343-812

SEARCH ROOM

May 13, 1969 R. T. LEITNER 3,444,558

RADOMES

Filed July 12, 1966

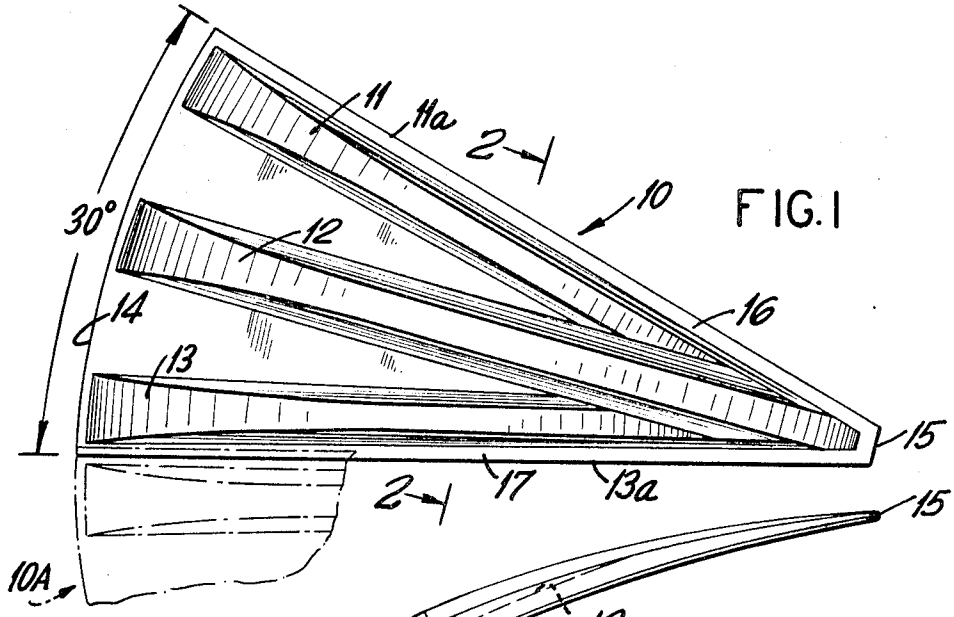


FIG. 1

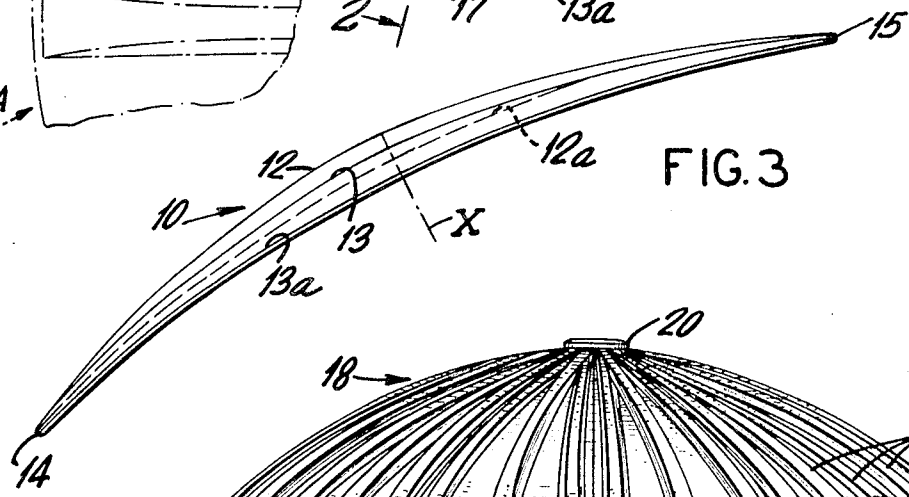


FIG. 3

FIG. 4

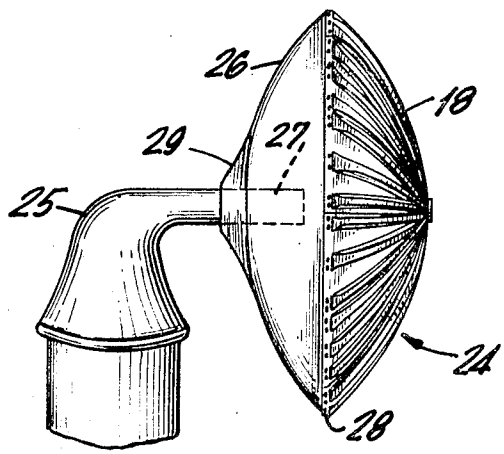


FIG. 5

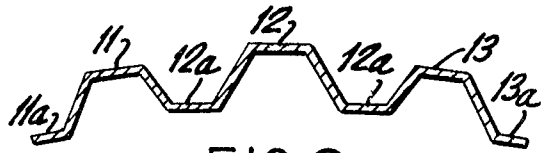


FIG. 2

INVENTOR.
ROBERT T. LEITNER

BY

Hopgood & Calimafde
ATTORNEYS.

United States Patent Office 3,444,558
Patented May 13, 1969

3,444,558

RADOMES

Robert T. Leitner, Norwich, N.Y., assignor to Technical Appliance Corporation, a corporation of New York

Filed July 12, 1966, Ser. No. 564,677
Int. Cl. H01q 1/42
U.S. Cl. 343—872 13 Claims

This invention relates to radomes and more specifically to a radome closure element of plastic material having an improved combination of physical and electrical properties.

The desirable radome is one having a protective housing with a closure element which is electrically transparent, environmentally opaque, resistant to weathering elements, and which does not impair the performance of the antenna electrically. However, certain limitations exist due to the structural and material make-up of closure elements which leave much to be desired.

Radomes can distort the radiating characteristics of the electromagnetic wave in many ways. They can adversely influence the phase and amplitude of the incident wave such as to produce a degradation in gain, beamwidth, side-lobe level and other pattern characteristics. Radomes may cause depolarization or rotation of polarization, or reflect or absorb an appreciable portion of the energy from the beam which may reduce the range, cause magnetron pulling, or change the effective impedance of the antenna.

Weight is an important consideration for very large ground-based radomes. Generally, thin-walled closure elements for such allications range in weight from about 0.2 to 2 pounds per square foot of wall surface. The prior art radomes for the most part utilized a fiberglass structure inasmuch as fiberglass was structurally satisfactory, but electrically it was more loss than desirable, in addition to being expensive.

Wherever it is structurally permissible, a sufficiently thin radome closure element of low-loss material offers the most satisfactory electrical wall. The use of thin wall structures depends on the minimum thickness which is physically and structurally tolerable and the required transmission properties. In this type, the most serious factor is reflection losses at the surface, that is where energy is reflected in a direction other than the collimated beam. The most desirable condition, electrically, with a low-loss material would be a smooth conical or spherical surface which is thin relative to the wavelength. A material having a lower dielectric constant and a correspondingly lower reflection coefficient would have definite advantages over conventional radomes of similar shape and thickness. However, the required physical properties of radome structures, such as flexural modulus, stiffness of the material and the like are in favor of fiberglass.

Certain plastics have desirable electrical properties superior to conventional materials, but generally these plastics are not satisfactory from a stiffness or flexural modulus standpoint for thin wall domes. Another unsatisfactory attempt included the use of radial ribs.

I have now found that I can provide a radome closure element of thin wall plastic material having the requisite structural rigidity and strength combined with optimum electrical properties, such as low dielectric constant, low reflection coefficient and low absorption among other properties. In accordance with the invention, compensation can be made for the mechanical deficiencies of a particular material, without substantially adversely affecting its electrical properties.

It is an object of my invention to provide a high strength radome closure element having a curved convex configuration formed of dielectric material transparent to radiant energy, for example, made of plastic material.

Another object is to provide a radome housing having a curved convex cover or closure element characterized by radially disposed corrugations.

These and other objects will be readily appreciated from the following disclosure taken in conjunction with the accompanying drawing, wherein:

FIGS. 1 to 3 depict a 30° sector of vacuum-formed plastic sheeting from which the radome closure element may be constructed;

FIG. 4 depicts one embodiment of a radome closure element partially broken away, provided by the invention; and

FIG. 5 is a fragment of one embodiment of an antenna and mast supporting the radome provided by the invention.

Stating it broadly, the radome provided by the invention comprises a closure element in the shape of a curved convex shell of dielectric plastic material transparent to and through which radiant energy is transmitted. The convex closure element is characterized by radially disposed corrugations which project radially from the apex of the closure element to its outer peripheral edge. Preferably, the corrugations are radially contoured so that the height of the corrugations vary gradually in depth along the radial direction from the apex of the convex shell to its outer peripheral edge, the corrugations being deeper at a section intermediate the apex and the outer peripheral edge, preferably at approximately the mid-section thereof. Stating the preferred embodiment in another way, the corrugations gradually vary in decreasing depth from the mid-section to the apex and from the mid-section to the outer peripheral edge, the corrugations merging into the wall thickness of the shell. By employing the foregoing preferred construction, an improved combination of mechanical and electrical properties is assured superior to fiberglass over a broad band of frequencies.

The most desirable depth of corrugation, such as in the area of the mid-section may be determined by the equation:

$$d=n\frac{\lambda}{4}$$

where d is the depth, n is an odd integer and λ is the wavelength. As two surface levels of reflection are involved because of the corrugations, the reflections will tend to cancel each other, resulting in an improvement even over the smooth surface. Generally speaking, n will be large to satisfy mechanical requirements since microwave frequencies are being dealt with. When d becomes an even number of half wavelengths, the resulting net reflection coefficient is worse than that of a smooth surface dome. Since bandwidths are normally required which would allow this condition to prevail at certain frequencies the solution to the problem is to provide a tapered corrugation depth. In this case the resonance and anti-resonance conditions of high and low loss tend to cancel each other at all frequencies. The tapered corrugations as described quite adequately provide the necessary mechanical strength. Whatever the plastic material used, it is desirable that it have a dielectric constant below 3.0 and a power factor below 0.01.

Since the design of the radome requires a consideration of its structural strength and weight, as well as the foregoing electrical characteristics, I have found that these requirements can be fulfilled by producing the convex closure element by vacuum-forming plastic sheeting compounded of high strength plastic, for example, plastics referred to as ABS copolymers or blends, the ABS designation standing for copolymers or blends of acrylonitrile-butadiene-styrene. The polymer blends generally involve a blend of styrene-acrylonitrile copolymer resins with butadiene-acrylonitrile rubbers. A sheet stock of the foregoing formulation is considered a plastic when the resin

ratio is over 60% by weight of the formulation. For the purpose of this invention, the material is referred to as a polymer blend (acrylonitrile-butadiene-styrene). Polymerization of styrene, or copolymerization with a variety of the monomers, including butadiene and acrylonitrile, may be accomplished by bulk, suspension, emulsion and solution polymerization techniques. Basically, the foregoing types of ABS polymer blends are characterized by improved shock resistance and increased elongation, while still retaining good electrical and mechanical properties.

The foregoing plastic which is sold under the trademark Cycolac, has low water absorption rate and exhibits uniform dielectric constant and power factor. It is the lightest of all truly rigid thermoplastics and has a specific gravity of about 1.04. The dielectric constant is approximately 2.8. It has high flexural modulus and exhibits good dimensional stability under extreme service conditions.

I have found that by vacuum-forming sections of the closure element from a plastic sheet using a section mold having a curved pie-shaped surface with radially disposed corrugations along the section, a structurally strong convex closure element can be constructed from the sections having the requisite physical and electrical properties. For my purposes, the thickness of the sheet may range from about 1/16 to about 1/8 of an inch.

Referring to FIGS. 1 to 3, a radial pie-shaped sector **10** is shown representing a 30° section of a 360° development of the closure element shown in FIG. 4. Looking at the profile of FIG. 3, the curved sector represents substantially a spherical segment. As depicted in FIG. 1, three corrugation elements **11**, **12** and **13** are shown which merge radially from the outer end **14** toward the apex-forming end **15**. The general shape of the corrugations are shown in FIG. 2 which is a cross-section taken along line **2—2** of FIG. 1 as viewed in the direction of the arrows. As shown in FIG. 3, the corrugations are uniformly tapered in the radial direction such that the depth of the corrugations vary gradually from the deepest portion near the mid-section at center line X to the smallest depth at the apex-forming end **15** (the thickness of the sheet) and the smallest depth at end **14** (the thickness of the sheet). As will be noted from FIG. 2, valleys **12***a* are adjacent corrugations **12** while valleys **11***a* and **13***a* are adjacent corrugations **11** and **12**, respectively. Radial fins **16** and **17** are provided along the sides of the sector shown in FIG. 1 to enable the lap-jointing of twelve sectors together to form the curved convexed shape of FIG. 4. The sectors may be lap-jointed together by using a solvent cement, such as methyl ethyl ketone. As illustrative of lapped sectors, reference is made to FIG. 1 which shows a fragmented sector **10A** in phantom juxtaposition to sector **10**.

The dished closure element **18** shown in FIG. 4 constructed from joining together radial sectors of the type shown in FIG. 1 is characterized generally by an array of radially disposed corrugations **19**, the corrugations extending from apex **20** to the peripheral edge **21**, the sectors being fastened to an aluminum rim **22** via fastening means **23**, for example, rivets. As will be noted, the corrugations are tapered in two directions, that is towards the apex and towards the peripheral edge similarly as in the profile view of FIG. 3.

In the antenna **24** of FIG. 5, the radome **18** is shown mounted to radar mast **25** and antenna reflector **26**, the radome being formed with substantially spherical curvature, being preferably formed of a polymer blend of acrylonitrile-butadiene-styrene. The dished shells are joined at their common rims **28** by means of rivets or other suitable fastening means, the antenna being supported by the mast via a flange **29** coupled to both the mast and antenna as shown. In the embodiment depicted in FIG. 5, the radiating element is diagrammatically shown as a feed horn **27** from which radiant energy is transmitted through the corrugated radome **18** to the atmosphere.

Tests have shown that the radome closure element provided by the invention has the required mechanical properties to withstand applied stresses. While the most realistic mechanical test is its field performance, a dead weight load test is sometimes resorted to. Such tests may comprise placing sand bags of a given weight all over the surface of the closure element while it is supported like a dome upon a floor as shown in FIG. 4. A total dead weight load corresponding to about 50 lbs./square foot of surface was applied to a closure element having a skin thickness of about 0.080 inch a span of about 10 feet and a dome height of about 3 feet with no ill effects to the structure.

In an electrical comparison test with a fiberglass radome results indicated that the radome of the invention was much less lossy than the fiberglass radome. For example, at 6 and 11 gc., the fiberglass radome showed a high loss of 0.7 db and 1.4 db, respectively. On the other hand, applicant's radome made from a copolymer blend of acrylonitrile-butadiene-styrene exhibited a much lower loss of 0.25 db and 0.9 db, respectively. In addition, the radome produced from the plastic material was satisfactory structurally.

While the closure is defined as having a curved convex surface, such a surface may have a spherical contour or a parabolic or similar contour.

While this radome has many applications, a specific application in the 6–11gc. range is described in the copending application, S.N. 578,217 filed Sept. 9, 1966 and entitled "Dual Frequency Dual Polarized Antenna."

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and the appended claims.

What is claimed is:

1. In an antenna having a radiating element, a housing having a closure element in the shape of a curved convex shell of dielectric plastic material transparent to and through which radiant energy is transmitted, said convex closure element having an apex and being characterized by spaced radially disposed corrugations emanating from said apex and terminating at its outer peripheral edge, said corrugations varying gradually in depth along the radial direction from the apex of said convex closure element to its outer peripheral edge, the corrugations being deeper intermediate the apex and said outer peripheral edge.

2. In the antenna of claim **1** wherein the depth of the corrugations intermediate the apex and the peripheral edge is determined by the formula:

$$=n\frac{\lambda}{4}$$

where d is the depth, n is an odd integer and λ is the wavelength of transmitted radiant energy.

3. In the antenna of claim **2** wherein the deepest portion of the corrugation is at substantially the mid-section intermediate the apex and the peripheral edge of the closure element.

4. In the antenna of claim **1** wherein the closure element is made of a plastic material of a polymer blend of acrylonitrile-butadiene-styrene.

5. In the antenna of claim **2** wherein the closure element is made of a plastic material of a polymer blend of acrylonitrile-butadiene-styrene.

6. A radome comprising a curved convex shell of dielectric plastic material transparent to and through which radiant energy is transmitted, said convex shell having an apex and being characterized by spaced radially disposed corrugations emanating from said apex and terminating at its outer peripheral edge, said corrugations varying gradually in depth along the radial direction from the apex of said convex shell to its outer peripheral edge, the corruga-

tions being deeper intermediate the apex and said outer peripheral edge.

7. The radome of claim 6 wherein the depth of the corrugations intermediate the apex and the peripheral edge is determined by the formula:

$$d=n\frac{\lambda}{4}$$

where d is the depth, n is an odd integer and λ is the wavelength of transmitted radiant energy.

8. The radome of claim 7 wherein the deepest portion of the corrugation is at substantially the mid-section intermediate the apex and the peripheral edge of the convex shell.

9. The radome of claim 6 wherein the convex shell is made of a plastic material of a polymer blend of acrylonitrile-butadiene-styrene.

10. The radome of claim 7 wherein the convex shell is made of a plastic material of a polymer blend of acrylonitrile-butadiene-styrene.

11. A radome comprising a curved convex shell of dielectric material through which radiant energy may pass, said shell having an apex and being characterized by spaced radially disposed corrugations emanating from said apex and terminating at its outer edge, said corrugations tapering gradually in depth along the radial direction

thereof to thereby provide resonance and antiresonance conditions.

12. The radome of claim 11 wherein the depth of the corrugations intermediate the apex and the peripheral edge is determined by the formula:

$$d=n\frac{\lambda}{4}$$

where d is the depth, n is an odd integer and λ is the wavelength of transmitted radiant energy.

13. The radome of claim 12 in which d is determined by the wavelength corresponding to a frequency between, approximately, 6–11 gc.

References Cited

UNITED STATES PATENTS

3,039,100	6/1962	Kay	343—872
3,175,220	3/1965	Schetne	343—872

HERMAN K. SAALBACH, *Primary Examiner.*

MARVIN L. NUSSBAUM, *Assistant Examiner.*

U.S. Cl. X.R.

52—630

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,444,558 May 13, 1969

Robert T. Leitner

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, lines 53 and 54, the formula should appear as shown below:

$$d=n\frac{\lambda}{4}$$

Signed and sealed this 21st day of April 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents