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[54] **APPARATUS FOR PROVIDING HIGHER ORDER MODE COMPENSATION IN HORN ANTENNAS**

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Related U.S. Application Data

[62] Division of Ser. No. 360,577, May 15, 1973, abandoned.

[52] **U.S. Cl.** **343/786**

[51] **Int. Cl.** **H01q 13/00**

[58] **Field of Search** 343/786

[56] **References Cited**

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[57] **ABSTRACT**

The unwanted higher order mode power that occurs in flared antenna horns is compensated for by inserting flare sections into the antenna horn feed structure. The feed structure flares also generate higher order mode power and are positioned and constructed in such a manner that the higher order mode power so generated is substantially equal to and in phase opposition with the higher order mode power occurring in the antenna horn. Various embodiments utilize single outward, double outward and double inward flares.

2 Claims, 3 Drawing Figures

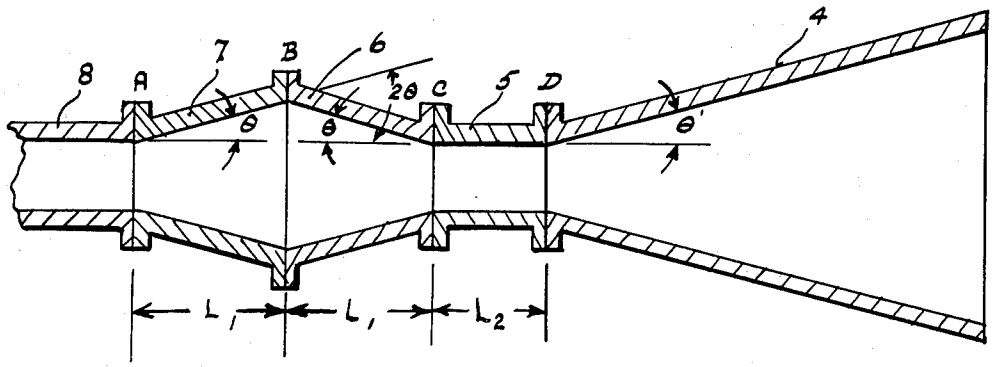


FIG. 1

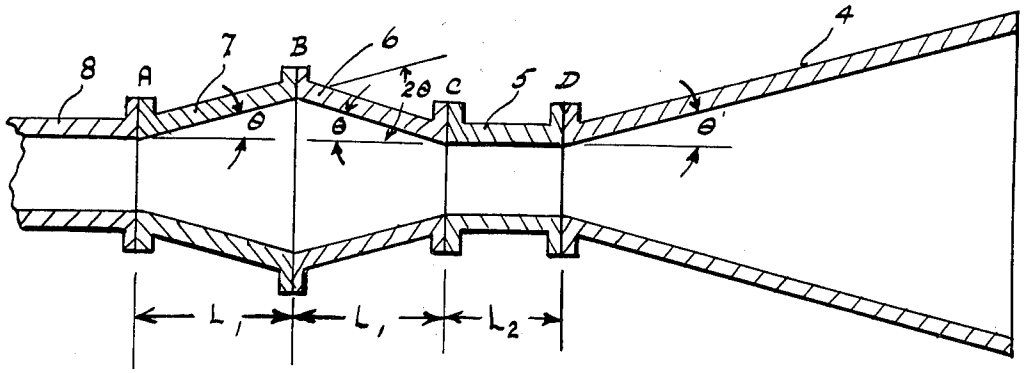


FIG. 2

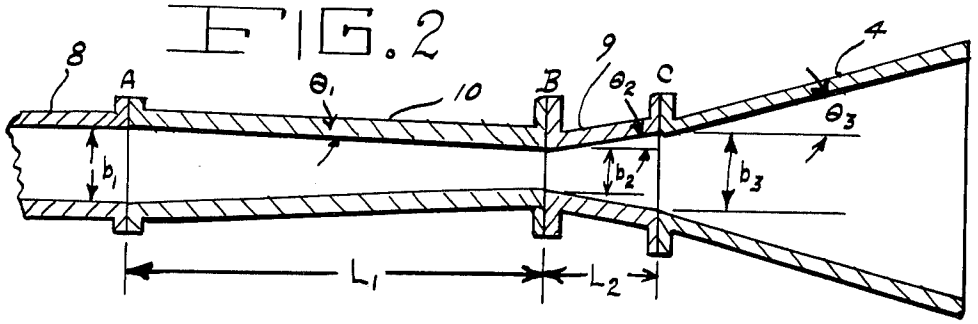
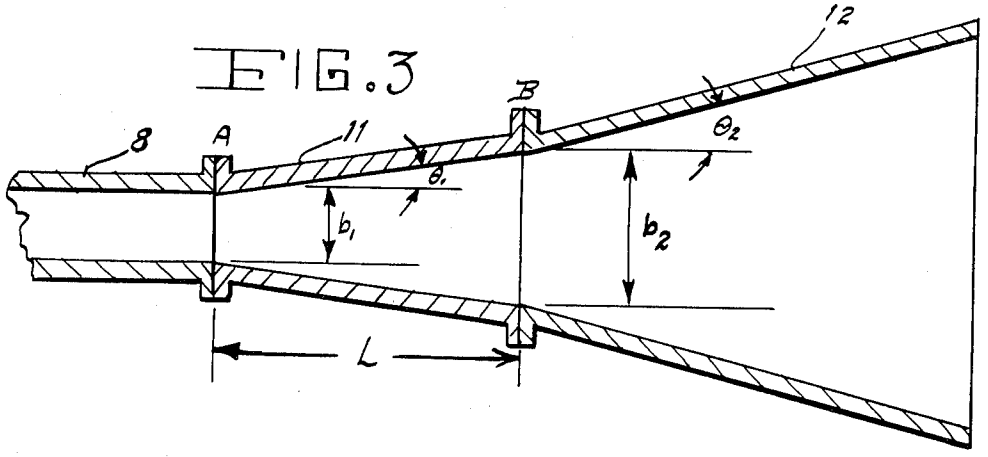


FIG. 3



APPARATUS FOR PROVIDING HIGHER ORDER MODE COMPENSATION IN HORN ANTENNAS

This is a division of application Ser. No. 360,517 filed May 15, 1973, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to microwave antenna horns, and more particularly to a method and means for eliminating the unwanted higher order mode power that results from the flared geometry of such antenna horns when fed from oversized waveguide.

The use of a flared rectangular antenna horn with oversized rectangular waveguide results in the generation of unwanted higher order mode power in the horn throat. For example, LSE_{12} mode power is formed in the horn throat due to a horn's E-plane flare geometry. This higher order mode power may radiate so as to make the first or other sidelobe of the overall antenna pattern higher relative to the beam peak than the pattern carried by the dominant TE_{10} mode. Accordingly, there currently exists the need for a method and means for reducing the magnitude of these sidelobes. The problem is further complicated in certain applications in which horn redesign, excessive feed circuit length, or reduced power handling capacity are not tolerated.

The present invention is directed toward satisfying such a need. The invention also provides various alternative embodiments that permit the selection of an appropriate higher order mode compensation device for any particular application.

SUMMARY OF THE INVENTION

The basic concept of the invention comprehends forming the correct amount of the higher order mode power to be compensated for by means of flares located in the antenna feed circuit and bringing it to the point in the horn throat where the unwanted higher order mode power is formed in the correct phase so that cancellation occurs.

A first embodiment of the invention utilizes double outward E-plane flares. It can be used with an E-plane flared rectangular horn and oversized rectangular waveguide and requires a 1½ wavelength extension of the feed circuit.

A second embodiment of the invention utilizes double inward E-plane flares. It can also be used with an E-plane flared rectangular horn and oversized rectangular waveguide. It is, however, limited in peak power handling capacity.

A third embodiment of the invention utilizes a single outward E-plane flare and when used with oversized rectangular waveguide requires redesign of the antenna horn. It has no peak power handling limitation and increases the feed circuit length by only one-half wavelength.

The same principles can be used to compensate H-plane flared rectangular antenna horns, or horns flared in both planes (i.e., pyramidal). They may also be used to compensate horns which are rectangular in cross-section at the throat and change to circular between the throat and the mouth.

It is a principal object of the invention to provide new and improved methods and means for eliminating unwanted higher order mode power in E-plane and H-plane flared rectangular antenna horns.

It is another object of the invention to provide a higher order mode compensated antenna that utilizes oversized waveguide and a conventional E-plane or H-plane flared antenna horn.

It is another object of the invention to provide a higher order mode compensated antenna that utilizes oversized waveguide and a conventional E-plane or H-plane flared antenna horn.

It is another object of the invention to provide a higher order mode compensated antenna that does not require excessive feed structure length.

It is another object of the invention to provide a higher order mode compensation for an E-plane or H-plane flared horn antenna without limiting its peak power handling capability.

These, together with other objects, advantages and features of the invention will become more apparent from the following detailed description when taken in conjunction with the illustrative embodiments in the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view of an embodiment of the invention employing double outward E-plane flares;

FIG. **2** is a section view of an embodiment of the invention employing double inward E-plane flares; and

FIG. **3** is a section view of an embodiment of the invention employing a single outward E-plane flare.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **1**, there is illustrated thereby the double outward E-plane flared embodiment of the invention. It comprises a flared rectangular horn **4**, waveguide transmission line segment 5, E-plane flared rectangular waveguide segments **6** and **7**, and waveguide transmission line **8**.

In operation, the outward flare at A of angle θ causes a certain amount of the transmitted TE_{10} mode power to be converted into LSE_{12} mode power. (The LSE_{12} mode is a combination of the TE_{12} and TM_{12} modes). The inward flare at B, of angle 2θ, creates a larger amount of LSE_{12} mode power (more than twice as great) of opposite sign. The outward flare at C of angle θ generates approximately the same amount of LSE_{12} as at A and of the same sign. In addition there is the LSE_{12} mode created in the horn throat of angle θ', which has the same sign as that at A and C. If the phase length difference between the TE_{10} mode and the LSE_{12} mode is 180° from A to B, from B to C, and from C to D, then all the LSE_{12} created by the double outward flare will be in phase and will be out of phase with the LSE_{12} in the horn throat.

The equation for the field strength of the LSE_{12} mode at A and C is

$$C_1 = \frac{b_1(b_2 - b_1)}{\pi \lambda L_1}.$$

b_1 is the E-plane height at A and C; b_2 is the E-plane height at B; L_1 is the distance between A and B, and B and C.

The equation for the field strength of LSE_{12} at B is

$$C_2 = \frac{2b_2(b_2 - b_1)}{\pi \lambda L_1}.$$

The phase difference between TE_{10} and LSE_{12} modes is

$$\Delta\Phi = 2\pi \frac{L}{\lambda}\left(\sqrt{1-(\lambda/\lambda_{c10})^2} - \sqrt{1-(\lambda/\lambda_{c12})^2}\right)$$

$$\lambda c10 = 2a$$

$$\lambda_{c12} = \frac{2ab}{\sqrt{b^2+4a^2}}$$

L is the length of the flare; a is the H-plane dimension or width of the waveguide; b is the E-plane dimension or height.

A second embodiment of the invention that utilizes a double inward E-plane flare configuration is illustrated by FIG. **2** of the drawings. It consists of a flared rectangular horn **4**, waveguide transmission line **8**, inwardly flared rectangular waveguide segment **10** and outwardly flared rectangular waveguide segment **9** connected as shown. By way of example, for a system using oversized 8 × 5.36 inches waveguide L_1 is made as long as possible, certainly over 24 inches. If b_2 is about 4.5 inches, then the LSE_{12} mode generated at A will be in the order of 2 percent in voltage of the incident TE_{10} mode for λ in the order of 4 inches and is almost negligible. Since b_3 is 5.36 inches (the E-plane dimension of the horn throat), the LSE_{12} mode generated at B will be in the order of 10 percent in voltage for L_2 in the order of 5 inches and b_2 roughly 1 inch less than b_3. θ_2 will then be about 6°. The effective flare angle at C is then $\theta_3 - \theta_2$, or about 7°, and the LSE_{12} mode generated at C is only about 0.13. If L_2 is half a beat wavelength long, then the net LSE_{12} mode propagating into the horn is quite small, since the LSE_{12} mode generated at B will largely cancel that generated at C. Furthermore, since L_2 is only a half wavelength at center frequency, its frequency sensitivity may be relatively small.

A third embodiment of the invention is illustrated by FIG. **3** of the drawings. This embodiment comprises E-plane flared antenna horn **12** in combination with the single outwardly flared waveguide segment **11**. The nonflared end of segment **11** is adapted to mate with oversized waveguide transmission line **8**.

The flare segments and horn must be designed together, because the optimum value of L will probably not be a half wavelength. L should be long enough so that the net LSE_{12} mode traversing the antenna horn should be in phase with the TE_{10} mode in the horn mouth at or near center frequency. Then the 180° relative phase reversal in the first sidelobe region will cause partial cancellation and could result in a lower sidelobe level.

The calculations are rather involved, because the horn length affects the optimum value of L and θ_1, and the values of L and θ_1 affect the horn length. Thus a simultaneous analytical solution may be used, or alternatively, optimum parameters may be determined empirically. Here, it appears that overcompensation should be used; the LSE_{12} mode generated at A should be greater than the LSE_{12} mode generated at B. L will be roughly a half wavelength; since the LSE_{12} mode is well above cutoff from A to B, the frequency sensitivity of the phase length of L should be roughly one-third of the three lengths used for the double outward E-plane flare. If the LSE_{12} mode generated at A is to be considerably more than that generated at B, θ_1 should be approximately 70 percent of θ_2. Since θ_2 will be approximately 13°, θ_1 will be approximately 10° and b_2 will be in the order of 10 inches if 5.36 inches high waveguide is used.

While the invention has been described with reference to various presently preferred embodiments, it is understood that the words which have been used are words of description rather than words of limitation and that changes within the purview of the appended claims may be made without departing from the scope and spirit of the invention in its broader aspects. In particular, although compensation methods for the LSE_{12} mode generated at the throat of E-plane flared rectangular horns have been shown, the same principles may be used to compensate for the TE_{30} mode generated at the throat of H-plane flared rectangular horns and for the LSE_{12} and TE_{30} modes generated at the throat of pyramidal rectangular horns.

What is claimed is:

1. An LSE_{12} mode compensated antenna comprising two rectangular waveguide segments, **(6),(7)**, each segment having an outward E-plane flare and having its nonflared end adapted for connection to a rectangular waveguide transmission line, said waveguide segments being jointed at their flared ends, said outward E-plane flares being at an angle that effects the generation of substantial amounts of LSE_{12} mode power,

a rectangular waveguide transmission line segment **(5)** connected to the nonflared end of one of said waveguide segments, and

a rectangular antenna horn **(4)** having an outward E-plane flare connected at its input end to said transmission line segment **(5)**, said waveguide segments **(6),(7)** and said transmission segment **(5)** having length dimensions that bring all LSE_{12} mode power generated in said waveguide segment into phase opposition with LSE_{12} mode power generated by the E-plane flare angle of said antenna horn.

2. An LSE_{12} mode compensated antenna as defined in claim **1** wherein said waveguide segment and said transmission line segment each have a length of substantially one-half wavelength.

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