIG. 10

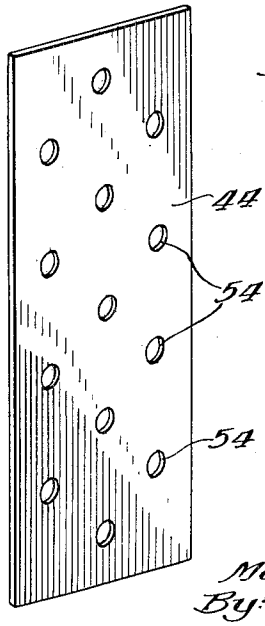
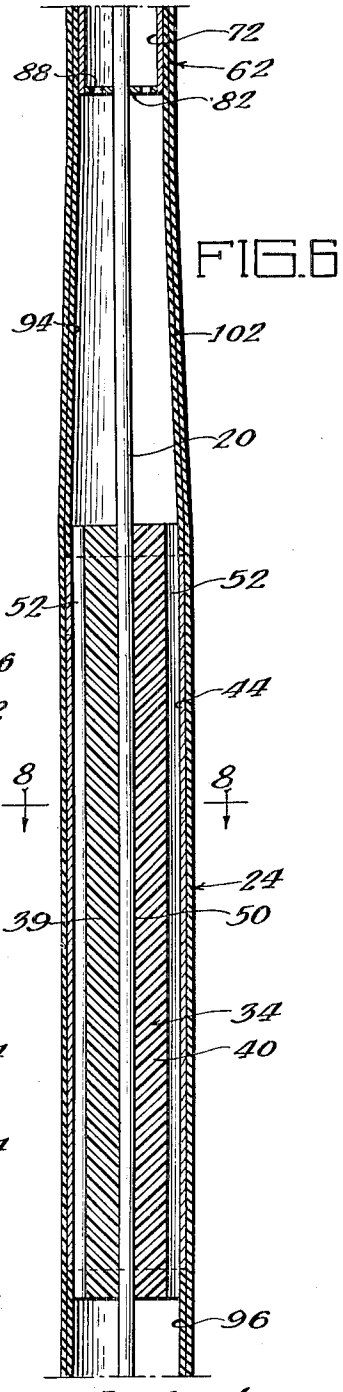


FIG. 6



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FIG 11

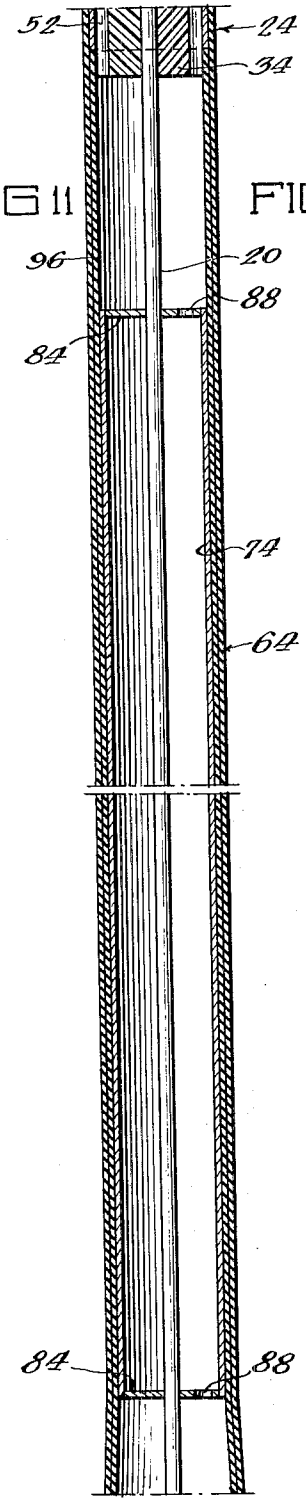


FIG 12

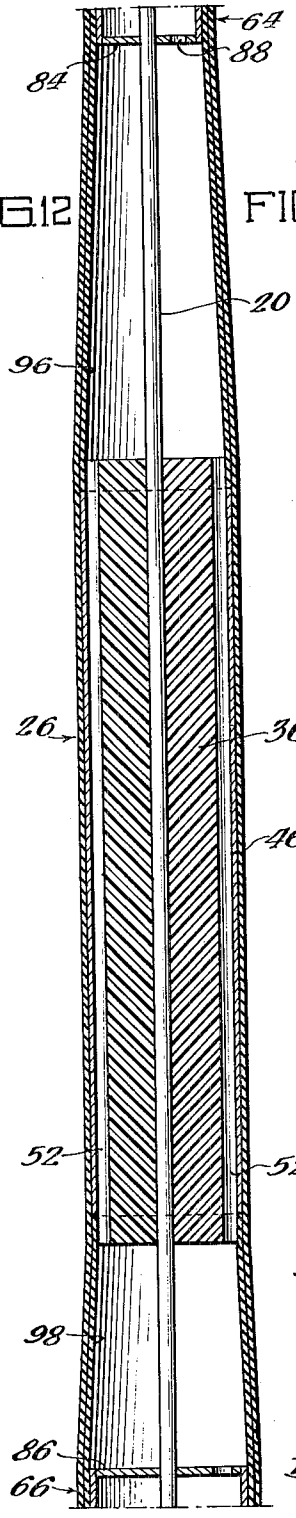
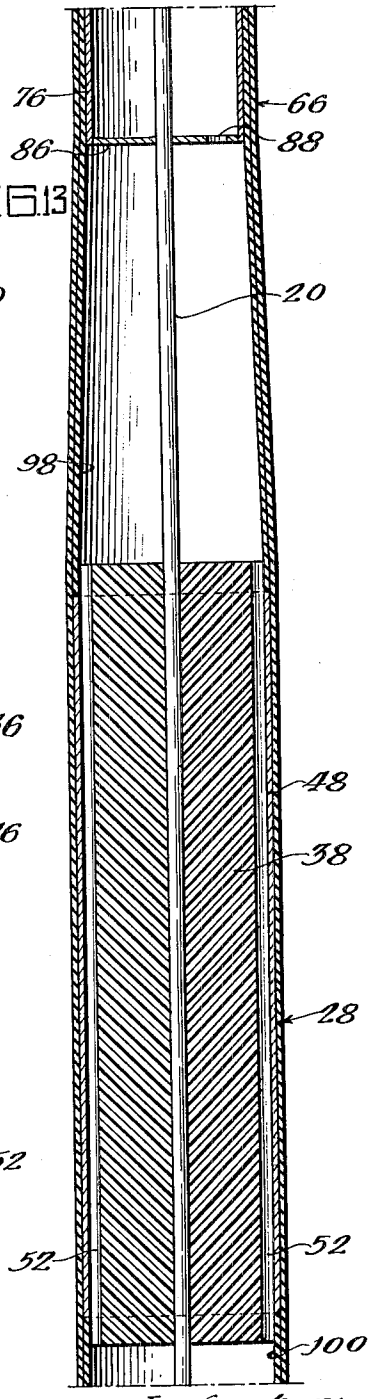


FIG 13



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FIG. 14

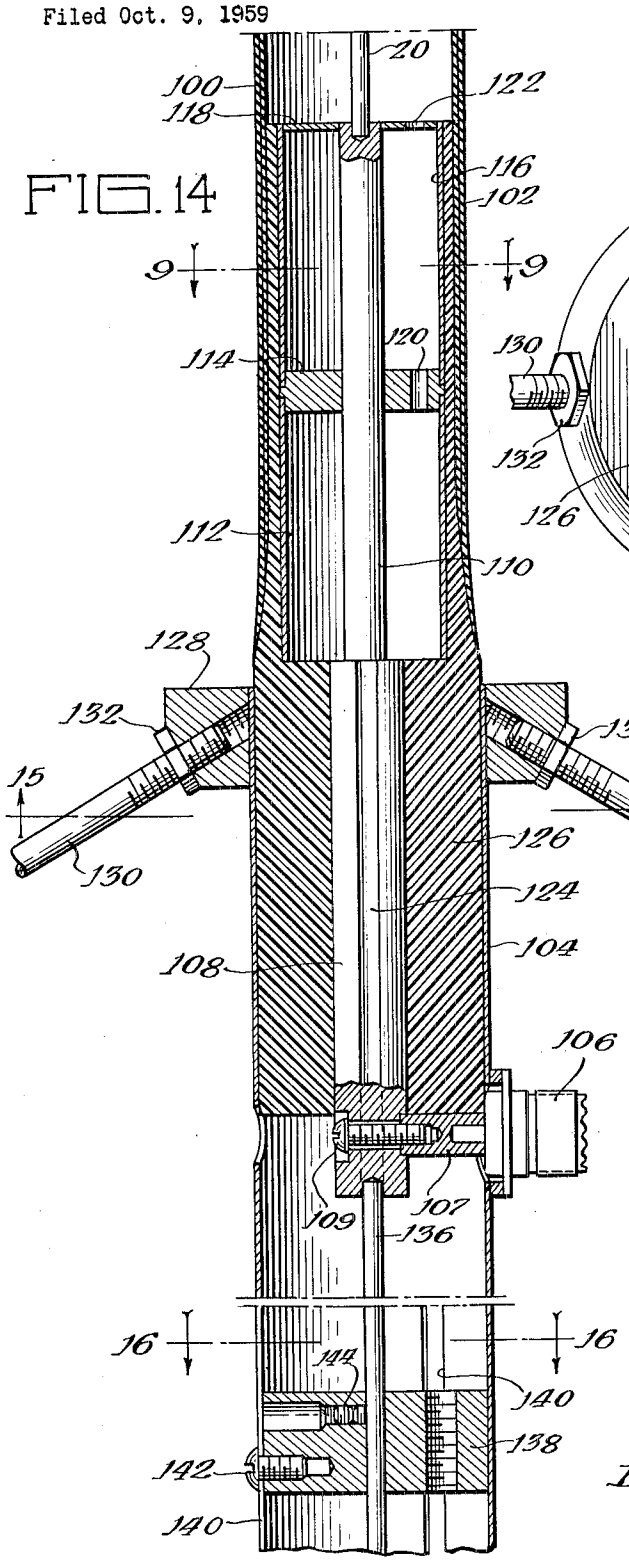


FIG. 15

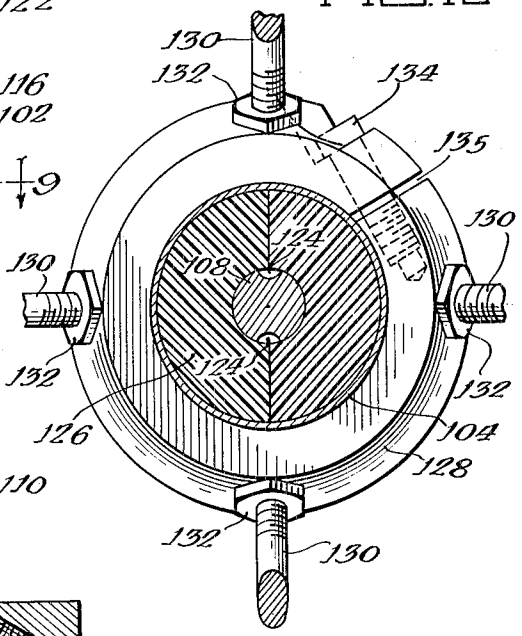
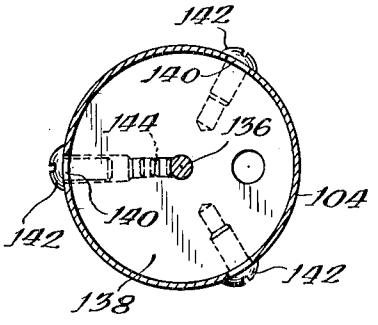


FIG. 16



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United States Patent Office 3,071,771 Patented Jan. 1, 1963

3,071,771

SUPPRESSED-RADIATION ANTENNA

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Filed Oct. 9, 1959, Ser. No. 845,466
6 Claims. (Cl. 343—828)

This invention relates to suppressed-radiation antennas, in which portions of a long conductor are surrounded by radiation suppressors, the exposed portions of the antenna radiating conductor forming in essence a collinear array in which each radiating element which is remote from the feed point of the antenna is fed through the adjoining suppressor.

The present invention, in its various aspects, stems from the development of a commercial embodiment of a wide band vertical-radiator suppressed-radiation antenna of high gain. In application Serial No. 735,090, now Patent No. 2,945,231, of the same inventor, filed May 12, 1958, there is shown and described a vertical tower-type antenna employing the suppressed radiation principle with a center feed. The antenna to be described in the present application is a ground plane antenna fed at the lower end and designed for simple and inexpensive fabrication and for high gain (low vertical radiation) wide band operation.

One important aspect of the present invention relates to improvement of the impedance bandwidth of the antenna, i.e., to the constancy of the impedance of the antenna over a wide band of frequencies. It is found that the impedance bandwidth of a vertical suppressor type antenna employing a ground plane structure can be greatly improved by making the ground plane structure conical, with the upwardly pointed apex at the base of the radiating structure, and by terminating the antenna at its tip in a conical structure forming at least a part of the uppermost radiating portion, this conical termination having a downwardly pointed apex. In the commercial embodiment to be described, the conical ground "plane," and the conical upper termination, are formed of radial rods in a manner analogous to the conventional formation of a ground plane by the employment of ground rods. Experiments performed with these conical constructions at the ground plane and outermost locations demonstrate that each makes a substantial contribution to the impedance bandwidth of the antenna. For best impedance bandwidth, the rods forming the ground "plane" and the upper termination, form angles of from 15° to 45° with the horizontal and the vertical, respectively, approximately 30° angles in both instances being found to give excellent results. One construction of an antenna illustrated and to be described herein is designed for operation in the 450 to 470 megacycle range. Comparative data taken on the impedance bandwidth of the antenna employing both conical constructions, each conical construction, and a construction employing horizontal ground rods and a simple vertical termination, clearly show the improvement (in contraction of the impedance curve on a Smith chart) effectuated by these features of construction, the impedance variation over the band of interest employing a conventional ground plane and linear tip or termination being a substantial multiple of that encountered in the structure employing both conical terminations, both as regards absolute value and phase angle.

The radiation suppressors employed in the antenna to be described in the present application are of the type shown in copending application Serial No. 811,502, now Patent No. 2,986,735, of the same inventor, filed May 6, 1959, in which the suppressor consists of a simple cylinder of a length substantially shorter than a half-wavelength (free space), the annulus between the radiator

conductor and the sleeve being filled with a dielectric having a k value such that the velocity in this medium makes the suppressor effectively a half-wavelength long, thus improving the gain pattern, as disclosed in the copending application mentioned. In the present construction, the suppressors are made with molded half cylinders of dielectric, grooved to receive the central conductor, the surrounding conducting sleeve being formed by a foil or sheet of suitable thickness bent around the cylindrical insulator thus formed.

In the present construction, parts of the exposed portions of the relatively thin center conductor are surrounded by tubes which are shorted at the ends thereof to the center conductor, thus producing, in a simple and inexpensive fashion, effective enlargement of the center conductor in parts of the exposed regions to improve the broad band radiating characteristics of the antenna. In the embodiment to be described, the conductor enlargements and the outer conducting tubes of the adjacent suppressors are of approximately the same size, but this size or diameter is gradually reduced in the higher vertical portions of the antenna to produce the tapering which is well known to be desired for mechanical stability against wind stresses. The structure as thus far described is, however, of inadequate mechanical stability, since it will be seen that the portions of the radiating conductor which are covered by neither the suppressors nor the conductor enlargements each bear the entire mechanical load of the entire antenna structure above them. To provide sufficient mechanical support for the vertical structure, there are provided elongated rigid insulating sleeves, each terminating at its ends on the end of adjacent suppressors, the sleeves thus covering all of the radiating portion of the structure and giving rigidity to the vertically extending antenna. In the embodiment to be herein described, the entire antenna as thus far described is encased in a suitable insulating sheath, and the various members so encased are provided with suitable vertical passages to connect all portions of the interior with the atmosphere at the bottom end of the antenna, thus preventing pressure differentials or moisture accumulation within the encased structure.

For more complete understanding of the manner in which the aims and objects of the invention described above, together with certain other features of construction and advantages, are achieved, reference is made to the embodiment of the invention illustrated in the annexed drawing, in which:

FIGURE 1 is a view in elevation of an antenna made in accordance with the invention;

FIGURE 2 is an enlarged sectional view of the topmost portion of the device of FIGURE 1;

FIGURE 3 is a further enlarged sectional view of a connector plug illustrated in FIGURE 2;

FIGURE 4 is a top plan view of the plug of FIGURE 3;

FIGURE 5 is a vertical sectional view of the portion of the antenna of FIGURE 1 immediately below the portion shown in FIGURE 2;

FIGURE 6 is a view in vertical section of the next lower portion;

FIGURE 7 is a sectional view taken along the line 7—7 of FIGURE 5;

FIGURE 8 is a sectional view taken along the line 8—8 of FIGURE 6;

FIGURE 9 is a sectional view taken along the line 9—9 of FIGURE 14;

FIGURE 10 is a view in elevation of a foil or sheet which is subsequently formed to constitute a portion of the illustrated device;

FIGURES 11, 12, 13, and 14 are vertical sectional views of successively lower portions of the antenna than that of FIGURE 6;

FIGURE 15 is a sectional view taken along the line 15—15 of FIGURE 14; and

FIGURE 16 is a sectional view taken along the line 16—16 of FIGURE 14.

The antenna of which an over-all view is shown in FIGURE 1 is basically constructed about a single central relatively thin rod conductor 20 extending from a point near the base to a point near the upper termination. At spaced intervals there are mounted on this central rod 20 suppressor assemblies designated, in descending vertical order, 22, 24, 26, and 28. Except for diameter, these suppressor assemblies are virtually identical, and are constructed in the manner illustrated in the cross-sectional view of FIGURE 8, as supplemented by the view of FIGURE 10. Each suppressor assembly has a core 32, 34, 36, and 38 of suitable dielectric such as cast fiberglass roving, bonded with a suitable resin. Each core is formed of two half-cylinders 39 and 40 (FIGURE 8), axially grooved to receive the central conductor. A foil or sheet 42, 44, 46, and 48 of conductor is wrapped about each core, being slightly shorter than the core. The cores have diametrically opposed grooves 52 extending longitudinally of the outer surface thereof to provide air passages through the suppressor assemblies so formed. Each foil or sheet has perforations 54 (see FIGURE 10). The foils or sheets are secured to their respective cores by a dielectric resin, a thin layer of which (not shown in the drawing) is on the outer surface of the foil or sheet, the perforations 54 serving to permit direct bonding of this outer layer to the core, thus making the bonding together of each assembly independent of adherence to the metal foil. The lengths of the suppressors and the dielectric constant of the material employed are so related that the suppressors, although of a length of in the neighborhood of only one-quarter of a free space wavelength at the frequency of operation of the antenna, are electrically one-half wavelength long because of the reduced velocity in the dielectric medium.

The major portions of the center conductor 20 in the regions of unsuppressed radiation between the suppressors bear conductor enlargement assemblies 62, 64, and 66 formed of tubes 72, 74, and 76 coaxially surrounding the center conductor 20, each of these tubes being provided with end caps 82, 84, and 86 shorting the respective tubes at both ends to the center conductor, thus effectively constituting these portions radiators of enlarged diameter, with the desirable broad band radiation characteristics flowing from such enlarged diameters. The end caps 86 are apertured at 88. The gaps between suppressors and adjacent enlargements are desirably at least equal to the diameters of these members, in order to prevent substantial endwise capacity coupling between the enlargements and the ends of the suppressor sleeves.

Although each conductor enlargement assembly is of a diameter approximating that of its neighboring suppressor assemblies, the suppressor 24 is slightly larger than the conductor enlargement 62, and the suppressor 26 is slightly larger than the enlargement 64, but is slightly smaller than the conductor enlargement 66, which is in turn slightly smaller than the lowermost suppressor 28, thus producing, in the over-all structure, a tapered construction in which the outer dimension diminishes with height.

Fitted over the slightly extending end of each suppressor core, and in end abutment with the respective outer conducting foils or sheets of the suppressors are insulating support sleeves 92, 94, 96, 98, and 100. The sleeves 94, 96, and 98, each bridging the entire gap between suppressors, completely enclose the conductor enlargement assemblies 62, 64, and 66 and relieve the otherwise exposed portions of the central rod 20 of the weight load of higher portions of the assembly. The uppermost sleeve 92 extends from the upper suppressor over a

portion of the uppermost or terminal conductor structure, later to be described, and the lower sleeve 100 terminates at the base of the radiating structure, being there bonded to other dielectric material employed in the support and feed for the antenna later to be described. The sleeves are bonded at their ends to the suppressor cores, this operation being performed preferably at the same time as the bonding of the foils or sheets to the cores, thus forming an over-all unitary self-supporting bonded structure, the conductor enlargements being secured to the central rod 20, as by brazing. This entire assembly is covered with a sheath 102, for example of bonded fiberglass cloth, for hermetic sealing against the elements. The apertures 88 in the end caps of the conductor enlargements and the grooves 52 on the outer surfaces of the suppressor cores provide a continuous air passage, which is vented at the bottom as hereafter described, to guard against internal moisture accumulation or pressure differentials.

The main body of the antenna thus described is supported at the bottom by a support tube 104 designed to fit over a grounded mast or pole (not shown). On the side of the support tube is a coaxial connector 106, the central conductor of which is secured by a connecting conductor 107 and a screw 109 to a large central conductor 108 extending upward through the upper end of the support tube 104 and terminating in a somewhat smaller conductor 110, the upper end of which is joined to the lower end of the central rod conductor 20 of the main body of the antenna. The lower portion of conductor 110 is surrounded by a radially spaced conducting tube 112 supported by a shorting disk 114. The upper portion of the conductor 110 is surrounded by a further tube 116 which is shorted to the central rod conductor 20 by an end cap 118 similar to the end caps 82, 84, and 86 on the ends of the conductor enlargements previously described. The shorting disks or caps 118 and 114 are apertured at 120 and 122, and the large conductor 108 has external longitudinal grooves 124 to complete the venting of the enclosed antenna assembly, as previously described.

The annulus between the conductor 108 and the support tube 104 is filled with dielectric 126 which extends upward to surround the tubes 112 and 116 just described, being bonded, as earlier stated, to the lowermost sleeve 100 to form a rigid insulating support at the base of the antenna.

The upper end of the support tube 104 is gripped by a collar 128 into which are threaded four ground rods 130, provided with lock nuts 132, clamping action being obtained by means of a bolt 134 bridging a split 135 in the collar.

Below the coaxial connector 106, an extension conductor 136, connected to the large central conductor 108, extends downwardly through the support tube 104. A shorting disk 138, adjustable in position by the provision of slots 140 in the support tube, is locked in position by screws 142, secure contacting of the central conductor being assured by set screw 144.

The electrical function of the portions of the lower or feed part of the antenna as thus described may be readily understood. The disk 138 is adjusted to provide a quarter-wave line below the coaxial input. The concentric dielectric-loaded coaxial structure immediately above the connector feeds the first radiating segment of the antenna, consisting of the tube 116 and the lower end of the conductor 20, through the short length of shorted line formed by the lower end of conductor 110 and the tube 112, these latter elements serving as a series inductance tuning out the capacitive reactance of the radiating portion over its entire frequency band. As previously indicated, the tilting of the ground rods 130, when combined with the conical termination at the upper end, to be described in more detail below, confines the impedance variation of the radiating structure to a very limited area

of absolute and vector values, so that the inductance provided by the illustrated structure makes the over-all antenna impedance, as matched by the dielectric-loaded line-matching section, closely approximate the resistive value of the characteristic impedance of the input cable over the entire frequency band.

The upper end of the central rod conductor **20** bears a conductor enlargement assembly **146**, consisting of a tube **147** and a lower end cap **148** generally similar to the enlargement construction previously described. The end cap **148** is apertured at **150** in a manner corresponding to the apertures **88**. The upper end of the tube **147** bears a conducting connector plug **152** having a conical outer end recess **154**. The walls of this recess bear four grooves at **156**, in which are seated the lower ends of rods **158** terminating at their upper ends in loops **160**. The rods are secured by a retainer member **162** fastened by a bolt **164** threaded into an axial aperture **166** in the plug **152**. As previously pointed out, this conical termination at the end of the antenna is found to add substantially to the impedance bandwidth of the antenna structure. In addition to the bandwidth characteristic, the conical termination is found to raise the center-frequency impedance at the feed point, thus reducing the necessary impedance transformation.

The theory of operation of the improvement in impedance characteristics achieved with the conical outer end termination and ground rod configuration, as compared with a conventional vertical upper termination and horizontal ground rods, is not completely understood, despite the empirical observation of the results obtained. The tilting of the ground rods (or other structure forming the conical ground "plane") is found to improve the performance in the mentioned respects of other types of antennas, such as the folded quarter-wave structure commercially known as the "Unipole," and the double helical construction shown in copending application Serial No. 750,417, filed July 23, 1958, of the present inventor. As regards the upper termination, it is believed that the improved broad band characteristics of the present antenna flow from reduction of the impedance of the upper terminal radiating portion as reflected to the feed point through the successive suppressors, which act as transformers in the suppressed radiation structures of this general type.

One embodiment of the antenna illustrated in the drawing was constructed for operation over the band from 450 to 470 megacycles. In this embodiment, the suppressors **24**, **26**, and **28** were of a length of 6 inches, the covering conducting sheets being slightly shorter as indicated. The spacings between adjacent suppressors (i.e., the radiating portions) were 16 inches in length, the central 11 inches of each radiating portion bearing an enlargement assembly as illustrated on a ⅛ inch central conductor. The diameters of the suppressors and enlargements were tapered from approximately 1½ inches at the bottom to approximately ⅝ of an inch at the top. The uppermost suppressor **22**, of the smallest diameter last stated, was found to be desirably slightly lengthened, and was accordingly made of a length of 6½ inches, such lengthening apparently being required by a small increase in effective velocity due to the small spacing of the concentric members of the suppressor. The top enlargement **146** was of a length of 3 inches, terminating in rods **158** of a length of 12 inches at angles of 30° to the vertical, the ground rods **130** being tilted at the same angle with respect to the horizontal.

It will, of course, be obvious to those skilled in the art that the novel constructional features of the antenna selected for illustration and description in accordance with the requirements of the patent laws may readily be adapted to other antennas of different appearance and details of operation and construction, which nevertheless embody the teachings of the invention. Accordingly, the scope of the protection to be afforded the invention should be determined from the descriptions of the invention contained in the appended claims, together with equivalents thereof, rather than being limited by the specific embodiment shown and described in detail herein.

What is claimed is:

1. A suppressed-radiation antenna comprising a unitary elongated conductor of substantially uniform diameter radiation suppressors surrounding the conductor at spaced intervals and insulatedly supported thereon the portions of the conductor between the suppressors being of substantially a half-wavelength, and conducting tubes surrounding the conductor between suppressors and conductively supported at their ends by the conductor to form enlargements of the conductor.

2. A suppressed-radiation antenna comprising an elongated conductor, radiation suppressors surrounding the conductor at spaced intervals, the portions of the conductor between the suppressors being of substantially a half-wavelength, enlargements on the conductor in the regions between the suppressors, and at least one rigid insulating sleeve of inner dimension substantially greater than the outer dimension of the unenlarged portions of the conductor bridging the gaps between the enlargements and the suppressors to reinforce the exposed unenlarged portions of the conductor.

3. A suppressed-radiation antenna comprising an elongated conductor, radiation suppressors surrounding the conductor at spaced intervals, the portions of the conductor between the suppressors being of substantially a half-wavelength, and enlargements on the conductor in the region between the suppressors, the enlargements being spaced from adjacent suppressors by a distance at least equal to the diameter of the respective suppressors.

4. A suppressed-radiation antenna comprising an elongated vertical conductor, radiation suppressors surrounding the conductor at spaced intervals and insulated therefrom the portions of the conductor between the suppressors being of substantially a half-wavelength, a feed point at the lower end, a conical ground-plane structure with an upwardly facing vertex at the lower end forming an angle of from 15° to 45° with the horizontal, and a termination at the upper end of the conductor in the form of a conical surface extending upwardly and outwardly at an angle of from 15° to 45° from the axis of the antenna.

5. A suppressed-radiation antenna comprising an elongated thin conductor, radiation suppressors surrounding the conductor at spaced intervals, the portions of the conductor between the suppressors being of substantially a half-wavelength, enlargements on the conductor between suppressors, such enlargements being spaced from adjacent suppressors by a distance at least equal to the diameter of the respective suppressors, and at least one rigid insulating sleeve bridging the gaps between the enlargements and the suppressors to reinforce the exposed unenlarged portions of the conductor.

6. A suppressed-radiation antenna comprising an elongated vertical conductor, radiation suppressors surrounding the conductor at spaced intervals, the portions of the conductor between the suppressors being of substantially a half-wavelength, a feed point at the lower end, a conical ground-plane structure with an upwardly facing vertex at the lower end forming an angle of from 15° to 45° with the horizontal, a termination at the upper end of the conductor in the form of a conical surface extending upwardly and outwardly at an angle of from 15° to 45° from the axis of the antenna, conducting tubes surrounding the conductor between suppressors and shorted at their ends to the conductor to form enlargements of the conductor, such enlargements being spaced from adjacent suppressors by a distance at least equal to the diameter of the respective suppressors, and at least one rigid insulating sleeve bridging the gaps between the

enlargements and the suppressors to reinforce the exposed unenlarged portions of the conductor.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,071,771 January 1, 1963

Marvel W. Scheldorf

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, lines 2 and 3, and in the heading to the printed specification, line 4, for "a corporation of Delaware", each occurrence, read -- a corporation of Illinois --.

Signed and sealed this 9th day of July 1963.

(AL)
est:

EST W. SWIDER
sting Officer

DAVID L. LADD
Commissioner of Patents