

July 30, 1968

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3,395,059

METHOD OF MAKING LIGHTWEIGHT HORN ANTENNA

Filed April 15, 1964

2 Sheets-Sheet 1

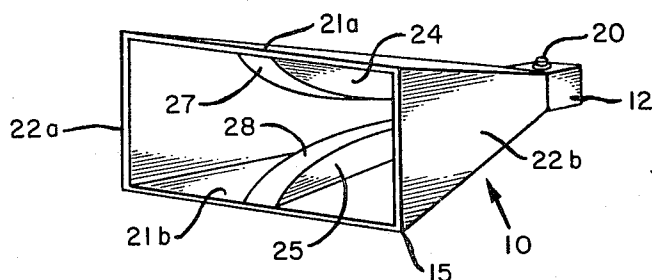


**FIG-1**

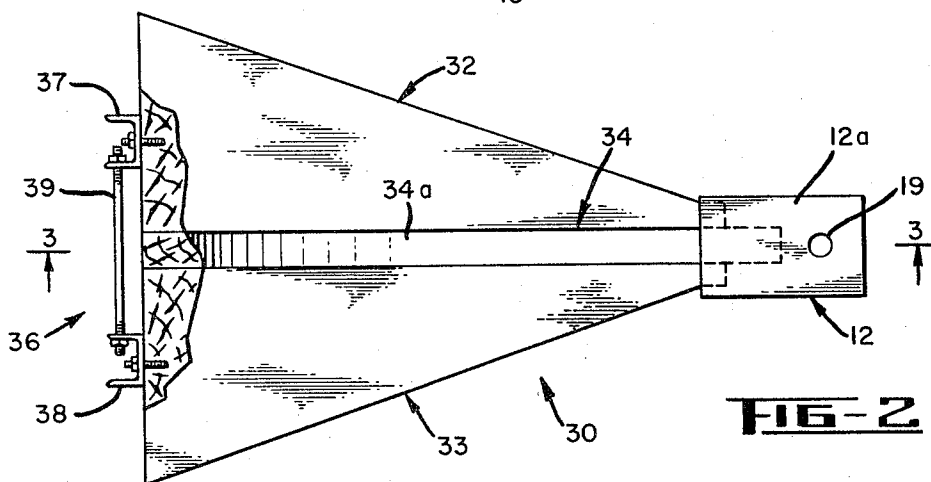


**FIG-2**

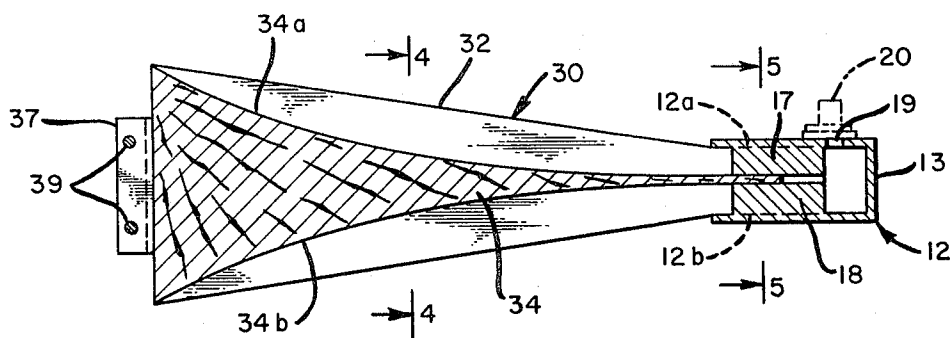


**FIG-3**

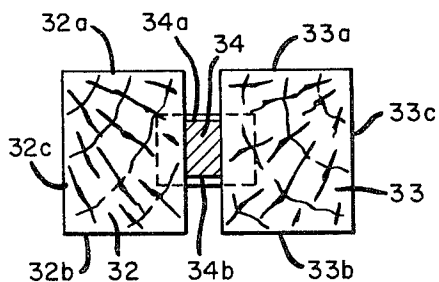


**FIG-4**

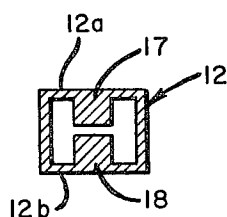


**FIG-5**

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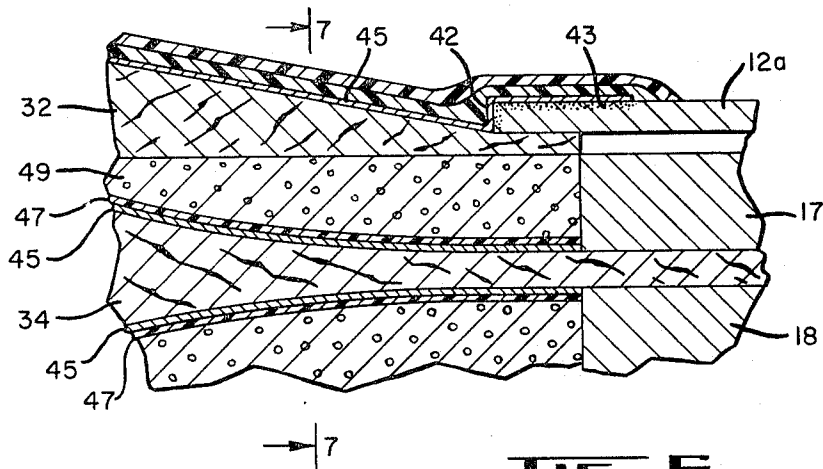


FIG-6

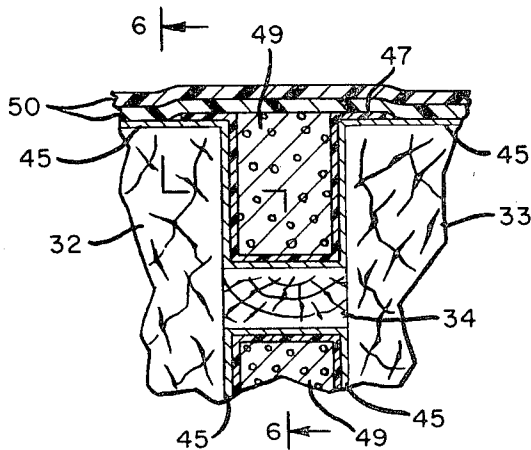


FIG-7

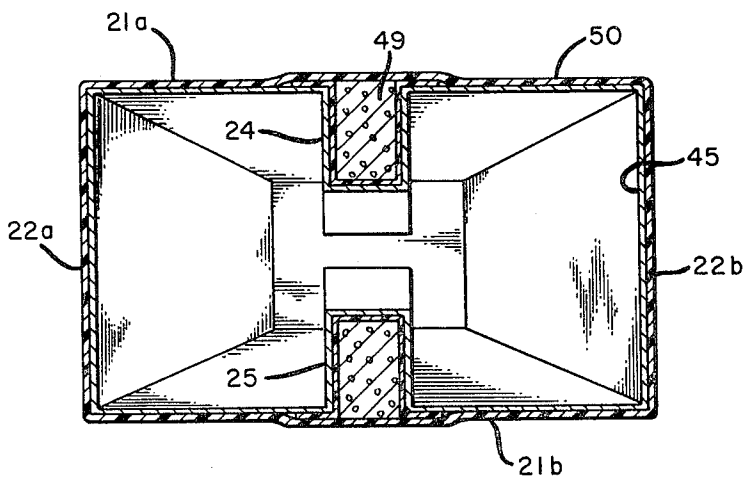


FIG-8

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3,395,059

## METHOD OF MAKING LIGHTWEIGHT HORN ANTENNA

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4 Claims. (Cl. 156—78)

### ABSTRACT OF THE DISCLOSURE

A ridged waveguide horn antenna is made by joining the smaller end of a three-piece flared pattern with a section of ridged waveguide, flame spraying a thin metal layer on the pattern, lining the ridge-defining cavity in the pattern with glass cloth and filling the cavity with thermosetting foam material, wrapping the pattern and front portion of the waveguide with glass cloth, impregnating the latter and removing the pattern after the impregnated cover is cured.

This invention relates to antennas and in particular to a ridged horn antenna and the method of making same with lightweight synthetic materials.

The horn antenna is essentially a waveguide with flared or diverging walls and two inwardly and longitudinally extending curved ridges. Because of its complex configuration, the ridged horn is costly to fabricate, one technique currently employed being electroforming the horn on a die of the same shape. Moreover, the weight of an all-metal horn limits its utility and application where weight limitations are severe.

An object of this invention is the provision of an improved method of making a lightweight ridged horn antenna, the term "lightweight" connoting one-third to one-half less weight than the corresponding all-metal horn.

A further object is the provision of such a method which may be performed rapidly without special equipment or skilled operators.

These objects are achieved by constructing the flared portion of the horn on a tapered multi-section mold or pattern which is joined at the smaller end to a ridged waveguide. The pattern preferably has three juxtaposed sections with the middle section defining the inner surfaces of horn ridges and the outer sections defining the remainder of the flared horn. A thin layer of metal is applied to the tapered pattern surfaces and a fibrous sheet, such as glass cloth, is placed against the ridge-defining cavity walls, impregnated with resin and cured. The junction of the flared portion with the ridged waveguide is critical and the metal is applied in such a manner that this joint is electrically continuous. Each of the lined ridge cavities is filled with low density foamed plastic and the flared structure and the front part of the waveguide are covered with two layers of the fibrous sheet which is then impregnated with a resin and cured. The pattern sections are then separately removed and the horn is complete.

These and other objects of the invention will become apparent from the following description of a preferred embodiment thereof reference being had to the accompanying drawings in which:

FIGURE 1 is a perspective view of a double ridged waveguide horn made in accordance with the invention;

FIGURE 2 is a top view of a flared wood pattern, partially broken away, and a ridged waveguide attached thereto;

FIGURE 3 is a longitudinal section taken on line 3—3 of FIGURE 2;

FIGURES 4 and 5 are transverse sections taken on lines 4—4 and 5—5, respectively, of FIGURE 3;

FIGURE 6 is a greatly enlarged longitudinal section of

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the junction of the flared and rear horn parts prior to removal of the pattern, the section being taken on line 6—6 of FIGURE 7;

FIGURE 7 is a transverse section taken on line 7—7 of FIGURE 6; and

FIGURE 8 is a transverse section of the finished horn, the thicknesses of the laminar parts being greatly exaggerated for clarity of the description.

Referring now to the drawings, FIGURE 1 illustrates a double-ridged rectangular waveguide horn 10 made in accordance with this invention. The horn is a composite structure comprising a rear part of standard ridged metal waveguide 12 closed by an end wall 13, and a front flared molded part 15 having an open front end defining the horn aperture. Waveguide 12 has broad walls 12a and 12b from which inwardly and forwardly projecting ridges 17 and 18 extend as view in FIGURE 1. An opening 19 in wall 12a behind the ridge 17 is formed to receive a feed element 20 which couples energy between the horn and external circuits.

Flared part 15 has broad walls 21a and 21b and narrow walls 22a and 22b which converge from the front end to a junction with waveguide 12. Ridges 24 and 25 depend from broad walls 21a and 21b and are electrically continuous with and longitudinally aligned with waveguide ridges 17 and 18, respectively. The spacing between ridges 24 and 25 increases non-linearly from a minimum at waveguide 12 equal to the waveguide inter-ridge spacing to a maximum at the horn aperture.

Ridged waveguide horns are well known in the art and do not per se constitute this invention. Similar horns are described and illustrated in Radiation Laboratory Series, volume 9, page 360 (McGraw-Hill, 1948).

In accordance with our invention, a sturdy lightweight ridged horn is fabricated with fibrous sheet material, such as glass cloth, thermosetting resins and low density rigid cellular material such as expanded polystyrene, foamable mixtures of polyesters and isocyanates and similar substances. These materials are molded on a three-section pattern 30, shown in FIGURES 2 and 3, which is initially telescoped into the open front end of the ridged waveguide. For a horn antenna capable of operating over a frequency range of 2 gc. to 12 gc. we have found that molding the flared portion on the front end of conventional ridged waveguide is quicker and more economical than molding the entire device, and the additional weight of the metallic waveguide is negligible for such an antenna.

Pattern 30 preferably is made of hard wood or the like and comprises substantially identical side sections 32 and 33 and a center section 34. Each of these sections is generally rectangular in cross section as shown in FIGURE 4, the side sections 32 and 33 having tapered surfaces 32a, 32b, 33a, 33b on which the broad walls 21a and 21b of the flared section are formed, and have outer side surfaces 32c and 33c, respectively, defining the side walls 22a and 22b of the flared section 15. The width of center section 34 defines the width of ridges 24 and 25 and has opposed longitudinally curved surfaces 34a and 34b for forming inner surfaces 27 and 28 of the horn ridges.

Pattern sections 32, 33 and 34 are releasably secured together at their forward ends by a clamp 36 comprising brackets 37 and 38 fastened to the faces of side sections and transverse tie rods 39 connected to the brackets. The rear ends of side sections 32 and 33 telescope into the front portion of ridged waveguide section 12, and center section 34 is supported in the space between the ridges of section 12. The multisection pattern is thus locked together at its front and rear ends.

It is important that the outer wall surfaces of the front portion of waveguide section 12 be roughened to insure that metal subsequently deposited on the pattern as described below is securely mechanically bonded to ad-

jacent portions of waveguide section 12. The front edge 42, see FIGURE 6, and adjacent parts of the walls of waveguide 12 preferably are made porous by metal grit blasting as indicated in the stippled area 43 in FIGURE 6. The sprayed metal in its molten state flows into the irregular indentations or pockets formed by this roughening step and becomes anchored in them upon hardening. As the metal cools, it contracts and draws the waveguide and the flared parts together. This bonding provides additional mechanical strength at the junction of the waveguide and flared parts, prevents separation thereof, and insures electrical continuity of the metal wall.

With the pattern and waveguide parts thus assembled, a releasing agent such as polyvinyl alcohol is applied to the pattern surfaces to facilitate separation of the pattern and the finished horn.

A thin electrically conductive layer shown at 45 in FIGURES 6, 7 and 8 with greatly exaggerated thickness is next applied to the surfaces of the pattern. The layer 45 may be metal, such as tin, preferably applied by flame spraying to a thickness of approximately 0.010 inch. It is applied also to the roughened forward edge 42 and surface 43 of waveguide 12 to a thickness of approximately 0.050 inch to reinforce the junction of the waveguide and horn as explained above. Layer 45 is the conductive surface for the flared portion 15 of the finished horn and is the only metal in that part of the assembly.

The metallized surfaces of the ridge cavities in the pattern are then covered with flexible fibrous sheets of suitable material such as glass cloth, each sheet being suitably pressed against the metallic layer 45 on the ridge-defining surfaces including adjacent sides of sections 32 and 33 and curved surface 34a or 34b of the center section 34. Sheets 47 are coated with a thermosetting resin such as an epoxy-based or bisphenol resin, a commercially available type being sold under the trademark "Epon 815" and made by Shell Chemical Company, to a thickness of approximately 0.010 inch and the entire assembly is placed in an oven and cured for three hours at a temperature of 130° F. Sheets 47 are thereby converted to a hardened shell tightly bonded to the conductive layer 45.

In order to reinforce the ridge cavities lined by sheets 47, a lightweight cellular material 49 is directed into spaces within the ridges so as to fill them up to the level of the outer surfaces of side sections 32 and 33. The cellular material may be any of the well-known types such as foamable mixtures of polyesters and isocyanates or other low density foamed synthetics which are extremely lightweight while retaining certain structural rigidity and strength. A mixture of this material is introduced into the spaces of the ridges and is allowed to react and expand until the spaces are filled. In practice, polyurethane foam having a density of two pounds per cubic foot was used, and was cured for 24 hours at 70° F. and thereafter at 130° F. for three hours.

The wall of the flared horn is next formed by wrapping two layers 50 of 0.010 inch glass cloth or the like coaxially of the pattern around the surfaces 32a, 32b, 32c, 33a, 33b and 33c thereof and across the exposed surfaces of the cellular material 49. The cloth as wrapped overlies the front of the waveguide for approximately two inches of its length. Layer 50 is then impregnated with a resinous material such as "Epon 815" and thereafter the entire assembly is cured in an oven at approximately 130° F. for three hours. Layer 50 is thus securely bonded to the conductive layer on the pattern and sets permanently into a rigid body.

When the assembly is cooled, the pattern is removed. This is accomplished by releasing the tension on tie rods 39 and drawing the center section 34 longitudinally from the side sections 32 and 33. The latter are then moved toward each other and forwardly from the horn. The horn assembly is then sanded to remove rough edges, connector assembly 55 is attached to the ridged waveguide 12, and the horn is complete.

By way of example and comparison, a horn antenna made in accordance with the invention and successfully tested has the following characteristics:

|                                               |               |      |
|-----------------------------------------------|---------------|------|
| Frequency range                               | -----gc--     | 2-12 |
| Over-all length                               | -----inches-- | 33   |
| Horn aperture:                                |               |      |
| Width                                         | -----do--     | 18   |
| Height                                        | -----do--     | 13   |
| Total weight                                  | -----lbs--    | 7    |
| Weight of corresponding aluminum horn antenna | -----lbs--    | 13   |
| Relative strength to weight ratio:            |               |      |
| Horn 10                                       | -----         | 1.14 |
| Aluminum horn                                 | -----         | 1.0  |

What is claimed is:

1. The method of making a ridged waveguide horn having a rectangular cross-section with dimensions that decrease from the front toward the rear of the horn consisting of the steps of

assembling a three-section flared pattern with a center section sandwiched between the side sections and having two opposed surfaces converging toward each other from front to rear of the pattern at a greater slope than corresponding surfaces on each of the side sections,

releasably securing said sections together,

attaching a section of ridged waveguide to the rear end of the pattern with the center section of the pattern longitudinally aligned with the ridges of the waveguide,

coating the converging surfaces of the mandrel with a release agent,

flame spraying a thin metal layer on said pattern surfaces,

placing glass cloth on the converging surfaces of said center section and coating said cloth with a thermosetting resin and curing same for a predetermined time,

filling the spaces between the center and side sections of the pattern with a thermosetting foam material to form the horn ridges,

wrapping the pattern and the front portion of the waveguide with glass cloth,

impregnating the glass cloth with a resin and curing same for a predetermined time to form the flared part of the horn, and

disconnecting the pattern sections from each other and removing from said horn the center section and the side sections in that order.

2. The method of making a ridged waveguide horn having cross-sectional dimensions which decrease from the front toward the rear of the horn consisting of the steps of

assembling a three-section flared pattern having a center section sandwiched between side sections and having two opposed surfaces converging toward each other from front to rear of the pattern at a greater slope than corresponding surfaces on each of the side sections,

attaching a section of rigid waveguide to the rear end of the pattern with the center section of the pattern longitudinally aligned with the ridges of the waveguide,

applying a thin metal layer on said pattern surfaces, placing glass cloth on said opposed surfaces of the center section and applying thereto a curing agent and curing the impregnated cloth for a predetermined time,

filling the spaces between the center and side sections with a rigid foam material to form the horn ridges, wrapping the pattern and the front portion of the waveguide with glass cloth,

impregnating the glass cloth with a resin and curing

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same for a predetermined time to form the front part of the horn, and

disconnecting said sections from each other and removing from said horn the center section and thereafter the side sections of the pattern.

3. The method of making a ridged waveguide horn having cross-sectional dimensions which decrease from the front toward the rear of the horn consisting of the steps of

assembling a three-section flared pattern with a center section sandwiched between the side sections and having two opposed surfaces converging toward each other from front to rear of the pattern at a greater slope than corresponding surfaces on each of the side sections,

attaching a section of ridged waveguide to the rear end of the pattern with the center section of the pattern longitudinally aligned with the ridges in the waveguide,

coating the converging surfaces of the mandrel with a releasing agent,

applying a thin metal layer on said pattern surfaces, placing resin impregnated glass cloth on the converging surfaces of the center section of the pattern and curing same for a predetermined time,

filling the spaces between the center and side sections of the pattern with low density plastic foam to form the horn ridges,

wrapping the pattern and the front portion of the waveguide with glass cloth,

impregnating the glasscloth with a resin and curing same for a predetermined time to form the horn, and

disconnecting said sections from each other and removing them from said horn.

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4. The method of making a ridged waveguide horn having cross-sectional dimensions which decrease from the front to the rear ends of the horn consisting of the steps of

assembling a ridged waveguide with a multisection flared pattern having opposed central longitudinal ridge cavities,

coating the pattern with a releasing agent, depositing a conductive layer on said pattern,

disposing flexible fibrous sheets in said cavities, impregnating said sheets with a thermosetting resin and curing same for a predetermined time,

filling the sheet-lined cavities of the pattern with an expanded cellular material,

wrapping the pattern and the adjacent part of the waveguide with fibrous sheet material,

impregnating the latter sheet material with a resin and curing same for a predetermined time to form the horn, and

removing the sections of the pattern from the horn.

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