Sept. 29, 1959 G. J. BROWN 2,907,033

WAVE-GUIDE ANTENNA

Filed Oct. 19, 1956

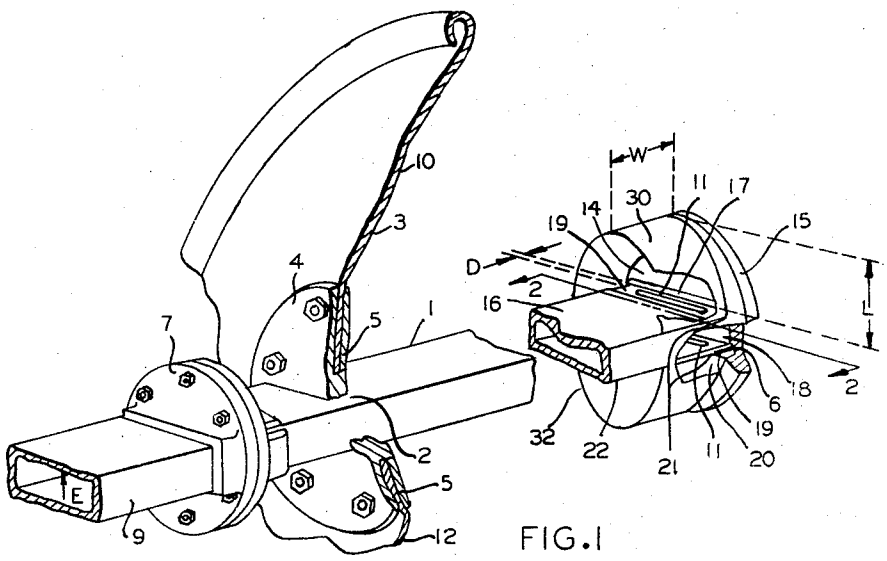


FIG.1

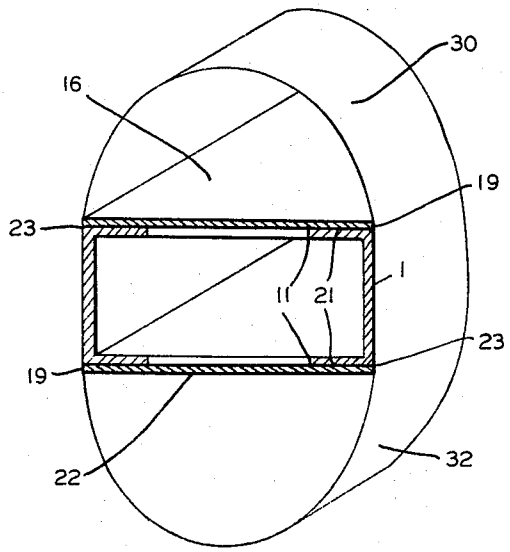


FIG.2

INVENTOR.
GERALD J. BROWN

BY Rines and Rines

ATTORNEYS

United States Patent Office 2,907,033 Patented Sept. 29, 1959

2,907,033

WAVE-GUIDE ANTENNA

Gerald J. Brown, Walpole, Mass., assignor to The Gabriel Company, Cleveland, Ohio, a corporation of Ohio

Application October 19, 1956, Serial No. 617,048

11 Claims. (Cl. 343—781)

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 paraboloidal 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.

In copending application of Lan J. Chu, Serial No. 332,839, filed January 23, 1953, now United States Letters Patent 2,778,015, issued January 15, 1957, for "Wave-Guide Antenna," there is disclosed a new and improved antenna embodying a wave-guide transmission line of this character that is not 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 comprises a longitudinally extending 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. This antenna has been found to operate very successfully in practice.

There are occasions, however, where strict limitations are placed upon the allowable magnitude of radiation side lobes. In addition, increased efficiency is sometimes demanded, namely, greater gain for the same radiation beam width. An object of the present invention, accordingly, is to provide a new and improved slotted wave-guide structure of the above-described type that provides greatly reduced side-lobe radiation and increased efficiency. In summary, this end is achieved through providing appropriate conductive chambers overlapping the before-mentioned radiating slots.

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 drawing, Fig. 1 of which is a fragmentary perspective view of the invention in preferred form, partly broken away to illustrate details of construction; and

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.

A longitudinally extending 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. 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, as explained in the said copending application, 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 pressuring, 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.

As explained in the said application, 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.

Ignoring, for the moment, the conducting-chamber surfaces 30 and 32, 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. In the absence of the chambers 30 and 32, the energy radiated through the slots 11 would become 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 would thus be 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 directed as a beam into space, as explained in the said application. 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. Undesirable effects produced by that energy which is reflected from the reflector 3 back into the slots 11 may be minimized 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, takes place over a relatively broad band of frequencies.

In accordance with the present invention, however, the slots 11 are not left free to radiate upward and downward into space as in the antenna of the said copending application. To the contrary, upper and lower hollow conductive-chamber surfaces 30 and 32 are provided extending from the upper and lower end-plate surfaces 14 and 20 back toward the reflector 3. It has been found that if, first, the length W of these chambers 30 and 32 is sufficient to overlap the slots 11 and to extend at least substantially a half-wavelength from the end plate 15, and even up to substantially three-quarters of the wavelength; and, if, secondly, the chamber height is substantially that of the dimension L of the end plate 15, an extremely beneficial result takes place. That result is the vastly improved reduction in side lobes of the radiation pattern and increased radiating efficiency. The explanation of this experimentally verified result may reside in the fact that the chambers 30 and 32 will be excited by radiation through the slots 11, acting as wave-guide radiators having substantially the same mode of electromagnetic field as the original guide 1. The radiation that normally "spills over" or is wasted when the slot radiation upward and downward is unconfined, as in the antenna of the said copending application, contributes to the production of side lobes and the diminution of energy in the primary radiation lobe or pattern. Since this slot-radiated energy is now confined to travel through the chambers 30 and 32 directly rearward toward the reflector 3, in accordance with the present invention, more energy is maintained in the primary lobe, resulting in greater efficiency and markedly reduced side-lobe radiation.

In order to simulate a point source, as before mentioned, the slots 11 may be brought closer together by reducing the height of the terminal section of the guide 1 containing the slots 11. The point of transition between the left-hand greater-dimensional guide section 1 and the said terminal section should be located sufficiently rearward of the apertures or mouths of the chambers 30 and 32 to prevent restriction of the energy directed therefrom. A guide 1 of uniform dimensions throughout, however, may be employed, if desired. The apertures or mouths of the chambers 30 and 32 may be covered with weatherproof, radio-wave permeable windows, not shown, as of polystyrene and the like.

While, in some cases, the chambers 30 and 32 might constitute merely walls of a cylinder extending rearward from the complete peripheral border of the plate 15, it is often desirable to maintain the horizontal radiation pattern relatively broad. This is achieved by limiting the maximum transverse dimension of the chambers 30 and 32 to the width of the guide 1, as by terminating the surfaces 30 and 32 at the side walls of the guide 1, as shown. Other surface configurations 30 and 32, including rectangular chambers, may also be employed, though the illustrated oval configuration has been found to operate very satisfactorily.

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. It has been observed that this structure, in addition, illuminates or feeds the reflector aperture in such a manner as to provide greatly reduced secondary lobes in the radiation pattern and increased efficiency.

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 $\frac{9}{10}$ 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 9/16 inches in diameter.

For substantially half-wavelength long chambers **30** and **32** and a six-foot parabolic reflector, moreover, extremely low-energy secondary lobes 29 and 26 decibels down, have been produced in the vertical and horizontal radiation pattern, respectively. The half-power beam widths of the principal vertical and horizontal lobes were 1.8° and 1.6°, respectively.

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, including substantially circular, in cross section.

While, moreover, 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 slot in a wall of the guide near the said end, a first conducting surface disposed at an angle to the wave-guide at the said end and extending transversely beyond the said wall, and a second conducting surface extending longitudinally from the first conducting surface back along the said wall overlapping the said slot and terminating along its side edges at the side edges of the said wall of the guide.

2. A longitudinally extending wave guide closed at one end having a slot in a wall of the guide near the said end, a first conducting surface disposed at substantially right angles to the wave guide at the said end and extending transversely beyond the said wall, and a second conducting surface extending longitudinally from the first conducting surface back along the said wall overlapping the said slot and terminating along its side edges at the side edges of the said wall of the guide.

3. A longitudinally extending wave guide closed at one end having a slot in a wall of the guide near the said end, a first conducting surface disposed at an angle to the wave guide at the said end and extending transversely beyond the said wall, and a second conducting surface extending longitudinally from the first conducting surface back along the said wall and shaped to provide a chamber having the said wall and the first conducting surface as its other bounding surfaces overlapping the said slot in order to be excited by radiation passing through the slot and terminating along its side edges at the side edges of the said wall of the guide.

4. A longitudinally extending wave guide closed at one end having a slot in a wall of the guide near the said end, a first conducting surface disposed at an angle to the wave guide at the said end and extending transversely beyond the said wall, and a second conducting surface extending longitudinally from the first conducting surface back along the said wall and shaped to provide a chamber having the said wall and the first conducting surface as its other bounding surfaces and overlapping the said slot in order to be excited by radiation passing through the slot, the dimensions of the chamber being sufficient to establish therein substantially the same wave-guide propagation mode as is established within the guide.

5. A longitudinally extending wave guide closed at one end having a slot in a wall of the guide near the said end, a first conducting surface disposed at an angle to the wave guide at the said end and extending transversely beyond the said wall, and a second conducting surface extending longitudinally from the first conducting surface back along the said wall and shaped to provide a chamber having the said wall and the first conducting surface as its other bounding surfaces and overlapping the said slot in order to be excited by radiation passing through the slot, the chamber terminating at the sides of the said wall in order to provide a chamber aperture the width of which corresponds to the width of the guide between the sides of the said wall.

6. A longitudinally extending wave guide closed at one end having a slot in a wall of the guide near the said end, a first conducting surface disposed at an angle to the wave guide at the said end and extending transversely beyond the said wall, and a second conducting surface extending longitudinally from the first conducting surface back along the said wall and shaped to provide a chamber having the said wall and the first conducting surface as its other bounding surfaces and overlapping the said slot in order to be excited by radiation passing through the slot, the chamber being of oval cross-section and terminating at the sides of the said wall in order to provide a chamber aperture the maximum width of which corresponds to the width of the guide between the sides of the said wall.

7. A longitudinally extending wave guide closed at one end having a pair of slots in oppositely disposed side walls of the guide near the said end, a first conducting surface disposed at substantially right angles to the said side walls of the wave guide at the said end and extending transversely beyond the said side walls, and further conducting surfaces extending longitudinally from the first conducting surface back along the said side walls overlapping the said slots and terminating along their side edges at the side edges of the said walls of the guide.

8. A longitudinally extending wave guide closed at one end having a pair of slots in oppositely disposed side walls of the guide near the said end, a first conducting surface disposed at substantially right angles to the said side walls of the wave guide at the said end and extending transversely beyond the said side walls, and further conducting surfaces extending longitudinally from the first conducting surface back along the said side walls shaped to provide chambers overlapping the said slots in order to be excited by radiation passing through the slots and terminating along their side edges at the side edges of the said walls of the guide.

9. A longitudinally extending wave guide closed at one end having a pair of slots in oppositely disposed side walls of the guide near the said end, a first conducting surface disposed at substantially right angles to the said side walls of the wave guide at the said end and extending transversely beyond the said side walls, and further conducting surfaces extending longitudinally from the first

conducting surface back along the said side walls and shaped to provide chambers overlapping the said slots in order to be excited by radiation passing through the slots, the chambers terminating at the sides of the said side walls of the guide in order to provide chamber apertures the width of which correspond to the width of the guide.

10. A longitudinally extending wave guide closed at one end having a pair of slots in oppositely disposed side walls of the guide near the said end, a first conducting surface disposed at substantially right angles to the said side walls of the wave guide at the said end and extending transversely beyond the said side walls, and further conducting surfaces extending longitudinally from the first conducting surface back along the said side walls and shaped to provide chambers overlapping the said slots in order to be excited by radiation passing through the slots, the chambers being of oval cross-section and terminating at the sides of the said side walls of the guide in order to provide chamber apertures the maximum width of each of which corresponds to the width of the guide.

11. A wave guide as claimed in claim 1 and in which the slot is positioned a distance from the first conducting surface corresponding to or less than substantially one-quarter the wavelength of the energy to be propagated within the wave guide, the first conducting surface extends transversely beyond the said wall of the guide a distance corresponding to from substantially one-half to three-quarters of the said wavelength, and the second conducting surface extends longitudinally a distance corresponding to from substantially one-half to three-quarters of the said wavelength.

References Cited in the file of this patent

UNITED STATES PATENTS

2,566,900	McArthur	Sept. 4, 1951
2,778,016	Chu	Jan. 15, 1957

FOREIGN PATENTS

708,614	Great Britain	May 5, 1954