April 8, 1952 | W. W. HANSEN | 2,591,695

HIGH-FREQUENCY RADIATOR APPARATUS AND RESONATOR

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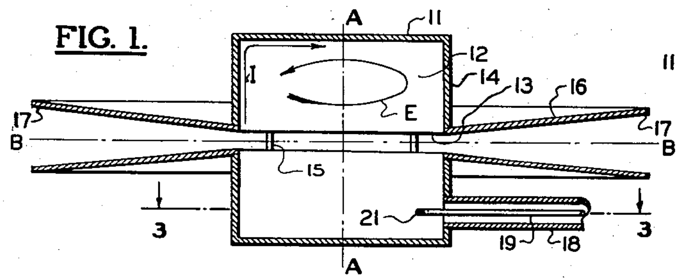
FIG. 1.



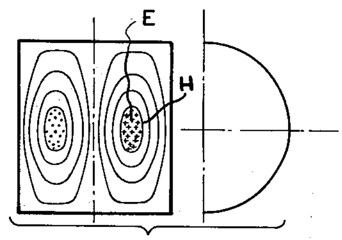
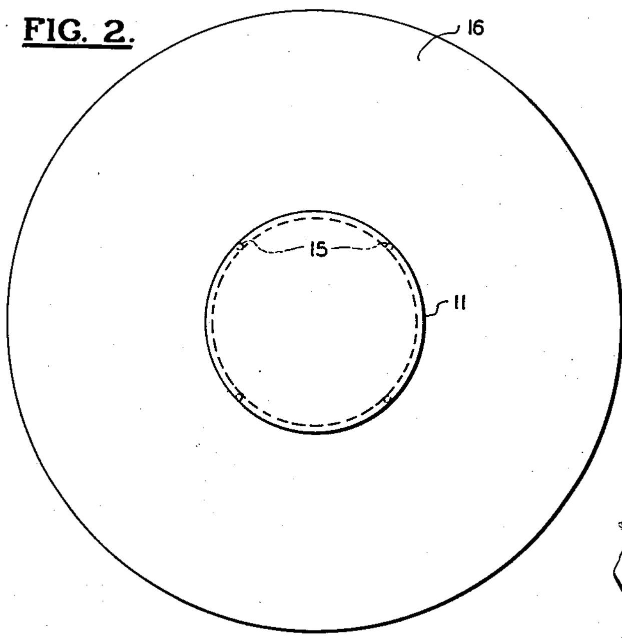


FIG. 4.

FIG. 2.



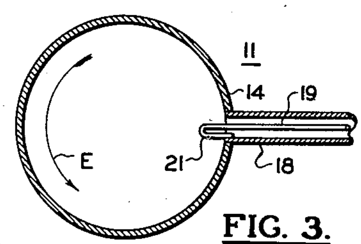


FIG. 3.

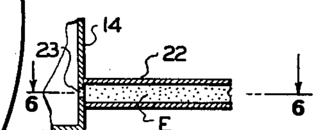


FIG. 5.

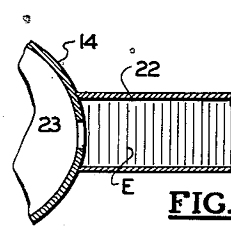


FIG. 6.

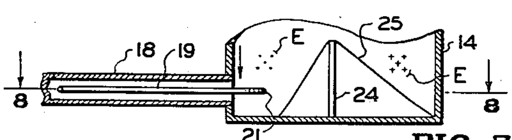


FIG. 7.

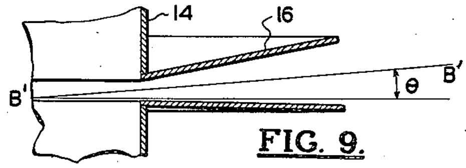


FIG. 9.

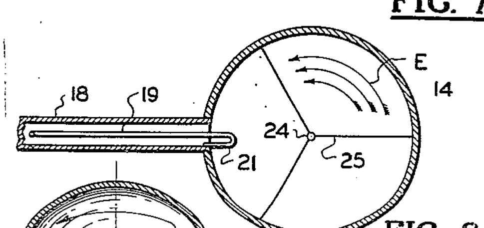


FIG. 8.

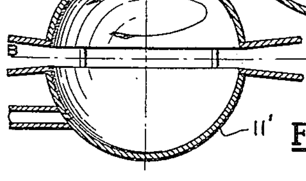


FIG. 10.

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FIG. 11.

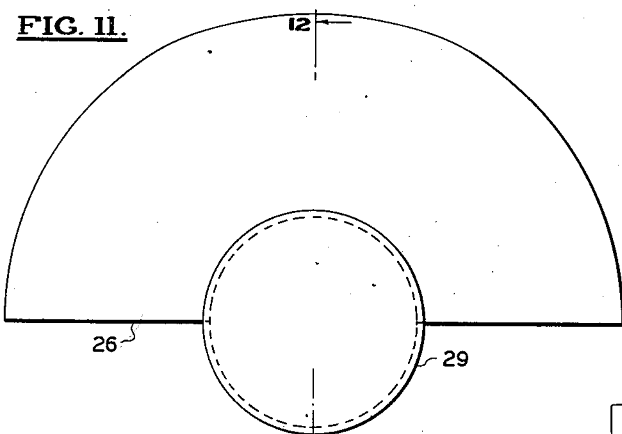
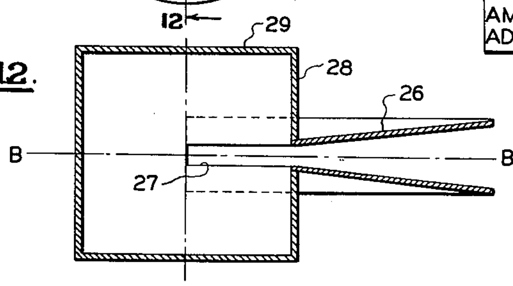


FIG. 12.



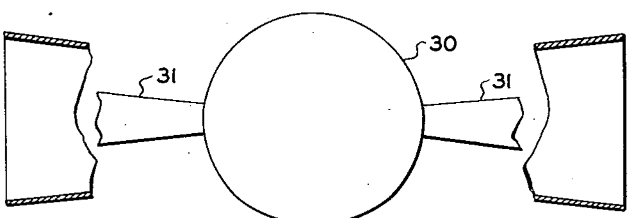


FIG. 13.

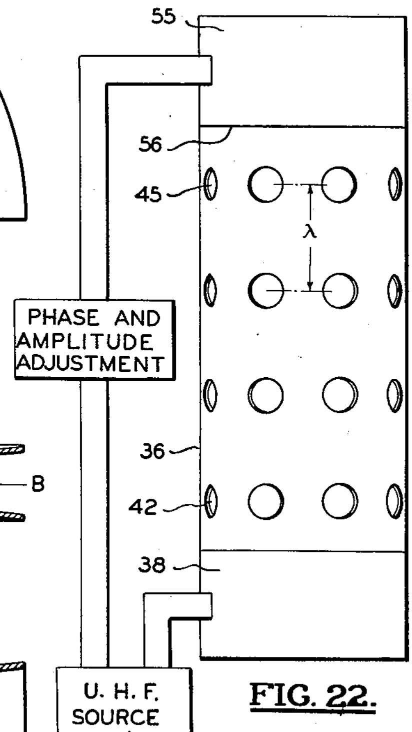


FIG. 22.

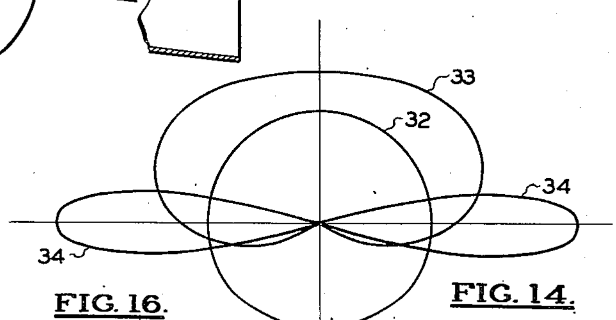


FIG. 14.

FIG. 15.

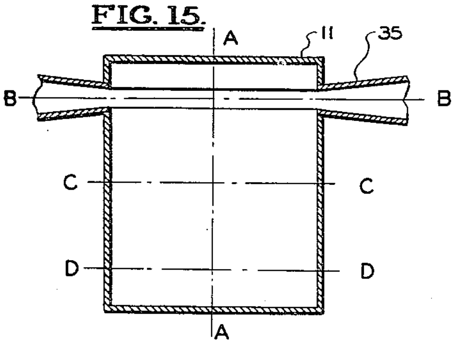
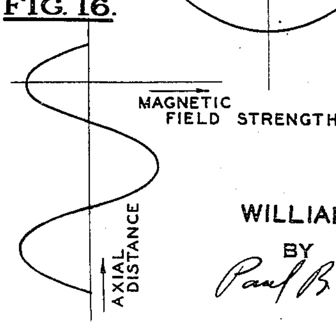


FIG. 16.



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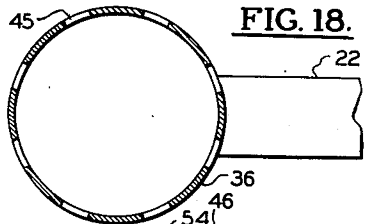

FIG. 18.

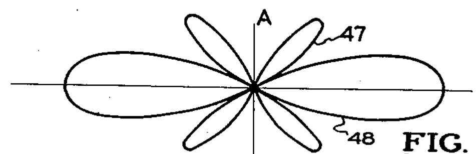

FIG. 20.

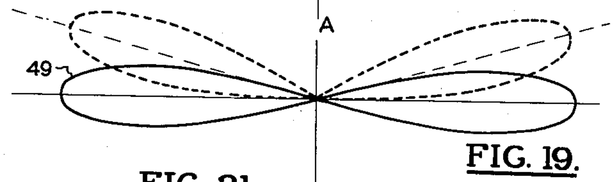

FIG. 19.

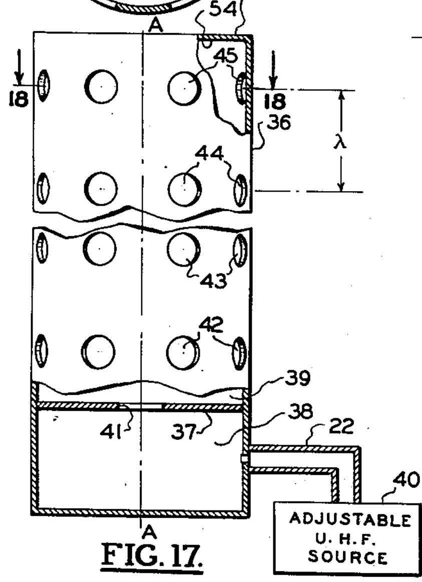

FIG. 17.

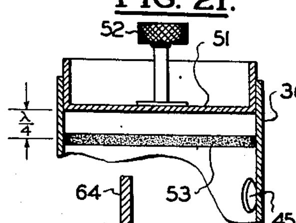

FIG. 21.

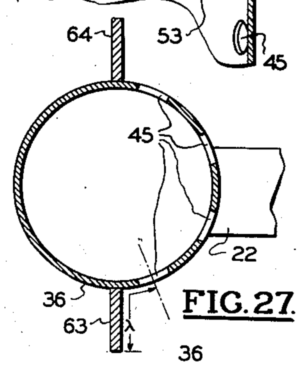

FIG. 27.

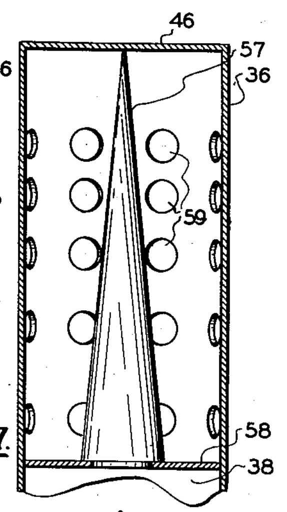

FIG. 23.

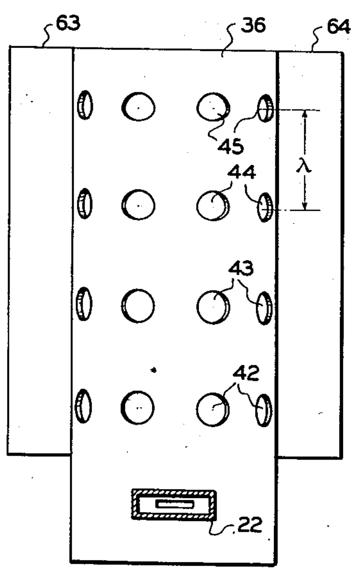

FIG. 25.

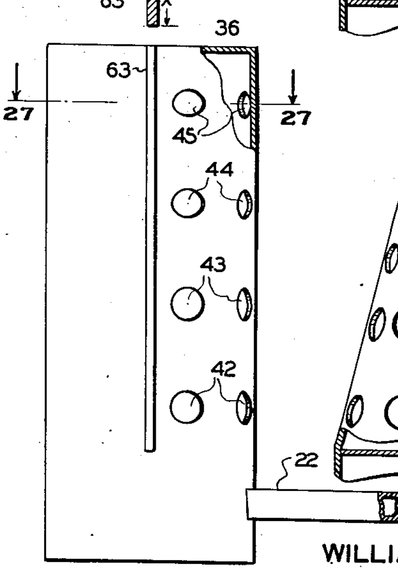

FIG. 26.

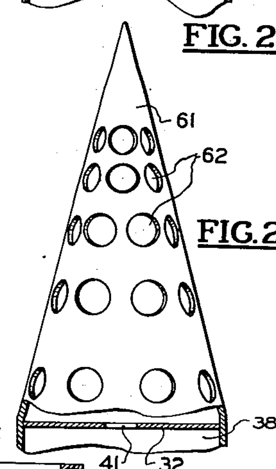

FIG. 24.

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Patented Apr. 8, 1952

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UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY RADIATOR APPARATUS AND RESONATOR

William W. Hansen, Garden City, N. Y., assignor to The Sperry Corporation, a corporation of Delaware

Application January 6, 1943, Serial No. 471,517

17 Claims. (Cl. 250—33.63)

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This invention relates to high frequency apparatus and is particularly concerned with antenna assemblies for radiating and receiving ultra high frequency electromagnetic waves and the excitation of and extraction of energy from such antenna assemblies. This application is a continuation-in-part of copending application S. N. 344,633, filed July 10, 1940, now Patent No. 2,489,288.

The invention will be described in its preferred embodiment as incorporated in an antenna assembly designed to produce a beam of ultra high frequency electromagnetic wave energy having high directivity in elevation, uniform broad directivity in azimuth, and substantially horizontal polarization. This type of beam is especially useful for warning and like signal systems operated over seas, deserts, plains or like relatively flat surfaces of the earth, as it is desirable in systems so used to employ a strong horizontally polarized uniform beam generally parallel to the earth's surface and having a wide continuous range in azimuth. Such systems do not of course require appreciable spread of the beam in elevation because of the very nature of their use, so that a large amount of energy can be concentrated in the azimuthal spread.

Examples of preferred use of such systems are between ships on the ocean, between ships and shore, and between armored vehicles in the desert.

It is therefore a major object of my invention to provide a wave guide type antenna having novel arrangements for coupling it with a generator of ultra high frequency energy.

It is another object of my invention to provide ultra high frequency apparatus comprising the novel combination of cavity resonator means enclosing an oscillating electromagnetic field, and associated antenna structure. The antenna structure proper may comprise any wave guide type antenna, such as an open ended antenna horn, or a wave guide adapted to radiate wave energy through properly arranged apertures, suitably coupled to the hollow resonator. The apparatus may alternatively be used for the radiation or reception of directional wave energy.

It is therefore also an object of my invention to provide novel antenna and associated apparatus for efficiently producing a reliable beam of electromagnetic wave energy having a relatively narrow spread in a given direction, uniform broad spread in another given direction, and polarization substantially in the plane of the broad spread. For the above-described specific purposes, such a beam has high directivity in elevation, broad and uniform spread in azimuth and horizontal polarization.

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A further object of the invention is to provide ultra high frequency apparatus wherein a hollow resonator of any suitable shape is adapted to be excited in a special mode of oscillation bearing a predetermined relation to the required directivity of associated antenna structure and the required polarization of the desired beam. Where the required directivity and polarization are horizontal, the lines of force of the oscillating electric field within the resonator are preferably horizontal. Where the resonator is a cylinder, the mode of excitation is preferably such that the oscillating electric field therein is everywhere parallel to the cylinder ends.

A further object of the invention is to provide a novel associated antenna and hollow resonator structure wherein an antenna horn is directly mounted on and coupled to be excited by the resonator.

A further object of the invention is to provide a novel associated antenna and hollow resonator structure wherein the antenna proper is an apertured hollow or dielectric filled wave guide. Preferably the resonator is coupled to excite a running wave along the guide.

It is a further object of the invention to provide a novel wave guide antenna structure embodying special shape and/or dielectric arrangements for controlling the emitted beam shape.

A further object of the invention is to provide a novel wave guide antenna having a tapered dielectric member therein.

A further object of the invention is to provide a novel wave guide antenna having tapered walls and specially arranged energy emission apertures.

A further object of the invention is to provide a novel wave guide type antenna wherein baffles are employed to control directivity of the beam.

Further objects of the invention will presently appear as the description proceeds in connection with the appended claims and the annexed drawings wherein,

Fig. 1 is an axial section illustrating in somewhat exaggerated relative proportions a resonator and antenna horn structure according to a preferred embodiment of my invention;

Fig. 2 is a top plan view of the structure of Fig. 1;

Fig. 3 is a section along line 3—3 in Fig. 1, showing a method of exciting the resonator;

Fig. 4 is a diagrammatic and graphical view associated with Fig. 1, and illustrates the preferred mode of excitation of the resonator, and the magnetic field gradient;

Fig. 5 is a fragmentary sectional elevation showing another manner of exciting the resonator of Fig. 1;

Fig. 6 is a section along line 6—6 of Fig. 5;

Fig. 7 is an axial section through the resonator of Fig. 1, and further illustrating optionally incorporated damper wires for eliminating all except the desired mode of oscillation;

Fig. 8 is a section along line 8—8 in Fig. 7;

Fig. 9 is a fragmentary elevation in section illustrating the structure of Fig. 1 provided with an antenna horn arranged at an angle to the horizontal;

Fig. 10 is a somewhat diagrammatic view illustrating a different shape of resonator which can be used in the type of assembly of Fig. 1, or in any of the embodiments of the invention.

Fig. 11 is a top plan view of a further resonator and antenna horn structure wherein the antenna extends over 180° as distinguished from 360° in Fig. 1;

Fig. 12 is a section along line 12—12 in Fig. 11;

Fig. 13 is a top plan view of still further resonator and antenna horn structure wherein 180° spaced antenna horns having low azimuthal spread are employed;

Fig. 14 is a graphical illustration and comparison of the projected high frequency beams from the structures of Figs. 1, 11 and 13.

Fig. 15 is an elevation of an antenna structure similar to Fig. 1 but operating on a higher mode of oscillation;

Fig. 16 is associated with Fig. 15 and illustrates graphically one perferred location of the antenna horn coupling;

Fig. 17 is an elevation, partly in section, of another embodiment of the invention wherein the resonator is coupled to a further form of wave guide type antenna through an axially located aperture;

Fig. 18 is a plan view along section line 18—18 of Fig. 17.

Fig. 19 is a diagrammatic elevation representation of the optimum beam form emitted by the antenna of Fig. 17 for most purposes.

Fig. 20 is a diagrammatic elevatioanl representation of another beam form which may be produced by altering certain physical characteristics of the antennae of the invention.

Fig. 21 is an elevation partly in section of a variation of the antenna structure of Fig. 17, wherein energy absorbing means is provided on the antenna;

Fig. 22 is a somewhat diagrammatical view through a further embodiment of the invention, similar to Fig. 17 but having resonators on both ends of the antenna;

Fig. 23 is an axial section illustrating a further antenna variation for the structure of Fig. 17, wherein a tapered dielectric member is disposed within the antenna chamber;

Fig. 24 is an elevation partly in section showing a conical form of antenna chamber available for the structure of Fig. 17;

Fig. 25 is a front elevation of a further form of resonator and antenna structure provided with associated aperture and baffle arrangements for obtaining and controlling the direction of radiated beam patterns.

Fig. 26 is a side elevation, partly in section, of the structure of Fig. 25; and

Fig. 27 is a section along line 27—27 in Fig. 26.

Referring to Figs. 1, 2 and 3, a hollow metallic resonator cylinder 11, which for the above-described preferred purposes is arranged with its axis A—A vertical, encloses a resonator space 12. A continuous circumferential slot 13 in the cylinder side wall 14 provides access to space 12. Since slot 13 is continuous and disposed at right angles to the axis A—A, it effectively separates cylinder 11 into two distinct parts, but these parts are rigidly interconnected by spaced insulator posts 15 so that the whole structure is effectively maintained to define a cylinder. In this embodiment of the invention, the hollow radiating wave guide type antenna comprises a continuous annular metallic antenna horn 16, which flares outwardly from a relatively narrow throat seated in slot 13 to an open mouth 17 rigidly fastened to cylinder 11. For most practical purposes the outer diameter of horn 16 may usually be considerably larger relative to the diameter of cylinder 11 than as shown in Fig. 1, so that it is to be remembered that the dimensions shown in Fig. 1 are somewhat exaggerated for purposes of illustration only and are not restrictive in any sense. The horn axis B—B, on opposite sides of which the horn walls taper substantially uniformly, is preferably disposed at right angles to axis A—A and parallel to the surface of the earth or other planar surface over which a signal is to be projected. Line B—B also indicates a reference plane representing the signal direction in elevation.

Adjacent horn 16, a coaxial transmission line, comprising a hollow outer conductor 18 and an inner conductor wire 19, extends into a suitable aperture 23 in wall 14. Conductor 18 is secured to wall 14, and wire 19 is reversely bent and secured to conductor 18. The reversely bent portion of wire 19 provides a loop 21 within space 12, which loop is arranged in a plane at right angles to the axis A—A. The size of loop 21 is selected to obtain a proper impedance match between the transmission line and resonator 11.

The purpose of the transmission line is to introduce ultra high frequency energy into resonator 11 for exciting an oscillating electromagnetic field therein in a desired mode. By arranging loop 21 at right angles to the cylinder axis, I insure a mode of oscillation in space 12 wherein the lines of electric force E are everywhere parallel to plane B—B; that is, in planes parallel to the horizontal for the preferred purposes. The conducted current flow on wall 14 within the resonator is in a plane perpendicular to axis A—A and parallel to the plane of loop 21 as shown in Fig. 1. This particular mode of oscillation of resonator 11 will be hereinafter referred to as the circular E mode.

As shown in Fig. 4, the strongest magnetic field is adjacent the longitudinal axis of the resonator 11, but it is not mechanically possible to couple the antenna horn at this region. For optimum practical results, I locate antenna horn 16 at the region where the accessible magnetic field is maximum according to Fig. 4, which is there half way along the cylinder wall. The horn 16 and coupling slot 13 may be located at any other region along the cylinder wall to obtain different degrees of coupling.

Energy introduced from the transmission line excites an oscillating electromagnetic field in the above-described circular E mode within space 12 with the lines of E in planes perpendicular to the resonator axis. This electromagnetic field loses energy through slot 13 into the antenna horn 16 which is shaped to direct it as an annular beam of desired spread in selected directions. The distance across mouth 17 determines the spread in one direction, vertical in the case taken. The circular E mode of excitation of resonator 11 insures that the electromagnetic waves in the beam broadcast by horn 16 are polarized horizontally which, as above explained, is desirable for most purposes of the invention.

The width of slot 13, parallel to axis A—A, must be chosen sufficiently large that the radiation loss through slot 13 is large compared to the ohmic loss within the metal resonator 11, for best efficiency. Also the width of slot 13 must be of optimum size for matching the impedance of horn 16 to resonator 11. It is further necessary during design to adjust the input coupling coefficient of loop 21 with the resonator to correspond with the chosen size of output slot 13 when the above considerations have been satisfied. The horn taper is preferably such that the emanating beam has a substantially planar transverse wave front.

Hence I provide a 360° spread horizontally polarized beam of high frequency electromagnetic radiant energy, which, because of the horn shape, has high directivity in elevation. This beam is useful for the above-explained desirable purposes. While resonator 11 is shown as of cylindrical shape, it may be of any suitable shape in which the above-described circular E mode can be excited. Thus it may be a spherical shell 11', as in Fig. 10, or may assume any of the other known equivalent shapes as will be apparent by reference to my earlier United States Patent No. 2,190,712.

Figs. 5 and 6 illustrate a further manner of exciting resonator 11 in the desired mode. A rectangular wave guide 22 is excited in a transverse E mode as shown, where the electric lines of force are parallel to the desired electric field direction in the resonator, here shown as horizontal. The wave guide is rigid with cylinder wall 14 and coupled to the resonator through a suitable orifice 23 in wall 14. The size of orifice 23 is designed to provide a proper impedance match between the resonator and guide 22. By introducing the exciting energy in this manner, I provide the same mode of oscillation in the resonator as in Fig. 1.

Figs. 7 and 8 illustrate a form of damper construction for insuring that the resonator is excited only in the desired mode of oscillation. An upstanding conductor post 24, preferably on axis A—A, is rigid with the bottom wall of cylinder 11. Three taut damper wires 25, each preferably of appreciable resistance, extend from the top of post 24 to spaced points on the periphery of that wall within the resonator. Wires 25 are so arranged that they are everywhere at right angles to the electric field of the mode of oscillation of Fig. 1, so that there are no currents induced in those wires by that field. However, any electric field corresponding to any other mode of oscillation within the resonator 11 will intersect wires 25 so as to induce currents therein, and the resistance of wires 25 is selected such that the energy in any other mode is entirely dissipated therein. Wires 25 therefore dampen all modes of oscillation within the resonator 11 except the desired circular E mode.

While I have illustrated plane B—B as horizontal in Fig. 1, it will be appreciated that for certain purposes it may be desirable to produce a beam everywhere directed at a slight angle to the horizontal. This may readily be done without appreciable sacrifice of any energy or beam polarization by tilting the antenna horn as shown in Fig. 9 so that its new direction axis lies

in the conical surface of revolution indicated at B'—B' which assumes an angle such as θ with the horizontal. The beam shape in general is as shown in Fig. 19 in dotted lines. I have discovered that tilting of the horn within reasonable limits does not interfere with the horizontal polarization of the beam, so that the other considerations in Fig. 1 need not be disturbed.

The azimuthal spread of the beam from the apparatus of the invention, shown as 360° in Fig. 1, may be made of any desired angular value. In Figs. 11 and 12, the beam spread is 180°, horn 26 being only one-half the size of horn 16, and slot 27 extends over only half the circumference of cylindrical wall 28 of resonator 29 corresponding to the position of horn 26.

Fig. 13 illustrates a further cylindrical resonator 30 wherein a pair of oppositely extending identical horns 31 are mounted in suitable 180° spaced slots or orifices (not shown) in the side wall of the cylindrical resonator. Horns 31 preferably have the same cross-section dimensions in elevation as horns 16 and 26, so as to have the same high directivity in elevation.

Figs. 1, 11 and 13 therefore illustrate the wide diversity of choice in azimuthal angular spread available under the invention. Fig. 14 illustrates graphically and in comparison the relative spreads and directivity of the different antenna arrangements. Circle 32 corresponds to Fig. 1, lobe 33 to Fig. 11, and lobes 34 to Fig. 13. Any other desired spread may be obtained by suitable antenna design.

In Fig. 15 the annular horn 35, which is preferably the same as horn 16 in Fig. 1, is shown as located at one of the positions available where the resonator is operated at a mode of oscillation higher than in Fig. 1. Horn 35 may optionally be located at any position along the cylinder wall, but for maximum coupling it would be located at a maximum in the magnetic field along the wall, as at B—B, C—C and D—D.

For higher modes of oscillation it is often difficult to maintain efficient operation unless the high frequency source for the exciting transmission is of constant frequency, because a small change in frequency may shift the magnetic field relative to the throat of the antenna horn. Hence, excitation of the resonator in its lowest mode is preferred as in Fig. 1, but the arrangement of Fig. 15 can be employed if the source is frequency stabilized, or if its output frequency is controlled to maximize the excitation of the resonator.

In all of the above-described embodiments an antenna horn of selected shape is coupled directly to a suitable resonator by means of an energy transferring slot through which the resonator delivers electromagnetic wave energy to the horn, and all have substantially the same principles of operation as for Fig. 1.

All of the above resonator or wave guide structures, or any individually as desired, may be filled with air, polystyrene or any other suitable dielectric material, for obtaining desired operational characteristics. It will be understood that when I refer anywhere herein to a resonator or wave guide or other space conductor, I intend to designate hollow conductor structure bounding a space containing a dielectric which may be air or any such suitable material.

Figs. 17 and 18 illustrate a further embodiment of the invention wherein the wave guide type antenna comprises a hollow cylindrical extension of the resonator side wall apertured to lose radiant energy along its length. It will be understood, however, that the resonator and antenna need not be of the same diameter, but may be of different diameters for obtaining desired characteristics.

Referring to Fig. 17, a hollow elongated right cylinder **36** of metal is separated by a transverse partition **37** arranged at right angles to the cylinder axis A—A into a resonator space **38** and an antenna space **39**. Wave guide **22**, which is the same as shown in Figs. 5 and 6, is excited in the same desired transverse E mode, here shown as horizontal, so as to produce in resonator space **38** the same circular E mode of excitation as above described for Fig. 1. Any equivalent excitation for obtaining this mode of oscillation may be employed.

Except for its absolute dimensions, and the particular manner of radiating energy to be described, the resonator defined by partition **37** and the lower end of cylinder **36** is similar in structure and mode of excitation to resonator **11** of Fig. 1. Further, as in Fig. 1, any resonator shape capable of excitation in the circular E mode may be used with antenna **36**.

Central orifice **41** in partition **37** functions somewhat similarly to annular slot **13** of Fig. 1, in that the orifice launches energy from space **38** into the antenna space **39**. The size of orifice **41** is chosen such that the energy loss into the antenna space is large compared to the ohmic loss within the resonator, and to match the impedances of the resonator and antenna.

The energy delivered from the resonator into the wave guide antenna sets up running waves inside the guide. A series of parallel circumferential rows of spaced circular apertures **42**, **43**, **44** and **45** are provided along the antenna side wall. The distance parallel to axis A—A between each row is preferably substantially one wavelength of the running wave measured within the guide. Measurement of the wavelength within the guide is essential, as the wavelength in space outside the antenna may be different than in the air-filled or dielectric filled guide. Any suitable number of rows, or spacing between the apertures of the respective rows may be employed, according to the desired design. The diameter of holes **42**—**45** must be small compared to the wavelength in the antenna.

The axial length of antenna space **39** is preferably so correlated to the outlet aperture spacing and size that all of the energy is radiated from the antenna before the running wave reaches the upper end wall **46**, so that wall **46** could very well be omitted, if desired.

Fig. 19 illustrates in elevation the optimum form of the beam radiated by the antenna of Fig. 17. The radiations from the several rows of antenna outlet apertures mutually combine through known interference phenomena to produce an annular lobe which is substantially uniform over 360° in azimuth and has high directivity in elevation.

I can, however, alter the beam in both shape and direction by variation of certain physical conditions in the antenna. For example, for some antenna sizes, where the dielectric in the antenna is air, some of the energy may be devoted to formation of secondary lobes **47** which are much weaker than the main lobe **48** as shown in Fig. 20. If these secondary lobes are unwanted, the antenna may be filled with a high dielectric constant material, such as polystyrene, whereby the wavelength in space outside the guide is made substantially equal to the wavelength inside the guide and a single main lobe **49** according to Fig. 19 is produced, which has maximum range and better directivity in elevation. The angle defined by the main lobe with the resonator axis may also be varied by varying the nature of the dielectric filling.

Similarly the direction of lobes **48** or **49**, or the formation or extinction of side lobes **47**, may be controlled by varying the longitudinal spacing between the rows of outlet apertures **42**—**45**. Equivalent effects can also be obtained by selected combinations of the above such as the combined use of a chosen dielectric filling and predetermined row spacing. The same considerations apply to beams of smaller azimuthal spread.

I have also discovered that control equivalent to varying the outlet aperture row spacing may be effected by varying the frequency of excitation of the resonator. For example, it is possible to change the beam form from the annular horizontal shape **49** in solid lines in Fig. 19 to the generally conical envelope indicated in dotted lines in Fig. 19.

Since this variation in frequency may be controlled, as by any suitable automatic means **40** for varying the resonator excitation, the device may be incorporated as an electronic scanning system wherein the beam sweeps back and forth between the solid and dotted line positions of Fig. 19.

Since the axis of the antenna of Fig. 17 is the same as the resonator, there is no alteration in the plane of polarization of the exchanged energy, so that the radiations in lobes **48** and **49** are horizontally polarized in the illustrated position of the antenna, similarly to the beam obtainable from Fig. 1. Further explanation of the general principles of operation of the apertured wave guide type of antenna of Fig. 17, if necessary, may be had by reference to my copending application Serial No. 344,633, filed July 10, 1940, now Patent No. 2,489,288, of which the instant application is a continuation-in-part.

Where it is not practical or possible to radiate all the energy from the antenna through the apertures **42**—**45**, I employ the arrangement shown in Fig. 21 for absorbing residual energy. The upper end of cylinder **36** is provided, in place of stationary conducting wall **46**, with an axially slidable wall **51** controlled by knob **52**.

An energy absorbing block **53**, which may be of carbon or the like, is disposed across the guide between wall **51** and the top row of apertures **45**. Any energy passing up the guide beyond apertures **45** is partially absorbed by block **53**. Adjustable wall **51** reflects back any energy passing beyond block **53** in such phase as to be completely absorbed thereby. When properly adjusted, wall **51** is located substantially one-quarter-wavelength from block **53**. This arrangement substantially totally dissipates any energy not radiated by the antenna.

Another arrangement which may be employed for the same general purpose is to locate a reflector on the bottom side of wall **46** as indicated at **54** in Fig. 17. In this embodiment also it is desirable to insure that the waves reflected back along the antenna wave guide are so phased as not to cancel the original waves, but to add to them. Thus the reflected waves will lose energy along the antenna in the same manner as the original waves and will soon become dissipated.

It is possible to increase the output of the antenna if necessary by providing a duplicate resonator space 55 of identical construction with space 38 at the upper end of cylinder 36 as shown in Fig. 22 for feeding the antenna. It is only essential to insure that the outputs of both resonators are so phased that the magnetic field maxima of the running waves derived from the respective resonators do not seriously oppose or cancel each other. This can be accomplished as by exciting both resonators from the same ultra high frequency source, and providing for phase and amplitude adjustment in the circuit leading to one of the resonators as shown in Fig. 22.

Fig. 23 illustrates a further form of the invention wherein the antenna encloses a solid tapered generally conical dielectric member 57 made of, for example, polystyrene, and which has its base secured to a partition 58 separating the resonator and antenna spaces. Partition 58 is centrally apertured to permit energy to be delivered from the resonator to the antenna.

The energy launched along the antenna from resonator space 38 is of continuually changing wavelength due to the nature of member 57. Hence, the spacing of the circumferential rows of outlet apertures 59 along the cylinder must be continually reduced to insure that a beam is emitted perpendicular to the axis.

Fig. 24 is a further variation of the hollow antenna structure of Fig. 17 approximately equivalent to Fig. 23. Here the antenna walls taper in substantially conical form from resonator 38, as indicated at 61. The running wave traveling toward the apex of cone 61 is of constantly changing wavelength, and the spacing between aperture rows 62 is therefore reduced toward the apex to locate rows 62 in such spacing that a beam perpendicular to the cone axis is produced.

Other arrangements of dielectric members and dielectric fillings may be employed to obtain desired antenna radiation characteristics. For example, variations in the aperture row spacing, the antenna wall shape and the dielectric filling may produce various predetermined beam patterns, with or without secondary lobes, and describing annular or conical section patterns as desired. This may be obtained by combining any of the features of Figs. 1, 17, 23 and 24.

Figs. 25–27 illustrate a further embodiment of the invention wherein the cylindrical antenna 36 has rows of outlet apertures 42—45 as in Fig. 17 but spread only over a hemicylindrical surface. A pair of diametrically aligned baffle plates 63, 64 extend from opposite sides of the antenna. As indicated in Fig. 27, the distance from tip of each baffle plate to the nearest outlet aperture, as measured along the baffle and around the guide circumference, must be a wavelength or more.

Baffle plates 63 and 64 combine to limit the azimuthal beam spread substantially to 180°. A beam spread of any desired azimuthal value can be obtained by suitable similar arrangements of baffle plates and apertures. The lower part of the cylinder in Fig. 25 comprises a resonator as in Fig. 17.

Obviously, the various forms of the invention may be employed for directive reception as well as transmission of wave energy.

While I have described the invention preferably for producing beams of horizontal polarization and direction, it will be appreciated that it is equally applicable for producing beams directed and polarized in other planes. This may be simply accomplished, for example, by locating axis A—A at any suitable angle so as to give axis B—B the desired direction.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In high frequency apparatus, a wave guide type antenna having means for producing a beam having a substantially circular spread in a selected plane, and means coupled to said antenna for feeding thereinto traveling electromagnetic waves having predetermined polarization corresponding to said selected plane said last-named means comprising means defining a hollow resonator directly coupled to said waveguide, and means for exciting said resonator in such mode of oscillation that the lines of force of the electric field therein are everywhere substantially parallel to said selected plane.

2. In high frequency apparatus, means defining a hollow resonator adapted to enclose an oscillating electromagnetic field, means for exciting said resonator in a circular E mode of oscillation, and antenna means directly coupled to said resonator for converting energy from said field into a high frequency radiant beam having a substantially uniform distribution in the plane of and a polarization substantially parallel to the electric field lines of said field.

3. In high frequency apparatus, means defining a hollow resonator, a wave guide type antenna, and means coupling said resonator and antenna for transmission of energy from one to the other said antenna comprising a hollow conductive tube apertured along its length and periphery to permit escape of electromagnetic waves in accordance with a directivity characteristic which is substantially circular in a selected plane and highly directive in a plane normal to said selected plane.

4. In high frequency apparatus, means defining a hollow resonator having an apertured wall, means for exciting said resonator so as to set up a standing wave field therein having a predetermined mode of oscillation, and a hollow wave guide type antenna means coupled to said resonator adjacent said aperture so that energy from said field is launched through said aperture and along said antenna means said antenna means comprising a circumscribing omni-azimuth open mouthed antenna horn having its throat disposed at said aperture.

5. In high frequency apparatus means defining a cylindrical resonator having an apertured wall, means for exciting waves in said resonator, and antenna means coupled to said resonator by said aperture so that axially symmetrical waves are launched therethrough and along said antenna means said aperture being located in a wall parallel to the electric field within said resonator, and said antenna means comprising a cylindrical conductor tube having a plurality of spaced parallel rows of outlet apertures.

6. In an electromagnetic wave radiator, an elongated hollow cylinder, and an axially apertured partition in said cylinder separating the cylinder into resonator and antenna chambers coupled through said aperture, said antenna chamber having apertures in the cylinder walls for broadside radiation.

7. In ultra high frequency apparatus, means defined a hollow resonator, a wave guide antenna

coupled to said resonator, means for exciting and maintaining an oscillating electromagnetic field within said resonator, and means for damping oscillation within said resonator in substantially every mode except that corresponding to a predetermined mode correlated in predetermined radiation of said antenna.

8. In ultra high frequency apparatus, a hollow wave guide type antenna apertured along its length for the escape of energy, and means for launching running electromagnetic waves into said antenna at opposite ends thereof, said waves being maintainind in predetermined relative phase.

9. In ultra high frequency apparatus, a hollow tubular wave guide antenna, a dielectric member of longitudinally varying size within said antenna, and means for launching running electromagnetic waves along said antenna, the side wall of said antenna having apertures therealong axially spaced in predetermined relation to the charging wavelength of said waves as determined by the varying size of said dielectric member.

10. A hollow tubular antenna assembly of the wave guide type having a hollow resonator coupled to one end, an adjustable reflecting wall across the other end, and energy absorbing means within the antenna adjacent said wall.

11. In a high frequency apparatus, a hollow resonator having an apertured end wall and adapted to enclose an oscillating electromagnetic field, means for exciting said resonator in a circular E mode of oscillation, a hollow wave guide type antenna means coupled to said resonator through said apertured end wall and in substantially axial alignment with said resonator for receiving therefrom a like circular E mode of oscillation, and means associated with said antenna means for radiating energy from said field as a high frequency radiant beam directed in the plane of and polarized substantially parallel to the electric lines of said field.

12. In a high frequency apparatus, a hollow resonator having an apertured end wall and adapted to enclose an oscillating electromagnetic field, means for exciting said resonator in a circular E mode of oscillation, a hollow wave guide type antenna means having a plurality of axially spaced outlet apertures permitting the radiation of energy as a high frequency radiant beam characterized by a substantially uniform spread in a selected plane and a relatively high directivity in a plane perpendicular to said selected plane, said antenna means being coupled to said resonator through said apertured end wall and in substantially axial alignment with said resonator for receiving a like circular E mode of oscillation.

13. High frequency directional apparatus comprising means for 360° radiation in a predetermined plane of high frequency energy simultaneously from a plurality of wave guide apertures arranged in a linear array, said means including resonant chamber means for producing equal phase delays between the radiation from adjacent equally spaced pairs of said radiation points, a source of high frequency energy, and means for exciting said radiation means from said source whereby upon change in frequency of said source the directivity characteristic of said apparatus is correspondingly changed.

14. An antenna of the broadside wave guide type having a multi-apertured conductive surface shaped as a figure of revolution about an axis, and encompassing a uniform dielectric having a conical volume changing along said axis.

15 An antenna of the broadside hollow wave guide type having a multi-apertured conductive surface shaped as a figure of revolution about an axis and encompassing a uniform dielectric having a conical volume changing along said axis.

16. An antenna of the broadside hollow wave guide type having a multi-apertured conductive surface shaped as a tapering conical figure of revolution about an axis encompassing a uniform dielectric.

17. In high frequency apparatus, means defining a hollow resonator, a wave guide type antenna, and means coupling said resonator and antenna for transmission of energy from one to the other, said antenna comprising a wave guide having a plurality of uniformly distributed apertures and being secured directly to said resonator at all points along its lower periphery.

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