June 5, 1956 J. A. KOSTRIZA 2749,545

ELECTROMAGNETIC HORN

Filed Aug. 1, 1951

Fig. 1

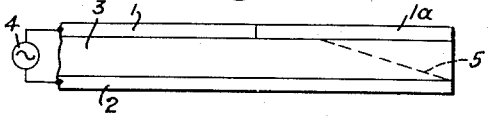



Fig. 2

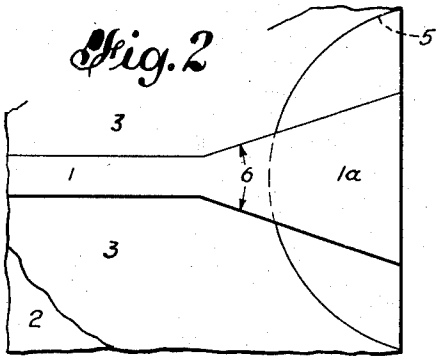



Fig. 3

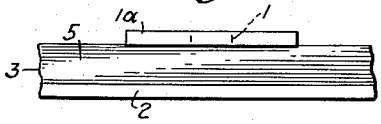



Fig. 4

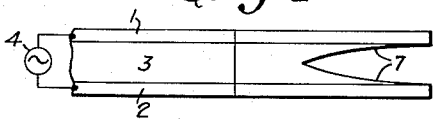



Fig. 5

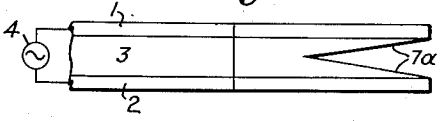



Fig. 6

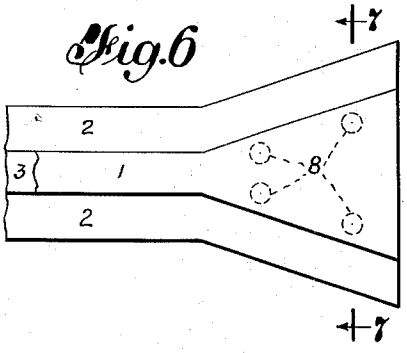



Fig. 7

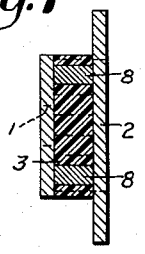



Fig. 7a

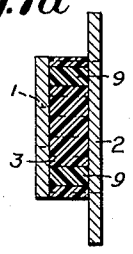



Fig. 8

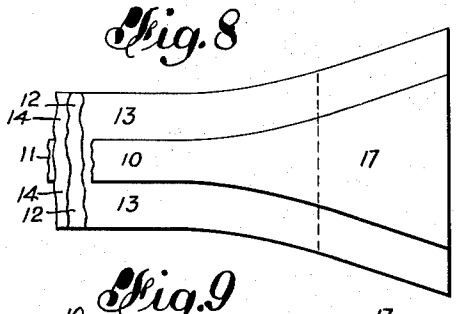



Fig. 9

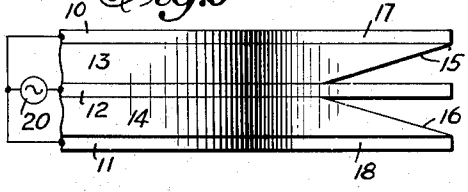



Fig. 10

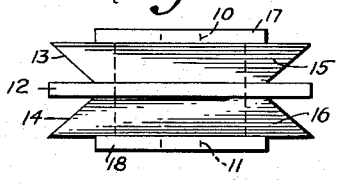
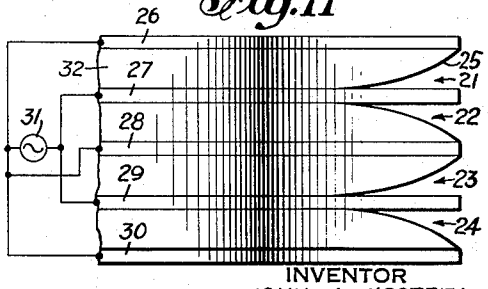



Fig. 11




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# ELECTROMAGNETIC HORN

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Application August 1, 1951, Serial No. 239,738

20 Claims. (Cl. 343—776)

This invention relates to electromagnetic horns and more particularly to electromagnetic horns for the propagation of microwave energy.

One of the objects of the invention is to provide a simplified form of electromagnetic horn which does not require the precision of manufacture of previous microwave horns.

Another object of the invention is to provide a microwave horn that may employ as a part of the radiation system a wall of the chassis or other apparatus associated therewith.

Still another object of the invention is to provide a microwave horn which is of a character readily adapted for the use of printed circuit techniques.

One of the features of the invention is the utilization of a basic principle present in a theoretically perfect parallel line transmission system as described more extensively in patents to H. F. Engelmann, No. 2,654,842 dated October 6, 1953 and to D. D. Grieg and H. F. Engelmann, No. 2,721,312, dated October 18, 1955. The present invention utilizes this theoretically perfect parallel line system without requiring exact identity and parallel spacing of the parallel conductors. The microwave horn of the present invention employs two or more closely spaced conductors with one of the conductors, hereinafter sometimes referred to as the "ground" conductor, wider than the other conductor, hereinafter sometimes referred to as the "line" conductor, so as to produce, in effect, an image of the line conductor in the ground conductor. The so-called ground conductor theoretically might have a width extending to infinity but for practical purposes need be only a little wider than the line conductor as long as its greater width provides for ample concentration of the electromagnetic field between the opposed faces of the two conductors. The width of the ground conductor should be approximately two or three times greater than that of the line conductor, although it might preferably be wider if circumstances provide such an extended surface. Another feature is the varied horn construction that is made possible by use of the "line-above-ground" type of transmission system and circuit printed techniques that may be employed.

The above-mentioned and other features and objects of the invention will become more apparent by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a view in side elevation of a horn in accordance with the principles of this invention;

Fig. 2 is a plan view of the horn shown in Fig. 1;

Fig. 3 is a view in end elevation of the horn shown in Fig. 1;

Fig. 4 is a view in side elevation of a horn similar to that shown in Fig. 1 but comprising exponential variations in the thickness of the dielectric;

Fig. 5 is a view in side elevation of a horn having a symmetrical linear variation;



Fig. 6 is a plan view of a horn according to the invention incorporating matching posts;

Fig. 7 is a cross-sectional view along line 7—7 of Fig. 6 showing metal posts for determining the dielectric characteristic of the medium between conductors;

Fig. 7*a* is a cross-sectional similar to Fig. 7 showing dielectric posts;

Figs. 8, 9, and 10 are plan, side, and end views, respectively, of a horn array according to the principles of the invention; and

Fig. 11 is a view in side elevation of a horn array according to the invention.

Referring to Figs. 1, 2, and 3 of the drawings, the horn is shown to comprise a termination of a transmission line made up of a line conductor **1** proximate a ground conductor **2** and separated therefrom by a dielectric material **3**. The line conductor **1** is energized with respect to ground conductor **2** by a source of electromagnetic energy **4**. The dielectric in the vicinity of the horn is shown to be linearly tapered as indicated at **5**. The purpose of this taper variation of the dielectric characteristic is to provide an impedance match or transition between the impedance of free space and the impedance of the transmission line comprised of conductors **1** and **2**. The flare angle **6** of the horn may be selected to obtain certain desired directive launching effects. The conductor **1** is flared as indicated at **1***a* to provide the horn effect, the conductor **2** being, in the embodiment of Figs. 1, 2, and 3, a wide sheet of conductive material. If desired, the conductor **2** may be a narrow sheet about two or three times wider than the width of conductor **1**, with the end portion flared similarly as part **1***a*. The line-ground conductors **1** and **2** may be printed, embossed, or photo-engraved upon the dielectric **3**.

Referring to Fig. 4, a side view of a horn is shown in which the dielectric material is divided at the end of the horn with the separate parts **7** varying in thickness exponentially. The line conductor **1** and the ground conductor **2** are separated by a dielectric **3** and the source of electromagnetic energy is indicated at **4** similarly as in Fig. 1. The purpose of the two symmetrical, exponential variations in thickness of dielectric is to provide a smooth transition from the impedance of the transmission line to that of free space which is required for certain symmetrical field patterns desired of the horn.

In Fig. 5 a side view of a horn is shown in which the dielectric is also divided at the horn and the thickness of the separated parts **7***a* vary linearly and symmetrically. The line conductor **1** and the ground conductor **2** are energized by a source **4** as in Fig. 1.

Figs. 6, 7, and 7*a*, which are plan and sectional views, respectively, of an electromagnetic horn similar to that shown in Fig. 1 show matching posts in the horn region where the dielectric in Fig. 1 is tapered. The matching posts provide a better match between the electromagnetic waves propagated between the line conductor **1** and ground conductor **2** and, in addition, provide mechanical support near the mouth of the horn for the separated conductors in the horn region. These posts may be made of dielectric material **9**, as shown in Fig. 7*a*, or may be of metallic material **8** as shown in Fig. 7, depending upon whether capacitive impedance or inductive impedance is desired to obtain the match between the transmission system and free space. The position and thickness of these posts may be calculated to obtain the desired dielectric characteristic. While in this embodiment the dielectric **3** is shown terminated at the small end of the horn, it may be continued out to the large end of the horn.

Figs. 8, 9, and 10 show two line conductors **10** and **11** proximate a single ground conductor **12**, separated by two layers of dielectric material **13** and **14**, whereby a double horn array is obtained. As is well-known in the

art, an array of two or more electromagnetic horns will provide a sharper directivity pattern than that of a single horn. The taper 15, 16 in thickness of dielectric is linear with distance, although the flare 17, 18 in width of the line conductors 10 and 11 and the flare 19 in the ground conductor 12 are shown to be exponential. The exponential variation in width of the conductors is for the purpose of providing a smooth match between the impedance of the transmission system and that of free space. The energy source 20 is shown to energize both the line conductors in phase with respect to ground.

In Fig. 11 a horn array is shown comprising effectively four horns 21, 22, 23, and 24 in a single array, each provided with an exponential variation 25 in thickness of the dielectric 32 between the line conductor and the ground conductors. Horn 21 comprises line conductor 26 and ground conductor 27, horn 22 comprises line conductor 28 and ground conductor 27, horn 23 comprises line conductor 28 and ground conductor 29, and horn 24 comprises line conductor 30 and ground conductor 29. A source of energy 31 is connected across the line and ground conductors in parallel. In such an array it is clear that there are a number N of line conductors, a number N−1 of ground conductors and a number of N+1 of dielectric layers 32. The exponential variation 25 in thickness of the dielectrics is shown to be asymmetrical between a given pair of line and ground conductors rather than symmetrical as shown in Fig. 4, but due to the face that an even number of horns is used, the net effect is to obtain a symmetrical pattern in space due to the back-to-back arrangements of the variations in thickness. The directivity pattern of such an array will be sharper than that of the array shown in Figs. 8, 9, and 10 and still sharper than that of the single horns shown in Figs. 1 through 7. It will be clear that arrays similar to that of Fig. 11 may be constructed by utilizing a greater number of horns and that more directive field patterns may be so obtained. It will also be clear that the variation in width of the line and ground conductors may be exponential as shown in Fig. 8 or linear as shown in Figs. 2 and 6. It will also be clear that matching posts similar to those shown in Figs. 6, 7, and 7*a* may be employed in the region of variation in thickness of dielectric.

While I have described above principles of the invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention, as set forth in the objects thereof and in the accompanying claims.

I claim:

1. An electromagnetic horn comprising first and second elongated strip-like conductors, dielectric means including solid dielectric material separating said conductors in closely spaced substantially parallel relation, said second conductor being wider than said first conductor to present thereto a planar surface whereby the electric field of radio frequency energy propagated along said conductors is concentrated therebetween similarly to the field distribution of the TEM mode, said conductors being terminated for end-fire radiation, said first conductor having a first part of uniform width and having a second part adjacent the terminated end thereof flared outwardly in a plane parallel to said planar surface to provide in conjunction therewith an open sided horn, and a characteristic of said dielectric means being varied from a point in said horn toward the large end thereof to provide an impedance transition between said conductors and free space.

2. An electromagnetic horn according to claim 1, wherein the dielectric material is in the form of a layer and the variation in the dielectric characteristic is a variation in the thickness of said layer.

3. An electromagnetic horn according to claim 2, wherein said variation of thickness is exponential.

4. An electromagnetic horn according to claim 2, wherein said variation of thickness is a linear variation.

5. An electromagnetic horn according to claim 2, wherein the variation in thickness of the layer of dielectric is symmetrical with respect to the mid-plane between said conductors.

6. An electromagnetic horn according to claim 3, wherein the variation in thickness of the layer of dielectric comprises a tapering of the dielectric from a maximum thickness from a given point in said horn to a minimum thickness adjacent the large end of said horn.

7. An electromagnetic horn according to claim 1, wherein the variation in the dielectric characteristic includes the provision of posts of metallic material disposed between said conductors.

8. An electromagnetic horn according to claim 1, wherein the variation in the dielectric characteristic includes the provision of posts of dielectric material disposed between said conductors in the area of the flared part of said first conductor.

9. An electromagnetic horn according to claim 1, wherein both said first and second conductors are flared to provide said horn.

10. An electromagnetic horn array comprising a pair of line conductors of elongated form spaced apart in substantially parallel relation, an elongated ground conductor disposed mid-way between said line conductors, said ground conductor being wider than either of said line conductors to present to each of said line conductors a planar conducting surface whereby the electric field of radio frequency energy propagated along said conductors is concentrated between each line conductor and the adjacent planar surface of said ground conductor similarly to the field distribution of the TEM mode, and each of said line conductors having a part adjacent the end thereof flared outwardly in a plane parallel to said ground conductor to provide therewith two adjacent open sided horns.

11. An electromagnetic horn array according to claim 10, wherein the spacing between the conductors includes dielectric material and wherein a characteristic of said dielectric material is varied from a point within each horn toward the large end of each horn to provide impedance transition between the conductors and free space.

12. An electromagnetic horn array according to claim 11, wherein the dielectric material is in the form of layers, and the variation in the dielectric characteristic thereof is a variation in the thickness of such layers.

13. An electromagnetic horn array according to claim 12, wherein the variation in thickness of the layer of dielectric material is symmetrical with respect to the ground conductor.

14. An electromagnetic horn array comprising a number N of line conductors, a number N−1 of ground conductors, a number N+1 of dielectric means separating said line and said ground conductors, said ground conductors being wider than said line conductors each of said line conductors having a part adjacent the end thereof flared outwardly in a plane parallel to said ground conductor to provide therewith an open sided horn, and a characteristic of said dielectric means being varied toward the large end of said flared line conductors to provide substantially smooth impedance transition between said conductors and free space.

15. An electromagnetic horn array according to claim 14, wherein said dielectric means comprises layers of solid dielectric, and the variation in the dielectric characteristic includes a variation of the dielectric layers with the variation being substantially symmetrical with respect to the ground conductors.

16. An electromagnetic horn array according to claim 14, wherein all the line and ground conductors are flared to provide the horn effects.

17. In an electromagnetic radiation system, a transmission line comprising first and second elongated con-

ductors and a layer of dielectric material disposing said conductors in substantially parallel spaced relation, said second conductor being wider than said first conductor to present to said first conductor a planar conducting surface whereby the electric field of radio frequency energy propagated along said conductors is concentrated therebetween similarly to the field distribution of the TEM mode and said first conductor having a first portion along its length of uniform width and a second portion flared outwardly in a plane parallel to said second conductor toward the output end of said conductors to provide in conjunction with said second conductor an impedance transition between the transmission path provided by said conductors and free space.

18. In an electromagnetic radiation system according to claim 17, wherein the characteristics of said layer of dielectric material are varied from a point between said conductors toward the output end of said conductors.

19. In an electromagnetic radiation system according to claim 18, wherein said characteristic variation comprises a variation in the thickness of said layer of dielectric material.

20. In an electromagnetic radiation system according to claim 18, wherein said characteristic variation comprises a tapering of said layer of dielectric material toward the output end of said conductors.



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