May 1, 1962 J. L. KERR 3,032,762

CIRCULARLY ARRAYED SLOT ANTENNA

Filed Jan. 2, 1959 2 Sheets-Sheet 1

FIG. 1

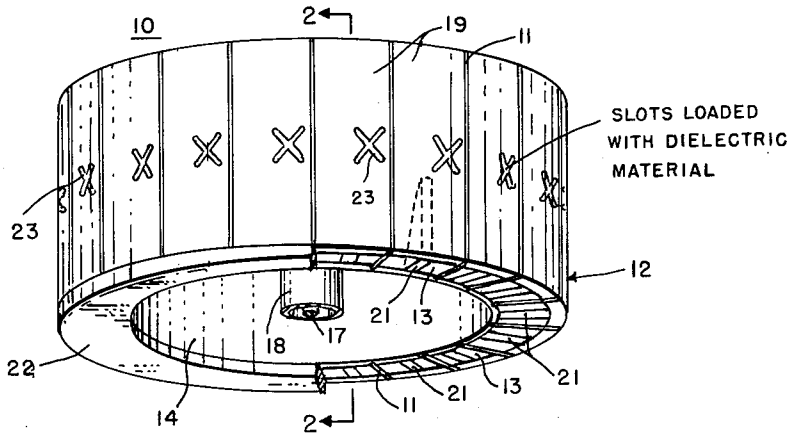


FIG. 2

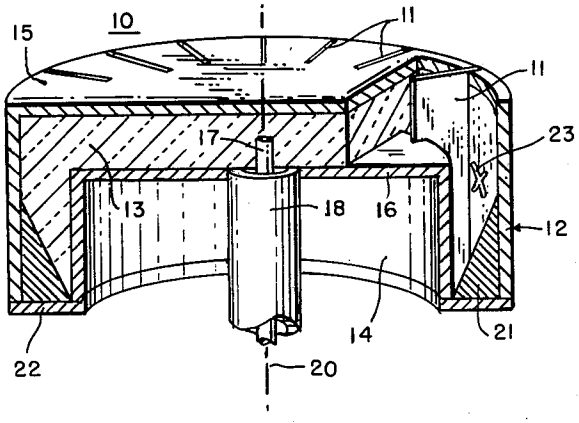


FIG. 3

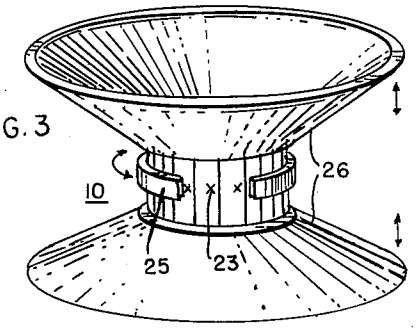
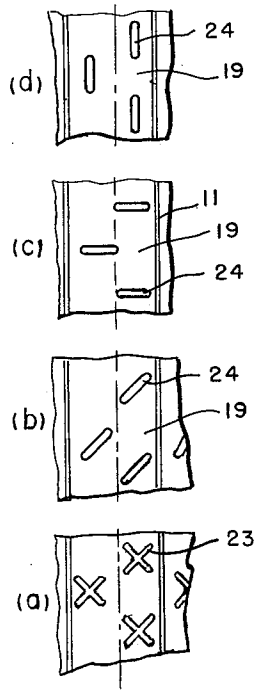


FIG. 4



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May 1, 1962 J. L. KERR 3,032,762

CIRCULARLY ARRAYED SLOT ANTENNA

Filed Jan. 2, 1959 2 Sheets-Sheet 2

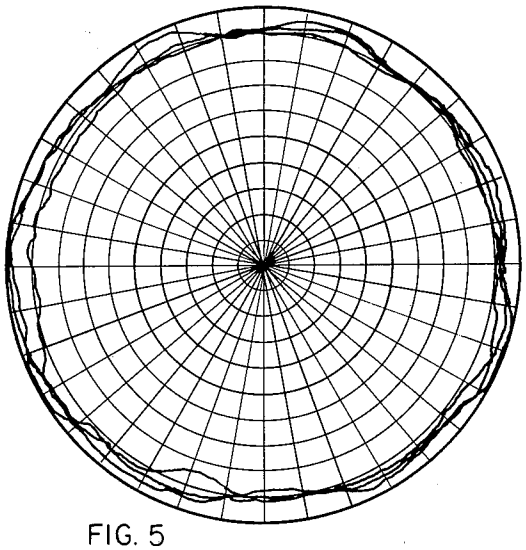


FIG. 5

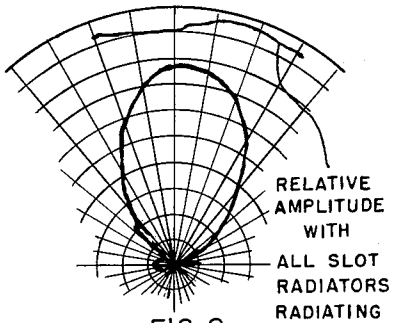


FIG. 8

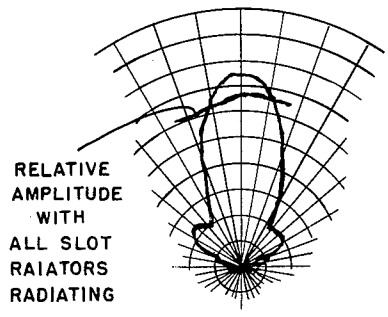


FIG. 7

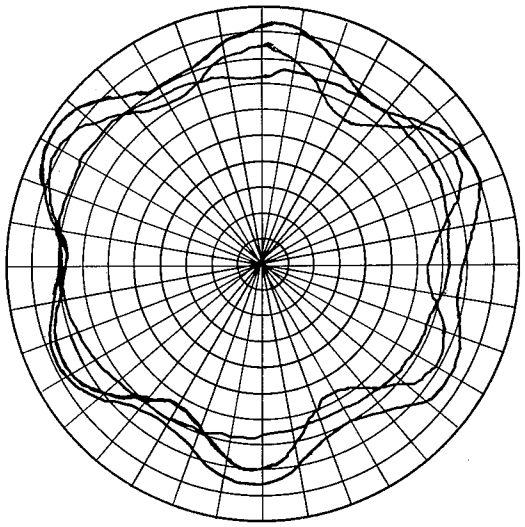


FIG. 6

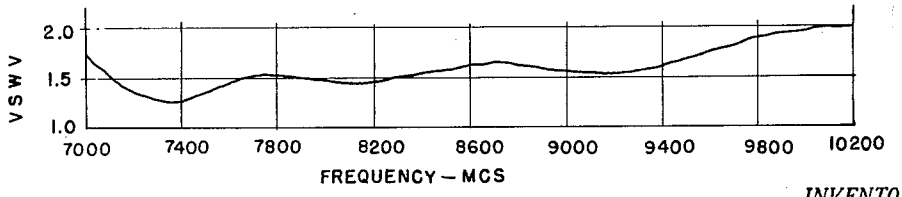


FIG. 9a

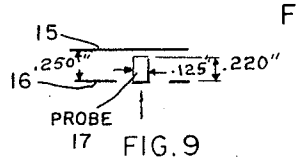


FIG. 9

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United States Patent Office 3,032,762 Patented May 1, 1962

3,032,762
CIRCULARLY ARRAYED SLOT ANTENNA

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Filed Jan. 2, 1959, Ser. No. 784,828
8 Claims. (Cl. 343—771)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

The invention relates to antenna devices and systems and particularly to such devices and systems for radiating polarized electromagnetic signal wave energy in different directions, for use in radio beacons or other microwave signaling systems.

A general object of the invention is to improve such devices and systems from the standpoint of providing the desired directional control of the radiated signal energy with apparatus which is of simple design, of relatively low cost, compact and of small size.

Another object is to provide an antenna device which is adjustable to give any one of several different types of directivity control of a radiated antenna beam.

A more specific object is to radiate polarized microwave signal energy omnidirectionally in a given plane; for example, uniformly in all horizontal directions.

Another specific object is to provide an antenna system which will radiate microwave signals with a desired polarization and in a broadly directive radiation pattern in any desired direction.

Another specific object is to provide an antenna system capable of radiating directive or shaped microwave beams in any desired direction.

These objects are obtained in accordance with the invention by an antenna structure comprising for its principal components, a parallel-plate, radial transmission line section and an array of like rectangular (or substantially rectangular), hollow-pipe waveguide sections each including one or more apertures or slots in one of its broad walls for radiating the incident wave energy in the desired polarized form. The parallel-plate, radial line section is fed at a centrally located point through a coaxial line input with the microwave signal energy to be radiated and propagates this energy outwardly and radially to the waveguide array. The individual apertured waveguide sections of the waveguide array are mounted adjacently around the circumference of the radial line section in such manner that different portions of the received signal energy in desired amplitude and phase relationships, for example with equal amplitudes and in the same phase, are respectively fed into the input of a different one of the waveguide sections and are propagated longitudinally thereover. All of the rectangular waveguide sections are oriented so that their narrow walls are disposed radially with respect to the longitudinal center line of the parallel-plate radial line, and these waveguide sections extend longitudinally in parallel with each other in a direction which is parallel to that center line. Each of the waveguide sections is terminated in an individual matched load.

In one embodimentt of the invention, each aperture or slot radiator in each waveguide section is of the conventional X-slot, circularly-polarized type and is responsive to the incident microwave energy received over that waveguide section to radiate that energy in circular polarized form into the surrounding air medium in a direction which is perpendicular to the broad wall of the waveguide section in which it is located. The wavelength spacing between the X-slot radiators in adjacent waveguide sections around the circumference of the radial line is made of the optimum value to provide the best omnidirectional radiation characteristic for the antenna structure, which is one-half of a free-space wavelength ($\lambda/2$) at the operating frequency. Each of the waveguide sections is dielectrically loaded to make the broad dimensions of the cross-section of the rectangular waveguide sections in the order of $\lambda/2$ to obtain this optimum spacing between the X-slot radiators in adjacent waveguide sections. The parallel-plate radial line section may or may not be dielectrically loaded. To compensate for undesired reduction in radiated wave power due to the limitation in slot length with reduction in the broad dimension of the cross-section of each waveguide, the X-slots are also dielectrically loaded to bring them near resonance for maximum radiated wave power. The use of the optimum wavelength spacing between the X-slot radiators, and the design of the antenna structure as described above, to insure that the circularly-polarized microwave energy radiated by each of its X-slot radiators is of the same amplitude and phase, results in a good overall omnidirectional radiation pattern in the horiozntal plane for the antenna beam.

In a modification of this first embodiment, one or more linearly-polarized slot radiators of suitable length extending in parallel with, perpendicular to, or at a 45-degree angle or other angle with respect to the longitudinal axis of the waveguide section, are employed at corresponding points in the broad walls of the adjacent waveguide sections, in place of the X-slot radiators therein, to produce linear polarization of the radiated microwave energy.

A second embodiment of the invention differs from the first embodiment in the addition of means, such as a sector of a shorting ring or other suitable wave blocking means, placed around any desired major portion of the circumference of the antenna structure in the plane of the X-slot or linearly-polarized slot radiators therein, which operates effectively to block off radiation from all of these radiators except for a small number of radiators in adjacent waveguide sections, say two or three, thereby confining radiation to the latter slot radiators and enabling a broadly directive pattern in the radiated microwaves to be attained in the general direction in which these slot radiators radiate.

A third embodiment of the invention involves the combination of the antenna structure of the first or second embodiment with a biconical horn to provide a more directive pattern for the radiated wave energy in the vertical plane.

A feature of the invention applicable to any one of the above-described embodiments thereof is a linear array of two or more X-slot or linearly-polarized slot radiators in a broad wall of each of the adjacent waveguide sections, such as to provide proper phase and amplitude distribution of the wave energy radiated thereby to give a more directive or shaped antenna beam in the vertical plane.

The various objects and features of the invention will be better understood from the following detailed description thereof when it is read in conjunction with the several figures of the accompanying drawings in which:

FIG. 1 is a front perspective view of one embodiment of an antenna device in accordance with the invention for radiating circularly-polarized microwaves omnidirectionally in a horizontal plane;

FIG. 2 is a cross-sectional view taken along the line 2—2 in FIG. 1 and partially broken away to show the internal structure of the antenna device more clearly;

FIG. 3 is a front perspective view of a second embodiment of the invention comprising the antenna device of FIG. 1 combined with auxiliary structures for adapting it to radiate circularly-polarized microwaves in a broadly

directive radiation pattern in any desired direction, or to provide a more directive radiation pattern in the vertical plane;

FIGS. 4(*a*), (*b*), (*c*) and (*d*) respectively show diagrammatically linear arrays of X-slot or linearly-polarized slot radiators of different types which could be used in accordance with the invention in the waveguide sections of the antenna device of FIG. 1 or 3 to provide a more directive or shaped pattern in the vertical plane for the radiated antenna beam;

FIGS. 5, 6, 7 and 8 respectively show different omnidirectional and directional antenna beam radiation patterns at frequencies within the X-band range actually obtained in tests of experimental models of antenna devices with structure essentially as shown in FIGS. 1 and 2 or FIG. 3 with suitable dimensions for the component elements; and

FIG. 9*a* is a curve showing the variation of voltage standing wave ratio (VSWR) with frequency in the X-band frequency range measured on an experimental model of the antenna device in accordance with the invention, in which the component elements have the dimensions indicated in FIG. 9*b*.

Referring to FIGS. 1 and 2, the embodiment of the antenna device of the invention shown therein comprises a cylindrical member **10** formed by three nesting, inverted cup-shaped members **12**, **13** and **14** of which the outer and inner cup-shaped members **12** and **14** are made from a conductive material, such as brass, and the intermediate cup-shaped member **13** from a dielectric material, such as "polystyrene." The top, horizontal plate portions **15** and **16** of the outer and inner cup-shaped members, to be referred to hereinafter as the plate **15** and plate **16**, respectively, with the inclosed space between them form a parallel-plate, radial transmission line section which is fed through a probe member **17** comprising an extension of the inner conductor of a coaxial line input section **18**, projecting through centrally-located, aligned holes in the plate **16** and the dielectric cup-shaped member **13** into the inclosed space between the plates **15** and **16** of the radial line section, for feeding the microwave energy to be radiated into that line section.

A plurality of hollow-metal pipe waveguide sections **19** of distorted rectangular cross-sections are respectively mounted at equally spaced points around the circumference of the radial line section formed by the plates **15** and **16** and the inclosed space between them, and form the outer portion of the cylindrical member **10**. The rectangular waveguide sections **19** are all oriented so that their narrow walls are disposed radially with respect to the center-line or longitudinal axis **20** of the radial line section which extends in a direction perpendicular to the planes of the plates **15** and **16** of the radial line section. The waveguide sections **19** extend longitudinally in parallel with each other in a direction which is perpendicular to the planes of the plates **15** and **16** of the radial line section and therefore in parallel with the longitudinal axis of that section. The waveguide sections **19** are terminated at their ends, near the bottom of the cylindrical member **10**, in individual matched loads **21** which as shown may be tapered pieces of a solid dielectric material, such as "Polyiron," inserted into the interiors of the waveguide sections at that point; and at their other ends, near the top of the cylindrical member **10**, connect directly with the dielectric material-filled space between the parallel plates **15** and **16** of the radial line section at respective points spaced around its circumference. As shown, the radially-disposed adjoining walls between the adjacent waveguide sections **19** may be formed by flat rectangular metal sheets or vanes **11** affixed at their upper ends to the plate **15** of the radial line section and at their lower ends to a ring-shaped retaining metal plate **22** forming the bottom of the cylindrical member **10**, and extending through radially-disposed slots in the intervening portion of the dielectric cup-shaped member **13**.

Each of the waveguide sections **19** contains at a corresponding point intermediate to the two ends of the section a circularly-polarized X-slot radiator **23** of conventional type, which, as shown, consists of two narrow slots of equal length crossed at right angles, cut into the outer broad wall of the waveguide section, that is, the wall forming a portion of the outer surface of the cylindrical member **10**, at the proper spot so that it will radiate any incident wave energy received over that section in circular polarized form outwardly into the surrounding air medium in a direction perpendicular to the plane of the broad waveguide wall in which it is located. Such X-slot or circularly-polarized slot radiators are described and their operation completely explained in the article "Circularly Polarized Slot Radiators" by Alan J. Simmons on pages 31 to 36 of the IRE Transactions on Antennas and Propagation, for January 1957. As stated in this article, such X-slot radiators have the following desirable properties:

(1) They are inherently matched, independent of slot length;

(2) When the slot arms are made resonant, approximately 75 percent of the incident wave power is radiated with a VSWR of 1.12; and

(3) When fed from one end of the waveguide, the slots radiate right-hand circular polarization; and from the other end, left-hand circular polarization.

Preferably, the center of the X-slot radiator **23** in each waveguide section **19** is located at a corresponding point halfway between one sidewall and the longitudinal center-line of the waveguide section.

The portions of the dielectric cup member **13** within the inclosed space between the plates **15** and **16** of the radial line section and extending into the interior of each of the waveguide sections **19** serve to load these sections dielectrically, which effectively enables the length of the broad dimension of the cross-section of each of the waveguide sections **19** to be reduced to a size to bring the wavelength spacing between the adjacent waveguide sections around the circumference of the radial line to the optimum value providing the best omnidirectional radiation characteristic for the antenna device, which is half of a free-space wavelength ($\lambda/2$) at the operating frequency. In order to effectively compensate for the reduction of radiated wave power with reduction in the broad dimension of each waveguide which limits the length of the X-slots, the slots themselves are also loaded with any suitable dielectric material to bring them near resonance for maximum radiated wave power.

The antenna device of FIGS. 1 and 2 operates as follows. The electromagnetic wave energy in the microwave frequency range fed into the parallel-plate radial line section through the coaxial line input **18** will be propagated outwardly and radially with its E-vector perpendicular to the planes of the plates **15** and **16** in that line section. Different portions of the energy arriving at the circumference of the radial line section which are of equal amplitude and in the same phase, will be fed into the input of each of the waveguide sections **19** and will energize them in the dominant TE_{10} mode. This energy will be propagated over these waveguide sections in a direction which is perpendicular to that of the propagated wave energy in the parallel-plate radial line section.

The matched load **21** of each waveguide section serves to substantially prevent reflections of the waveguide energy received over that section, and to prevent generation of spurious modes. The X-slot radiator **23** in each of the waveguide sections **19** in response to the microwave energy incident thereon will radiate a circular polarized wave of the same phase and amplitude for each radiator, outwardly into the surrounding air medium in a direction which is normal to the plane of the particular broad wall of the waveguide section in which it is located. Because of the selected optimum wavelength spacing of

λ/2 between the X-slot radiators and the above-described design of the antenna device which insures that the radiation from each of the X-slot radiators **23** is of same amplitude and phase, a uniform omnidirectional radiation pattern in one plane of the radiated antenna beam is obtained.

The overall size of the antenna device of FIGS. 1 and 2 may be increased or decreased to accommodate different numbers of waveguide sections **19** spaced around the circumference of the parallel-plate line section, without substantial deterioration in the omnidirectional radiation characteristic of the antenna. One experimental model which was built and tested, employing twenty X-slot radiators having an angular displacement of 18 degrees between adjacent radiators, had an outside dimention of 4.1" diameter. The actual omnidirectional radiation patterns obtained by tests on this model at an operating frequency of 9300 mcs., for horizontal, vertical and 45-degree polarization, respectively, of a linearly polarized receiving antenna, are given in FIG. 5. It will be noted that the omnidirectional characteristics obtained for this antenna are extremely uniform and the ellipticity ratio is less than 1 decibel. The radiation patterns are relative voltage plots.

Another experimental model of an antenna device in accordance with FIGS. 1 and 2, which was built and tested, having six waveguide sections each with a single X-slot radiator, spaced around the circumference of the parallel-plate radial line section, with an angular displacement of 60 degrees between the slot radiators in adjacent waveguide sections, had an outer diameter of 1.3". FIG. 6 shows the actual omnidirectional radiation patterns obtained by tests on this model at an operating frequency of 8900 mcs., for horizontal, vertical and 45-degree polarization, respectively, of the linearly-polarized receiving antenna. It will be noted from these patterns that satisfactory omnidirectional radiation characteristics and ellipticity ratio (better than 3 decibels) are obtained also with this smaller antenna device.

The antenna device of the invention shown in FIGS. 1 and 2 may be modified to include in each waveguide section an individual linearly-polarized slot radiator **24** of the type illustrated in FIGS. 4*b*, *c* or *d* disposed so that it extends in parallel with, perpendicular to, or at a 45-degree or other angle with respect to the longitudinal axis of the waveguide sections, in place of the X-slot radiator shown, at a corresponding point, in order to produce linear polarization instead of circular polarization of the radiated omnidirectional antenna beam. Also, by making the waveguide sections in the antenna structure of FIGS. 1 and 2 somewhat longer, vertical linear arrays of two or more of the X-slot radiators or of the linearly-polarized slot radiators of different types, as illustrated diagrammatically in FIGS. 4*a*, *b*, *c* and *d*, respectively, for the different types of radiators, to provide a desired phase and amplitude distribution of the radiated wave energy portions, such as can be utilized in each waveguide section to give a more directive or shaped radiated antenna beam in the vertical plane.

FIG. 3 shows an antenna structure of the general type shown in FIGS. 1 and 2 with auxiliary arrangements in accordance with the invention for modifying the radiation characteristics of the antenna directionally. One of these arrangements comprises a sector of shorting ring **25** placed around the circumference of the cylindrical member **10** in the plane of the X-slot radiators **23** and operating effectively to block radiation from all these radiators except for a small number of adjacent radiators, say two or three of them, not covered by the ring, which are maintained open to radiate the incident wave energies in respective directions perpendicular to the broad waveguide wall in which they are located. The open slot radiators in combination will radiate a microwave beam with a broadly directive radiation pattern in the general direction in which the slots radiate. For example, in an experimental model of the general type shown in FIGS. 1 and 2, with three X-slot radiators radiating and seventeen of them blocked by the shorting ring sector **25**, a radiation pattern with half power beamwidth of 32 degrees was measured. The input impedance of the antenna would be virtually unaffected by the shorting ring sector since the X-slot radiators exhibit almost reflectionless characteristics. As indicated by the curved arrows in FIG. 3, the shorting ring sector **25** can be made adjustable in either direction so that it may be utilized for blocking radiation from all the radiators except for any group of three slot radiators (or any other selected small number) in adjacent waveguide sections located in any sector around the circumference of the radial line section, and thus effectively to change the direction of the radiated microwave beam accordingly.

FIG. 7 shows an actual broadly directive radiation pattern in the horizontal direction at an operating frequency of 9300 mcs., obtained with an experimental model of the antenna device of the invention shown in FIGS. 1 and 2 equipped with a shorting ring structure such as illustrated in FIG. 3, adjusted to block radiation from seventeen X-slot radiators and to allow radiation from three adjacent X-slot radiators, for a horizontal polarization of the receiving antenna. For comparison purposes, the smaller relative amplitude of the radiated antenna beam obtained with all twenty X-slot radiators radiating is shown in FIG. 7. FIG. 8 shows the actual broadly directive radiation pattern in the horizontal direction at an operating frequency of 9300 mcs. obtained with an experimental model of the same antenna structure equipped with a sector of shorting ring similar to that illustrated in FIG. 3 but adapted to block radiation from eighteen X-slot radiators and to allow radiation from the remaining two adjacent X-slot radiators. A radiation pattern with half-power beamwidth of 52 degrees was measured. As shown in FIG. 8, in this case the relative amplitude of the radiated antenna beam is less than the relative amplitude obtained with all twenty X-slot radiators radiating.

Another possible modification of the antenna structure of the invention illustrated in FIG. 3 involves the use of a biconical horn arrangement **26** placed around the circumference of the cylindrical member **10** so that it is fed from the radiating X-slot radiators therein, and operating to provide a more directive radiation pattern of the radiated microwave beam in the vertical plane. As indicated by the vertical arrows in FIG. 3, the biconical horn arrangment could be arranged to be slid vertically in either direction along the outer surfaces of the waveguide sections to change the directivity in the vertical plane provided by this modification.

FIG. 9*a* is a curve showing the variation in voltage standing wave ratio (VSWR) over the X-frequency band from 7000 to 10,200 mcs./sec. noted by measurement with a standing wave detector in a model of the antenna structure of FIGS. 1 and 2 which was constructed. As shown in the diagram of FIG. 9*b*, the vertical distance between the plates **15** and **16** in this structure was 0.250 inch, the probe **17** (extension of inner conductor of a 50-ohm coaxial line input) supplying the microwave energy to be radiated to the radial line section had a diameter of 0.125 inch and extended into the inclosure between plates **15** and **16** for a distance of 0.220 inch. As shown, the measured VSWR was less than 2:1 over this microwave frequency range. This VSWR curve indicates that the antenna is not a narrow band device impedance-wise.

Although in the foregoing description, the antenna devices of the invention have been explained with reference to their use as transmitting devices for radiating microwave energy, it should be understood that these same devices can be employed as well to provide equivalent operations in the opposite direction for microwave re-

ceiving purposes. The invention is not limited to the precise structural arrangements illustrated and described since various modifications of these arrangements which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. An antenna device comprising a parallel-plate radial transmission line section fed at a central point with high frequency electromagnetic wave energy to be radiated, and adapted to propagate that energy outwardly and radially with respect to that point, a plurality of substantially rectangular hollow-pipe waveguides having unequal cross-sectional dimensions, mounted in a circular arrangement at respectively different spaced points around the circumference of the radial line section in such manner as to be fed therefrom respectively with different portions of this energy in a desired relative amplitude and phase, said waveguides extending longitudinally in parallel with each other in a direction which is perpendicular to the planes of the parallel plates in the radial line section so that each waveguide will propagate a different one of the received energy portions in the dominant wave mode longitudinally in that direction, said waveguides being oriented so that their narrower walls are disposed radially with respect to said central point, an individual matched load terminating each waveguide for suppressing reflections and preventing generation of spurious waves modes, and at least one slot radiator at selected corresponding points in an outer broad wall of each of said waveguides for radiating the incident wave energy received over that waveguide in a desired polarized form outwardly into the surrounding air medium in a direction normal to that wall, to provide elements of a omnidirectionally radiated antenna beam.

2. The antenna device of claim 1, in which the arrangement of said waveguides with respect to the parallel-plate radial line section is such as to cause the radiation from each of the slot radiators in each of the waveguides to be in the same phase and of the same amplitude, and the spacing between corresponding slot radiators in adjacent waveguides around the circumference of the radial line section is approximately a half-wavelength at the operating frequency in order to produce a more uniform omnidirectional radiation pattern in a given plane for the radiated antenna beam.

3. The antenna device of claim 1, in which both the parallel-plate line section and each of the waveguides are dielectrically loaded to enable the spacing between the slot radiators in adjacent waveguides around the circumference of the parallel-plate radial line section to be of the order of half a free-space wavelength at the operating frequency of the antenna device, which is the optimum spacing to give a more uniform omnidirectional radiation pattern for the radiated antenna beam, and the slot radiators are also dielectrically loaded to bring them near resonance for maximum radiated power and thereby to compensate for the reduction in radiated power due to the limitation in slot length with reduction in the broad dimension of the cross-section of each waveguide to obtain said optimum spacing between the slot radiators in adjacent waveguides.

4. An antenna system comprising in combination a parallel-plate radial transmission line section fed at a central point with electromagnetic wave energy of microwave frequencies to be radiated and adapted to propagate this energy outwardly and radially with respect to said central point, a plurality of hollow-pipe waveguides of elongated, substantially rectangular cross-section mounted at spaced points around the circumference of the radial line section in such an arrangement that the waveguide sections respectively receive therefrom different portions of this wave energy which are of the same amplitude and in the same phase and propagate the received energy portions over the respective guides in a direction which is normal to the propagation direction of the wave energy in the radial line section, an individual matched load terminating each of said waveguides, each of said waveguides being oriented so that its narrower walls are radially disposed wtih respect to said central point, a plurality of radiators of the X-slot circularly polarized type in an external broad wall of each waveguide at corresponding selected points, normally adapted to radiate the wave energy incident thereon into the surrounding air medium in a direction which is normal to the broad wall of the particular waveguide in which it is located, and adjustable wave blocking means placed around a portion of the circumference of the antenna structure in the plane of the corresponding slot radiators in the adjacent waveguides, for blocking out radiation in that plane from any desired major portion of the radiators in adjacent waveguides, and thereby providing a broadly directive radiation pattern for the beam radiated by the antenna device in the general direction in which the other slot radiators radiate.

5. The antenna system of claim 4, in which said wave blocking means comprises a sector of a shorting ring adjustably movable in either direction around the circumference of the antenna structure to cover the desired number of adjacent slot radiators to control the directivity of the radiated antenna beam accordingly.

6. Microwave energy radiating antenna apparatus of overall cylindrical shape comprising three nesting, inverted cup-shaped members of circular cross-section the inner and outer members of which are made from conductive material and the intermediate member from dielectric material, a ring-shaped plate member affixed to the bottom of said outer and inner cup-shaped members, the upper plate portions of said outer and inner members with the inclosed dielectric material-filled space between them forming a parallel-plate radial transmission line section which is supplied at a central point with the microwave energy to be radiated and is adapted to propagate this energy outwardly and radially with respect to said central point, a plurality of hollow-pipe waveguides of substantially rectangular cross-section at respective spaced points around the circumference of said radial line section respectively adapted to receive therefrom and propagate longitudinally over the respective guide different portions of the received wave energy which are of the same amplitude and in the same phase, the adjoining walls of said waveguide sections being formed by conductive plate vane members respectively extending longitudinally through radially disposed grooves in the side portions of said intermediate dielectric cup-shaped member at respectively different spaced points around the circumference of the radial line section and affixed at their upper ends to said upper plate portion of the outer cup-shaped number of the radial line section and at their lower ends to said ring-shaped plate member, said rectangular waveguides being oriented so that their narrower walls are disposed radially with respect to said central point and one of the broader walls of each guide forms a portion of the outer surface of the cylindrically-shaped antenna apparatus, and at least one slot radiator in said one broad wall of each of said waveguides for radiating the incident wave energy in the desired polarized form outwardly into the surrounding air medium and in a direction which is normal to that of the broad wall in which it is located.

7. The antenna apparatus of claim 6, in which the dielectric loading of said parallel-plate radial line section and of each of said waveguides provided by the dielectric cup portions inserted therein is utilized to enable the optimum spacing of a half-free space wavelength at the operating frequency of said antenna apparatus to be atttained, and the slot radiators in the waveguides are also loaded dielectrically to bring them near resonance for maximum radiated power.

8. The microwave energy radiating apparatus of claim 6, in which the radiators in the outer broad wall of each of said waveguides are of the X-slot circularly polarized

type, and a biconical horn arrangement is placed around the circumference of said cylindrically-shaped antenna apparatus so as to be fed from the radiators therein, and operating to provide a more directive radiation pattern of the radiated beam in the vertical plane, said biconical horn arrangement being arranged to be slid vertically in either direction along the outer surfaces of the waveguides to change the directivity in the vertical plane of the radiated beam.

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