United States Patent

[11] 3,618,112

[72] Inventors **Robert J. Grove**
Coronado;
Merrill M. Reeder, Spring Valley, both of Calif.

[21] Appl. No. **21,569**
[22] Filed **Mar. 23, 1970**
[45] Patented **Nov. 2, 1971**
[73] Assignee **General Dynamics Corporation**

[54] **RADOME AND METHOD OF MAKING SAME**
11 Claims, 13 Drawing Figs.

[52] **U.S. Cl.** **343/872,** 264/257
[51] **Int. Cl.** **H01q 1/42**
[50] **Field of Search** 156/204, 205, 206; 264/257, 258, 286; 343/872

[56] **References Cited**

UNITED STATES PATENTS

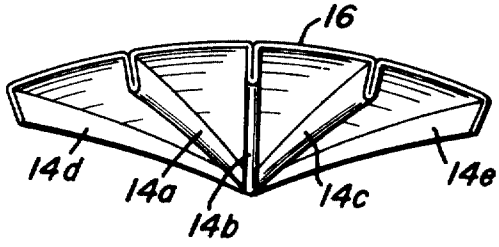
3,349,157	10/1967	Parsons	264/258
3,444,558	5/1969	Leitner	343/872

OTHER REFERENCES

Oleesky & Mohr, Handbook of Reinforced Plastics, Feb. 21, 1964, pp. 133–136, copy 343–872

Primary Examiner—Eli Lieberman
Attorney—Martin Lukacher

ABSTRACT: A radome is described which is formed from resin-impregnated glass, quartz, or other fiber sheets which are folded to provide longitudinally extending radial ribs. The folds are formed by means of a tool made up of several sector-shaped members. These members are matched along one edge and the sheet, while pliable, is formed into double thickness folds between adjacent ones of the members. The sector shaped members are clamped together as each fold is made to provide the ribs.



PATENTED NOV 2 1971

3,618,112

SHEET 1 OF 4

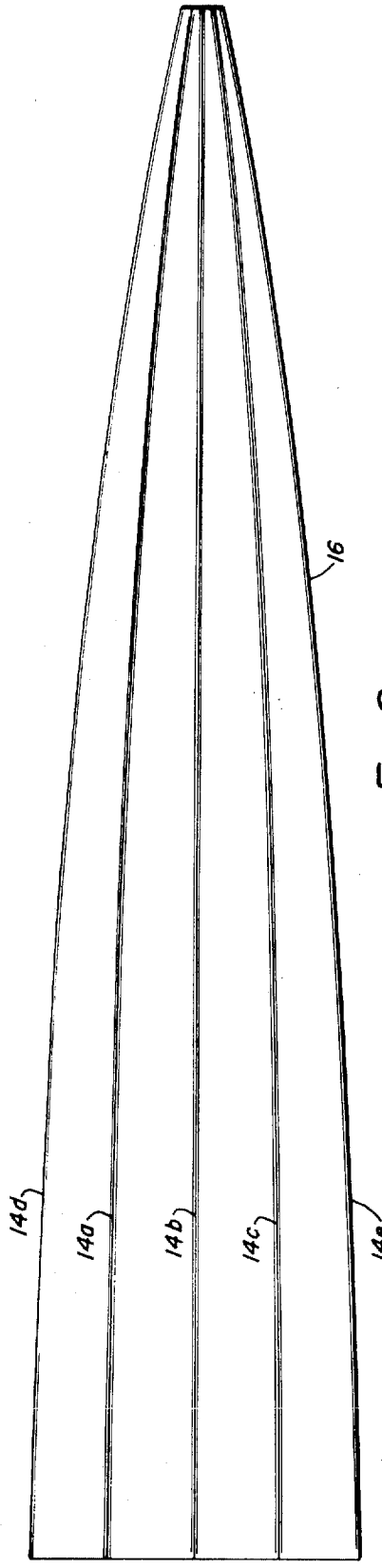


FIG. 2.

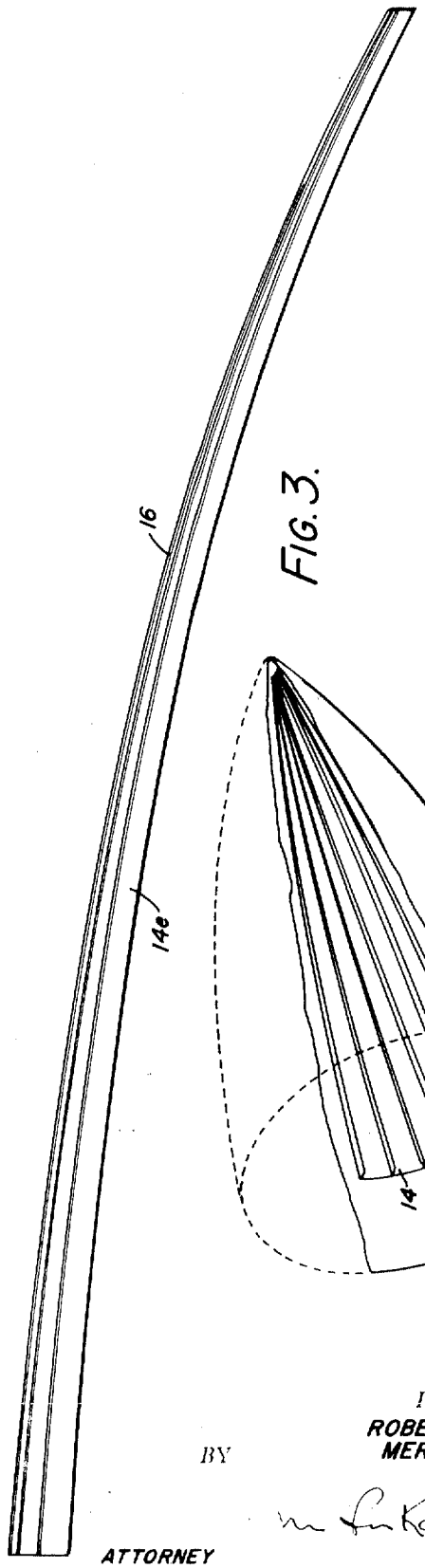


FIG. 3.

FIG. 1.

INVENTORS
ROBERT J. GROVE AND
MERRILL M. REEDER

BY

ATTORNEY

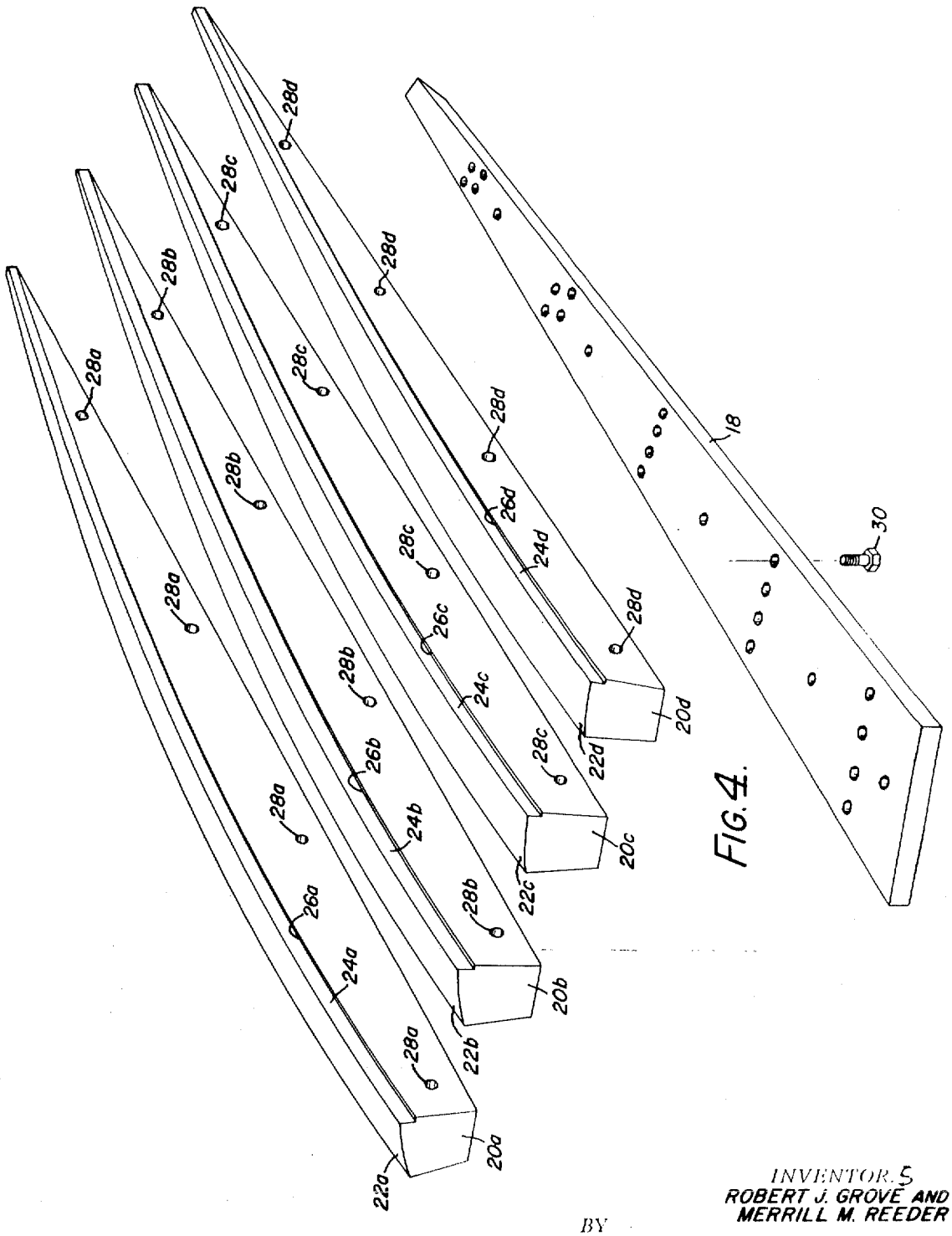


FIG. 4.

INVENTORS
ROBERT J. GROVE AND
MERRILL M. REEDER

BY

ATTORNEY

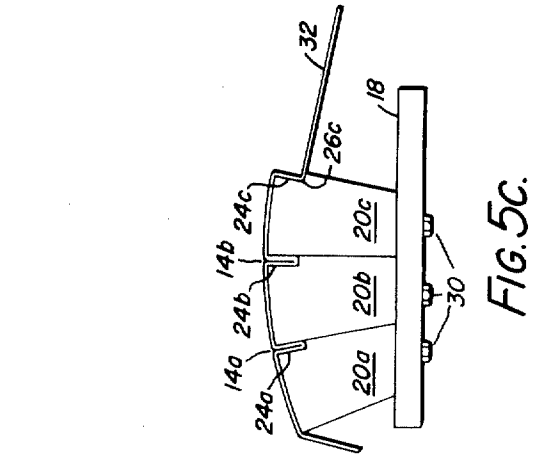


FIG. 5c.

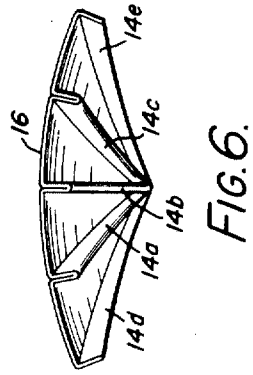


FIG. 6.

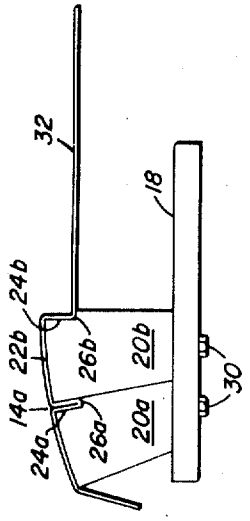


FIG. 5b.

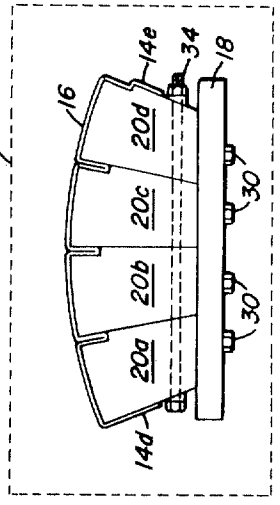


FIG. 5e.

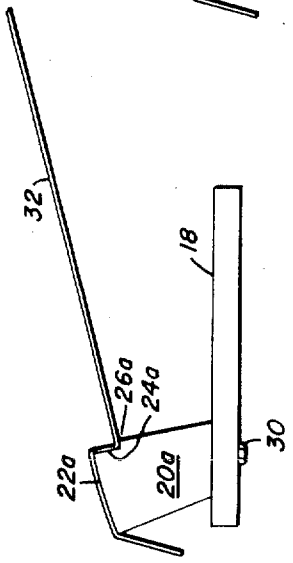


FIG. 5a.

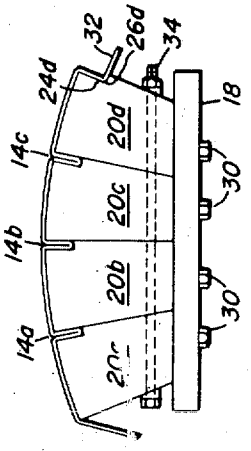


FIG. 5d.

INVENTORS
ROBERT J. GROVE AND
MERRILL M. REEDER

BY

ATTORNEY

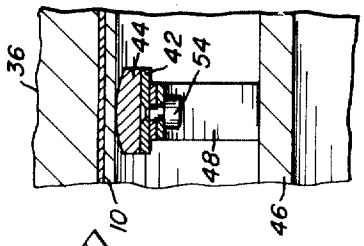
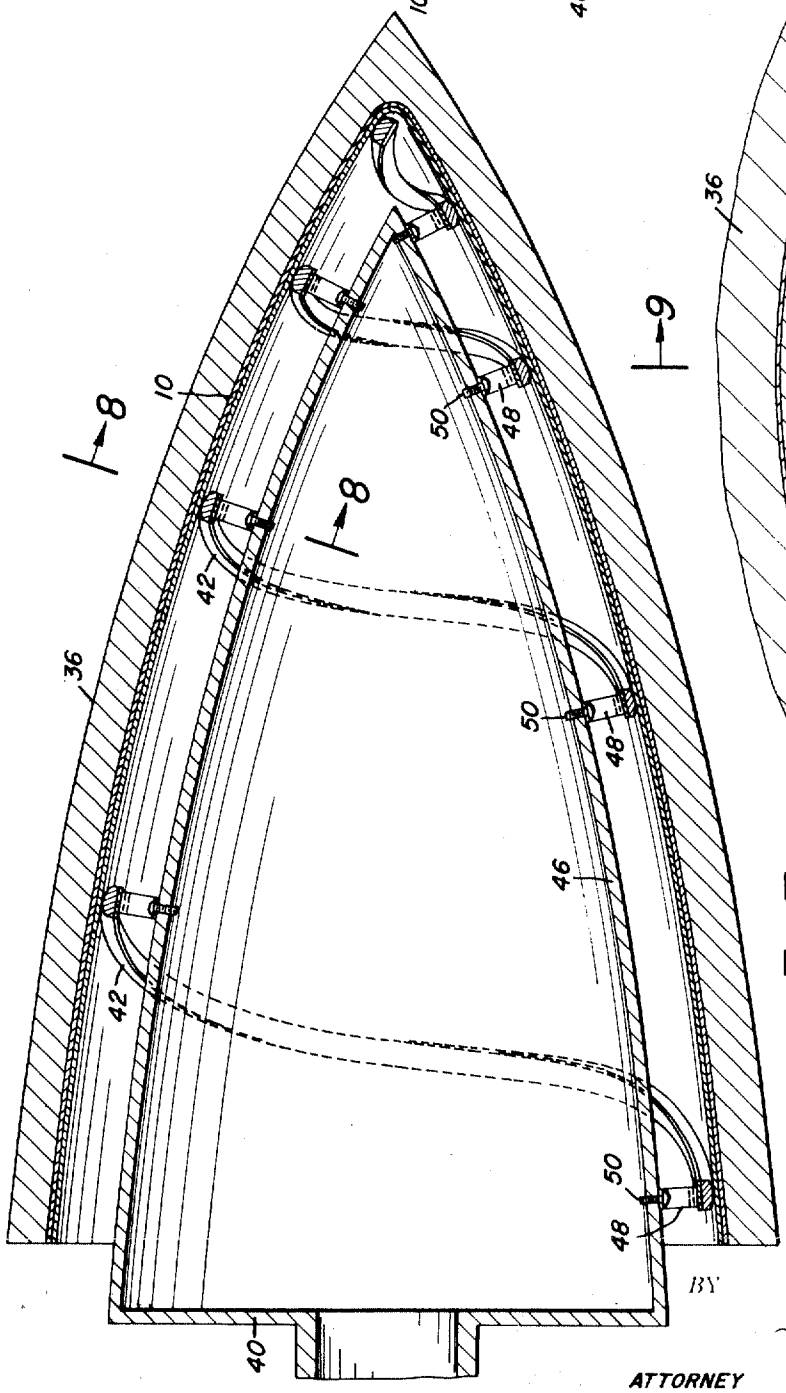


FIG. 9.



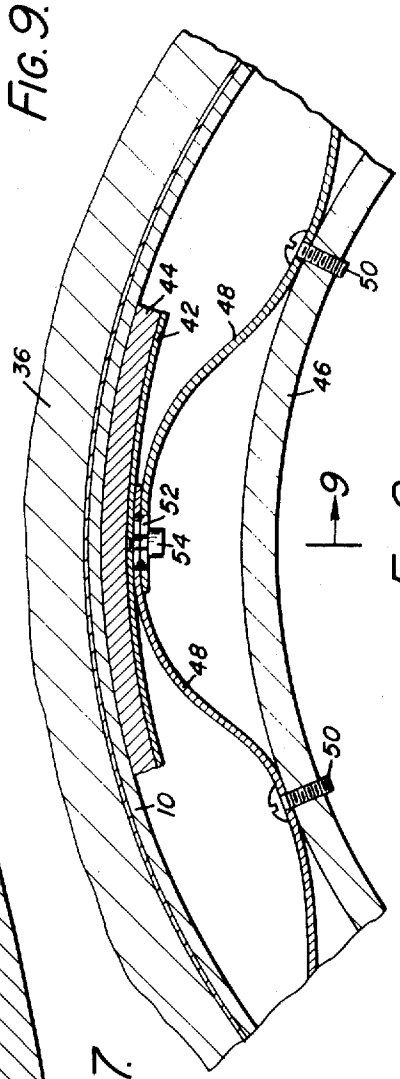


FIG. 8.

FIG. 7.

INVENTOR.
ROBERT J. GROVE AND
MERRILL M. REEDER

BY

ATTORNEY

RADOME AND METHOD OF MAKING SAME

The present invention relates to radomes and methods of making same and particularly to a radome having longitudinal ribs which are formed with the aid of a clamping tool.

The invention is especially suitable for use in fabricating a radome of the type described in U.S. Pat. application, Ser. No. 752,948, filed Aug. 15, 1968, in the names of Gus P. Tricoles and Eugene L. Rope and assigned to the same assignee as this application now U.S. Pat. No. 3,576,581. As described in the Tricoles and Rope application, longitudinally extending ribs improve the radiation transmission characteristics of the radome.

Radomes, in order to minimally interfere with the transmission of microwave energy are desirably very thin walled. The radomes must, however, be structurally strong in order to withstand the forces applied thereto when they are operationally in the nose of an aircraft. Inasmuch as these two desirable properties are contradictory, much effort has been directed towards providing a thick radome which has the necessary structural properties and yet does not interfere with the transmission of radiation. It has been found, as described in the above-referenced Tricoles and Rope application, that radomes transmissivity may be enhanced and, in fact, improved by equipping the radome with ribs.

Accordingly, it is an object of this invention to provide an improved radome in which ribs are fabricated in a manner to provide structural rigidity and strength while providing thin wall construction.

It is a further object of the invention to provide a radome in which the walls of the structure as well as the ribs are thin.

It is a still further object of the invention to provide an improved radome having stiffeners, which apply structural rigidity thereto, formed as an integral part of the structure.

It is a still further object of the invention to provide an improved method manufacturing a radome.

It is a still further object of the invention to provide an improved method of fabricating structural rigid parts of thin sheet material, which parts are especially suitable for use in radomes.

It is a still further object of the invention to provide an improved method of manufacturing internally ribbed shells.

It is a still further object of the invention to provide an improved method of manufacturing laminated radomes.

Briefly described, a radome embodying the invention is formed as a sheet of pliant material such as cloth which may be impregnated with epoxy, polyester, polyimide or similar resins. A tool is used which has a plurality of sector-shaped members; the outer surfaces of which define the shape of the radome. The sheet is placed over each of the sector-shaped portions in sequence and folds are formed between adjacent sector-shaped members. The members are then clamped together and the entire structure stiffened, as by curing a resin impregnated in the cloth. If desired, the ribbed radome structure may be laminated to an outer shell of similar material to provide an especially strong and rigid structure.

The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof will become more readily apparent from a reading of the following description in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of a radome in accordance with the present invention, the view being broken away and partially shown in phantom in order to illustrate the internal construction of the radome;

FIG. 2 is a top view of one of the ribbed segments which is used in constructing the radome shown in FIG. 1;

FIG. 3 is a side view of the ribbed segment shown in FIG. 2;

FIG. 4 is an exploded view of the tool used to make the ribbed segment shown in FIGS. 2 and 3;

FIGS. 5*a* through 5*e* are end views illustrating the steps involved in the method of making the ribbed segment shown in FIGS. 2 and 3;

FIG. 6 is a view from the rear of the ribbed segment after the completion of the steps shown in FIGS. 5*a* through 5*e*;

FIG. 7 is a sectional view showing one of the steps in construction of the outer shell of the radome shown in FIG. 1;

FIG. 8 is a fragmentary sectional view of the apparatus shown in FIG. 7, the view taken along the line 8—8 in FIG. 7 and viewed in the direction of the arrows;

FIG. 9 is a fragmentary sectional view of the portion of the apparatus shown in FIG. 8, the section being taken along the line 9—9 when viewed in the direction of the arrows.

Referring more particularly to FIG. 1, there is shown a radome made out of an outer shell **10** and a ribbed shell **12**. These shells may be made up of sheets of cloth which are very thin. The sheets are desirably impregnated with resin, such as epoxy, polyester, polyimide, or other suitable resin. The shells are laminated together to provide an essentially strong, structurally rigid radome suitable for mounting in the nose of a missile, rocket or aircraft. The shape of both the inner and outer shells is generally cylindrical, conical or ogive. The inner shell has a multiplicity of longitudinal ribs **14** which are desirably thin and are made up of two thicknesses of the sheet which forms the inner shell **12**.

Reference may be had to the above-mentioned Tricoles and Rope application for a discussion as to how the ribs **14** improve the electrical properties of the radome and increases its transmission to radiation.

The inner shell **12** is made up of a number of segmental portions, one of which **16** is shown in FIGS. **2** and **3**. The three inner ribs **14***a*, **14***b* and **14***c* are made up of a double thickness of the material from which the segmental portion **16** is constructed. The outer ribs **14***d* and **14***e* are made up of single thicknesses of the sheet material. Thus, when adjacent segmental portions are joined together to form the entire inner shell **12**, all ribs will be made up of a double thickness of sheet material. It will therefore be observed that the ribs, as well as the shells themselves, will be exceedingly thin, say 0.020 inches. This thickness may be much, much less than a quarter-wavelength of the radiation which is to be transmitted to the radome, and thus, the radome will be essentially invisible to the radiation. The ribs act as stiffeners and impart the necessary structural rigidity to the radome without requiring added thickness and weight in the shell walls.

The segmental portion **16** may be fabricated with the aid of the tool shown in FIG. **4**. This tool includes a baseplate **18** and a plurality of wedgelike, sector-shaped members **20***a*, **20***b*, **20***c* and **20***d*. When the sector-shaped members **20** are disposed on the baseplate, their outer surfaces **22***a*, **22***b*, **22***c* and **22***d* are contiguous to each other and define the shape of the sector of the radome to be provided by the portion **16**. The bottom surface of the members **20** have different angles with respect to the sides, so that when secured to the baseplate by means of screws **30** which extend through the holes in the baseplate, form the desired surface shape by their contiguous upper surfaces **22***a* through **22***d*. One side of each of the members **20***a* through **20***d* has a notch **24***a*, **24***b*, **24***c* and **24***d*. This notch extends radially downward towards the baseplate, a predetermined distance equal to the desired height of the ribs. The bottom of each notch defines a shoulder **26***a*, **26***b*, **26***c* and **26***d*. Holes **28***a* in the sector-shaped member **20** *a* and corresponding holes **28***b*, **28***c* and **28***d* in members **20***b*, **20***c* and **20***d* are aligned with each other when the members **20***a*, **20***b*, **20***c* and **20***d* are mounted on the baseplate **18**. The members may be bolted together in side-by-side relationship via these holes **28**.

Referring to FIGS. **5***a* through **5***e*, it will be observed that the segmental portion **16** is constructed by first fastening the member **20***a* to the baseplate **18** by means of the screws **30**. The sheet of pliant material **32** is then placed on the surface **22***a* of the member **20***a*. This sheet is folded over the edges of the surface **22***a*. In order to form the rib **14***a*, the sheet is folded into the notch **24***a* until it reaches the shoulder **26***a*. A 180° fold is then made at the shoulder **26***a*. Next, as shown in FIG. **5***b*, the next member **20***b* is placed against the member **20***a* so as to confine the fold which provides the rib **14***a*. An approximately 90° fold is then made at the left edge of the member **20***b*, so that the sheet **32** conforms to the upper sur-

face 22*b* of the member 20*b*. The next rib 14*b* is formed in the same manner as explained in connection with FIGS. 5*a* and 5*b* by making the folds in the notch 24*b* and placing the next number 20*c* against the member 20*b*. Each member is fastened in place by means of screws 30 on the baseplate 18. The notch 24*c* is then used and the process continued in order to provide the rib 14*c*. After all of the members 20*a* through 20*d* are assembled on the baseplate, they are clamped together by means of bolts 34. The entire structure is then placed in a vacuum chamber, auto clave or pressure boot 21 which causes the outer folds 14*d* and 14*e* to conform to the notch 24*d* in the member 20*d* and against the left side wall of the member 20*a*. The sheet 32 may then be partially or completely cured by heating in the chamber and allowing the clamped-together structure to remain in the chamber for a period of time, varying with the resin. The structure is then disassembled by removing the bolts 34 and screws 30 and the single-thickness ribs 14*e* and 14*d* cut to the required length. The completed segmental portion 16 is shown in FIG. 6.

In the event that an outer shell 10 is not to be used, the several segmental portions 16 may be placed directly in a mold, such as the conically shaped mold 36, as shown in FIG. 7. A conical form (not shown) may then be placed in the mold. Additional resin may be applied to the outer surfaces of the single-thickness ribs 14*e* and 14*d*. The conical form then holds the entire structure in position by applying pressure against the ribs. The mold is then heated, if necessary, so that the resin will cure and the various segmental portions 16 will become attached to each other at the single-thickness ribs 14*e* and 14*d*.

In the event that an outer shell 10 is used, it may be desirable to build up the outer shell 10 in the mold 36 from a plurality of sheets, say layers as shown in FIG. 7 of resin-impregnated cloth. These sheets may be placed against the internal surface of the mold 36. In order to smooth out the shell and remove any excess resin or bubbles formed during curing that weaken the radome structurally, the squeegee device 40 shown in FIG. 7 may be used. This device is made up of a helical band 42 of flexible material, such as steel which is coated on its upper surface by plastic material, the coating 44 imparting additional thickness to the helical band 42. A suitable plastic material is polytetraflourethylene, which is sold by the E. I. Dupont DeNemours Co. of Wilmington, Del., under their trademark "Teflon." The coated band 42 is mounted on a rotatable conical member 46 by means of leaf-type springs 48. Coil springs may also be used with a slight modification of the attachment. These springs may be screwed into the conical member 46 by means of attaching screws 50. The edge of the springs which are attached to the band 42 have aligned holes 52 therein. These holes may be in the form of slots through which rivets 54 which hold the springs 48 in position against the band 42, are disposed. The springs 48 may then have freedom of motion to compress and expand so as to apply the necessary spring pressure against the band and force the Teflon coating 44 against the sheets of material which define the shell 10. The conical member 46 may be rotated in order to squeegee any excess resin out of the sheets which define the shell 10 and to cause these sheets to conform to the shape of the mold. An opening (not shown) may be provided in the nose of the shell 36 through which the excess material may be forced. This nose opening may be connected to a vacuum source for draining off the excess resin. After the shell 10 is formed, the segmental portions 16 may be placed within the shell and laminated thereto, as heretofore described.

From the foregoing description, it will be apparent that there has been provided an improved radome and the method of making same. While materials which are desired in a preferred form of the invention have been described, as well as preferred forms of tools used in practicing the invention, it will be appreciated that variations and modifications therein within the scope of the invention will suggest themselves to those skilled in the art. Accordingly, the foregoing description should be taken merely as illustrative and not in any limiting sense.

We claim:

1. A radome which comprises a continuous sheet of cloth providing a shell having a generally conical slope, a plurality of radially inwardly extending ribs, each provided by a fold in said sheet which extends radially inward from the surface of said shell and is folded back 180° upon itself and then extends radially outwardly to said surface, said ribs reinforcing said shell for improving the structural rigidity thereof and the electromagnetic wave transmissively of said radome, and said cloth being impregnated with hardened resin so as to be self-sustaining.

2. The invention as set forth in claim 1 wherein said shell is made up of a plurality of said continuous sheets each adjoining another to provide a different segment of said shell, the adjoining walls of said segments each being provided by a single thickness of said cloth extending radially inwardly of said sheet to the same extent as said fold, the single thickness adjoining walls as joined together providing additional ribs of said shell.

3. The invention as set forth in claim 2 further comprising a generally conical-shaped outer shell of hardened resin impregnated cloth, the internal surface of said outer shell being of essentially the same shape and dimensions as the external surface of said internally ribbed shell, said internally ribbed shell being disposed within said outer shell with its external surface juxtaposed secured to the internal surface of said outer shell.

4. The invention as set forth in claim 3 wherein said ribbed and outer shells are laminated to each other at their juxtaposed surfaces.

5. The method of making a radome which comprises the step of:

a. laying a sheet of pliant material over the surface of several sector-shaped members having longitudinally extending spaces therebetween,

b. folding said sheet into said spaces so that overlapping portions of said sheet form several longitudinal ribs in said sheet,

c. securing said members together to apply clamping pressure laterally against said ribs, and

d. stiffening said sheet while it is clamped to provide a rigid body having the shape of at least a portion of said radome.

6. The invention as set forth in claim 5 wherein said sheet is impregnated with resin prior to stiffening.

7. The invention as set forth in claim 6 wherein said sheet is of fiber glass material.

8. The invention as set forth in claim 5 wherein said sector-shaped members have sides which radially extend from the curved surface over which said sheet is laid, one of said sides having a notch in the edge thereof which is formed with said curved surface, which notch forms a shoulder at a predetermined distance from said curved surface, and wherein said folding step is accomplished by laying said sheet downwardly into said notch, bending said sheet upwardly to form the fold with the bottom of said fold extending longitudinally along said shoulder, thereby having two thicknesses of said sheet in said notch, placing the unnotched side of another of said sector-shaped members in juxtaposition with said notched member in which said fold is formed so that the curved surfaces of said sector-shaped members are contiguous and continuous, bending said sheet laterally over said curved surface of said other sector-shaped member, then repeating the foregoing steps with said other sector-shaped members and said several additional sector-shaped members until said several ribs are formed.

9. The invention as set forth in claim 8 wherein said sheet is formed into a segmental portion of said radome, and including the steps of securing a plurality of said segmental portions together along their radially extending folded sides thereof to form a complete surface of revolution.

10. The invention as set forth in claim 9 further comprising the steps of laying a sheet of resin-impregnated material into a mold having the shape of said radome, placing said completed

surface of revolution provided by said ribbed segmental portions within said mold so that its outer surface is in juxtaposition with said resin-impregnated sheet, and laminating said resin-impregnated sheet and said ribbed portion together.

11. The invention as set forth in claim 10 including the step performed prior to said step of placing said ribbed portion into said mold of inserting a helically band of yieldable material into said mold, applying spring pressure to urge said band against said sheet, and rotating said band to squeegee any excess resin from said sheet and conform it to the shape of said mold.

* * * * *