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Burton et al.

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[54] **PROCESS FOR MANUFACTURING DOMED SPIRAL ANTENNAS**

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[73] Assignee: **The Bendix Corporation**, North Hollywood, Calif.

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[52] **U.S. Cl.** ..... **96/36.2**; 96/36; 96/38.4; 96/27 R; 156/7; 156/8; 343/872; 343/873; 343/878

[51] **Int. Cl.**[2] **G03C 5/00**

[58] **Field of Search** ..... 96/27 R, 36, 36.2, 38.4; 156/7, 8; 343/872, 873, 878, 895, 887

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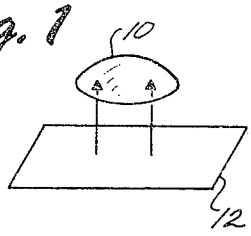
Primary Examiner—Norman G. Torchin
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[57] **ABSTRACT**

An antenna and method of manufacture are described in which a spiral microwave antenna is formed over a domed substrate of epoxy glass resin. A copper foil member is formed over a die by spinning or burnishing to a domed configuration matching that of the substrate. The copper member is then given a coating of primer and clamped over the substrate which has been coated with an epoxy cement, and the assembly subjected to heat and pressure sufficient to bond the foil to the substrate. The assembled antenna blank is then coated with photo-resist material and illuminated from a source of collimated light through a photo negative which is carefully centered to expose the desired spiral pattern on the photo-resist material. The photo-resist is then developed and rinsed, and the blank is baked to harden the exposed photo-resist. The blank is then etched to remove the unwanted copper, leaving the desired antenna pattern. The copper pattern is then preferably plated with tin and the assembly trimmed and drilled as desired.

10 Claims, 11 Drawing Figures

Fig. 1



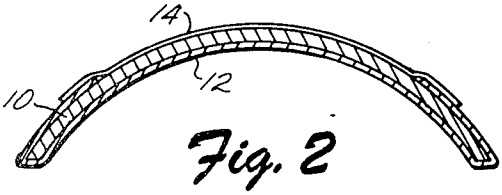
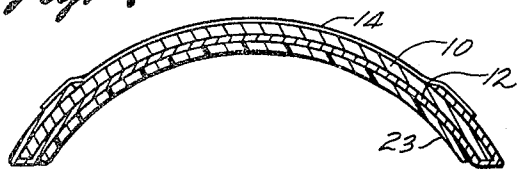


Fig. 2

Fig. 4



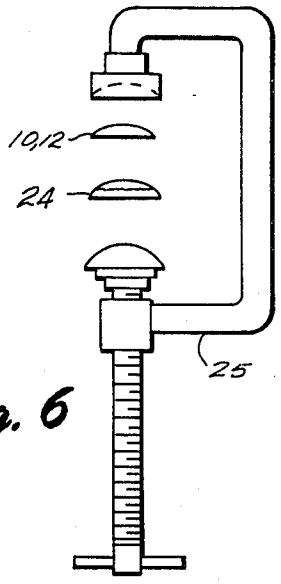


Fig. 6

Fig. 5

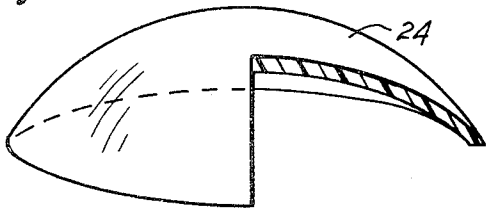


Fig. 7

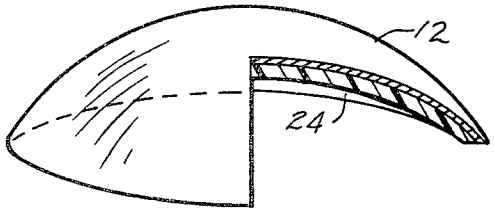


Fig. 8

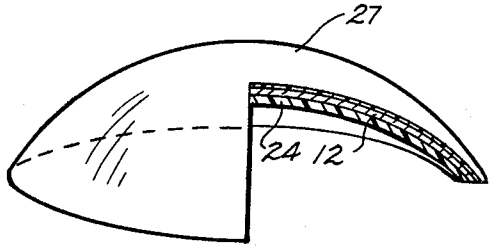


Fig. 10

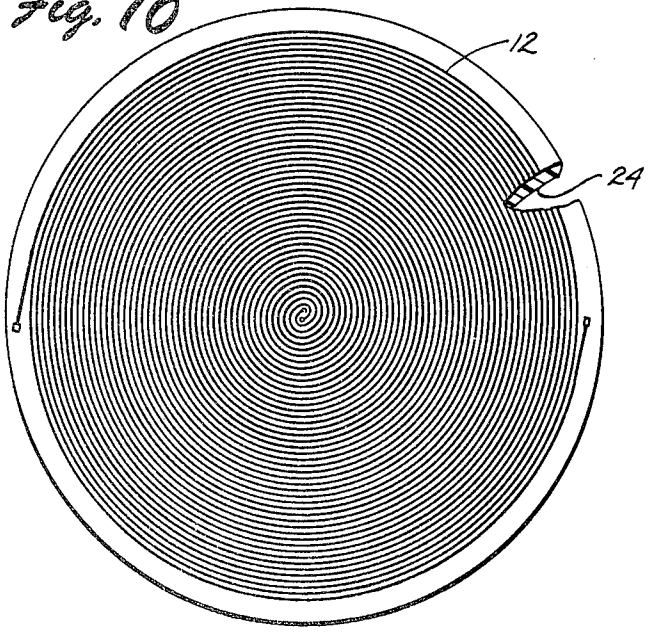


Fig. 9

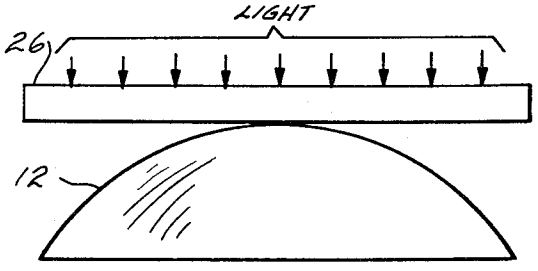


Fig. 3

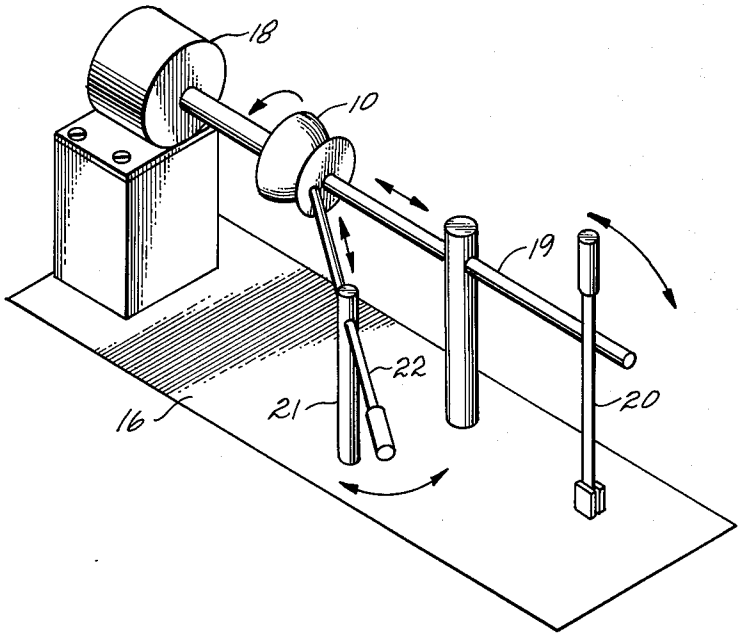
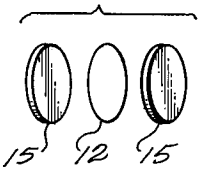


Fig. 3A



PROCESS FOR MANUFACTURING DOMED SPIRAL ANTENNAS

BACKGROUND OF THE INVENTION

Many applications for which small planar spiral element microwave antennas are useful involve installation on aircraft and require mounting the antenna structure on the inside surface of a radome. In such installations, the physical configuration of the radome is usually chosen for its aerodynamic properties rather than its electromagnetic propagation properties. A typical small planar spiral microwave antenna consists of a printed circuit pattern attached to a plastic or glass epoxy substrate and is mounted on a housing such that it is backed with a microwave cavity. When such an antenna is fastened to the inside surface of a curved radome, a space frequently remains between the surface of the antenna itself and the interior surface of the radome. This variable air space becomes a discontinuity of substantial proportion at the microwave frequencies for which such antennas are usually employed. Such discontinuities affect performance of the antenna adversely, both as to loss of signal and as to pattern distortion, and it is highly desirable that they be eliminated or minimized. Recent requirements for extending operating frequencies with existing systems and existing radomes have resulted in air gap discontinuities which have been shown to be prohibitive.

It has been determined that the electrical characteristics of a typcial microwave spiral antenna are not significantly affected if the substrate is formed in a somewhat domed configuration rather than perfectly flat. The curvature resulting from the dome-shaped substrate effectively removes a substantial portion of the space between the antenna surface and the inside surface of the radome, thus significantly reducing the electromagnetic propagation discontinuity referred to above and the resulting power dissipation. Typically, a configuration is chosen such that its curvature will match a symmetrical mean dimension of the associated radome.

An antenna and interface structure for dealing with the above problem was described in copending Application Ser. No. 313,286 to Roger D. Hall (common assignee), now U.S. Pat. No. 3,820,118, and the present application is concerned with a method of manufacturing a domed spiral antenna structure such as that shown in said copending application. Where the curvature of the domed antenna member is slight, it has been found feasible to distort a flat antenna by subjecting it to heat and pressure and to cause it to assume a domed configuration. This technique is limited in the amount of curvature which can be produced without causing the spiral pattern to be so distorted that electrical performance is degraded. Another technique which was tried was to provide a dome-shaped substrate of epoxy glass resin and then coat the substrate with an electroless deposition of copper. This proved unsatisfactory since the copper did not adhere satisfactorily to the curved surface of the epoxy. Other techniques which have been tried have proven unsatisfactory for antenna configurations having substantial curvature. It has become apparent, therefore, that there is a need for a satisfactory process for providing small spiral element microwave antennas having a substantially domed or curved configuration, which process is amenable to reasonably high volume production.

SUMMARY

It has been determined that a satisfactory process for fabricating domed high frequency spiral antennas may include fabrication of a domed substrate of the desired configuration, which may be a spherical segment or a similar curved surface matching that of the radome in which the antenna is to be installed. This substrate is of a reinforced polymeric material with good dielectric properties, usually a thin section of reinforced epoxy glass resin. A sheet of copper foil is formed by burnishing or spinning against a die which is of a mating configuration to the substrate, and the two dome-shaped members are then cemented together, using an epoxy cement and substantial heat and pressure to provide a unitary antenna blank.

The blank is then coated with photo-resist material which is preferably applied by spinning to assure even and thorough coverage of the copper surface. A photo negative, which may be on a glass plate, is carefully centered over the blank, and the blank is illuminated through the photo negative from a collimated light source for a desired period to expose the photo-resist material. The photo-resist material is then developed and rinsed. A subsequent baking process hardens the remaining photo-resist material and increases its adhesion to the underlying copper. The blank is then etched to remove the unwanted copper, leaving the desired spiral pattern. The photo-resist is then removed and the copper conductor track tin-plated to improve solderability and corrosion resistance. The antenna may then be trimmed and drilled as desired. Because of the curvature of the blank, illumination from the light source will result in a slight widening of the lines toward the outside edge of the dome, but this is generally not a problem so long as the spiral lines remain sharp and distinct. Should the curvature be such that this widening is unacceptable, the negative may be replaced with one having compensating line thicknesses toward the outside.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a foil layer and a domed die which is used in forming the foil layer as by burnishing.

FIG. **2** is a sectional view of the foil layer formed on the die of FIG. **1.**

FIG. **3** is a perspective view of an apparatus for spinning a domed foil layer.

FIG. **3***a* is an exploded view of a disk and foil sandwich arrangement as used in the apparatus of FIG. **3** prior to spinning.

FIG. **4** is a sectional view of the FIG. **2** assembly with a layer of cement applied to the under side of the dome-shaped foil member.

FIG. **5** is a perspective view, partly in section, of a dome-shaped epoxy substrate member according to the present invention.

FIG. **6** is an exploded view showing the manner in which the foil and substrate members are assembled together for curing.

FIG. **7** is a perspective view, partly in section, of the structure resulting from the curing step of FIG. **6.**

FIG. **8** is a perspective view, partly in section, of the structure of FIG. **6** with an additional layer of photo-resist material.

FIG. 9 is a side view showing the manner in which the device of FIG. 8 is illuminated to photographically expose the desired spiral antenna pattern.

FIG. 10 is a plan view of a completed spiral antenna on a dome-shaped substrate.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Applicants have fabricated a dome-shaped member of copper foil, but which may be aluminum foil, silver foil, etc., by either of two processes. FIG. 1 shows a dome-shaped die **10** which may be of aluminum or any suitable material into which is formed a thin layer (0.001 inch) of foil **12.** The foil is formed tightly against the concave surface of die **10** by pressing and burnishing it to the desired contour, using a mandrel. This is essentially a hand operation. FIG. **2** is a sectional view showing the foil layer formed against the inner concave surface of the die **10** with any remaining foil not in the die bent over the edges of the die and smoothed against the outside surface thereof and taped in place by means of tape strips **14.**

Alternatively, and for larger volume production, a technique which has been found effective involves pressing the copper foil between two aluminum disks (about 0.020 inch thickness) and the assembly (see FIG. 3*a*) is then formed over a dome-shaped die by spinning the disks while using a forming tool to force the disks and foil to the required domed shape as shown in FIG. **3.** FIG. **3** is a perspective view of a forming fixture comprising a platform **16** upon which is mounted an electric motor **18** for rotatably driving a die **10** of the desired domed shape. The sandwich of aluminum disks **15** and foil member **12** is positioned at the end of a shaft **19** movable axially by means of a handle **20** to press the sandwich structure against the die **10.** A post **21** supports a forming rod **22** which is movable axially and rotationally to apply pressure to the aluminum disks and copper foil member to force these members to conform to the shape of die **10.** In this manner, it is possible to form the copper foil quickly and smoothly to the desired configuration without tearing or wrinkling. When the sandwich structure is removed from the fixture, one aluminum member **15** may be removed, leaving the formed copper foil layer against the concave surface of the other aluminum member in much the same manner as shown in FIG. **2.**

After the copper is formed and secured to the die **10** as shown in FIG. **2,** its exposed (concave) surface is scrubbed with a mildly abrasive cleanser and a stiff brush to provide a water break free surface. This surface is rinsed with 2-propanol and blown dry with nitrogen. The surface is then very clean and has applied to it a thin coat of primer material which may be Abletech 150-6, and the assembly is then baked for one hour at 275° F. The coat of primer is represented as layer **23** in FIG. **4** which is otherwise identical to FIG. **2.** After the baking process, the foil surface is again scrubbed, rinsed and blown dry as described.

Also forming part of the antenna assembly is a substrate which is a dome of a reinforced polymeric material with good dielectric properties such as a spherical section or other curved surface such as that shown at numeral **24** in FIG. **5.** The surface of this member **24** is scrubbed and dried in essentially the same manner as described above. An epoxy cement or other suitable cement is then applied in a thin coat to the convex surface of the epoxy glass dome **24.** The substrate structure **24** with its epoxy adhesive layer is then placed in a clamp structure **25** along with the foil die structure **10, 12** (or **12, 15**), and the entire structure is assembled as shown in FIG. **6** and is clamped together and baked at 125° C. for two hours. After baking, the assembly is allowed to cool to room temperature and unclamped, the aluminum die **10** is removed, and the excess (unbonded) copper, if any, is cut away, leaving a structure such as that shown in FIG. **7** where the domed copper layer **12** is firmly bonded to the glass epoxy substrate **24.**

Antenna blanks, such as those shown at FIG. **7,** are then again scrubbed on the copper surface with a dolomite slurry, rinsed with water, then with 2-propanol, and blown dry with nitrogen. After cleaning, a photo-resist material **27** is then applied to the copper surface of the blank, and this may be applied through a spinning process to assure even distribution. The blank, with the layer of photo-resist **27,** is shown in FIG. **8.** A photo negative, which may be a pattern on a glass plate as shown at numeral **26** in FIG. **9,** is carefully centered over the copper surface **12,** and the photo-resist layer **27** is exposed to light through the photo negative **26** from a collimated light source as shown. The effect of the light is to harden the photo-resist material **27** where it strikes it, as is well known in the art, and this photo-resist layer is then developed and rinsed to remove the photo-resist material which has not been exposed. The blank is then baked for 15 minutes at 125° C. to harden the photo-resist layer and to improve its adhesion to the copper surface. The blank is then etched to remove the unprotected copper, thereby leaving the protected spiral pattern under the photo-resist material. After the etching process, the blank is rinsed, dried, and the remaining photo-resist material is removed. After an additional rinse and dry process, the spiral conductor pattern is preferably tin-plated to improve the solderability and also the resistance to corrosion of the antenna conductor surface. The completed antenna will then appear as shown in FIG. **10.**

It will be obvious to those skilled in the art that many alternatives exist with respect to particular aspects of the above process. Thus, while it appears that a copper foil is the most practical conductor which one might select, silver foil would function as well and in some installations might not require the tin-plating step. Aluminum foil could be used but would require more plating steps to aid in insuring solderability. Obviously, as different materials are used for the conductors, different etchants will also be required. Either photo positive or photo negative image patterns might be used during the light exposure step, and this would result in using either negative or positive photo-resist material. While it has been stated that the photo-resist material is preferably applied to the copper surface by a spinning process, it is also quite feasible to spray on the photo-resist material. The specific times and temperatures set forth above are closely related to the use of particular materials in the process and may vary somewhat as the materials are varied.

We claim:

1. A process for manufacturing a domed spiral high frequency antenna comprising the steps of:

forming a thin shell domed substrate of reinforced polymeric material,

forming a sheet of metal foil over a die to essentially the configuration of the substrate,

placing a layer of epoxy cement on one side of one of said substrate and said foil,

placing said foil over said substrate and subjecting the composite to heat and pressure to bond said substrate and said foil together,

coating said foil with a layer of photo-resist material,

placing a photo negative of the desired spiral pattern between said coated foil layer and a source of collimated light and exposing said layer to said light source for a desired period,

developing said photo-resist layer and rinsing away the unexposed photo-resist material,

etching away the unprotected foil layer to leave the desired spiral pattern, and

removing the remaining photo-resist material.

2. A process for manufacturing a domed spiral high frequency antenna as set forth in claim **1** wherein said spiral pattern is plated with an additional metal layer.

3. A process for manufacturing a domed spiral high frequency antenna as set forth in claim **2** wherein said spiral pattern is of copper and said plated layer is tin.

4. A process for manufacturing a domed spiral high frequency antenna as set forth in claim **1** wherein said foil is conformed to said die by a spinning process.

5. A process for manufacturing a domed spiral high frequency antenna as set forth in claim **1** wherein said foil is conformed to said die by stretching and burnishing said copper over said die.

6. A process for manufacturing a domed spiral high frequency antenna as set forth in claim **1** wherein mating surfaces of said substrate and said foil layer are scrubbed to provide water break free surfaces before said epoxy cement is applied.

7. A process for manufacturing a domed spiral high frequency antenna as set forth in claim **1** wherein said photo-resist material is applied to said foil layer by means of a spinning process.

8. A process for manufacturing a domed spiral, high frequency antenna comprising the steps of:

forming a layer of metal foil over a die into the desired domed configuration;

forming a domed substrate of reinforced polmeric material having good dielectric properties to said desired domed configuration;

bonding said domed metal foil member to said domed segment, and

photo-etching the desired spiral antenna pattern from said metal foil layer.

9. A process for manufacturing a domed spiral high frequency antenna as set forth in claim **8** wherein said bonding process includes thoroughly cleaning said foil member and said domed substrate, applying epoxy cement to one of said foil layer and said domed substrate and clamping said foil member and said substrate together under high temperature and pressure.

10. A process for manufacturing a domed spiral high frequency antenna as set forth in claim **8** wherein said metal foil is copper, and said domed substrate is of glass epoxy resin.

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