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RECENT ADVANCES IN LIGHTWEIGHT ANTENNA DESIGNS FOR SPACECRAFT

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Summary

This paper describes some advanced techniques used in the design and construction of lightweight antennas. The process involves copperplating on foam dielectrics. The design feasibility has been demonstrated, showing that antennas of this type can be used advantageously for many applications. Additionally, it shows how completely integrated antenna-waveguide networks can be constructed. Composite structures of this type reduce the waveguide wall thickness where most of the weight is concentrated. The use of this construction method also serves to eliminate coupling flanges and other excess metal, thus substantially lowering the overall weight.

The conventional waveguide wall acts as a boundary for the electromagnetic energy, however the current associated with the propagating wave is concentrated in a very thin layer of the inside wall surface. The depth of the conduction current or skin depth is expressed as

$$\delta = \frac{1}{2\pi}\sqrt{\lambda\rho\ 30\ \mu} \qquad (1)$$

δ is in cm, ρ is the resistivity of the conductor in ohms-cm, μ is the permeability of the conductor, and λ is the free-space wavelength. If a low-loss dielectric material (substrate) is used as the waveguide filler rather than air, a thin metallic surface (0.003-in. wall) encapsulating the substrate would be sufficient to carry the r-f current, thus, a small lightweight waveguide can be effected.

Several low-loss dielectric materials (organic and inorganic) have been investigated. In this report attention is given primarily to polystyrene foam because of its unusually good characteristics. This material has a closed cellular structure with good compression strength. It has a low loss ($\tan \delta = 4 \times 10^{-4}$), and the dielectric constant (ϵ) is 1.05. The "electroless" plating process is used for copperplating the dielectric substrate. This technique allows the metal thickness to be controlled, prevents buildup of metal along the edges, and provides a smooth surface finish consistent with that of the substrate.

Typical copperplated dielectric foam waveguide sections are shown in Figure 1. Here various waveguide sizes and shapes are seen. The weight savings of the largest waveguide section is greater than 7.5 to 1. These waveguides are characterized by their extremely lightweight, smooth surfaces, and sturdy appearance. The copperplated walls usually vary from 0.003 to 0.005-in., and the adherence of the copper to the dielectric is very good. Attenuation loss for X-band waveguide is less than 0.2 dB/ft. This loss is considered negligible, since this technique is intended for use on short waveguide lengths.

One of the simplest antennas to design in the lightweight construction is the slotted waveguide array[1]. Several planar arrays designed in different frequency bands will be described. The technique has also been applied to the design of flat two-dimensional monopulse antennas. An illustration of a X-band planar array (4 by 32 in.) with radiation patterns is shown in Figure 2. This antenna is a traveling wave design, and uses post-excited slots. The inductive posts are formed from plated-through holes. The voltage standing wave ratio of this antenna is about 1.15 measured over a 500-MHz frequency band, and the radiation pattern characteristics are good over the same range.

The technique lends itself quite well to the design and construction of electromagnetic horns. An extremely lightweight horn designed with two corrugated walls are shown in figure 3. The main feature of this horn aside from its lightweight is its lower side lobes in both planes[2]. Several larger size horns designed in the S, C, and X-band regions have been successfully constructed. Other types of antennas designed by this method such as parabolic reflectors, cavities, etc., will be discussed and illustrated. It has been demonstrated that in most cases lightweight waveguide components and devices associated with antenna systems can also be constructed. Some of these devices will be shown along with techniques of coupling them together in a complete assembly.

The results obtained from this investigation show that lightweight, well constructed, efficient, microwave antenna systems can be adequately designed employing copperplated dielectric foam techniques. Also, the technique offers system design flexibility, permitting an integrated-type design at low cost, thus eliminating many system design problems where weight is an essential factor.

A typical example is the C-Band planar array shown in Fig. 4. This antenna is a standing wave design, with all couplings, junctions, and feed networks designed and fabricated from the copperplated dielectric foam material. The weight of the array is 125 grams compared to 950 grams for its aluminum counterpart. The electrical performance is the same for each design, and the overall cost is less for the lightweight version.

This design approach has already found wide usage in antenna system development. The increase demand for these antennas has led to the design of a variety of practical models reflecting additional improvements.

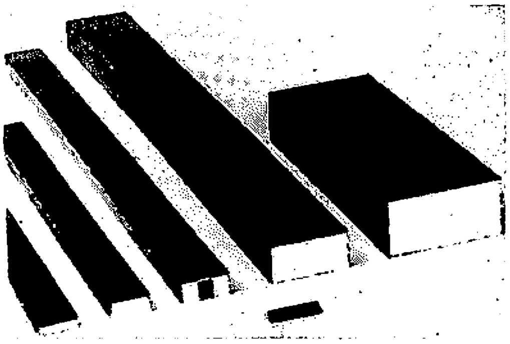


FIG. 1

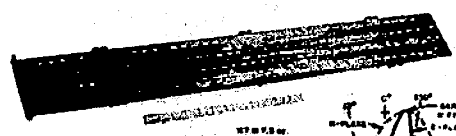
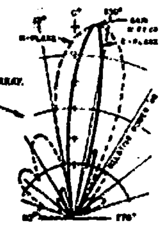


FIG. 2 COPPERPLATED FOAM-DIELECTRIC X-BAND PLANAR ARRAY.

RADIATION PATTERN



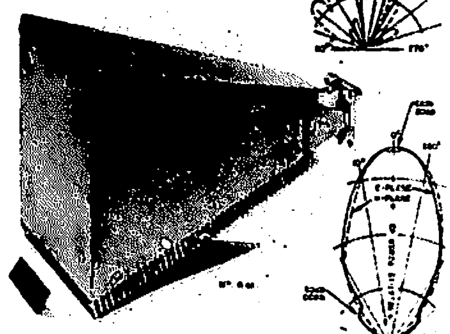


FIG. 3 LIGHTWEIGHT CORRUGATED-WALL X-BAND HORN.

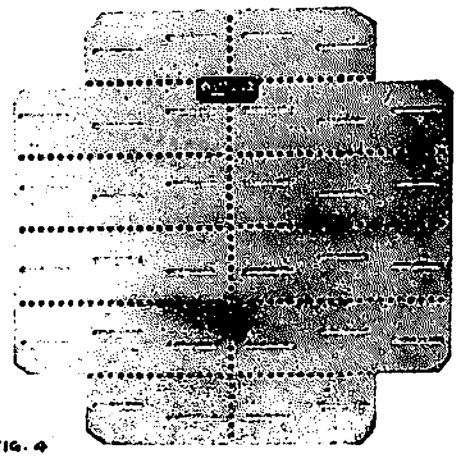


FIG. 4

Literature Cited:

1 "Lightweight Copperplated Dielectric-Foam Microwave Antennas", Howard S. Jones, Jr., HDL-TR1492, May 1970.

2 "Modification of Horn Antennas for Low Sidelobe Levels", R.E. Lawie and L. Peters, Jr., IEEE Trans. AP, Vol. AP-14, No. 5, Sept. 1966.