

Jan. 15, 1957

H. J. ROWLAND

2,778,014

ANTENNA SYSTEM

Filed Oct. 16, 1951

5 Sheets-Sheet 1

Fig. 1

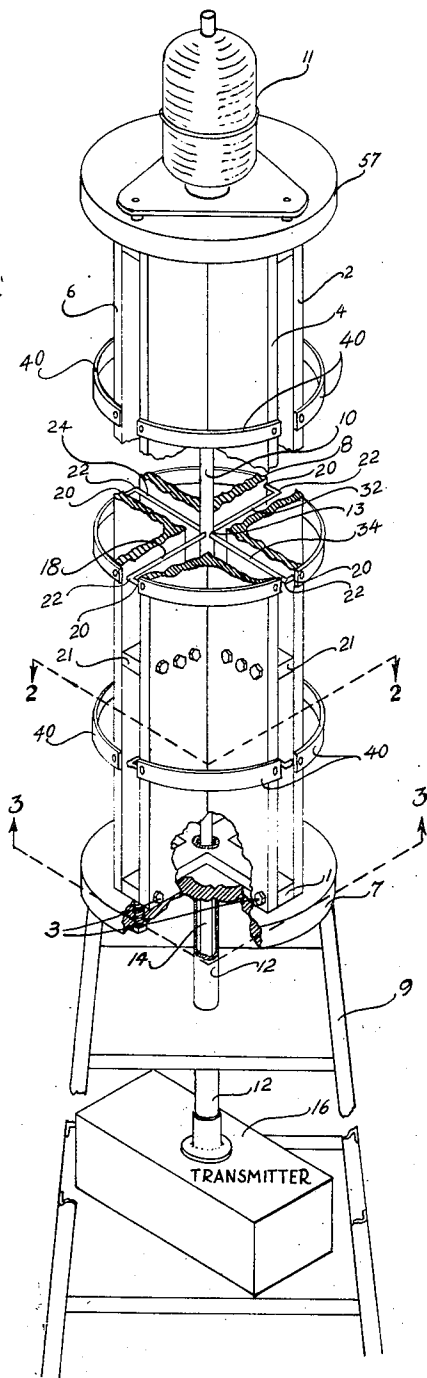


Fig. 2

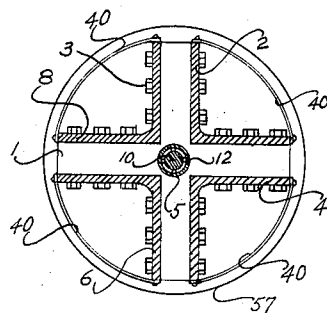
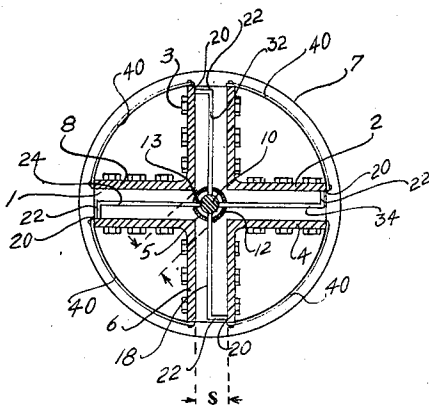


Fig. 3

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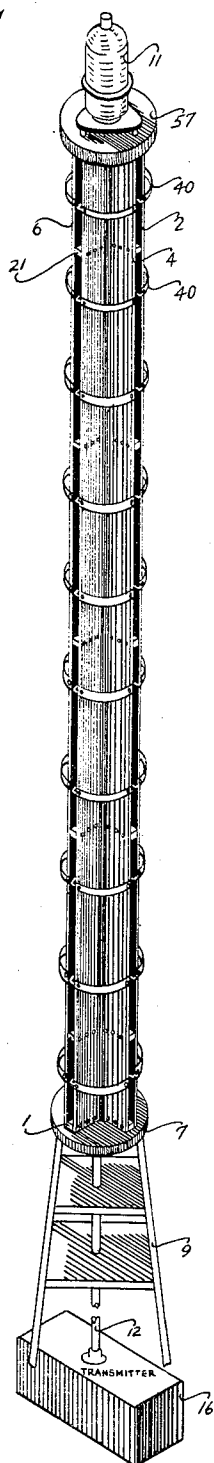
2,778,014

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Fig. 11



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Fig. 9

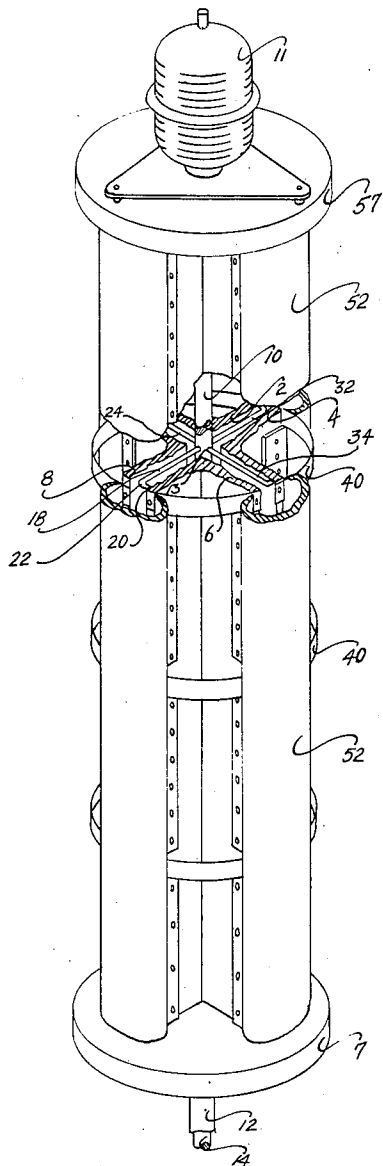
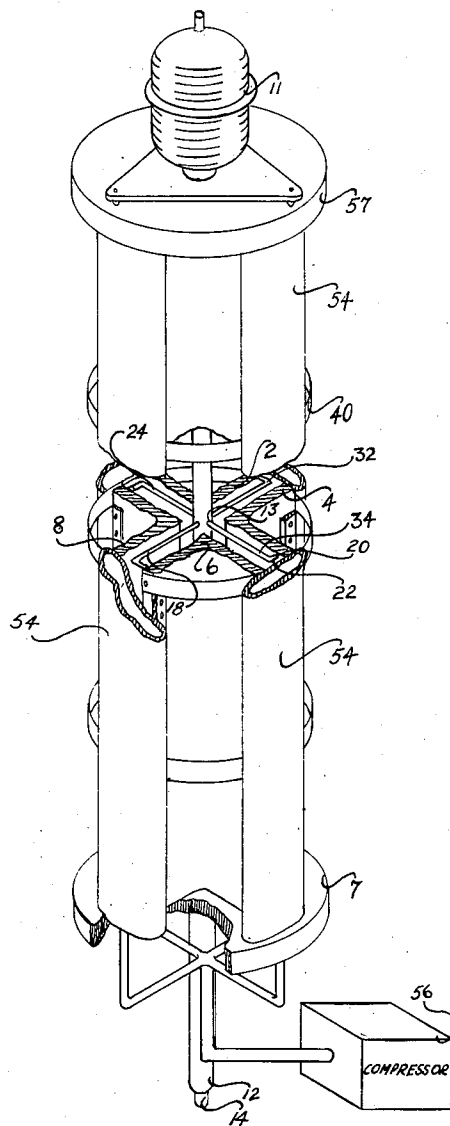


Fig. 10



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Fig. 7

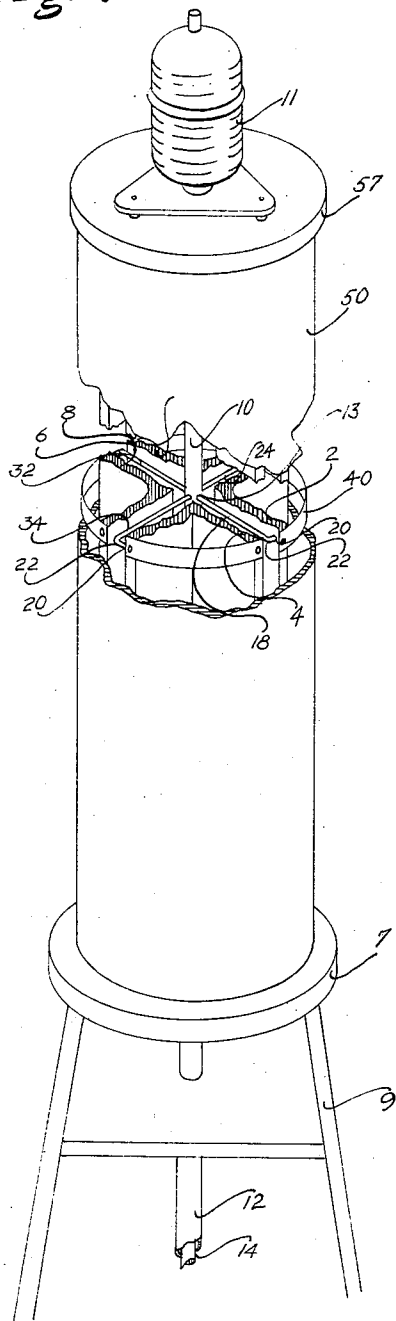
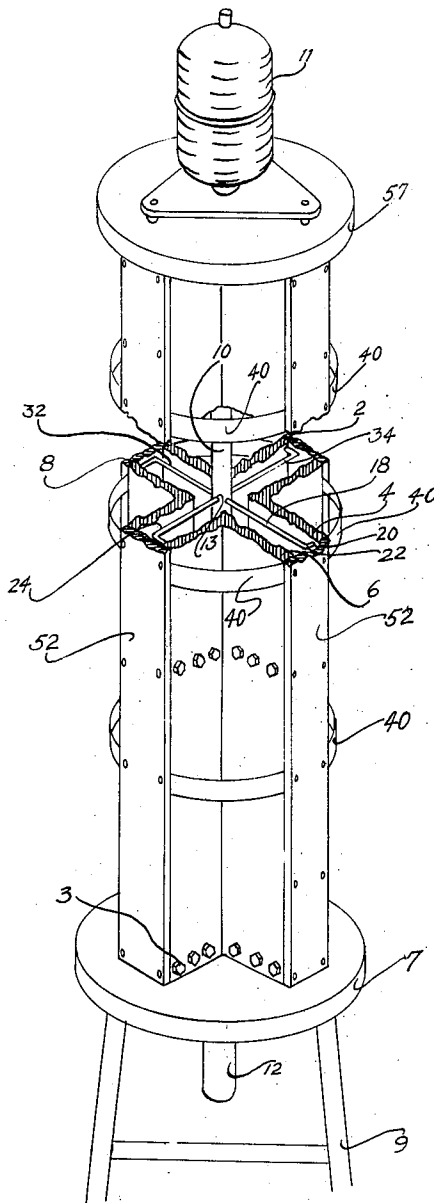


Fig. 8



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Fig. 4

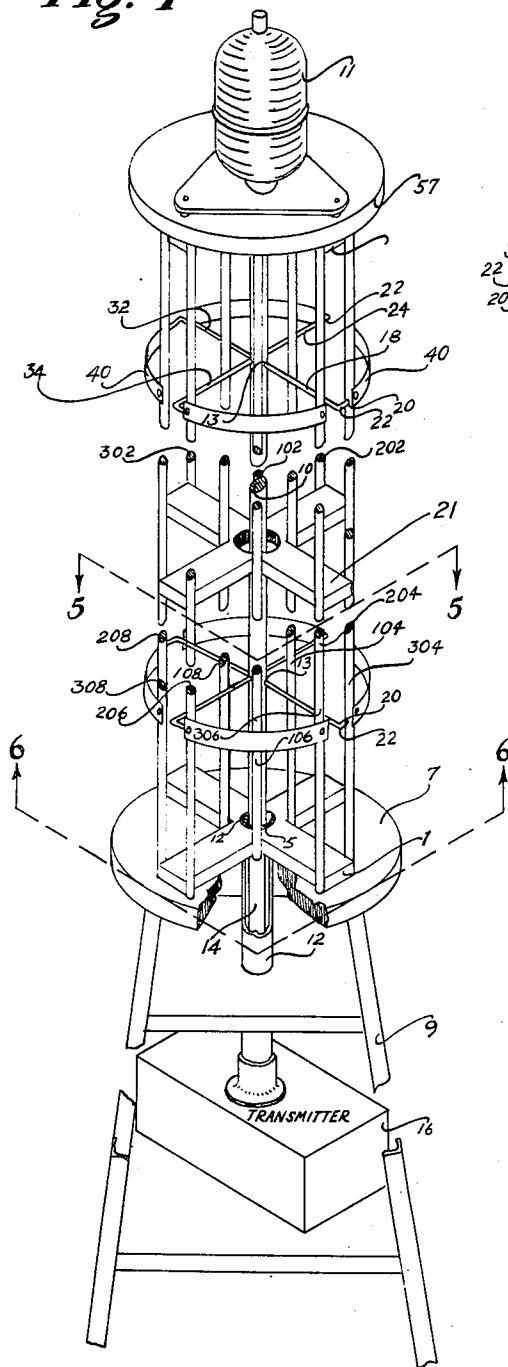


Fig. 5

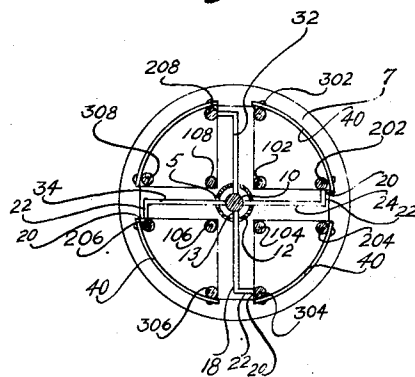
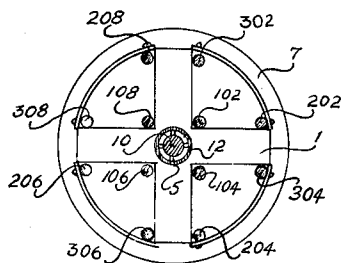


Fig. 6



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2,778,014

ANTENNA SYSTEM

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Application October 16, 1951, Serial No. 251,516

33 Claims. (Cl. 343—770)

The present invention relates to antennas and more particularly to antenna structures particularly adapted for use in the ultra-high-frequency range.

In some ultra-high-frequency and very-high-frequency antenna transmitting systems, such as, for example, those employed for television transmissions, an omni-directional horizontal radiation pattern and a high-gain vertical radiation pattern are required to provide uniform broadcasting in all directions of azimuth and over a desired field of coverage. It is often the requirement, moreover, that the polarization of the radiated energy be horizontal. Many antennas have been designed for producing such patterns. Some of these antennas are in the form of helical arrays; others, in the form of circular loops; still others employ antennas of various other configurations such as "bat wings" and the like; and antennas have also been proposed embodying a plurality of angularly disposed wave guides or horns, including biconical horns. Antennas of this character, however, are quite costly to manufacture, requiring specially designed components. Present-day commercial antennas of this type, moreover, utilize large numbers of cumbersome and expensive insulators which are subject to periodic deterioration under the influence of atmospheric conditions, and they require, also, phase- and impedance-correcting networks and other devices associated with the feed transmission lines that add cost and complexity to the equipment. Not only is it desirable to reduce the cost of manufacture of such antennas, therefore, but it is quite advantageous to eliminate the necessity for the use of insulators and such phase- and impedance-correcting devices.

An object of the present invention is to provide a new and improved antenna that is adapted to produce a horizontally polarized omni-directional radiation pattern in the horizontal plane and a high-gain radiation pattern in the vertical plane, and that obviates the necessity for insulators and for special phase- and impedance-correcting devices.

A further object of the invention is to provide such an antenna that is particularly adapted for use in the ultra-high-frequency range.

Still another object of the invention is to utilize as an antenna, standard constructional members that are currently in mass production for other purposes than making antennas, thereby further to reduce the cost of manufacture of the antenna.

Other and further objects will be explained hereinafter and will be more particularly pointed out in the appended claims.

In summary, the invention relates to an antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality of, preferably five, substantially parallel transmission-line conductors four of which preferably comprise right-angular beams the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of the

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adjacent angular beam transmission-line conductors. Means is provided, preferably in the form of a coaxial line, for energizing the fifth transmission-line conductor from the inner coaxial-line conductor and the angular beam transmission-line conductors in anti-phase therewith from the outer coaxial-line conductor. Several branch-conductor groups each comprising four appropriately dimensioned branch conductors are disposed in substantially parallel planes normal to the transmission-line conductors and spaced therealong at intervals corresponding substantially to the said predetermined wavelength. The four branch conductors of each group are connected at one of their ends to the fifth transmission-line conductor and at their other ends to the respective four angular beam transmission-line conductors to radiate horizontally polarized waves omni-directionally. Preferred constructional details and dimensions will be hereinafter pointed out.

The invention will now be described in connection with the accompanying drawings Fig. 1 of which is a perspective view of a preferred form of the invention, partly cut away to illustrate structural details; Figs. 2 and 3 are sectional views taken up the respective lines 2—2 and 3—3 of Fig. 1, looking in the direction of the arrows; Fig. 4 is a view similar to Fig. 1 of a modification; Figs. 5 and 6 are sectional views taken up the respective lines 5—5 and 6—6 of Fig. 4, looking in the direction of the arrows; Figs. 7 to 10 are perspective views of various weather-protecting mechanisms particularly adapted for operation with the antenna system of Fig. 1; and Fig. 11 is a perspective of a complete antenna installation.

Among the commercially available self-supporting structures mass-produced for other fields of endeavor, such as building construction, are right-angular beams, as of steel. In accordance with the present invention, four such angular beams are utilized as an antenna structure. In Figs. 1, 2, 3 and 10, vertically arranged angular beams are shown at 2, 4, 6 and 8 with their corner edges or vertices symmetrically disposed with respect to a preferably substantially parallel centrally disposed transmission-line conductor 10 of less transverse surface dimensions and with substantially equal spacing S between the parallel sides of the adjacent angular beams. The angular beams are connected together at the top and bottom of the antenna by end plates 1, with the aid of bolts 3. The top end plate 1 may be utilized to mount a platform 57 which may be welded or otherwise secured thereto for supporting a beacon light 11. The bottom end plate 1 is provided with an aperture 5 for receiving the centrally disposed transmission-line conductor 10, and is carried by a mounting 7 that may be secured to the top of a conventional antenna tower 9. The bottom end plate 1, the mounting 7 and the top of the tower 9 may all be welded together or joined by any other desired means. As will hereinafter appear, the structural properties of the angular beams and the associated energizing conductors are such that no bracing or other auxiliary supporting devices are required.

The angular beams 2, 4, 6 and 8 are all connected to the outer conductor 12 of a coaxial-feed transmission line to serve as equipotential transmission-line conductors energized thereby. The inner transmission-line conductor 10 is energized in anti-phase therewith through its connection with the inner conductor 14 of the coaxial-feed transmission line that, in turn, connects with, for example, a television transmitter 16 located, perhaps, at the base of the tower 9. The antenna structure may be grounded through the tower 9.

Along the transmission-line conductors 2, 4, 6, 8 and 10, several branch-conductor groups are provided each comprising four branch conductors 18, 24, 32 and 34,

disposed in substantially parallel planes preferably substantially normal to the transmission-line conductors and spaced therealong at intervals corresponding substantially to the predetermined wavelength with which the antenna is to operate.

The branch conductors 18, 24, 32 and 34 are connected at one of their ends to the centrally disposed transmission-line conductor 10, as at 13, and at their other ends to the respective angular beam transmission-line conductors 4, 6, 8 and 2 by preferably horizontally disposed connecting elements 22, as at points 20. Each branch conductor, such as, for example, the branch conductor 18, becomes one element of a further three-element branch transmission line the other two elements of which comprise the side of the angular beam conductor to which it is connected, such as the left-hand side of the angular beam conductor 4, and the parallel side of the adjacent angular beam conductor, such as the right-hand side of the angular beam conductor 6. Current then flows outward along the branch conductor 18 and back in the opposite direction along the left-hand side of the angular beam conductor 4, but in the same direction along the right-hand side of the angular beam conductor 6 as along the conductor 18. The appropriate impedance adjustment for this unbalanced three-conductor feed may be effected by adjusting the position of the point 20 along the left-hand side of the angular beam conductor 4. For the purposes hereindescribed, it has been found advantageous to locate the point 20 right near the edge of the angular beam conductor, as shown. If desired, a stub, not shown, may be used at the top of the array for assisting in matching the complete array. The location of the points 20 along one of the side edges of each angular beam may also be adjusted to effect desired phase relationships. The spacing S between the parallel sides of adjacent beams and the spacing of the vertices of the beams from the inner conductor 10 may also be varied to effect desired impedance and phase relationships without the necessity for utilizing special lines, networks or other devices.

While the length of the branch conductors 18, 24, 32 and 34 can be made small, consistent with preventing the short-circuiting of the energy that is passed upward along the five-conductor transmission lines 2, 4, 6, 8, 10, and outward to the edges of the angular beam conductors 2, 4, 6, and 8, it can not be made too large without producing sharp lobes in the radiation pattern of the antenna that destroy the circularity of the desired omnidirectional radiation pattern. The overall width or diameter of the antenna array, on the other hand, must be large enough to support the necessary structure. If the degree of circularity or omnidirectionality of the horizontal field pattern produced by the antenna, defined in terms of the maximum-to-minimum field intensity ratio in the pattern, is to be maintained under ± 2 decibels, the length of the branch conductors 18, 24, 32 and 34 should be substantially equal to or less than about the half-wave-length of the radio energy. The spacing S between the parallel side surfaces of the adjacent beam conductors 2, 4, 6 and 8, furthermore, is preferably adjusted to a value considerably less than the length of the branch conductors in order to maintain the omnidirectional radiation pattern characteristic. An antenna particularly suited for the ultra-high-frequency range of from about 500 to about 890 megacycles per second, for example, having branch conductors 18, 24, 32, 34 of length about four and one-half inches, angular beams of width on each side about four inches and a spacing S between the parallel sides of adjacent angular beams of about one inch, has been found to produce a degree of circularity in the omnidirectional horizontal pattern under the said ± 2 decibels. For antennas designed for operation with different predetermined wavelengths in the said 500 to 890 megacycle range, the length of the branch conductors may vary from about three and one-

half to about five and one-half inches; the width of the side of the angular beam conductors, from about three to about five inches; and the spacing S, from about one-half inch to about two inches.

The theory of operation of such an antenna may be explained as follows. The radiation is transmitted from the co-planar rectangular radio wave-guiding or wave-transmission loops or frames sub-dividing each opening between adjacent transmission-line conductors 2, 4, 6, 8, and formed by the outer edges of the transmission-line conductors 2, 4, 6, 8 and the spacers 1, 21, etc. One such frame or loop, for example, is formed by the members 2—21—4—1, provided with long sides 2, 4 about a wavelength in length, shorter sides 1, 21 less than a half-wavelength in length, and an effective depth or thickness of negligible dimensions since only essentially the outer edges are effective for radiation, as is perhaps more evident from Fig. 4. The feed system embodying the branch-conductor exciters 18, 24, 32, 34, moreover, is disposed with the end portions 22 lying substantially in the plane of the frames or loops, as shown, and oriented substantially parallel to the shorter sides 1, 21, thus insuring the emission from the openings between the adjacent transmission-line conductors 2, 4, 6, 8 of radio-frequency energy of polarization substantially perpendicular to the plane of the longer sides of the frame or loop, i. e. horizontal polarization in the disclosed system.

It has been found, furthermore, that the circularity of the omni-directional pattern may be improved by providing an auxiliary current path between the divergent edges of the sides of the angular beam transmission-line conductors. While this path may take the form of dipole extensions or elements of other configuration, it is preferable for the purposes of the present invention to utilize substantially circular band sections 40 connected between the divergent edges of the sides of the beams as with the aid of screws or other securing means. It so happens that in the 500 to 890 megacycle region, before mentioned, the position of the bands 40 for providing an improved circularity to the horizontal radiation pattern is also consistent with providing ladder steps with the aid of which one may climb the antenna structure. While the bands 40 produce some circularity improvement when disposed at several positions along the angular beams, it has been found preferable to place the bands substantially in the planes of the branch conductors. The bands 40 then also appear to minimize cross-polarization effects since any vertically polarized radiation components that may be set up are interrupted by the horizontal path for current provided by the bands across the angular beams at approximately wavelength intervals along the array. If the bands are located elsewhere than at the particular regions illustrated in Fig. 1, such as below or above the plane of the branch conductors, it is preferable to utilize pairs of bands in connecting with each wavelength section of the antenna in order to maintain symmetry.

As an illustration of the effectiveness of the bands, when the before-described antenna was operated at a frequency of about 800 megacycles about the bands, the degree of circularity of the horizontal field pattern was measured to be about $3\frac{1}{2}$ decibels. With the bands added, as shown in Fig. 1, the circularity ratio improved to about 1.9 decibels.

An array of this character, about ten to twenty wavelengths long, will produce sufficient directivity and gain in the vertical plane for the television purposes before mentioned. A ten-wavelength array, for example, will produce a half-power vertical principle lobe angle of about 4.8 degrees.

Not only does the use of the angular beams and the associated transmission-line system completely obviate the necessity for bracing or other auxiliary supports, as before pointed out, but the necessity for insulators has also become obviated. Except for providing additional struc-

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tural rigidity, moreover, the spacer elements 21, shown in Figs. 1 and 11, disposed at each wavelength interval along the array, need not be employed insofar as electrical performance is concerned. Bolts or other securing means, if any, may, indeed, be substituted therefor.

This type of antenna may, of course, be utilized for other purposes than providing the best possible omnidirectional pattern, in which event symmetry may not be required and less than or more than four angular beams may be utilized. The branch conductors 18, 24, etc. may then extend in other directions than at right angles to the axis of the conductor 10. Though the antenna structure of the present invention has been discussed in connection with its application to ultra-high-frequency transmissions, such as in the television field, furthermore, it will be understood that the antenna may, if desired, be adapted for use, also, as a receiving structure in which event the transmitter 16 will be replaced by a receiver. The antenna may, also, by appropriate scaling of its dimensions, be applied to frequencies in the very-high-frequency range as well as to frequencies above the ultra-high-frequency range. It is not essential, moreover, though it is most convenient, to utilize the coaxial type of transmission-line feed, for other types of feed lines may be employed.

While the before-described arrangement of the preferred embodiment of Fig. 1 is particularly adapted for television purposes, furthermore, angular beam structures may be used having an angle less than or greater than ninety degrees and having sides that flare outward or converge inward with respect to the sides of the adjacent angular beams. A section of cylindrical or other curved tubing may be utilized as the structural element instead of the angular beam of rectangular configuration. Still other common structural elements adapted to embody the techniques of the present invention may be employed, such as steel rods, solid or hollow, again providing low material cost and obviating the necessity for insulators, supports and phase- or impedance-compensating devices and the like.

Referring to Fig. 4, for example, five transmission-line rod conductors are shown connected to an end plate 1, as by welding, that may, in turn, be secured to a mounting 7 upon the tower 9 as discussed in connection with the antenna of Figs. 1 and 10. Four of the rod conductors 102, 104, 106 and 108, corresponding, respectively, to the angular beam conductors 2, 4, 6 and 8 of Fig. 1, are symmetrically disposed about the fifth rod conductor 10. The transmission-line rod conductors 102, 104, 106 and 108 are connected to the outer conductor 12 of the coaxial transmission line that is fed from, for example, the television ultra-high-frequency transmitter 16. The inner conductor 14 of the coaxial line connects with the centrally disposed transmission-line rod conductor 10. Associated with each transmission-line rod conductor 102, 104, 106 and 108 are a pair of further rod conductors 202-302, 204-304, 206-306, 208-308, connected by the end plates 1 and intermediate spacer plates 21 along axes corresponding to the divergent edges of the corresponding angular beam conductors of Fig. 1. Branch conductors 18, 22, 32 and 34, corresponding identically with the branch conductors of Fig. 1, similarly connect with the transmission-line conductor 10 at one of their ends and to the respective rod conductors 204, 206, 208 and 202 at their other ends at points 20. Circularity and cross-polarization improvement may be achieved by the bands 40 in the same manner discussed in connection with the antenna system of Fig. 1. The modifications previously and hereinafter suggested for the structure of Fig. 1 may also be applied to the antenna of Fig. 4.

If it is desired to provide a means for de-icing the antenna array of the present invention, this may be effected by utilizing a housing 50, Fig. 7, as of Plexiglas or similar radio-wave transparent material. Strips 52, Fig. 8, of the same material may be secured, as by screws or other means, to the edges of the angular beam transmission-line conductors to close off the space between the

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parallel sides of the adjacent angular beam transmission-line conductors to the effects of the atmosphere. By providing flexibility to the strips 52, as in Fig. 9, through the use of, for example, rubber or a suitably plasticized synthetic plastic, to permit the strips to contract and expand, the same end may be achieved. If desired, hot air may be continuously circulated within the system since it is of hollow construction, or a blast of air may be periodically passed from a compression chamber 56 into flexible tubes 54, Fig. 10, as of rubber or like substance, covering the edges of the adjacent angular beam conductors, periodically to throw off accumulated ice.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality in excess of two of substantially parallel transmission-line conductors of length at least equal to the said predetermined wavelength, one of the transmission-line conductors being symmetrically disposed with respect to the other transmission-line conductors, means for energizing the said one transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the said other transmission-line conductors in anti-phase therewith, and a plurality of branch conductors equal in number to one less than the plurality of transmission-line conductors completely disposed within the space between the transmission-line conductors connected at one of their ends to said one transmission-line conductor and at their other ends to the respective other transmission-line conductors and each of length not greater than substantially one-half the said predetermined wavelength.

2. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality in excess of two of substantially parallel transmission-line conductors of length at least equal to the said predetermined wavelength, one of the transmission-line conductors being symmetrically disposed with respect to the other transmission-line conductors, means for energizing the said one transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the said other transmission-line conductors in anti-phase therewith, and a plurality of branch conductors equal in number to one less than the plurality of transmission-line conductors completely disposed within the space between the transmission-line conductors in a plane substantially normal thereto connected at one of their ends to the said one transmission-line conductor and at their other ends to the respective other transmission-line conductors and each of length not greater than substantially one-half the said predetermined wavelength.

3. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality in excess of two of substantially parallel transmission-line conductors of length equal to several times the said predetermined wavelength, one of the transmission-line conductors being symmetrically disposed with respect to the other transmission-line conductors, means for energizing the said one transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the said other transmission-line conductors in anti-phase therewith, and several branch-conductor groups each comprising a plurality of branch conductors equal in number to one less than the plurality of transmission-line conductors, the branch-conductor groups being completely disposed within the space between the transmission-line conductors in substantially parallel planes substantially normal to the transmission-line conductors spaced therealong at intervals corresponding substantially to the said predetermined wavelength, the plurality of branch conductors of each group being connected at one of their ends to the said one transmission-line conductor and at

said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, several branch-conductor groups each comprising a plurality of branch conductors equal in number to the number of angular beam transmission-line conductors, the branch-conductor groups being disposed in substantially parallel planes substantially normal to the transmission-line conductors spaced therealong at intervals corresponding substantially to the said predetermined wavelength, the plurality of branch conductors of each group being connected at one of their ends to the said one transmission-line conductor and at their other ends to the respective angular beam transmission-line conductors and each of length not greater than substantially one-half the predetermined wavelength, and substantially circular band sections disposed substantially in the said planes of the branch-conductor groups connecting the edges of each angular beam transmission-line conductor to provide auxiliary radio-frequency current paths.

11. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising five substantially parallel transmission-line conductors of length at least equal to the said predetermined wavelength, four of the transmission-line conductors comprising substantially right-angular beams the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of the adjacent angular beam transmission-line conductors, means for energizing the fifth transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, and four branch conductors connected at one of their ends to the fifth transmission-line conductor and at their other ends to the respective four angular beam transmission-line conductors and completely disposed within the space between the transmission-line conductors.

12. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising five substantially parallel transmission-line conductors of length at least equal to the said predetermined wavelength, four of the transmission-line conductors comprising substantially right-angular beams the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of the adjacent angular beam transmission-line conductors, means for energizing the fifth transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, and four branch conductors completely disposed within the space between the transmission-line conductors in a plane substantially normal to the transmission-line conductors connected at one of their ends to the fifth transmission-line conductor extending between the said parallel sides of the adjacent angular beam transmission-line conductors and connected at their other ends to the respective four angular beam transmission-line conductors at points near one of the edges thereof.

13. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising five substantially parallel transmission-line conductors of length at least equal to the said predetermined wavelength, four of the transmission-line conductors comprising substantially right-angular beams the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of the adjacent angular beam transmission-line conductors, means for energizing the fifth transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, four branch conductors connected at one of their ends to the fifth transmission-line conductor and

at their other ends to the respective four angular beam transmission-line conductors, and means for providing auxiliary radio-frequency current paths between the edges of each angular beam transmission-line conductor.

14. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising five substantially parallel transmission-line conductors of length at least equal to the said predetermined wavelength, four of the transmission-line conductors comprising substantially right-angular beams the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of the adjacent angular beam transmission-line conductors, means for energizing the fifth transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, four branch conductors disposed in a plane substantially normal to the transmission-line conductors connected at one of their ends to the fifth transmission-line conductor extending between the said parallel sides of the adjacent angular beam transmission-line conductors and connected at their other ends to the respective four angular beam transmission-line conductors at points near one of the edges thereof, and substantially circular band sections disposed substantially in the said plane connecting the edges of each angular beam transmission-line conductor to provide auxiliary radio-frequency current paths.

15. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising five substantially parallel transmission-line conductors of length at least equal to several times a predetermined radio-frequency wavelength, four of the transmission-line conductors comprising substantially right-angular beams the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of the adjacent angular beam transmission-line conductors, means for energizing the fifth transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, and several branch-conductor groups each comprising four branch conductors, the branch-conductor groups being completely disposed within the space between the transmission-line conductors in substantially parallel planes substantially normal to the transmission-line conductors spaced therealong at intervals corresponding substantially to the said predetermined wavelength, the four branch conductors of each group being connected at one of their ends to the fifth transmission-line conductor and at their other ends to the respective four angular beam transmission-line conductors and each of length not greater than substantially one-half the predetermined wavelength.

16. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising five substantially parallel transmission-line conductors of length at least equal to several times a predetermined radio-frequency wavelength, four of the transmission-line conductors comprising substantially right-angular beams the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of the adjacent angular beam transmission-line conductors, means for energizing the fifth transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, several branch conductor groups each comprising four branch conductors, the branch-conductor groups being disposed in substantially parallel planes substantially normal to the transmission-line conductors spaced therealong at intervals corresponding substantially to the said predetermined wavelength, the four branch conductors of each group being

connected at one of their ends to the fifth transmission-line conductor and at their other ends to the respective four angular beam transmission-line conductors and each of length not greater than substantially one-half the predetermined wavelength, and substantially circular band sections disposed substantially in the said planes of the branch-conductor groups connecting the edges of each angular beam transmission-line conductor to provide auxiliary radio-frequency current paths.

17. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising five substantially parallel transmission-line conductors of length at least equal to several times a predetermined radio-frequency wavelength, four of the transmission-line conductors comprising substantially right-angular beams the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of the adjacent angular beam transmission-line conductors, means for energizing the fifth transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, several branch-conductor groups each comprising four branch conductors, the branch-conductor groups being disposed in substantially parallel planes substantially normal to the transmission-line conductors spaced therealong at intervals corresponding substantially to the said predetermined wavelength, the four branch conductors of each group being connected at one of their ends to the fifth transmission-line conductor and at their other ends to the respective four angular beam transmission-line conductors and each of length not greater than substantially one-half the predetermined wavelength, substantially circular band sections disposed substantially in the said planes of the branch-conductor groups connecting the edges of each angular beam transmission-line conductor to provide auxiliary radio-frequency current paths, and means for preventing the formation of ice in the spaces between the said parallel edges of the adjacent angular beam transmission-line conductors.

18. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising five substantially parallel transmission-line conductors of length at least equal to several times a predetermined radio-frequency wavelength, four of the transmission-line conductors comprising substantially right-angular beams the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of the adjacent angular beam transmission-line conductors, means for energizing the fifth transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, several branch-conductor groups each comprising four branch conductors, the branch-conductor groups being disposed in substantially parallel planes substantially normal to the transmission-line conductors spaced therealong at intervals corresponding substantially to the said predetermined wavelength, the four branch conductors of each group being connected at one of their ends to the fifth transmission-line conductor and at their other ends to the respective four angular beam transmission-line conductors and each of length not greater than substantially one-half the predetermined wavelength, substantially circular band sections disposed substantially in the said planes of the branch-conductor groups connecting the edges of each angular beam transmission-line conductor to provide auxiliary radio-frequency current paths, and means disposed at each end of the antenna for connecting together the corresponding ends of the four angular beam transmission-line conductors in order to provide for mounting the antenna at one end and for supporting a beacon light at the other end, the connecting means at the said one

end being provided with an aperture for receiving the fifth transmission-line conductor.

19. An antenna system for transmitting radio-frequency energy in the band extending from substantially 500 megacycles to substantially 890 megacycles comprising five substantially parallel transmission-line conductors of length at least equal to substantially ten to twenty wavelengths of the energy, four of the transmission-line conductors comprising substantially right-angular beams substantially three to five inches on a side, the vertices of which are symmetrically disposed with respect to the fifth transmission-line conductor with substantially equal spacing between the parallel sides of adjacent angular beam transmission-line conductors of from substantially one-half inch to substantially two inches, means for energizing the fifth transmission-line conductor with the radio-frequency energy and the angular beam transmission-line conductors in anti-phase therewith, and from substantially ten to twenty branch-conductor groups each comprising four branch conductors, the branch-conductor groups being disposed in substantially parallel planes substantially normal to the transmission-line conductors spaced therealong at intervals of substantially the said wavelength, the four branch conductors of each group being connected at one of their ends to the fifth transmission-line conductor and at their other ends to the respective four angular beam transmission-line conductors and each of length of from substantially three and one-half to substantially five and one-half inches.

20. An antenna system for transmitting or receiving radio-frequency energy of a predetermined wavelength comprising a plurality of transmission-line conductors of length substantially equal to or greater than the predetermined wavelength parallel and substantially symmetrically disposed with respect to a centrally disposed transmission-line conductor, means whereby the centrally disposed transmission-line conductor may be energized with radio-frequency energy of the predetermined wavelength and the plurality of transmission-line conductors in anti-phase therewith, and a plurality of branch conductors equal in number to the plurality of transmission-line conductors completely disposed within the space between the transmission-line conductors respectively connected to the centrally disposed conductors and the respective plurality of transmission-line conductors and each of length not greater than substantially one-half the predetermined wavelength.

21. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality of substantially parallel angular beam transmission-line conductors of length at least equal to the said predetermined wavelength positioned to define a space therebetween, further transmission-line conductor means disposed within the said space, means for energizing the said further transmission-line conductor means with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductors in anti-phase therewith, and a plurality of branch conductors completely disposed within the said space, one for connecting each of the angular-beam transmission-line conductors to the further transmission-line conductor means.

22. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality of substantially parallel transmission-line conductor means of length at least equal to the said predetermined wavelength, all but one of the transmission-line conductor means comprising angular beams surrounding the said one transmission-line conductor means, means for energizing the said one transmission-line conductor means with radio-frequency energy of the said predetermined wavelength and the angular beam transmission-line conductor means in anti-phase therewith, and a plurality of branch conductors equal in number to the number of angular beam transmission-line conductor

means completely disposed within the space between the transmission-line conductor means connected at one of their ends to the said one transmission-line conductor means and at their other ends to the respective angular beam transmission-line conductor means and each of length not greater than substantially one-half the said predetermined wavelength.

23. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality in excess of two of substantially parallel transmission-line conductors of length at least equal to the said predetermined wavelength, one of the transmission-line conductors being symmetrically disposed with respect to the other transmission-line conductors, the said other transmission-line conductors being of substantially circular cross section, means for energizing the said one transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the said other transmission-line conductors in anti-phase therewith, and a plurality of branch conductors equal in number to one less than the plurality of transmission-line conductors completely disposed within the space between the transmission-line conductors connected at one of their ends to the said one transmission-line conductor and at their other ends to the respective other transmission-line conductors and each of length not greater than substantially one-half the said predetermined wavelength.

24. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality in excess of two of substantially parallel transmission-line conductors of length at least equal to the said predetermined wavelength, one of the transmission-line conductors being symmetrically disposed with respect to the other transmission-line conductors, the said other transmission-line conductors being of substantially circular cross section, means for energizing the said one transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the said other transmission-line conductors in anti-phase therewith, and a plurality of branch conductors equal in number to one less than the plurality of transmission-line conductors completely disposed within the space between the transmission-line conductors in a plane substantially normal thereto connected at one of their ends to the said one transmission-line conductor and at their other ends to the respective other transmission-line conductors and each of length not greater than substantially one-half the said predetermined wavelength.

25. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality in excess of two of substantially parallel transmission-line conductors of length equal to several times the said predetermined wavelength, one of the transmission-line conductors being symmetrically disposed with respect to the other transmission-line conductors, the said other transmission-line conductors being of substantially circular cross section, means for energizing the said one transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the said other transmission-line conductors in anti-phase therewith, and several branch-conductor groups each comprising a plurality of branch conductors equal in number to one less than the plurality of transmission-line conductors, the branch-conductor groups being completely disposed within the space between the transmission-line conductors in substantially parallel planes substantially normal to the transmission-line conductors spaced therealong at intervals corresponding substantially to the said predetermined wavelength, the plurality of branch conductors of each group being connected at one of their ends to the said one transmission-line conductor and at their other ends to the respective other transmission-line conductors and each of length not greater than substantially one-half the said predetermined wavelength.

26. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality in excess of two of substantially parallel longitudinally extending transmission-line conductors of length at least equal to the said predetermined wavelength, one of the transmission-line conductors being symmetrically disposed with respect to the other transmission-line conductors and each of the other transmission-line conductors having a transverse surface dimension large compared to that of the said one transmission-line conductor in order to define between the said other transmission-line conductors longitudinally extending openings of transverse dimensions small with respect to the said transverse surface dimension, means for energizing the said one transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the said other transmission-line conductors in anti-phase therewith, and a plurality of branch conductors equal in number to one less than the plurality of transmission-line conductors disposed within the said openings and connected at one of their ends to the said one transmission-line conductor and at their other ends to the respective other transmission-line conductors in order to provide radio-frequency excitation at the said openings.

27. An antenna system as claimed in claim 26 and in which the length of each branch conductor is not greater than substantially one-half the said predetermined wavelength.

28. An antenna system as claimed in claim 26 and in which each branch conductor comprises a first portion extending from the said one transmission-line conductor outward along one of the said openings and a second portion extending at right angles to the first portion and terminating upon one of the conductors of the said other transmission-line conductors.

29. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising a plurality of substantially parallel longitudinally extending transmission-line conductors of length at least equal to the said predetermined wavelength, one of the transmission-line conductors being symmetrically disposed with respect to the other transmission-line conductors and each of the other transmission-line conductors having a transverse surface dimension large compared to that of the said one transmission-line conductor in order to define between the said other transmission-line conductors a plurality of longitudinally extending openings of transverse dimensions small with respect to the said transverse surface dimension, means for energizing the said one transmission-line conductor with radio-frequency energy of the said predetermined wavelength and the said other transmission-line conductors in anti-phase therewith, and a plurality of branch conductors equal in number to the number of the said other transmission-line conductors disposed in a plane substantially normal thereto connected at one of their ends to the said one transmission-line conductor and at their other ends to the respective other transmission-line conductors in order to provide radio-frequency excitation at the said openings.

30. An antenna system for transmitting radio-frequency energy of a predetermined wavelength comprising five substantially parallel longitudinally extending transmission-line conductors of length at least equal to several times a predetermined radio-frequency wavelength, four of the transmission-line conductors being symmetrically disposed with respect to the fifth transmission-line conductor and each of transverse surface dimension large compared to that of the fifth transmission-line conductor in order to define between adjacent conductors of the four transmission-line conductors substantially equal longitudinally extending openings of transverse dimensions small with respect to the said transverse surface dimension, means for energizing the fifth transmission-line conductor with radio-frequency energy of the said predeter-

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mined wavelength and the four transmission-line conductors in antiphase therewith, several branch conductor groups each comprising four branch conductors, the branch-conductor groups being disposed in substantially parallel planes substantially normal to the transmission-line conductors spaced therealong at intervals corresponding substantially to the said predetermined wavelength, the four branch conductors of each group being connected at one of their ends to the fifth transmission-line conductor and at their other ends to the respective conductors of the four transmission-line conductors and each of length not greater than approximately one-half the predetermined wavelength in order to provide radio-frequency excitation at the said openings.

31. An antenna system as claimed in claim 30 and in which each branch conductor comprises a first portion extending from the said fifth transmission-line conductor outward along one of the said openings and a second portion extending at right angles to the first portion and terminating upon one of the four transmission-line conductors.

32. An antenna system as claimed in claim 30 and in which the said transverse dimension of each of the openings is less than one-half the said predetermined wavelength and connecting elements are provided connecting the four transmission-line conductors together at points substantially mid-way between successive branch-conductor groups in order to subdivide each of the said openings

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longitudinally into a plurality of co-planar radiating wave-transmission-loop frames of longitudinal dimension corresponding substantially to the said predetermined wavelength and of transverse dimension corresponding to less than one-half of the said predetermined wavelength.

33. An antenna system as claimed in claim 32 and in which each branch conductor comprises a first portion extending from the said fifth transmission-line conductor outward along one of the said openings and a second portion extending at right angles to the first portion substantially parallel to the connecting elements and terminating upon one of the four transmission-line conductors to excite the corresponding wave-transmission-loop frame.

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