

April 24, 1956

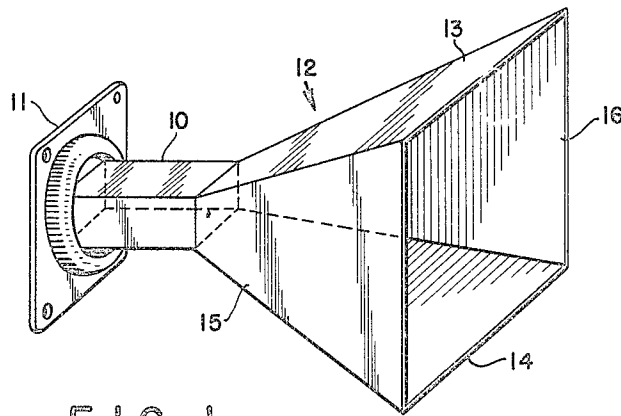
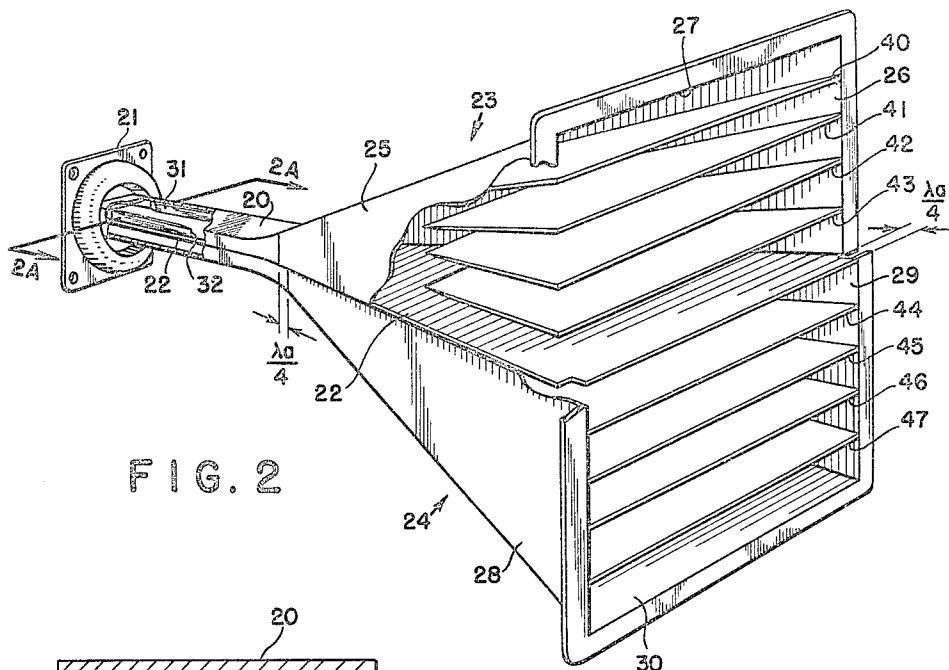
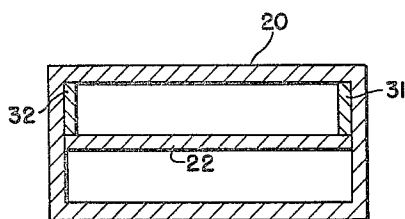
H. J. RIBLET

2,743,440

ELECTROMAGNETIC HORN

Filed July 19, 1951

2 Sheets-Sheet 1



INVENTOR
HENRY J. RIBLET

BY *D.E. Snider*
ATTORNEY

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2 Sheets-Sheet 2

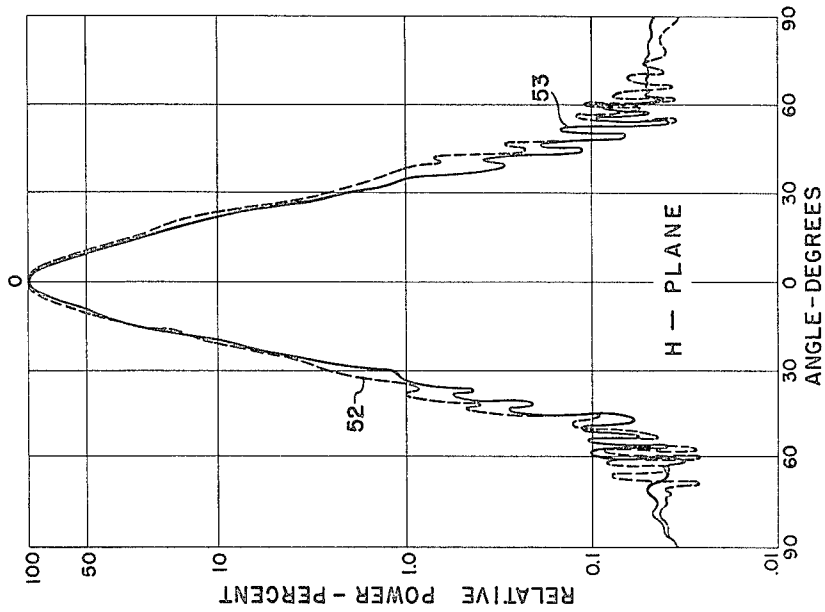


FIG. 4

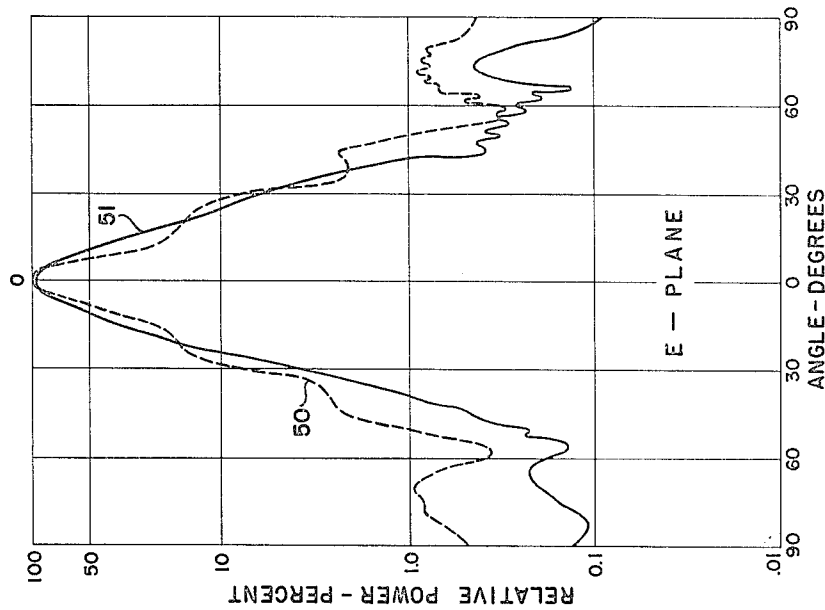


FIG. 3

INVENTOR
HENRY J. RIBLET

BY *D. C. Snyder*
ATTORNEY

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ELECTROMAGNETIC HORN

Henry J. Riblet, Wellesley, Mass., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

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6 Claims. (Cl. 343—778)

This invention relates generally to electromagnetic radiation systems and, more particularly, to means and methods for improving the operational characteristics of an electromagnetic horn.

As is well known in the art, electromagnetic horns of various configurations have long been used as impedance transformers between the wave guide systems of microwave apparatus and free space. The principal considerations in the design of prior art electromagnetic horns were the minimization of the energy reflected into the wave guide system coupled to the horn by the horn termination; that is, the reduction of standing waves excited in the transmitter apparatus by reason of an improper impedance transformation between the wave guide and free space, and the provision of a desirable radiation pattern. Thus, since it was desired to reduce standing waves in the microwave apparatus coupled to the horn, caused by reflection of a portion of the energy transmitted through and radiated by the horn, little or no attention has been given to the problem of minimizing the reflections encountered by a plane wave from an external source incident on the mouth of a horn. This consideration is important when the horn is used with receiving apparatus for making radiation field measurement tests of transmitting apparatus, for example, since on-axis reflections from the receiving horn, caused by the horn itself, prevent the passage of the total energy incident on the horn to the receiving and measuring apparatus, and further excite standing waves in free space which affect the field pattern of the apparatus being tested. This phenomenon is particularly apparent if the receiving horn and the equipment being tested are located close together. In order that accurate measurements be made at the receiver, it is desirable that the reflections back into free space along the axis of the horn be eliminated or at least reduced to a minimum.

Accordingly, it is an object of the present invention to provide an electromagnetic horn having a minimum of on-axis reflection of incident radiation.

Another object of the present invention is to provide an improved electromagnetic horn whose radiation pattern is generally symmetrical in the E- and H-planes.

Another object of the present invention is to provide an improved electromagnetic horn constructed and arranged such that on-axis reflections for all modes are effectively canceled.

Another object of the invention is to provide a partitioned electromagnetic horn having an electric field intensity at the mouth of said horn, that is, substantially a half sinusoid, in both the horizontal and vertical directions, being maximum on the axis of said horn and zero at its edges.

Other objects and advantages will become apparent from the specification taken in connection with the accompanying drawings wherein the invention is embodied in specific form and in which:

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Fig. 1 is a perspective representation of a conventional pyramidal electromagnetic horn;

Fig. 2 is a perspective view, partly broken away, of an electromagnetic horn constructed in accordance with the present invention;

Fig. 2A is a cross-sectional view of the wave guide portion of the horn taken along the cutting plane line 2A—2A of Fig. 2;

Fig. 3 is a graph comparing the measured radiation patterns in the E-plane of the conventional horn of Fig. 1 and the horn of the present invention, relative power being plotted as a function of the angle from the horn axis; and

Fig. 4 is a graph comparing the measured radiation patterns in the H-plane of the conventional horn of Fig. 1 and the horn of the present invention.

Referring now to Fig. 1, there is shown a conventional pyramidal electromagnetic horn, the theory of operation of which is well known. The horn radiator consists of a section of standard rectangular wave guide 10, suitably dimensioned for the frequency of operation, having a coupling flange 11 at one end for attachment to other apparatus, for example, transmitting or receiving equipment. The other end of the wave guide section is connected to the throat of the horn 12. The horn is formed of sides 13 and 14, each disposed at an angle to the longitudinal axis of wave guide 10 and forming the upper and lower surfaces of the horn, and sides 15 and 16 also disposed at an angle with respect to the same axis and forming the sides of the horn. The horn is thus pyramidal in appearance, having flare angles in both the horizontal and vertical directions. As normally excited from a rectangular wave guide system coupled to flange 11, the lines of electric intensity are vertical; that is, parallel to the sides 15 and 16 throughout the interior of the horn. By the suitable choice of the flare angle of the horn defining plates, the radiation pattern may be made sharply directive in the H-plane, perpendicular to the electric vectors within the horn, with a narrow principal lobe and negligible side lobes. The electric field intensity, across the mouth of the horn radiator in this plane varies in half-sinusoidal fashion, being substantially zero at the plates 15 and 16 and a maximum on the axis of the horn. Thus, when the horn of Fig. 1 is used as a radiator, that is, as an impedance transformer for the transmission of energy into free space, a desirable and useful radiation pattern is obtained.

Measurements have indicated, however, that when a symmetrical horn of the type illustrated in Fig. 1 is used to receive electromagnetic energy, on-axis reflections from the horn toward the source are of considerable magnitude. The on-axis reflections are believed attributable to the higher modes, excited in the aperture of the horn by the incident plane waves, which are ultimately reflected when the horn narrows to a point where the higher order modes can no longer propagate individually. It has been found that the excitation of higher order modes can be minimized and on-axis reflection can be made to effectively cancel for all modes by bisecting a horn of the type shown in Fig. 1 and displacing the two halves relative to one another by one-quarter wave length at the frequency of operation.

Referring to Fig. 2, there is shown an electromagnetic horn consisting of a wave guide portion 20 having a coupling flange 21 secured at one end thereof for connection to a microwave receiver or other apparatus. Conductive septum 22 extending completely across the wave guide section and electrically connected to the narrow walls of the wave guide section divides the wave guide in the narrow direction into two equal rectangular channels, the combined area of which is equal to the

cross-sectional area of wave guide 10 of the radiator of Fig. 1 for the same frequency. Thus, the dimensions of wave guide section 20 are slightly larger than the dimensions of wave guide 10 of Fig. 1 because of the thickness of plate 22. Septum 22 extends along the axis of the horn and is flared into a trapezoidal shape to form a conducting partition between the two sections of the horn, the construction of which will now be described. The horn itself consists of two symmetrical sections 23 and 24, each of which corresponds essentially to one-half of a pyramidal horn. The upper section is formed of sides 25 and 26, each disposed at an angle to the longitudinal axis of wave guide 20 and plate 27, also disposed at an angle to the same axis and forming the upper surface of the upper section. The lower section is formed of sides 28 and 29 disposed similarly to plates 25 and 26 with respect to said central axis, and plate 30 disposed similarly to plate 27 and forming the lower surface of the lower section. The upper section 23 is displaced relative to lower section 24 along the axis of the horn toward wave guide 20 a quarter wave length in air at the frequency of operation. Because of the relative disposition of the two sections, the upper section extends beyond the lower section along septum 22.

To prevent the introduction of undesirable discontinuities and the attendant excitation of objectionable standing waves, wave guide 20 is shaped at its junction with the throat end of the horn to provide a smooth transition. It has been found that the transition section between the wave guide and the horn can conveniently be made by the electroforming process. The complete horn is generally pyramidal in appearance, similar to the horn of Fig. 1, and has a rectangular aperture with the planes of the apertures of the upper and lower sections displaced from each other a quarter wave length, as discussed above.

In the operation of the structure thus far described, when used as a receiving horn, plane waves incident on the aperture of the horn are propagated into the horn, most of the energy passing into wave guide section 20 to suitable receiving apparatus which may be coupled to flange 21. Because of septum 22, two channels are provided for the transmission of energy with the result that fewer higher order modes are excited within the horn. Higher order modes excited in the throat of the horn and reflected back along the axis of the horn when the two sections of the horn narrow to a point where the higher modes can no longer propagate individually, as aforesaid, are canceled in the following manner. Since the two sections of the horn are symmetrical in all respects, a plane wave entering the horn travels a quarter wave further into the upper section as measured from the plane of the aperture of the lower section to where the upper horn section narrows to a point where on-axis reflections occur than the same wave must travel to reach the corresponding point in the lower section. In other words, reflections from the lower section start back toward the aperture of the horn a quarter wave length sooner than reflections from the upper section. This quarter wave delay in the excitation of on-axis reflections in the upper section and the further quarter wave delay encountered in returning to the plane of the aperture of the lower section, causes the wave reflected from the upper section to arrive at said plane a half wave length later than the reflections from the lower section. Arrival of the reflected waves from the two sections 180 degrees out of phase results in their effective cancellation with the result that on-axis reflections are substantially eliminated. All of the energy reflected from the two sections of the horn, due to excitation of higher order modes, will be canceled in the manner described above because of the symmetrical construction of the two sections of the horn.

It will be apparent from the construction of the horn of Fig. 2, that a plane wave incident on the horn from free space, in order to reach the plane of coupling flange 21, or similar reference plane, is propagated through a

conducting medium a quarter wave length further in the lower section than in the upper section. Accordingly, since the velocity of propagation of energy is somewhat less in a conducting medium than in free space, there is a slight phase shift between the waves propagated in the two sections. To compensate for this phase shift and to cause energy from both sections to arrive in phase at the plane of flange 21, a phase-shifting structure designed to introduce a phase delay equal to the phase shift described above is inserted in the shorter conducting path, namely, in the upper section. A convenient structure for providing the necessary phase shift is illustrated in Figs. 2 and 2A and consists of a pair of conducting plates 31 and 32 secured to the narrow walls of the upper channel of wave guide section 20 and extending longitudinally of the wave guide. The length and thickness of plates 31 and 32 are selected to provide the proper phase shift. The ends of the plates are smoothly blended with the walls of wave guide 20, as shown in Fig. 2, to prevent the excitation of objectionable standing waves in the channel. Septum 22 is tapered at its left end as viewed in Fig. 2, to further reduce standing waves in the horn structure.

The structure thus far discussed provides a radiation pattern which varies as a half-sinusoid across the aperture in the H-plane having a single principal lobe and secondary lobes of insignificant amplitudes. In the E-plane, however, that is, in the plane parallel to the electric vectors, the electric field intensity across the horn is nearly uniform with resulting secondary lobes of comparatively high amplitudes. To redistribute the energy in order to produce substantially a half-sinusoidal distribution in the E-plane as well as in the H-plane, eight conducting partitions 40-47 are arranged inside the horn, four being disposed in each section, as shown. The partitions are conductively secured to the side plates of their corresponding section with the outer ends thereof spaced across the aperture of each half. The inner ends of said partitions are tapered and are so spaced relative to the top and bottom plates and septum 22 and with respect to each other, that energy entering the channels defined by the partitions is of an amount to cause a half-sinusoidal distribution across the mouth of the horn in the E-plane as the energy leaves the channels. Since the horn is bilateral in operation, the receiving pattern is also of the same configuration. With the foregoing redistribution of energy, the radiation patterns are substantially similar in both the E- and H-planes, having a single principal lobe and negligible side lobes.

The beneficial results of displacing the sections of the horn and inserting partitions therein are illustrated in Figs. 3 and 4. Fig. 3 shows by curve 50 measured radiation patterns in the form of radiated power as a function of the angle from the axis of symmetry of the radiator in the E-plane for a pyramidal horn, such as shown in Fig. 1; and by curve 51 for a horn having displaced sections and partitions spaced as aforesaid. Fig. 4 is a similar representation for the radiation pattern in the H-plane, curve 52 being for a pyramidal horn and curve 53 being for the horn of Fig. 2. It will be observed that the gains of the two horns differ only slightly but that the radiation pattern of the improved horn is quite uniform, being only slightly narrower in the H-plane. The side lobes of the septated horn are of much lower amplitude, however, particularly in the E-plane. Comparison of measured on-axis reflections from the horns of Fig. 1 and Fig. 2, when each was used as a receiving horn, indicated that there was a reduction in on-axis reflected power of the order of ten decibels in favor of the horn of the present invention.

Although the present invention has been described primarily in connection with the reception of energy, where it has its principal application, it will be obvious that it is equally useful as an energy transmitting means. It will also be apparent to one skilled in the art that the quarter wave displacement feature of the disclosed pyramidal

horn may be applied to other forms of horns. Thus, since many changes could be made in the above construction, and many apparently different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electromagnetic horn having two symmetrical sections of generally pyramidal shape joined by a conducting septum along a plane of symmetry and joined at its throat end to a section of rectangular wave guide, said septum extending into and dividing said wave guide into equal channels, said sections being displaced one from the other along said plane of symmetry a quarter wave length at the frequency of operation of said horn, phase-shifting means positioned in one of the channels of said wave guide section, and partitioning means positioned within said sections generally parallel to said septum for modifying the radiation pattern of said horn.

2. An electromagnetic horn having two symmetrical flared sections joined along a plane of symmetry by a conducting septum, a section of rectangular wave guide, one end of said wave guide being joined to said sections at their throat ends, said septum extending into and dividing said wave guide into two rectangular channels of equal area respectively communicating with the two sections of said horn, said sections being displaced one from the other along the axis of said horn a quarter wave length at the frequency of operation of said horn, means positioned in one of the channels in said wave guide section for constricting the area thereof for a portion of its length for introducing a phase shift to energy propagated therein, and spaced partitioning means disposed within said sections generally parallel to said septum defining a plurality of channels for modifying the radiation pattern of said horn.

3. An electromagnetic horn having first and second symmetrical flared sections joined along a plane of symmetry by a conducting septum, a section of rectangular wave guide, joined at one end to said sections at their throat ends, said septum extending into and being conductively joined to the narrow walls of said wave guide and dividing said guide into first and second equal area rectangular channels respectively communicating with said first and second sections, said first section being displaced toward said wave guide section axially of said horn a quarter wave length at the frequency of operation of said horn relative to said second section, means positioned in said first channel of said wave guide for constricting the area thereof for a portion of its length for introducing a phase shift to energy propagated therethrough, and spaced partitioning means disposed within said sections generally parallel to said septum for modifying the radiation pattern of said horn.

4. An electromagnetic horn comprising, first and second symmetrical sections of generally pyramidal shape joined along a plane of symmetry by a conducting septum,

a section of rectangular wave guide joined at one end to the throat ends of said sections, said septum extending into and bisecting said wave guide in the narrow direction, said first section being displaced toward said wave guide relative to said second section a quarter wave length at the frequency of operation of said horn for effectively cancelling on-axis reflections of energy incident on the aperture of said horn, phase-shifting means positioned in the half of said wave guide communicating with said first section, and a plurality of spaced conducting partitions disposed within said sections substantially parallel to said septum and being arranged to produce a desired redistribution of electric field intensity across the aperture of said horn in the plane perpendicular to said septum.

5. An electromagnetic horn comprising, first and second symmetrical sections of generally pyramidal shape joined along a plane of symmetry by a conducting septum, a section of hollow rectangular wave guide joined at one end to the throat ends of said sections, said septum extending into and dividing said wave guide in the narrow direction into first and second symmetrical channels, said first section being displaced toward said wave guide relative to said second section substantially a quarter wave length at the frequency of operation of said horn for effectively cancelling on-axis reflection of energy incident on the aperture of said horn, a pair of conducting plates located on opposing narrow walls of said first channel and proportioned to introduce a phase shift to energy propagated therethrough, and a plurality of spaced conducting partitions disposed within each of said sections substantially parallel to said septum and arranged to produce a desired redistribution of field intensity across the aperture of said horn in the plane perpendicular to said septum.

6. Apparatus for minimizing the reflection produced by the incidence of electromagnetic waves at the mouth portion of a horn comprising first and second symmetrical pyramidal horn sections of equal length having mouth and throat orifices and a common sidewall portion, said sections being offset by an amount corresponding to a quarter wave length of the operating frequency of said horn sections in the direction of energy propagation whereby the higher transmission modes excited in said horn sections and reflected at the throat orifices reappear at the mouth orifices in an out-of-phase relationship, a wave guide connected to each throat orifice and a phase-shifting means inserted in one of said wave guides to compensate for the phase displacement of electromagnetic energy arriving at said wave guides via the unequal propagation paths of said first and second horn sections.

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