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Wright

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[54] **BROADBAND MICROWAVE ENERGY ABSORPTIVE STRUCTURE**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 720,512, March 10, 1958, abandoned.

[52] **U.S. Cl.** ..... **343/18 A**
[51] **Int. Cl.** **H01g 17/00**
[58] **Field of Search** ..... 343/18 A; 229/90

[56] **References Cited**

UNITED STATES PATENTS

2,233,592	3/1941	Dunajeff	229/90
2,464,006	3/1949	Tiley	343/18
2,977,591	3/1961	Tanner	343/18
3,234,549	2/1966	McMillan	343/18 A

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[57] **ABSTRACT**

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

7 Claims, 3 Drawing Figures

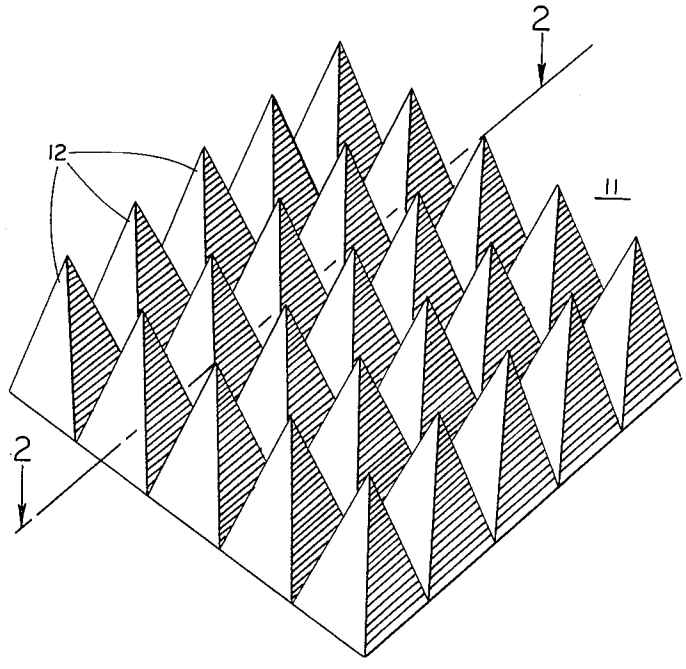


FIG. 1

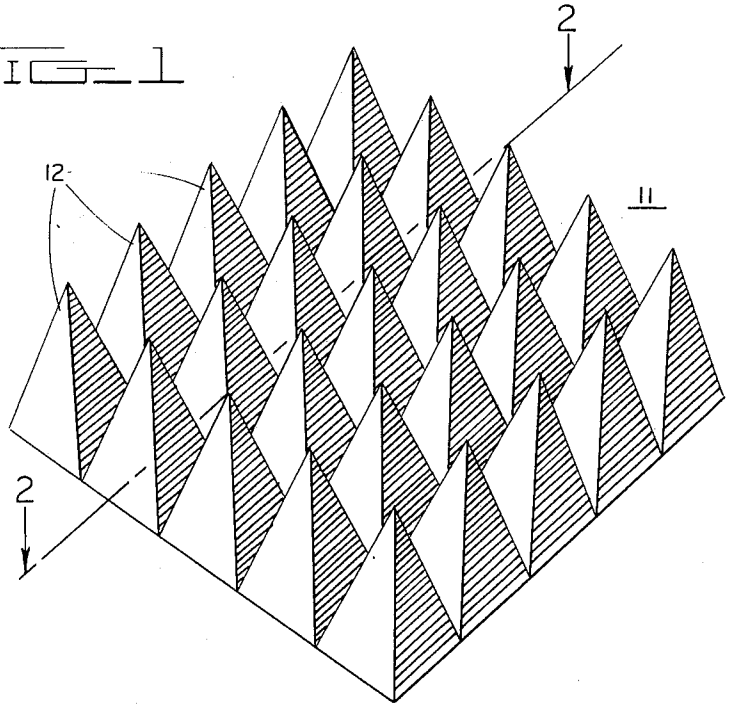


FIG. 2

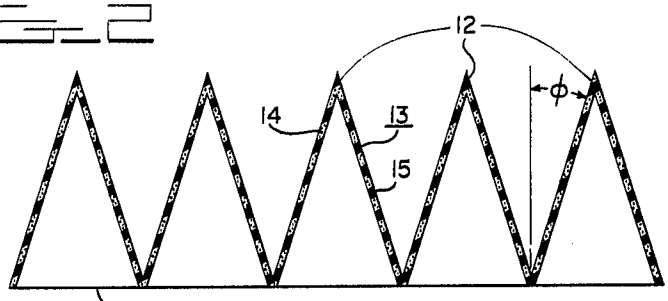
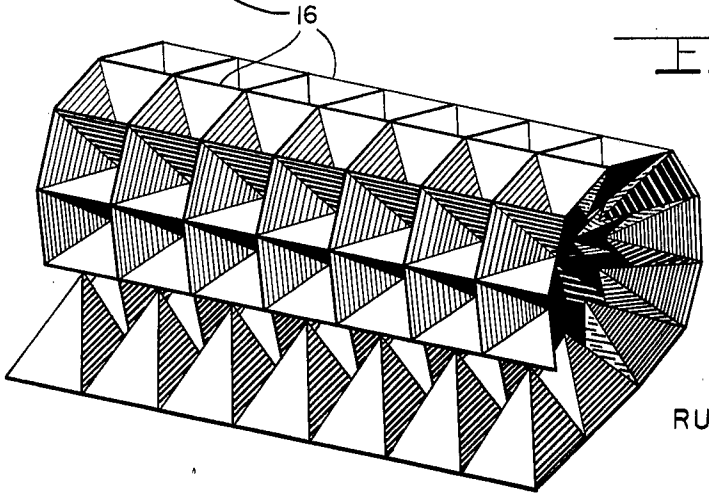


FIG. 3



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BROADBAND MICROWAVE ENERGY ABSORPTIVE STRUCTURE

This application is a continuation-in-part of application Ser. No. 720,512, filed Mar. 10, 1958 for RADIO FREQUENCY ENERGY ABSORPTIVE STRUCTURE, now abandoned.

This invention relates in general to a structure for impeding the reflection of a beam of electromagnetic waves from the surface of an object and more particularly to a flexible, thin-wall structure which is suitable as a broadband absorber of microwave energy.

Previous developments in lossy dielectric type absorbers involved the use of a dielectric body on or in which was distributed a high loss substance in the form of finely divided conductive material. Absorbers of this type usually provided a low density dielectric as the supporting material, shaped into a pattern of geometric projections, such as wedges, cones or pyramids, and having on the surface thereof a lossy coating of conductive particles with a suitable binder material. A low dielectric substance has previously been used as a matrix or binder in which conductive particles, such as graphite or finely divided carbon, have been distributed throughout the substance to form an absorbent composition in depth.

It has been found in practice that these absorbent structures were somewhat bulky and heavy in the amount of supporting material that was required to maintain the desired configuration; they were, for the most part, substantially rigid structures and therefore unwieldy in applying them to surfaces of varying contours. Moreover, considerable manufacturing effort and costs were involved in assembling and coating different materials to provide composite structures. Additionally, many of these absorbers were not effective over a wide range of frequencies.

A practical absorbent material that involved the use of a low density mat of fibers coated with a thin film of conducting rubber, as described in U.S. Pat. No. 2,977,591, was found to operate over a wide range of microwave frequencies, but the fibrous structure was not suitable for general outdoor use because the performance thereof in wet weather is degraded by the amount of energy reflected from the drops of water that remain suspended in the medium.

It is an object of the present invention, therefore, to provide a new and improved lossy dielectric microwave absorber which overcomes the limitations of prior art absorbers of the type described.

Another object of the invention is to provide a microwave energy absorber which can absorb satisfactorily over a wide range of frequencies and angles, and its mode of operation does not depend on the relative to said absorber reflecting surface being in a fixed position.

A further object of the invention is to provide a broadband microwave energy absorber which is effective in improving radar performance, camouflaging radar targets and in reducing wave energy reflections which limit antenna test ranger.

A still further object of the invention is to provide a new and improved microwave energy absorber of simple structure, substantially lower weight and relatively inexpensive construction.

And yet another object of the invention is to provide an improved absorber having extremely flexible structure capable of easy mounting on curved surfaces and one that can be conveniently arranged for storage or shipment.

Other and further objects of the present invention will become apparent by reference to the descriptions herein and the accompanying drawings, in which:

FIG. 1 is a perspective view illustrating the pyramidal absorptive structure embodying the present invention;

FIG. 2 is a cross sectional view of the absorptive structure on a line through the apices of FIG. 1; and

FIG. 3 illustrates the flexible nature of the absorber by rolling over the dentate surface thereof and bringing the rear hollow structure into view.

In accordance with the present invention, a substantially thin sheet of lossy material may be shaped into a surface of adjoining, hollow, essentially thin-skin, tapered projections to provide a novel type absorbent structure that is capable of reducing reflection of microwave energy over a wide range of frequencies. The thin sheet lossy material which is employed for this purpose consists of a resistive composition of finely divided conducting particles dispersed in a flexible matrix. The novel absorber provides an extremely lightweight structure of about 0.3 lb. per sq. ft. in which the conductive sheet has been found to be self-supporting and capable of withstanding the outdoor rigors. The particular pyramidal configuration of the invention has physical characteristics that are applicable to a number of general outdoor uses. The performance of this absorber over a wide frequency range and over a wide range of incidence achieves power reductions of more than 15 decibels.

Referring now more particularly to the perspective view of FIG. 1 and the cross sectional view of FIG. 2, the absorber 11 consists of hollow, four-sided pyramids 12 formed by a high loss thin sheet 13 which is composed of conducting particles 14 (shown in the drawing as tiny dots), for example finely divided carbon or metal particles, embedded within a matrix 15 of rubber, neoprene or other similar flexible material. The high lossy material, which is prescribed for the present invention, is a conductive film that must be very thin electrically to avoid increased reflectivity at higher microwave frequencies.

The new absorber may be made by preparing a composition of natural rubber, neoprene or flexible plastic material to which is added a dispersion of finely divided carbon black in concentrations of about 20 to 30 percent by weight. Among well known techniques which may be used in preparing the hollow pyramidal structure include compression molding, latex dipping, lateex filtration dipping and latex-filtration casting, and provide means for shaping the desired surface configuration in a matrix or mold in which the thin sheet composition is to be formed. When the resistance of the thin sheet is to be varied for any given set of conditions, this may be accomplished by changing both film thickness and carbon black concentration. The effective range of resistive sheet thickness is in the range of about 0.008 inch to 0.045 inch with the preferred range being in the region of about 0.01 to 0.02 inch. Resistive film thicknesses as fine as 0.003 to 0.005 may also be utilized if a backing of approximately 0.01 inch of unpigmented rubber is included for support. Typically, a 0.01–0.02 inch sheet of rubber containing 20–30 percent concentration of carbon black particles by weight is capable of absorbing efficiently up to 25,000 megacycles per

second (mcs). The lower frequency limit of the absorber is determined by the absorber thickness (height of the pyramids) and occurs when said absorber thickness is approximately 0.3 λ air (wavelength in air).

Experiments conducted on absorber samples having 3/4 inch high pyramids have demonstrated that the hollow, thin skin structure is capable of reducing reflection of incident energy to less than 2 percent from about 5,000 through 25,000 mcs. Comparable performance was attained over both higher and lower frequency ranges with absorber samples having pyramid heights (absorber thickness) of ½, 2, 4, and 8 inches. The pyramids had apex angles of 40 ° and a film thicknss of 0.02 inch and were composed of rubber containing therein carbon black particles of about 22 percent by weight and wherein the composition and thickness of the film provided a surface resistance of about 125 ohms per square. The performance of these samples in reducing reflection to less than 2 percent of the incident energy is shown in the table by means of their effective ranges of operation:

ABSORBER THICKNESS	RANGE OF EFFECTIVE ABSORPTION
½ inch	8,400 - 24,500 mcs
¾ inch	5,000 - 24,500 mcs
2 inches	2,500 - 24,500 mcs
4 inches	1,100 - 24,500 mcs
8 inches	500 - 24,500 mcs

These absorber structures were tested to obtain reflection data by mounting the samples directly on a metal surface. The low frequency data was obtained with a single horn waveguide system. The waveguide measurements for reflected energy include any small amount of scattered energy. The high frequency data was obtained with a double horn, free space setup. The data obtained by this system does not include scattered energy, but comparison of the two systems indicates scattered energy to be negligible. The double horn system has become the standard technique throughout industry for testing absorber materials. Generally, the absorber materials tested are used to reduce reflections from metal surfaces, and the testing procedures prescribe that the absorber structures be placed directly on the reflecting surfaces. The performance of well designed broadband absorbers is only slightly dependent on the position of the absorber in relation to the reflecting surface, except at the very low frequency limit of their performance. The magnitude of reflection was plotted through 500 to 50,000 mcs. For frequencies above the 25,000 mcs range, the absorbed radiation amounted to at least 75 percent of the incident beam.

The effect of increasing the height of the absorber is to lower the low frequency limit. It has been observed that increasing the height of the pyramids, while maintaining the ratio of pyramid height to base width constant, will not change the surface area of the absorber. Hence in the present absorber, weight per unit area is independent of the height of the pyramids. Thus, higher pyramids are required to absorb energy at lower frequency, but the weight of the absorber material per unit area of surface protected remains constant.

The limit for increasing the height of the absorber is based on a practical consideration of size and ease of handling. Also, a limitation in decreasing the height of the absorber has been observed, assuming a constant height to base ratio, when the projections become so numerous that the peaks and valleys account for much of the absorber area and have considerable effect upon reflectivity characteristics. This disadvantage can be minimized by including additional projections with sharp peaks and valleys between the main tapered projections.

The peaks and valleys of the projection also limit the side angle ϕ that can be prescribed for the projections, i.e., beyond a certain minimum side angle ϕ (about 15°) the projections become so numerous for a given area that, as previously mentioned, the peaks and valleys become virtually a reflecting area. The "side angle ϕ," as shown in FIG. 2 is the angle formed by the side of the pyramid with a perpendicular to the base of the pyramid. Pyramidal projections with side angles of about 15° to 25° are found to be particularly effective in accordance with the teachings of the present invention.

It has been determined that the radio frequency resistance of a flat conducting sheet will be the same as the dc resistance only when the sheet thickness is very small compared with the skin depth. Thus as sheet thickness is increased, for constant surface resistance, reflectivity rises above expectations, based on the dc resistance, to a maximum when the sheet is a quarter wave thick electrically. Since an electric quarter wavelength is approached sooner at higher frequencies, the sheet thickness must be reduced to values as small as 0.003 to 0.005 inches, in order to have broadband absorption extend to higher frequencies beyond 25,000 mcs without an increase in reflectivity. As previously mentioned, film thicknesses in the range of 0.003 to 0.005 can be formed by incorporating a higher concentration of carbon black in the film and providing a rubber sheet of approximately 0.01 inch thick for support. This range of thickness will effectively absorb microwave frequencies beyond 30,000 mcs.

The sheet thickness is a most significant aspect of the present broad band absorber in maintaining a relatively uniform absorption throughout a wide range of microwave frequencies. A sheet resistance equal to that of free space, i.e., 377 ohms per square, while suitable for a resonant absorber, is not the most suitable sheet resistance for a shaped broadband absorber. Depending upon such factors as absorber height, sheet thickness and height to base ratio, an optimum resistance exists for broadband absorption. Higher than optimum values of resistance will decrease reflection from the shaped sheet itself, but will result in higher overall reflection because of a decrease in attenuation which allows a greater amount of energy to be returned from the reflecting surface. A lower than optimum resistance will cause higher overall reflection due to increased reflection from the surface of the sheet even though energy returned from the reflecting surface may be negligible. In the region of optimum resistance the amount of energy returned from both sources is approximately the same and also small. It has been found that a sheet resistance in the region of about 50–200 ohms per square is generally suitable for broadband absorption.

The pyramidal configuration has been preferred over other types of surface figures because of simplicity of construction and because the surface provides free draining of water from the sloping surface and thus

avoids the increased reflection that occurs in wet weather from standing water. Conical shapes give rise to considerable reflection because of the flat areas surrounding their bases; when the cones are overlapped at the bases to minimize flat areas, they form narrow pockets that accumulate water and contribute to high reflectivity.

The pyramidal shaped resistive skin is a good absorber because it is capable of providing high attenuation to an electromagnetic wave in a short distance with low reflection. It provides an advantage over many absorber structures in that all its volume is air (free space) except for the small amount of active conducting material. Reduction of the amount of solid binder material, such as rubber or plastic, facilitates low reflection. The physical features appear equally attractive: It can be made extremely lightweight because of the small amount of material, such as carbon or graphite required to make a sufficiently conducting film. This physical shape can provide a very flexible absorber, as shown in FIG. **3**, which facilitates mounting an curved surfaces.

It can readily be seen that the foregoing disclosure will provide an absorber of superior performance with a minimum of weight, greater flexibility in mounting, and ease of handling. The hollow thin skin structure is also conveniently inter-stacked for storage and shipment.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A microwave radiation absorber comprising a plurality of uniform, hollow, tapered projections contiguously disposed over an area, said projections being formed of a conductive sheet composed of conducting particles dispersed in a flexible medium.

2. A microwave radiation absorber comprising a plurality of uniform, hollow, tapered projections contiguously disposed over an area, said projections being formed of a conductive sheet having a thickness in the range of from about 0.008 to about 0.045 inch, said sheet being composed of conducting particles dispersed in a flexible medium.

3. A microwave radiation absorber comprising a plurality of uniform, hollow, tapered projections contiguously disposed over an area, said projections being formed of a conductive sheet having a thickness in the range of from about 0.008 to about 0.045 inch, said sheet being composed of carbon particles dispersed in rubber.

4. A microwave radiation absorber comprising a plurality of uniform, hollow, pyramids contiguously disposed over an area, said pyramids being formed of a conductive sheet having a thickness in the range of from about 0.008 to about 0.045 inch, said sheet being composed of carbon particles dispersed in neoprene.

5. A microwave radiation absorber comprising a plurality of uniform, hollow pyramids contiguously disposed over an area, said pyramids being formed of a conductive sheet having a thickness in the range of from about 0.01 to about 0.02 inch, said sheet being composed of carbon particles dispersed in neoprene.

6. A microwave radiation absorber comprising a plurality of uniform, hollow pyramids contiguously disposed over an area, said pyramids being formed of a conducting sheet having a thickness in the range of from about 0.01 to about 0.02 inch, said sheet being composed of about 10 to 20 percent by weight of carbon particles dispersed in neoprene.

7. A microwave radiation absorber comprising a plurality of uniform hollow pyramids contiguously disposed over an area, said pyramids being formed of a rubber sheet having a thickness in the range of from about 0.01 to about 0.02 inch, the face surface of said sheet comprising 20 to 30 percent by weight of finely divided carbon particles to a depth therein approximately 0.003 to 0.005 inch.

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