

United States Patent

[11] 3,631,502

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 [73] Assignee **The Ohio State University Research**
Foundation
The portion of the term of the patent
subsequent to July 28, 1987, has been
disclaimed.

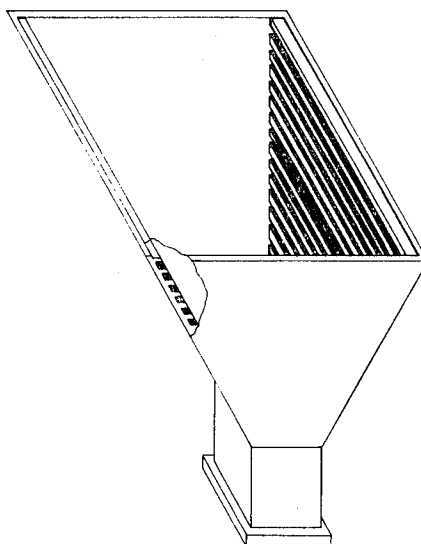
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[54] **CORRUGATED HORN ANTENNA**
5 Claims, 10 Drawing Figs.

[52] U.S. Cl..... **343/786**
 [51] Int. Cl..... **H01q 13/00**
 [50] Field of Search..... **343/786,**
840

ABSTRACT: A horn type of antenna for the propagation of electromagnetic energy having a modified structure for the reduction of backlobes and sidelobes in the radiated beam by controlling the illumination of the E-plane edges. Specifically, the control of illumination of the E-plane edges is achieved by electrically modifying the walls of the horn having an E-plane edge as an element.



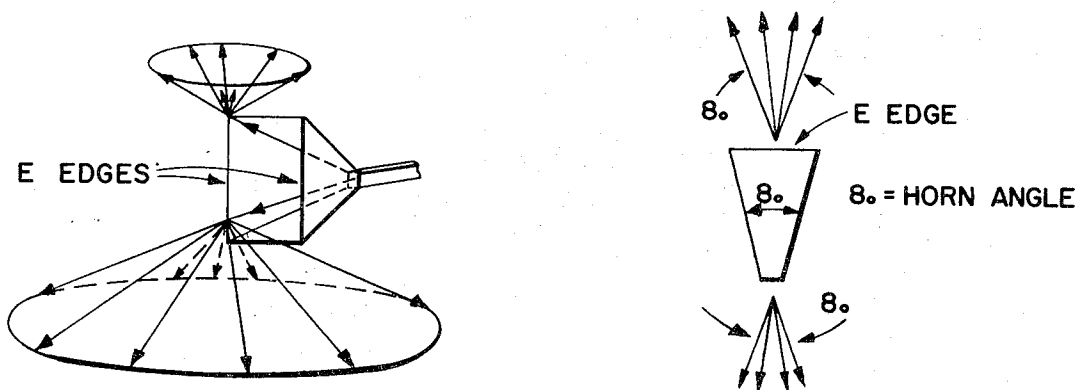


FIG. 1

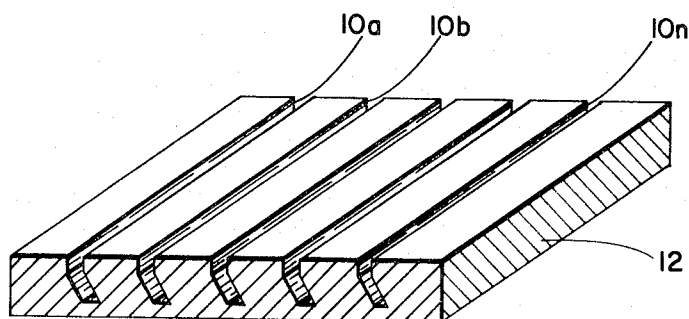


FIG. 2

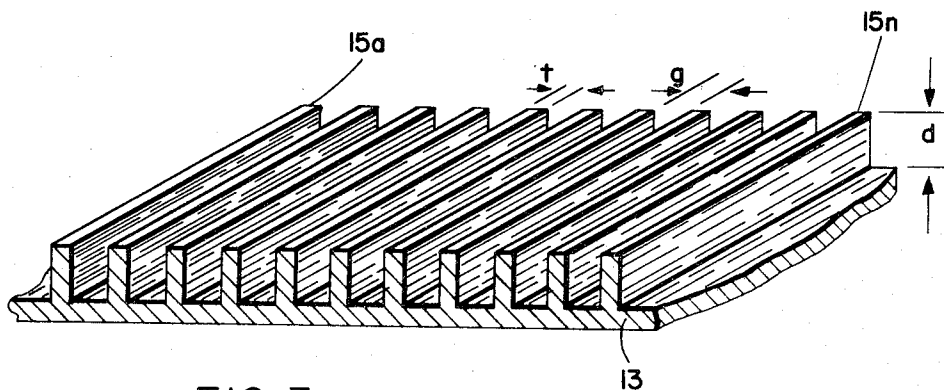


FIG. 3

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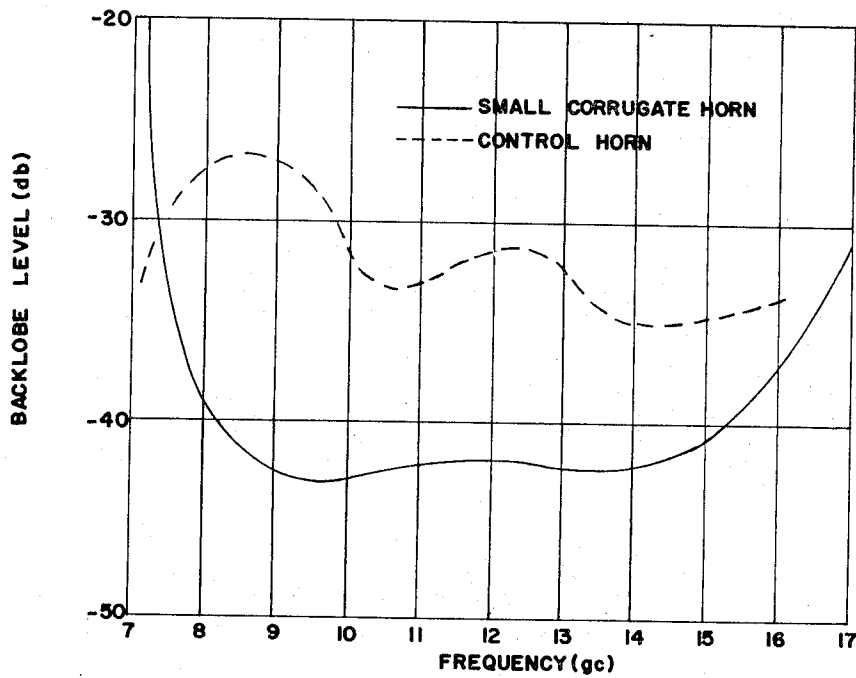


FIG. 5

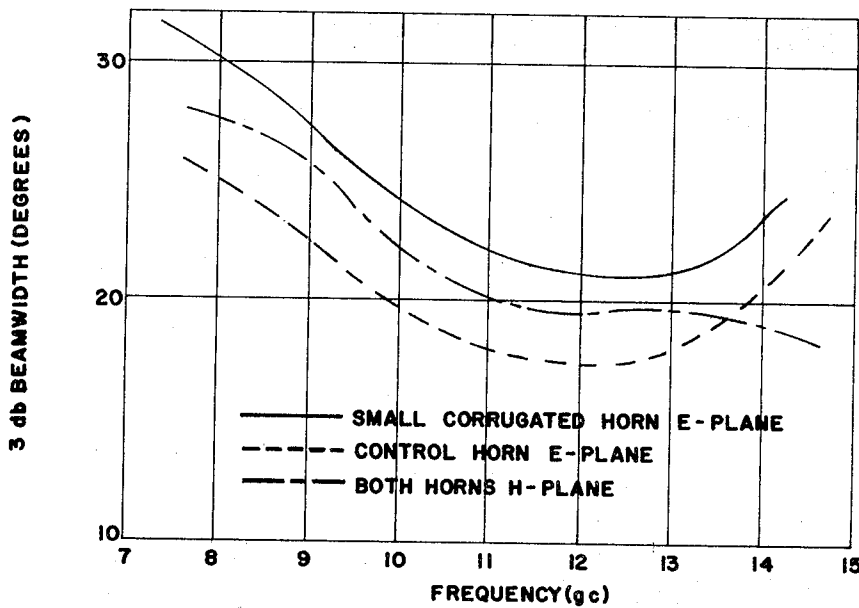


FIG. 4

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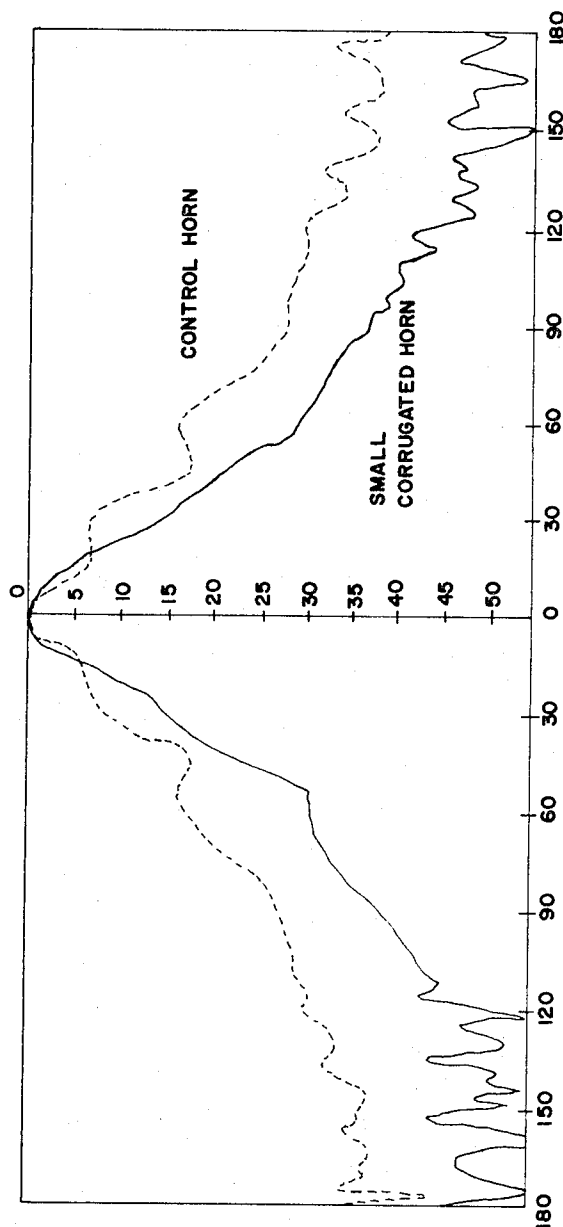


FIG. 6

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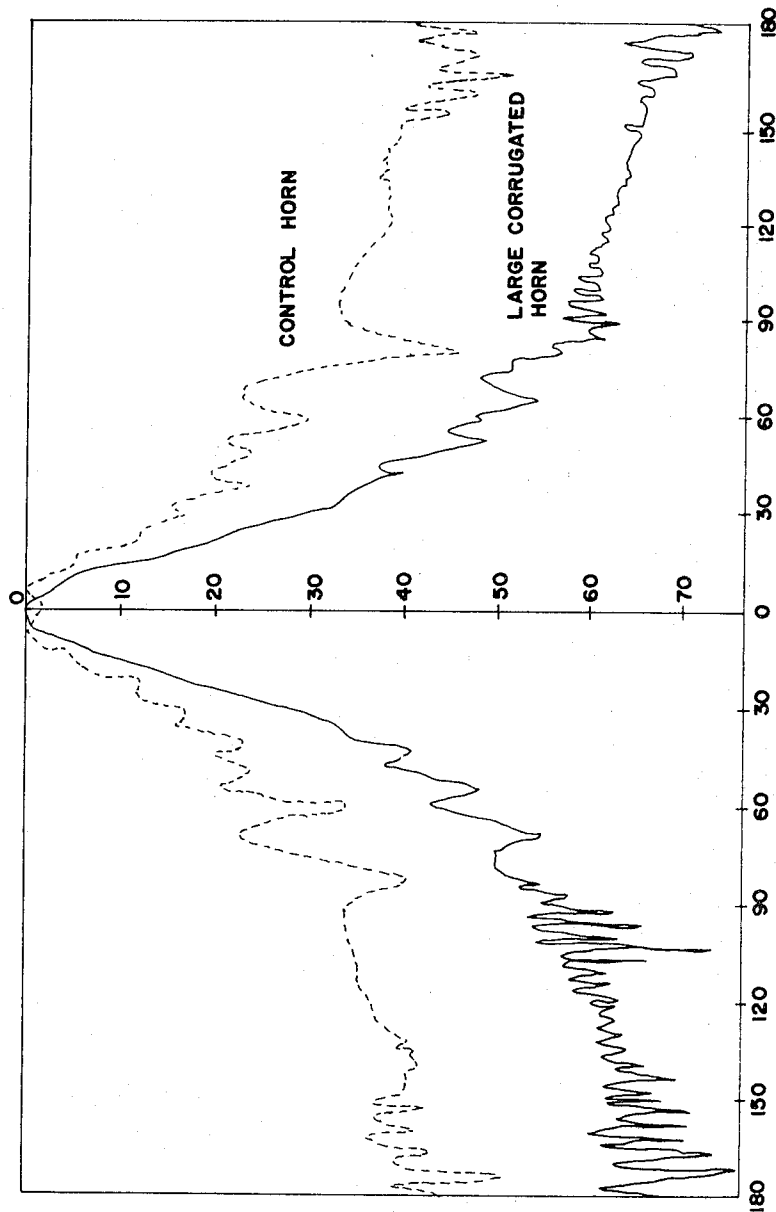


FIG. 7

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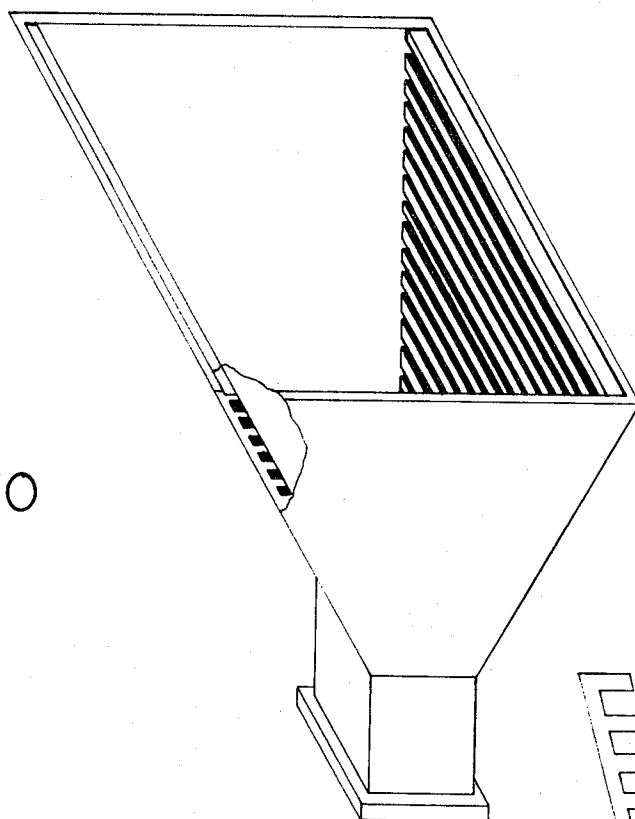


FIG. 10

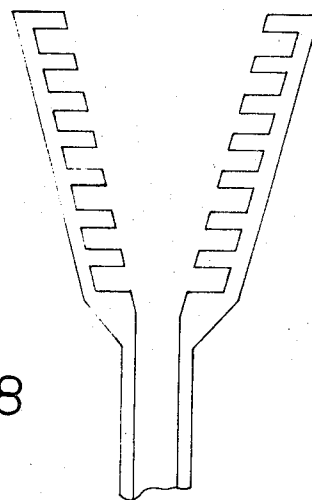


FIG. 8

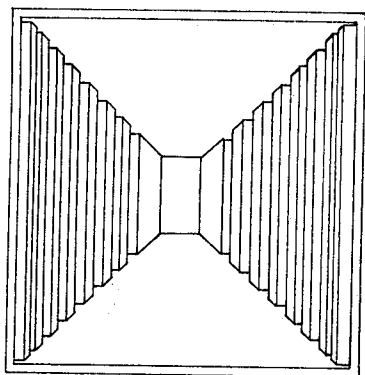


FIG. 9

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CORRUGATED HORN ANTENNA

BACKGROUND OF THE INVENTION

It is well known that most antennas have sidelobe structures which can create interference. The general problem has been reported and the sources of these sidelobes have also been described.

In a pyramidal horn antenna the electric field vector is perpendicular to one pair of aperture edges, designated as E-plane edges. It has been shown that most of the backlobe structure of a horn is due to energy diffracted by the E-plane edges of the horn. In fact, the entire E-plane pattern of a particular horn has been accurately calculated by treating the diffraction from such edges as well as the geometrical optics field.

SUMMARY

The present invention is directed to the elimination of the sidelobes and backlobes by controlling the illumination of the E-plane edges. That is, the energy is prevented from illuminating the edges from which it is diffracted into the back regions.

Specifically, the control of illumination of the E-plane edges, to eliminate the undesirable backlobes from a radiation field, is achieved by electrically modifying the walls of the horn having an E-plane edge as an element.

OBJECTS OF THE INVENTION

It is accordingly a primary object of the present invention to control the energy distribution in a radiated beam.

Another object of the present invention is to reduce the sidelobes and backlobes in the radiated beam of a horn antenna.

A further object of the present invention is to electrically modify the walls of the antenna having an E-plane edge.

Still another object of the invention is to provide means for eliminating sidelobes and backlobes from a radiated beam and which means are readily adaptable to existing structures.

Further objects and features of the present invention will become apparent from the following detailed description when taken in conjunction with the drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of the edge diffraction from a pyramidal horn antenna;

FIG. 2 illustrates the surface of a circular horn modified to include an array of bent choke slots;

FIG. 3 illustrates the surface of a horn modified in a preferred embodiment to include a corrugated surface;

FIG. 4 3 db. beamwidth of the small corrugated horn and the control horn as a function of frequency;

FIG. 5 ratio of backlobe to main lobe level of the small corrugated horn and the control horn as a function of frequency;

FIG. 6 E-plane patterns of the small corrugated horn and the control horn measured at 10 gc.;

FIG. 7 E-plane patterns of the large control horn and the large corrugated horn measured at 10 gc.

FIG. 8 is a side view schematic illustration of a horn utilizing the corrugated surface of the present invention;

FIG. 9 is an end view —looking into the throat— of a constructed embodiment of the invention; and

FIG. 10 is a perspective view of a constructed embodiment of a horn antenna utilizing the corrugated surface of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 there is illustrated the edge diffraction from a pyramidal horn antenna. The portion of the energy directly radiated from the horn throat and not diffracted by the sides of the structure results in the desired radiation pattern. Radiation due to energy incident upon the E-plane edges is diffracted into space as shown in FIG. 1. No significant similar diffraction occurs at the H-plane edges for the angles

of incidence involved. The diffracted energy from the E-plane edges results in the unwanted backlobes and sidelobes.

Illumination of the E-plane edges is prevented by electrically modifying the walls of the horn having an E-plane edge as an element. The modification may be achieved by the of three methods: by lining the walls 12 with a microwave absorber; by a series of choke slots, as shown in 10a xxx 10n of FIG. 2, cut into the walls 12; or by creating a reactive surface at the walls 13, as shown in 15a xxx 15n of FIG. 3.

The analysis of the preferred embodiment of an infinite corrugated surface, shown in FIG. 3, may be considerably simplified by making the following assumptions:

1. The slot walls (teeth) are vanishingly thin;
2. Only the TEM mode in the slots is reflected from the base of the slots. The higher order modes are attenuated before reaching the base.

The second assumption is equivalent to requiring that the slot width (g) be small compared with both the free-space wavelength and the slot depth (d). For such a surface, it is shown that the reactance of the surface is given to a good approximation by

$$(1) \quad x = \frac{g}{g+t} \sqrt{\frac{\mu}{\epsilon}} \tan k_0 d$$

provided that

$$\frac{g}{g+t} \approx 1$$

wherein

g = slot width

t = thickness of a tooth

μ = permeability of material used

E = dielectric constant of material used

k_0 = propagation factor

d = depth of slot

This condition is satisfied if $t \leq g/10$ and the second assumption is valid for $g \leq \lambda/10$

The surface reactance must be capacitive so that the surface will not support a surface wave, or, from Eq. (1) $\lambda/4 < d < \lambda/2$. Of course d may be within some odd integral multiple of this interval. It has been shown that the cutoff depth d_c depends to some extent on the slot width (g). However, curves previously derived indicate that for $g \leq \lambda/10$ the cutoff region is approximately $\lambda/4 < d < \lambda/2$.

Microwave-absorbing material applied to the walls of a horn produced a significant reduction in the backlobe level. Unfortunately, it also produced a serious reduction in the overall gain of the antenna.

The absorber lined horn comprised an X-band, pyramidal horn, 13½ inch high with a 9-inch = 9-inch aperture. A ¼-inch thick absorber was placed along the walls of the horn so that it protrudes slightly beyond the E-plane edges. The resultant pattern resulted in a 13 db. change in the beam maximum from energy loss in the absorber. Smoothing of the main beam and reduction of the backlobes with respect to the main beam was achieved as the result of the elimination of E-plane edge illumination. In any communication system, the severe loss in gain due to energy loss in the absorber would completely nullify the improvement in backlobe and sidelobe levels.

It has been shown that choke slots cut into the walls of a horn can significantly reduce the back lobe level. This arrangement satisfies the above two assumptions and yields a significant reduction in backlobe levels without a loss of overall gain but only over a narrow frequency gain.

A prior art horn antenna of FIG. 2 is a circular horn with the type of bent choke slot modified as shown in FIG. 2. The choke slots are separated by nearly half a wavelength and thus do not meet the condition of Eq. (1). Nevertheless the results obtained with this modification were impressive and the backlobes reported are approximately 34 db. below the pattern maximum at the design frequency. This feed is not as ef-

fective over as broad a frequency band as the preferred embodiment of FIG. 3, i.e., the corrugated horn and the backlobes are an order of a magnitude higher.

A small choked horn was constructed with a designed aperture $3\frac{1}{2}$ inch square and with 92° flare angle. The E-plane walls are five-eighths inch thick with four evenly spaced choke slots per wavelength. The choke slots are designed to be three-eighths wavelength deep at 10 gc. A controlling parameter for the choked horn was obtained by placing strips of aluminum tape over the chokes and painting over the chokes with silver paint. This leaves a horn with smooth thick E-plane walls whose effect on the antenna pattern has already been investigated.

The backlobe level of the choked horn is about 38 db. at the design frequency of 6.6 gc. where the choke depth is one-quarter wavelength but increases exponentially as the frequency increases. The backlobe level of the choked horn was 3 db. below that of the control horn at 12 gc. whereas it is 12 db. below the control horn at the design frequency of 6.6 gc. The performance of the choked horn is only slightly improved from that of the prior art feed.

In a first preferred embodiment a relatively small corrugated horn was constructed in accordance with FIG. 3 with $3\frac{1}{2}$ -inch square aperture having an internal E-plane wall structure of many slots per wavelength (about four times that of the choked horn, or 15 per wavelength at 10 kmc.). This new horn was designed with a flare angle of 50° to compare with small horn patterns previously assembled.

The conventional control horn for this structure was again that when the slots were covered with aluminum tape and paint. The curves of backlobe level vs. frequency for both antennas are shown in FIG. 5. From this a definite passband within which the corrugated walls have their greatest effectiveness can be seen from 8 to 14 gc. The average backlobe is found at -42 db. below the main beam and is nearly independent of frequency in this band, while the beamwidth at these frequencies ranges from 16° to 22° . The backlobe level of the control horn for these same frequencies varies, with an average of -32 db. or 10 db. above the corrugated horn.

FIG. 4 shows the 3 db. beam width-vs.-frequency curves of the corrugated horn and the control horn. The two are similar but displaced by about 4.2° . In contrast with the choked horn, the corrugations have resulted in an increase in beamwidth.

The E-plane pattern of the small corrugated horn superimposed on the E-plane pattern of the control horn is shown in FIG. 6. Both patterns were obtained at 10 gc. It is also significant that the pattern of the small corrugated horn is free of the more rapid variations seen in the pattern of the control horn. These undesirable rapid variations are typical of horn antennas.

In a second preferred embodiment a relatively large corrugated horn was constructed and tested. The horn shown in the several views of FIGS. 8, 9 and 10 comprised a thick-walled pyramidal horn having a flare angle of 34° , a height of 5.85 inches, and a 9.7 inch aperture. The corrugated surface is machined into the proper walls from within 1 inch of the throat to the mouth. The large control horn is a thick-edged horn having the same interior dimensions. The E-plane pattern of the large control horn is shown in FIG. 7. The H-plane patterns of the large corrugated horn are nearly identical to that of the large control horn and are not shown. These patterns were obtained at 10 gc.

The approximate directivity of the large control horn is $21\frac{1}{2}$ db. and hence the energy that would yield higher backlobes and hence cause interference has been converted to useful energy in main beam. The change in directivity is caused by the reduction of the E-plane beamwidth and by the removal of the saddle in the E-plane pattern of the control horn. The saddle is attributed to edge effects which are removed by the action of the corrugated surface.

The backlobe of the large corrugated horn is 57 db. below the main beam. Thus it is 27 db. better than the difference between the main and backlobes of the control horn.

Initial measurements of the E-plane pattern of the large corrugated horn indicated severe interference effects throughout the back hemisphere. It was found that the primary source of the interfering signals was leakage through the waveguide joints and components (i.e., detector, attenuator). A rearrangement of components and the judicious application of aluminum tape and metallic paint greatly reduced the interference. The remaining interference is attributed to scattering from various structures in the vicinity of the pattern range.

The use of a cutoff corrugated structure in the walls of a horn antenna have been demonstrated to be effective methods of reducing the backlobe level of the horn. The use of corrugated surfaces produces a greater improvement than the choke slots and results in an increase in beamwidth, gain and a bandwidth. The attainable reduction in backlobe level is limited by diffraction from the wedge formed by the waveguide and the wall of the horn to the edge of the opposite wall. It was found that the usable bandwidth of the modified horns is at least as great as the bandwidth of the transmission line feeding the horn.

The type of modified horns described above may find applications, such as use in pattern ranges and radar cross section ranges. The application of this type of antenna as a feed will result in a good low-temperature performance required in many modern systems, and will also be useful in the reduction of interference between various systems. Further uses for cutoff corrugated surfaces may be in screening fences for the reduction of interference and ground clutter in radar systems. Furthermore, cutoff corrugated surfaces might find application in the isolation of an antenna from surrounding surfaces, such as an air frame; however, such applications require further study.

With reference to FIG. 8 there is shown schematically an antenna horn having the above-described corrugated surfaces. In FIG. 9 there is a pictorial illustration—looking into the throat of the antenna horn—of the corrugated surface of the present invention. Also in FIG. 10 there is a pictorial illustration of the antenna horn utilizing the corrugated surface of the invention.

Although in the embodiments shown in FIGS. 8, 9, and 10, the corrugated surfaces are in the upper and lower panels (E plane), it is to be understood—as set forth above—that the invention is equally applicable with the corrugated surfaces in the side panels (H plane).

Other modifications to the embodiments shown are within the scope of the invention.

We claim:

1. An antenna including a pyramidal horn structure having a flare angle less than 90° for directing the electromagnetic energy in a given direction and wherein energy is diffracted from certain of the surfaces of said structure, the improvement comprising means for controlling the illumination of said surfaces, said means including corrugated slots formed in said surface perpendicular to the transverse E vector and the iris of said horn; wherein the depth of said slots is defined by

$$\frac{\lambda}{4} < d < \frac{\lambda}{2}$$

and the slot width and spacing is defined by

$$g + t < \frac{\lambda}{10}$$

with t much less than g , where g is the slot width and t is the wall thickness of the corrugations.

2. An antenna as set forth in claim 1 wherein said slot corrugated surface further comprises corrugations protruding into said structure to create a reactive surface.

3. An antenna as set forth in claim 2 wherein said slot corrugations are vanishingly thin and wherein the energy reflected from the base of the slots is limited to the TEM mode.

4. An antenna as set forth in claim 1 wherein the reactance of said corrugated slot is given by

$$x = \frac{g}{g+t} \sqrt{\frac{\mu}{\epsilon}} \tan k_0 d$$

5

where

g = spacing between corrugations

t = wall thickness of corrugations

d = depth of corrugations

and wherein

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$$\frac{g}{g+t} \approx 1$$

5. An antenna as set forth in claim 1 wherein the walls of
5 said corrugated slots are vanishingly thin.

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