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WAVE-GUIDE ANTENNA

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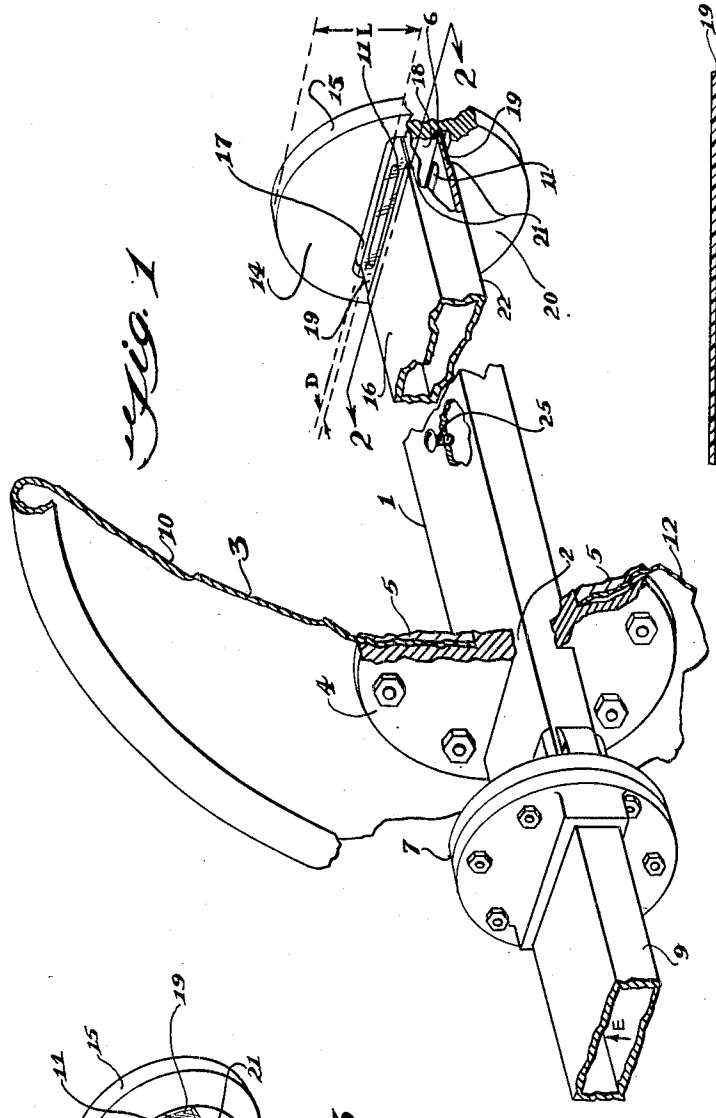


Fig. 1

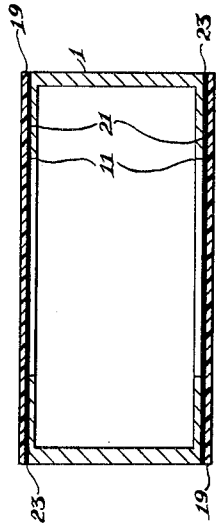


Fig. 2

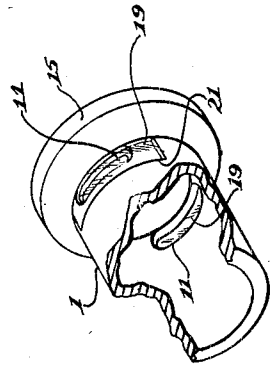


Fig. 3

INVENTOR.
LAN J. CHU
BY Rines and Rines
ATTORNEYS

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WAVE GUIDE ANTENNA

Lan J. Chu, Lexington, Mass., assignor to The Gabriel Company, Cleveland, Ohio, a corporation of Ohio

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The present invention relates to wave-guide antennas and more particularly to antennas of the type embodying a surface reflector cooperating with a slotted wave-guide structure.

Various techniques have been proposed and utilized for feeding radio-frequency energy to surface reflecting elements, such as paraboloidal reflectors. A wave-guide transmission line, for example, has been mounted through the vertex region of a paraboloidol reflector along the axis of the reflector, with the mouth of the guide terminating near the reflector focus. A secondary reflector surface positioned beyond the mouth of the guide redirects the waves propagated along the guide back upon the paraboloidal reflector, whence the waves are directed as a beam into space. This same structure has, of course, been used, also, as a device for receiving radio waves from space. In order to effect this radio-wave feeding-and-directing process efficiently, it has been proposed to terminate the wave-guide mouth, which may be of rectangular cross section, in a resonant chamber of transverse dimensions larger than the smaller wave-guide transverse dimension. Slots are provided in the surface of the resonant chamber facing the paraboloidal reflector parallel to each of the wider sides of the guide, thereby permitting energy to flow from the slots to the portions of the reflector disposed on each side of the guide, or to permit energy to pass from each portion of the reflector into the corresponding slot of the resonant chamber. Among the disadvantages of such systems, is the mechanical complexity of the structure and the difficulty in fabricating the same. It is usually customary to taper the wave guide as it joins the resonant chamber in order that the slots in the chamber may be placed close enough together with respect to the wave-length of the radio energy to appear substantially as a point source. It is quite difficult and costly, however, to provide these tapers in wave-guide structures, and it is expensive and complicated to manufacture and assemble the associated resonant chambers. A further disadvantage of such systems resides in the relatively narrow band of radio frequencies that can be used with tapered guides and resonant chambers.

An object of the present invention is to provide a new and improved antenna embodying a wave-guide transmission line of this character that shall not be subject to the above-mentioned disadvantages and that, on the contrary, is easy and less costly to manufacture, and is adapted for wide-band frequency operation. To achieve these ends, the antenna of the present invention comprises, in preferred form, a longitudinally extending imperforate wave guide within the interior of which radio waves of predetermined electric-vector polarization may be longitudinally propagated and provided near its mouth with a pair of slots communicating with the interior of the guide through oppositely disposed transverse side-wall portions of the guide substantially perpendicular to the plane of the said electric vector. A substantially planar conducting surface closes off the mouth of the guide and

extends outward beyond the said side-wall portions of the guide in a plane substantially parallel to the plane of the said electric vector and perpendicular to the longitudinal axis of the wave guide. Preferred constructional details and dimensional limits are hereinafter discussed.

A further object is to provide a new and improved slotted wave-guide structure.

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

The invention will now be described in connection with the accompanying drawings Fig. 1 of which is a fragmentary perspective view of the invention in preferred form, partly broken away to illustrate details;

Fig. 2 is a section upon a larger scale taken upon the line 2—2 of Fig. 1, looking in the direction of the arrows; and

Fig. 3 is a perspective, partly broken away, of a modification.

Referring to Fig. 1, a wave-guide transmission-line section 1 of rectangular configuration is shown passing through a rectangular hole 2 in the vertex region of a paraboloidal reflector 3 and extending along the axis of the reflector. The guide 1 is mounted in the vertex region 2 by bolting a bracket 4 secured thereto to the outer surface of the reflector 3, shown to the left in Fig. 1. An annular conducting plate 5 is mounted upon the inner surface of the reflector in the vicinity of the vertex region 2 for a purpose that will later be explained. The guide 1 may be fed with radio energy from, or may feed radio energy to, a further guide section 9, coupled to the guide 1 at the left of the reflector 3, by a conventional wave-guide flange coupling 7. The guide section 9 may be connected to a receiver or transmitter, not shown. The mouth or right-hand end 6 of the guide 1 is received in a rectangular recess 17 formed intermediately of a circular planar conducting surface or plate 15 disposed preferably at right angles to the guide 1. The base or end 18 of the recess 17 thus closes off the mouth 6 of the guide 1. Transverse planar recesses 21, preferably of rectangular shape, are formed, as by milling, in oppositely disposed side walls of the wave guide 1, illustrated as the upper and lower walls 16 and 22, near the mouth or end 6 of the guide. Transverse slots 11 are cut through the upper and lower walls intermediate the milled recesses 21 to cooperate with the inner space of the guide 1, which may be air or any other desired dielectric medium. In order to protect the slots 11 from the atmosphere and to adapt the medium within the wave guide for pressurizing, if desired, windows 19 having substantially the same dimensions as the recesses 21 are secured within the recesses 21, thereby hermetically sealing the slots 11. The thickness of the windows 19 preferably corresponds to the depth of the recesses 21 in order that the outer faces of the windows 19 may be substantially flush with the adjacent outer surfaces of the wave-guide 1. The windows 19 may be of any desired radio-wave transparent material, such as polystyrene and the like, though a preferred window is constituted of Corning Type 707 glass.

In practice, a very strong leak-proof joint between the the windows 19 of the recesses 21 must be established, sufficient to withstand from about 2½ to about 12 pounds of pressure of the medium within the guide 1. The following technique has been found particularly well suited to achieve this end, and to do so consistent with the demands of mass-production techniques. Once the recesses 21 and the slots 11 have been milled or otherwise formed in the upper and lower outer surfaces 16 and 22 of the wave-guide 1, the slots 11 are masked as with masking tape. A heat-curing thermo-setting resin 23, Fig. 2, is then applied to the unmasked surface of each

recess 21. The masks are then removed and the windows 19 are applied upon the resin 23 in the recesses 21. A strip, as of teflon, is then placed over each window 19, and a further strip of metal is placed upon each teflon strip, the assembly then being clamped together and heated to about 120 degrees centigrade. The assembly is then withdrawn from the heating unit and unclamped. Air or other gaseous bubbles that might be present in the resin layer 23 are forced out by pressing upon the windows 19. The assembly is then again clamped and heat-cured for about an hour and a half at about 180 degrees centigrade. The metal and teflon strips are then removed, leaving the windows 19 hermetically and securely locked in place within the recesses 21. The reason that the teflon strips are interposed, is that teflon will not adhere to the windows 19 should some of the resin 23 ooze out and over the windows, whereas metal would become stuck to the windows.

The depth of the conducting-surface recess 17 preferably corresponds to, just slightly less than, the distance D from the mouth 6 of the guide 1 to the edge of each slot 11 further from the reflector 3, in order that the said edge may lie substantially in the plane of the surface of the conducting plate 15, facing the reflector 3. As will later be explained, however, certain variations in the position D of the slot may be tolerated. The ends of the milled sections 21 of the guide 1 at the mouth 6 may be secured in place in the recess 17 by soft solder, the recess 17 being of somewhat larger dimensions than the transverse guide dimensions in order to permit the securing process to be effected with ease and to facilitate removal of the same, if necessary.

The operation of this system as a transmitting antenna appears to be somewhat as follows. Radio waves propagated longitudinally along the guide 1 toward its mouth 6, in, for example, the $TE_{0,1}$ mode, having vertical electric-vector polarization, represented by E, are radiated through the upper and lower slots 11, the slots lying in planes perpendicular to the electric vector. The energy radiated through the slots 11 becomes initially guided between the upper and lower outer surfaces 16 and 22 of the guide 1 and the adjacent respective upper and lower portions 14 and 20 of the plate 15. From another point of view, the slots 11 may be considered as exciting elements disposed substantially along the vertex of a pair of substantially right-angularly disposed corner guiding surfaces 14—16 and 20—22. The energy is thus directed back along the upper and lower outer surfaces of the guide 1, reflecting from the upper and lower surface portions 10 and 12 of the reflector 3, thereby being directed as a beam into space. Since the separation between the upper and lower guide side-walls 16 and 22 of a rectangular guide operated as above described can be made small compared to the wavelength of the radio energy, the slots 11 are rather close together and for all practical purposes behave substantially as a single point source, thus taking advantage of the parallel-ray focusing properties of the paraboloidal reflector 3 to produce the before-mentioned directive beam in space. The reverse process takes place in reception of energy from space.

The optimum position of the slots 11 for producing the most satisfactory undistorted major radiation lobe in the plane of the electric vector, consistent with maximum antenna gain, has been found to be that previously described, with the distance D substantially the same as the depth of the recess 17 so that the slot 11 lies just outside the plane of the inner surface of the conducting plate 15. It has been determined, however, that satisfactory, though less desirable, results can be obtained if the slots 11 are disposed somewhat closer to the paraboloidal reflector 3, though intolerable distortion of the radiation lobe pattern and loss of antenna gain has been found to occur if the slots 11 are spaced closer to the reflector 3 than about one-quarter of the wavelength of the radio energy from the position D shown in Fig. 1. It has also been determined that the transverse dimension L of the upper and lower portions 14 and 20 of the plate 15 should have a value of about one-half the said wavelength, though variations therefrom up to about three quarters of the wavelength may be tolerated. The length of the slots 11 is rather critical, though variations in the width of the slots may be effected. The position of the tuning slug 25 at a point intermediate the slots 11 and the reflector 3, and the depth of the slug penetration into the interior of the wave guide may be chosen to minimize reflections from the slot radiators 11 for specific lengths and widths of the slots. It has been found, furthermore, that this construction may compensate for such reflections, providing adequate impedance matching, over a relatively wide frequency band. The undesirable effects of that energy which is reflected from the portions of the reflector 3 back into the slots 11 may also be minimized, but with the aid of the previously described plate 5 superimposed upon the reflector 3 about the guide 1. While some energy reflected from the outer portions of the reflector 3 may re-enter the slots 11, cancellation or substantial cancellation thereof at the slots 11 has been found to occur as a result of reflections from the surface of plate 5 protruding closer to the slots 11 than the adjacent portions of the reflector 3. This effect, moreover, again takes place over a broad band of frequencies.

Not only does the above-described construction eliminate the necessity for tapering the wave guide and for providing resonant slotted chambers, but this construction is admirably suited to rapid and accurate mass-production techniques. The broad-band character of the structure, effected through the impedance matching and reflection-compensating features thereof, moreover, permits its use with many different radio-frequencies. It has been observed that this structure, in addition, illuminates or feeds the reflector aperture in such a manner as to provide most satisfactory minimal secondary lobes in the radiation pattern.

As an illustration of typical dimensions, given in units of inches instead of fractions of a wavelength, though they may easily be converted into such, a 7000-megacycle system may utilize a $TE_{0,1}$-mode-operated wave guide 1 having side walls about $\frac{1}{16}$ of an inch thick. The recesses 21 may be about $\frac{1}{32}$ of an inch deep and about $\frac{1}{4}$ of an inch wide. The slots 11 may be about $\frac{5}{10}$ of an inch long and $\frac{3}{16}$ of an inch wide and spaced about $\frac{3}{32}$ of an inch from the mouth 6 of the guide 1. The depth of the recess 17 in the conducting plate 15 may also be about $\frac{3}{32}$ of an inch for optimum results. The plate 15 may be of circular contour, about $2\frac{9}{16}$ inches in diameter.

While, as before explained, the rectangular guide 1 is particularly well-suited to the purposes of the present invention inasmuch as the height dimension, shown vertical, may be small compared to the wave length of the radio energy, so that the slots 11 may be close together, if some distortion can be tolerated, the same technique may be applied to wave guides of other configuration, such as guides that are oval in cross section. In Fig. 3, as an illustration, a circular guide 1 is shown provided with oppositely disposed arcuate recesses 21, slots 11 and windows 19, bounding sectors of a circle. The mouth of the guide 1 is closed off by a flat conducting plate 15. This termination, for purposes of illustration, is shown as a direct solder connection between the mouth of the guide 1 and the inner face of the plate 15. The same type of recessed connection at the plate 15 described in connection with Fig. 1, could, of course, be used, much as the flat termination of Fig. 2 could be used with the rectangular guide of Fig. 1. The slots 11 in the recesses 21 of the circular guide 1 of Fig. 2, may be formed almost at the periphery of the opening at the end of the guide for optimum results, as before described in connection with Fig. 1.

While the invention has heretofore been described in connection with the use of such systems as transmitting

apparatus, it is to be understood that they are equally well suited for the reception of radio waves. The slotted wave guide and end-plate structure, moreover, may find application as an antenna in and of itself, without the use of a surface reflector 3, to obtain radiation patterns of the character produced by such a slotted guide. If desired, furthermore, but a single slot may be utilized where symmetrical results are not wanted. A plurality of unsymmetrically disposed slots may also be employed, if unsymmetrical patterns are to be achieved, the plurality of slots, for example, being parallel to one another on one side only of the guide. While the slots 11 have been shown as provided with rounded ends, this is merely because a milling machine may produce such ends. It is to be understood, however, that the slots may be of strictly rectangular or other configuration and that they may be formed by punching and other processes as well. Similarly the plates 15 may be other configuration than circular. The length and orientation of the slots may also be varied depending upon the desired radiation pattern configuration. As a further illustration, the terminal slots may be provided in the narrower side walls parallel to the wave-guide axis and perpendicular to the end plate 15.

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. A longitudinally extending wave guide closed at one end having a pair of slots in oppositely disposed sides of the guide near the said end and a conducting surface disposed at substantially right angles to the said sides of the wave guide at the said end and extending transversely beyond the said sides of the guide.

2. A longitudinally extending wave guide having a pair of slots in opposite sides of the guide disposed a predetermined distance from one end of the guide and a transversely extending conducting wall provided with an intermediately disposed recess for receiving and closing off the said one end of the guide, the depth of the recess being less than the said predetermined distance, and the conducting wall extending transversely beyond the said sides of the guide.

3. A longitudinally extending wave guide, means for transmitting or receiving radio waves of predetermined electric-vector polarization in the waveguide, the wave guide being closed at one end and having a pair of slots in oppositely disposed sides of the guide substantially perpendicular to the said electric vector near the said end, and a conducting surface disposed substantially at right angles to the said sides of the wave guide at the said end and extending transversely beyond the sides of the wave guide.

4. A longitudinally extending wave guide, means for transmitting or receiving radio waves of predetermined electric-vector polarization in the wave guide, the wave guide having a pair of slots in opposite sides of the guide substantially perpendicular to the said electric vector disposed a predetermined distance from one end of the guide, and a conducting wall provided with an intermediately disposed recess for reeciving and closing off the said one end of the guide, the depth of the recess being less than the said predetermined distance, and the conducting wall extending transversely beyond the said sides of the wave guide.

5. Apparatus as claimed in claim 1 and in which the conducting surface extends transversely beyond the said oppositely disposed sides a distance corresponding to from about one-half to about three quarters of the wavelength of the radio waves propagated through the wave guide.

6. An antenna comprising a longitudinally extending wave guide within the interior of which radio waves of predetermined electric-vector polarization may be longitudinally propagated, the wave guide being provided near its mouth with a pair of slots communicating with the interior of the guide through oppositely disposed transverse side-wall portions of the guide, and a substantially planar conducting surface closing off the mouth of the guide and extending outward beyond the said side-wall portions of the guide in a plane substantially perpendicular to the said side-wall portions of the guide.

7. An antenna comprising a paraboloidal reflector and a longitudinally extending wave guide mounted through the vertex of the reflector along the axis thereof and within the interior of which radio waves of predetermined electric-vector polarization, substantially parallel to one of the wave-guide walls, may be longitudinally propagated, the wave guide being provided near its mouth with a pair of slots disposed substantially in the focal plane of the reflector communicating with the interior of the guide through oppositely disposed transverse side-wall portions of the guide substantially perpendicular to the said one wave-guide wall, and a substantially planar conducting surface closing off the mouth of the guide and extending outward beyond the said side-wall portions of the guide in a plane substantially perpendicular to the said one wave-guide wall.

8. An antenna comprising a paraboloidal reflector and a longitudinally extending wave guide mounted through the vertex of the reflector along the axis thereof and within the interior of which radio waves of predetermined electric-vector polarization, substantially parallel to one of the wave-guide walls, may be longitudinally propagated, the wave guide being provided near its mouth with a pair of slots disposed substantially in the focal plane of the reflector communicating with the interior of the guide through oppositely disposed transverse side-wall portions of the guide, a substantially planar conducting surface closing off the mouth of the guide and extending outward beyond the said side-wall portions of the guide in a plane substantially perpendicular to the said one wave-guide wall, and a conducting plate mounted about the wave guide and upon the adjacent regions of the reflector in the vicinity of its vertex.

9. An antenna as claimed in claim 7 and in which the edges of the slots further from the reflector substantially coincide with the planar conducting surface.

10. An antenna as claimed in claim 7 and in which the slots are positioned a distance corresponding to or less than about one-quarter of the wavelength of the said waves from the said planar conducting surface and the said surface extends beyond the said side-wall portions of the guide a distance corresponding to from about one-half to about three-quarters of the said wavelength.

11. An antenna comprising a paraboloidal reflector and a longitudinally extending wave guide mounted through the vertex of the reflector along the axis thereof and within the interior of which radio waves of predetermined electric-vector polarization may be longitudinally propagated, the wave guide being provided near its mouth with a pair of recesses in the outer surfaces of oppositely disposed transverse side-wall portions of the guide, a slot disposed a predetermined distance from the said end in each of the said side-wall portions of the guide at each recess, a window secured within each recess to cover the corresponding slot, and a substantially planar conducting wall provided with an intermediately disposed recess for receiving and closing off the mouth of the guide and extending outward beyond the said side wall portions of the guide in a plane substantially perpendicular to the said side-wall portions of the guide, the depth of the conducting-wall recess being less than the said predetermined distance.

12. An antenna comprising a paraboloidal reflector and a longitudinally extending wave guide mounted through the vertex of the reflector along the axis thereof and within the interior of which radio waves of predetermined electric-vector polarization, substantially parallel to one

of the wave-guide walls, may be longitudinally propagated, the wave guide being provided near its mouth with a pair of recesses in the outer surfaces of oppositely disposed transverse side-wall portions of the guide substantially perpendicular to the said one wave-guide wall, a slot disposed a predetermined distance from the said end in each of the said side-wall portions of the guide at each recess, a window secured within each recess to cover the corresponding slot, a substantially planar conducting wall provided with an intermediately disposed recess for receiving and closing off the mouth of the guide and extending outward beyond the said side wall portions of the guide in a plane substantially perpendicular to the said one wave-guide wall, the depth of the conducting-wall recess being less than the said predetermined distance, a conducting plate mounted about the wave guide and upon the adjacent regions of the reflector in the vicinity of its vertex, and a matching device inserted within the wave-guide between the reflector and the said slots.

13. An antenna as claimed in claim 11 and in which the wave guide, the side-wall recesses and windows and the planar conducting-surface recess are substantially rectangular, and the planar conducting surface is substantially circular.

14. An antenna as claimed in claim 11 and in which the wave guide and the planar conducting surface are oval and the side-wall recesses and windows are arcuate.

15. An antenna as claimed in claim 11 and in which the wave guide and the planar conducting surface are substantially circular and the side-wall recesses and windows bound substantially sectors of a circle.

16. A longitudinally extending wave guide of substantially rectangular transverse cross-section having an imperforate end wall and the oppositely disposed wider side walls of which are each provided with a transverse slot near the end wall, the side walls being imperforate except for the slots, and a planar conducting surface extending transversely beyond the said wider side walls at the said end wall.

17. A longitudinally extending wave guide of substantially rectangular transverse cross-section closed at one end and having a transverse slot in each of the wider sides of the guide near the said end, and a conducting surface disposed at substantially right angles to the wave guide at the said end and extending transversely beyond the said wider side walls to form with each of the portions of the said wider side walls near the said end a pair of diverging wave-guiding surfaces external to the wave guide.

18. A longitudinally extending wave guide as claimed in claim 1 and in which the wave guide is of substantially rectangular cross-section.

19. A longitudinally extending wave guide as claimed in claim 1 and in which the wave guide is of oval cross-section.

20. A longitudinally extending wave guide as claimed in claim 1 and in which the spacing of the said slots from the said conducting surface is substantially equal to or less than about one-quarter of the wavelength of the radio waves propagated within the wave guide.

21. A longitudinally extending wave guide as claimed in claim 1 and in which the said conducting surface has substantially planar regions and said slots are disposed adjacent the plane of the said planar regions.

22. A longitudinally extending wave guide as claimed in claim 1 and in which the said slots are disposed within recesses provided in the outer surfaces of the said oppositely disposed sides of the guide near the said end, and the slots are covered by windows secured within the said recesses.

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