Feb. 16, 1954 H. L. JACKSON 2,669,658

PHASE CORRECTION OF ASYMMETRIC DUAL FEED HORNS

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Fig.1.

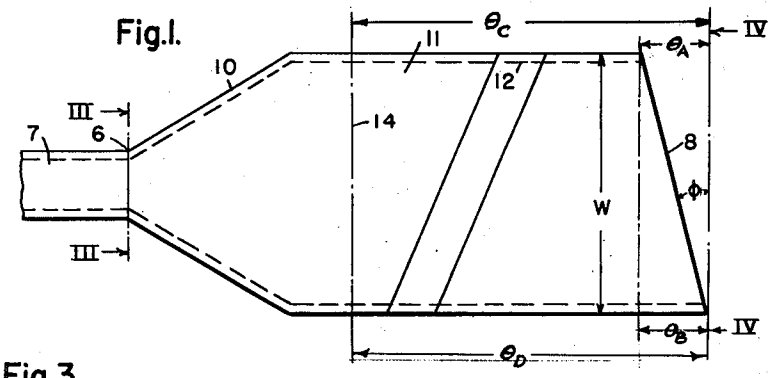


Fig.3.

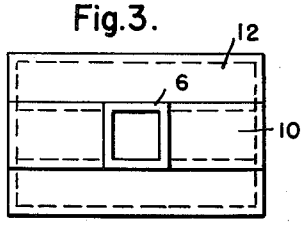


Fig.2.

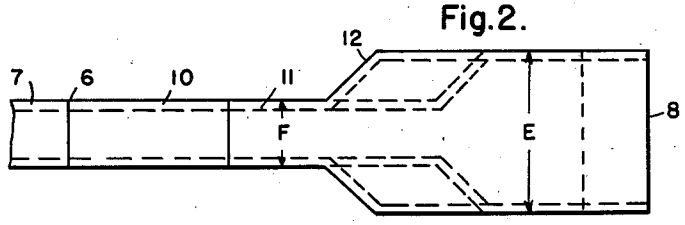


Fig.4.

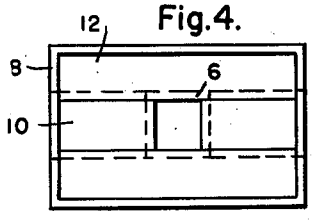
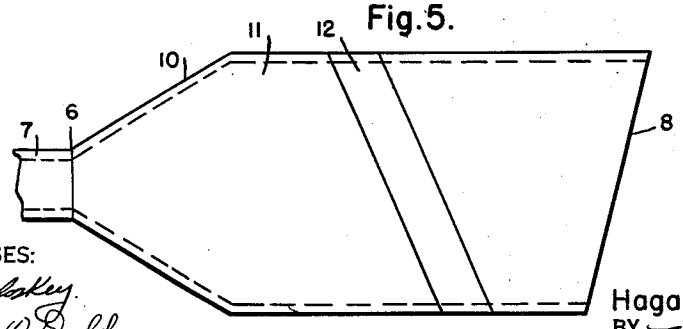


Fig.5.



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PHASE CORRECTION OF ASYMMETRIC DUAL FEED HORNS

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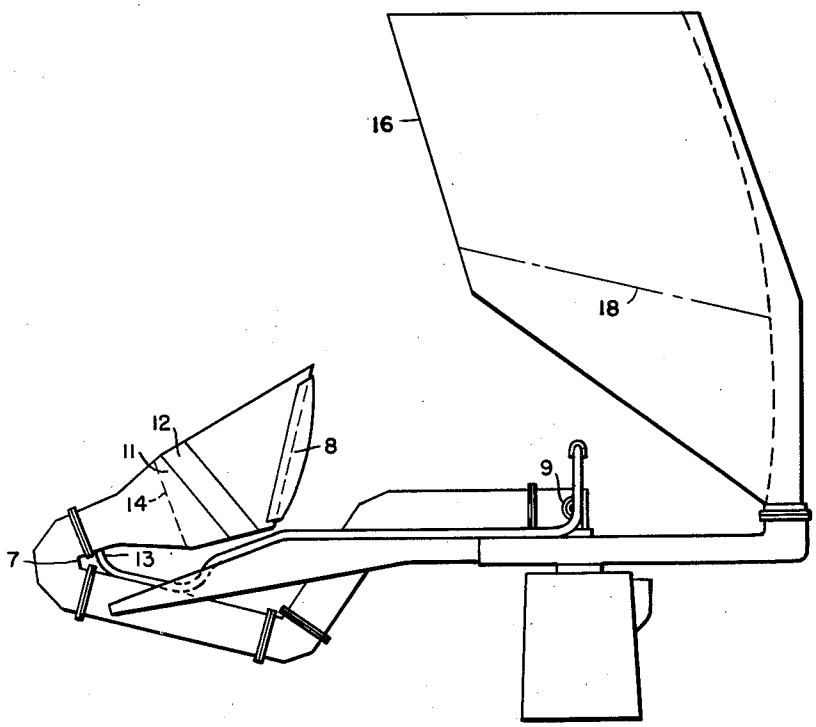
Fig.6.



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PHASE CORRECTION OF ASYMMETRIC DUAL FEED HORNS

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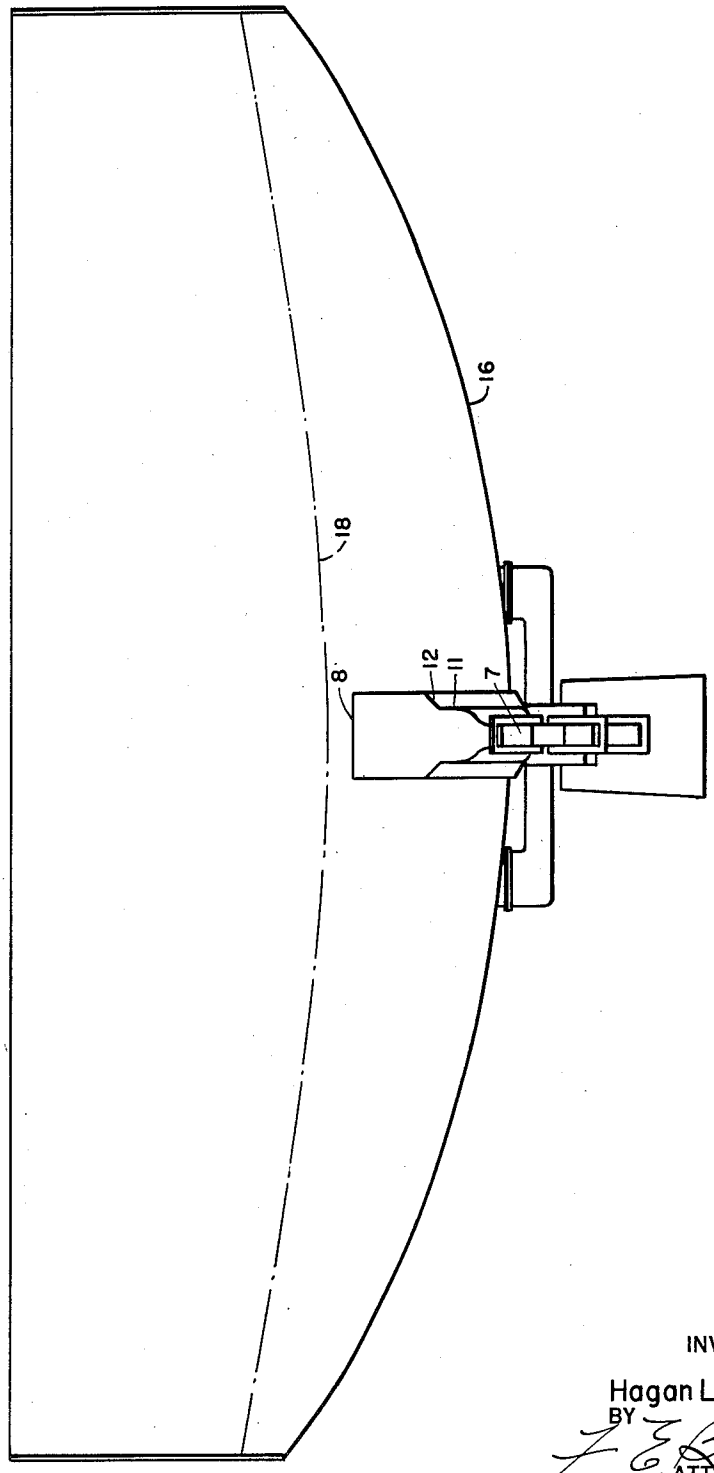

Fig.7.

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PHASE CORRECTION OF ASYMMETRIC DUAL FEED HORNS

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Application July 2, 1951, Serial No. 234,701

9 Claims. (Cl. 250—33.63)

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My invention relates to the propagation of electromagnetic oscillations, and more particularly to phase correction in a conductor for electromagnetic oscillations.

In accordance with the prior art of which I am aware, waveguides have been designed for use with two sets of oscillations polarized at right angles to each other. For some purposes, as for example, where a waveguide of this type is to be used as a feed horn for a radar transmitting apparatus, it is desirable that the two waves which are polarized at right angles to each other have a certain predetermined phase front relationship. Where the waveguide is being used as a feed horn, this phase front relationship is critical because it is desirable that the major lobes of the two sets of oscillations emitted from the feed horn substantially coincide.

It is, accordingly, an object of my invention to provide a waveguide wherein the phase front relationship between two sets of oscillations polarized at right angles to each other is controlled.

It is another object of my invention to provide a radar feed horn for use with two sets of oscillations polarized at right angles to each other whereby the phase front relationship of the two sets of oscillations is controlled.

Still another object of my invention is to provide a radar feed horn for use with two sets of oscillations polarized at right angles to each other wherein the phase front of one of the sets of oscillations is changed without substantially changing the phase front of the other set of oscillations, so that ridge lines of the two sets of oscillations coincide.

Still another object of my invention is to provide a radar antenna system for use with two sets of oscillations polarized at right angles to each other.

Still another object of my invention is to provide a waveguide having therein means for changing the phase front of oscillations therein having a predetermined polarization.

The novel features which I consider characteristic of my invention are set forth with more particularity in the appended claims. The invention, however, with respect to both the organization and the operation thereof, together with other objects and advantages may be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Fig. 1 is a plan view of apparatus embodying my invention.

Fig. 2 is an elevational view of the apparatus shown in Fig. 1.

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Fig. 3 is a sectional view of the apparatus shown in Fig. 1 taken along the line III—III of Fig. 1.

Fig. 4 is a view of the apparatus shown in Fig. 1 taken along the line IV—IV of Fig. 1.

Fig. 5 is a bottom plan view of the embodiment of my invention shown in Fig. 1.

Fig. 6 is an elevational view of an apparatus embodying my invention in which the feed horn is used to feed a parabolic reflector, and

Fig. 7 is a front view of the reflector employed in the embodiment shown in Fig. 6.

In accordance with my invention, I provide a feed horn comprising a waveguide, a first end 6 of which is designed for connection to a standard waveguide 7 and the opposite end 8 is open for omitting electromagnetic oscillations such as for projecting electromagnetic energy against a parabolic antenna 16. The standard waveguide has connections for feeding thereto oscillations polarized in one direction at one place 9 and for feeding oscillations polarized in another direction at another place 13. Preferably, the open end of the feed horn is cut at an angle as desired so as to direct the electromagnetic oscillations emitted therefrom toward a parabolic reflector in such a manner that a maximum length of the line maximum radiation intensity lies in the reflector. Between the point 6 of connection with a standard waveguide and the open end 8 of the horn, there is a horizontal flaring out section 10 wherein the feed horn flares out in width gradually for a short distance while the thickness or elevation remains constant. This flaring out in width should be sufficiently gradual as not to cause substantial reflections of the oscillations being propagated through the horn. Adjacent the horizontal flaring section in which the feed horn flares out in width, there is a short section of rectangular waveguide 11 having a constant cross-section. An elevation flared out section 12 is provided between the section of constant-section rectangular waveguide 11 and the open end 8 of the horn wherein the width of the horn remains constant while the elevation or thickness increases rapidly as one proceeds along the horn toward the open end 8.

The elevation flared out portion of the feed horn extends across the horn horizontally at an acute angle with a cross-section of the horn. In other words, the elevation flared out section does not extend across the waveguide at right angles to the axis of the horn but rather the elevation flared out portion extends across the waveguide at an angle ϕ to a line which is perpendicular to the axis of the horn.

In the preferred embodiments of my invention, the flaring out occurs in two directions at the same place along the length of the horn, however, in accordance with another embodiment of my invention the horn might have only a flare upward and not have a flare downward. Also, in accordance with still another embodiment of my invention, the two horizontal flares or the two elevation flares need not occur at the same place along the length of the feed horn.

It is also understood that in accordance with another embodiment of my invention the horizontal and vertical flaring sections need not be in the order shown. Instead, it may be desirable in some instances that the elevation flaring section be further from the antenna than is the horizontal flaring section.

At the open end 8 of the horn, which is the end opposite that to which the standard waveguide 7 is attached, the cross-sectional area is determined by the size and shape of the reflector to be fed by the horn. The open end 8 of the feed horn is cut at an angle ϕ to a cross-section of the feed horn.

The following is a mathematical explanation of the manner in which it is believed that an apparatus built in accordance with my invention operates.

When a feed horn is to be used with a first set of oscillations having a frequency F_1, which are polarized vertically, i. e., polarized so that the electric vector extends in a vertical direction, and a second set of oscillations having a frequency F_2 polarized horizontally, the angle ϕ, the height F of the feed horn on the transmitter side of the flared out section, and the height E on the antenna side of the flared out portion are so selected that:

$$(\theta_A \text{ for } F_1 - \theta_B \text{ for } F_1) - (\theta_D \text{ for } F_2 - \theta_C \text{ for } F_2) = 0$$

where θ_A, θ_B, θ_C and θ_D are measured in electrical degrees, and represent distances in electrical degrees for the oscillations to be employed.

θ_A represents the electrical degrees corresponding to the distance $W \tan \phi$ as measured in air.

θ_B represents the electrical degrees corresponding to the distance $W \tan \phi$ as measured in the feed horn.

θ_C represents the electrical degrees corresponding to the distance along the short side of the horn between an arbitrary line 14, extending across the horn and located between the elevation flare and the horizontal flare, and the mouth of the horn, plus the electrical degrees corresponding to the distance $W \tan \phi$ as measured in air.

θ_D represents the electrical degrees corresponding to the distance along the long side of the horn between the arbitrary line 14, extending across the horn and located between the elevation flare and the horizontal flare, and the mouth of the horn.

Since the distance in electrical degrees between two points inside the horn is a function of the cross-sectional dimensions of the horn the distance in electrical degrees can be varied by varying the location of the flaring out portions along the length of the horn. By placing the flaring section at an angle the electrical degrees along one side of the horn can be changed with respect to the electrical degrees along the other side of the horn.

When the conditions of the above equation are satisfied, the main lobe of the first set of oscillations and the main lobe of the second set of oscillations will coincide. This may be better understood by noting the effect of the following equations:

$$(1) \qquad \lambda g = \frac{\lambda \text{ air}}{\sqrt{1-\left(\frac{\lambda \text{ air}}{\lambda \text{ cutoff}}\right)^2}}$$

$$(2) \qquad \lambda 1 = 2W$$

$$(3) \qquad \lambda 2 = 2E$$

where the wavelength of oscillations in the guide is λg, the cutoff wavelength in the guide for F_1 is λ_1, and the cutoff wavelength in the guide for F_2 is λ_2. From these equations it is seen that the dimension E does not affect the cutoff of F_1, and the dimension W does not affect the cutoff of the oscillations with a frequency F_2. I am thus able to adjust the main lobe of oscillations of one frequency without substantially affecting the main lobe of oscillations of another frequency which are polarized at right angles to the oscillations of the first frequency. Thus, by adjustment of the respective dimensions the major lobe of the first set of oscillations may be caused to coincide with the major lobe of the second set of oscillations.

In accordance with one embodiment of my invention as shown in Figs. 6 and 7, a reflector 16 is employed which is a section of a parabola, a section of a parabola is employed where it is desired that the beam have a longer cross-sectional dimension in the vertical direction than in the horizontal direction or vice versa. In accordance with a preferred embodiment of my invention, the feed horn is then so oriented with respect to the reflector 16 that as much as possible of the line of maximum radiation intensity 18 lies in the reflector 16.

I have described primarily an embodiment of my invention which is in the form of a feed horn for feeding a parabolic reflector of a radar apparatus. However, it is understood that the invention may be employed in other situations where it is desirable to change the relative phase front of two sets of oscillations passing through a waveguide, which oscillations are polarized at substantial angles to each other.

Although I have shown and described a specific embodiment of my invention, I am aware that other modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and the spirit of the invention.

I claim as my invention:

1. A hollow conductor for electromagnetic oscillations having a substantially rectangular cross-section, said conductor having an end thereof which is cut at an acute angle to the axis of said conductor, said conductor flaring outward in the vertical direction at a sharp angle over a part of its length, the flaring portion where said conductor flares out sharply ending at a different place along said conductor at one side of said conductor than at the other side of said conductor.

2. A hollow conductor for electromagnetic oscillations having a rectangular cross-section, said conductor having a flared out portion in one of the sides thereof, said flared out portion extending across said one side at an acute angle to the axis of said conductor.

3. A hollow conductor for electromagnetic oscillations having a rectangular cross-section, said conductor having a flared out portion in one of the sides thereof, said flared out portion extend-

ing cross said one side at an acute angle to the axis of said conductor, said conductor having an end thereof which is at an acute angle with the axis of said conductor.

4. A hollow conductor for electromagnetic oscillations having two sides, a top and a bottom and being of substantially rectangular cross section, said top having a portion thereof where said top rises sharply, said portion extending across said top at an acute angle to a cross section of said conductor.

5. A radar feed horn having two sides, a top and a bottom, said top having a portion thereof where the distance between the top and bottom of said feed horn increases sharply, said portion extending across said top at an angle so that said portion lies at a different place along the length of said horn at one side of said horn from the place where said portion lies on the other side of said horn.

6. A radar antenna apparatus comprising a waveguide, connections for applying oscillations of one polarization to said waveguide at one point along the length of said waveguide and connections for applying oscillations of another polarization to said waveguide at another place along the length of said waveguide, a feed horn, said waveguide being connected so as to supply oscillations to said feed horn, said feed horn having a flaring out portion where one dimension of said horn increases sharply, said flaring out portion having one end thereof located at a different point along the length of said horn from the other end thereof.

7. A radar antenna apparatus comprising a

waveguide, connections for applying oscillations of one polarization to said waveguide at one point along the length of said waveguide and connections for applying oscillations of another polarization to said waveguide at another place along the length of said waveguide, a feedhorn, said waveguide being connected so as to supply oscillations to said feed horn, said feed horn having a flaring out portion where one dimension of said horn increases sharply, said flaring out portion having one end located at a different point along the length of said horn from said other end, and a parabolic reflector of electrically conducting material, said feed horn being so oriented that oscillations emitted therefrom are directed against said reflector.

8. Apparatus substantially as claimed in claim 7 characterized in that said parabolic reflector comprises a section of a parabola.

9. Apparatus as described in claim 7 characterized in that the mouth of said feed horn is cut at such an angle that oscillations emitted therefrom produce a line of maximum radiation intensity across said reflector, said line of maximum intensity being so located that substantially a maximum length of said line lies in said reflector.

HAGAN L. JACKSON.

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