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Wesch

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[54] ABSORBER FOR ELECTROMAGNETIC RADIATION

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[52] **U.S. Cl.** ..... **343/18 A**

[51] **Int. Cl.** **H01q 17/00**

[58] **Field of Search** ..... 343/18 A

[56] **References Cited**

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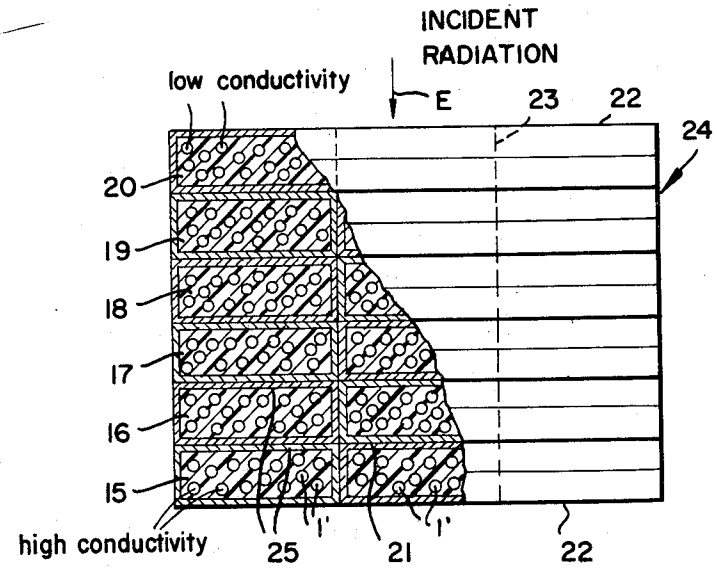
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[57] **ABSTRACT**

A body designed to absorb electromagnetic radiation in the UHF, SHF and EHF includes a multiplicity of closely juxtaposed spheres, whose diameters lie between about 0.1 and 5 times the wavelength of that radiation, imbedded in a polymeric matrix and/or lodged in cavities of a cellular supporting structure. Each sphere has a nonconductive, preferably highly porous spherical core coated with one or more layers of radiation-responsive (electrically conductive and/or magnetically permeable) material each advantageously overlain by a protective dielectric coating. The conductivity and/or permeability of the coatings of successive strata of spheres may progressively diminish in the direction of propagation, toward the source of radiation, to approach the conditions of ambient air or free space.

12 Claims, 4 Drawing Figures



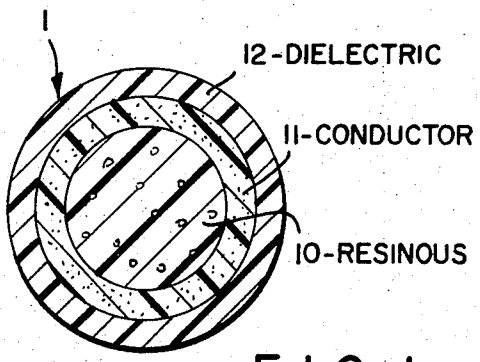


FIG. 1

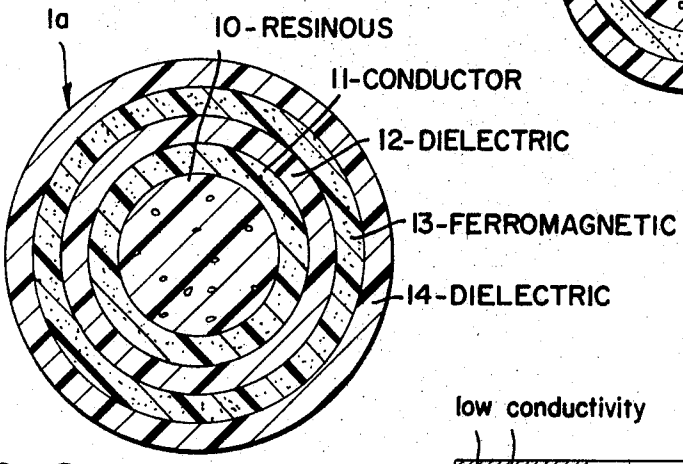


FIG. 2

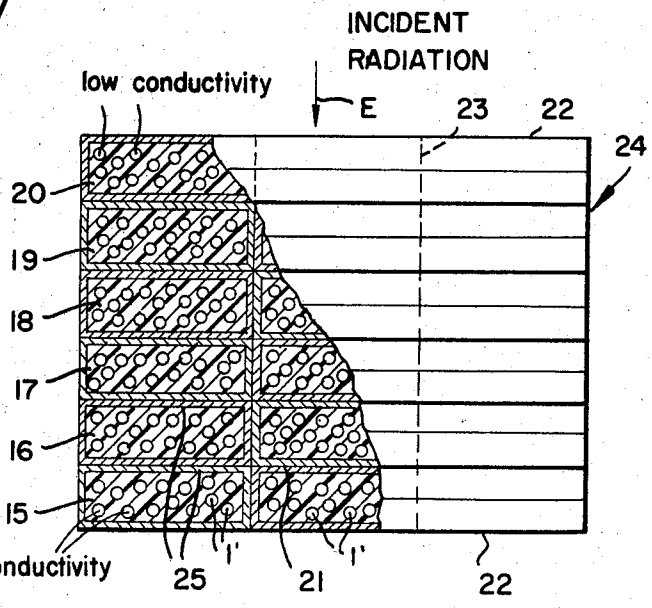


FIG. 3

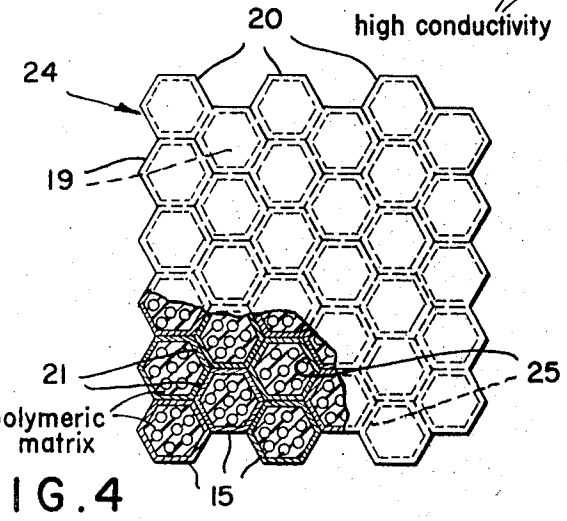


FIG. 4

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ABSORBER FOR ELECTROMAGNETIC RADIATION

The present invention relates to an absorber for electromagnetic radiation, especially radar waves in the ultrahigh-frequency, superhigh-frequency and extremely-high-frequency (decimeter, centimeter and millimeter) range.

Such absorbers, whose physical structure may take a variety of shapes, are conventionally made from porous ceramic materials such as expanded clay with randomly distributed internal discontinuities which dissipate the incident radiant energy. By these discontinuities, representing abrupt changes in dielectric constant, the waves are reflected and refracted so as to be diffused throughout the ceramic mass in the which their energy is absorbed; to promote dissipation, this mass may include an admixture of conductive material such as graphite.

In order to produce larger radiation shields in the form of walls, blocks or the like from such lossy materials, it is generally convenient to imbed the ceramic particles in a polymeric matrix, advantageously of foam resin. The specific radiation absorptivity of these fillers, however, is relatively limited so that in many instances it is necessary to load the plastic matrix with a high proportion of ceramic material whose presence then impairs the cohesiveness of the structure. The foaming process is also impeded by the presence of these particles.

The general object of the invention, therefore, is to provide an improved absorber of greatly increased ability to dissipate incident high-frequency electromagnetic waves.

This object is realized, in accordance with the present invention, by the provision of a multiplicity of juxtaposed spheres whose diameters are on the order of magnitude of the shortest wavelength λ of the radiation to be intercepted (and which therefore may be regarded as macroscopic in contradistinction to the fine-grained particles of about 1 micron forming part of certain previously proposed radiation shields), each sphere having a nonconductive and nonmagnetizable core enveloped by one or more active layers of radiation-responsive material. The term "radiation-responsive" denotes electric conductivity and/or magnetic permeability since either of these properties will have a substantial effect upon the path of the incident radiation. By "order of magnitude" is meant a range of about 0.1 λ to 5 λ.

In general, core diameters between 1 and 10 mm will be suitable for most applications in the field of radar waves; it has been found that effective absorption may extend over a band of three or four octaves, even though best results are achieved for wavelengths on the order of magnitude of the core diameter.

The radiation-responsive layer on that core may have a thickness of not more than about one-tenth of the core diameter, e.g., between 0.01 and 0.05 mm in the case of cores of 1 mm and larger. If several such layers are present, they are advantageously separated by protective layers of electromagnetically inert (i.e. substantially nonconductive and nonpermeable) material. Such a protective layer may also be provided as an outer coating for the sphere regardless of the number of active layers.

Electrical conductivity may be imparted to an active layer by imbedding a mass of carbonaceous particles, such as carbon black and/or graphite, in a nonconductive binder adapted to bond to the core without objectionable interaction.

For magnetic permeability, the layer may include ferromagnetic particles of low remanence in such a binder, e.g., iron carbonyl or ferrites. It will frequently be desirable to provide separate layers of predominantly conductive and permeable character, respectively, even though the two types of particles could also be combined in a single layer.

The body of the absorber may have a more or less rigid structure, e.g., one constituted by solid walls formed with internal compartments to accommodate the spheres. Thus, a honeycomb-type webbing may be employed, with the cells of the honeycomb forming several tiers subdivided by partitions extending generally in the direction of wave propagation. Within the cells these spheres may be immobilized by a surrounding matrix of foam polymer; in a more flexible structure, the rigid webbing may be omitted so that the body of the absorber consists essentially of a polymeric sheet, block, tube or the like with the spheres dispersed therethrough.

In either case, reflections at the point of incidence of the intercepted radiation may be minimized by a progressive decrease of the conductivity of the layer material (and therefore of its absorptivity) in the direction of propagation, toward the source of radiation, with gradual approach of the conditions of ambient air or free space in that direction. Thus, the spheres may be arrayed in a plurality of strata generally transverse to the direction of incidence, with progressive diminution of conductivity from the remotest stratum to the stratum nearest the source. In practice, this variation in conductivity can be achieved by choosing different concentrations of conductive particles in the active layers of the spheres of the respective strata. When graphite is used as the conductor, its concentration may vary between 1 and 200 kg per cubic meter of spheres; with substantially higher concentrations the absorber becomes ineffectual.

While the spheres could all be of the same size, the use of spheres of different diameters in a single tier has the advantage of enabling a better distribution of the spheres within the coherent matrix, aside from extending the effective frequency range of the absorber. The mean value of these diameters may then be chosen about midway within the aforestated range of 0.1 λ to 5 λ.

The increased efficiency of the improved radiation absorber is attributed to the fact that the radiation-responsive material is distributed over predetermined surfaces of a shape and size related to the wavelength, with a resulting volumetric effect not realizable by a random dispersion of minute reflectors.

The invention will be described in greater details hereinafter with reference to the accompanying drawing in which:

FIG. 1 is a greatly enlarged cross-sectional view of a radiation-absorbing sphere according to the invention;

FIG. 2 is a view similar to FIG. 1, showing a modified sphere;

FIG. 3 is a side-elevational view, partly in section, of a radiation-absorbing body incorporating spheres similar to those shown in FIGS. 1 and 2; and

FIG. 4 is an end view of the body of FIG. 3, with parts broken away.

In FIG. 1 there has been shown a sphere 1 with a central core 10 of expanded polymeric material, e.g., polystrene foam, coated with a conductive inner layer 11 and a dielectric outer layer 12. Layer 11 may consist of an adhesive binder having particles of graphite and/or carbon black imbedded therein; layer 12 may consist of a conventional lacquer, enamel or the like.

In FIG. 2 there is shown a more elaborate sphere 1*a* with the same elements 10 – 12 as sphere 1 of FIG. 1 but with a further active layer 13 surrounding the inert layer 12 and with another inert, i.e., dielectric, outer layer 14 applied to layer 13. The latter layer differs from layer 11 by incorporating ferromagnetic rather than highly conductive particles, e.g., grains of ferrite or iron carbonyl. Layers 12 and 14 may be identical.

The thickness of the layers 11 – 14, which may be a small fraction of the diameter of core 10, has been exaggerated in FIGS. 1 and 2 for the sake of clarity.

The core 10 may be formed by expanding a tiny globule of polystyrene or other foamable polymeric material until it reaches the desired diameter. Alternatively, it may have been cut from a block or sheet of foam polymer and then tumbled with a mass of similar pieces until properly rounded.

The layers 11, 12 etc. may then be applied by dipping, spraying or any other convenient coating process, as by letting the spheres drop through a mist of a desired composition.

FIGS. 3 and 4 show a honeycomb structure 24 with webs 21 forming internal cells 25 of hexagonal profile arranged in several tiers 15 – 20 which are stacked in the direction of incidence of electromagnetic radiation E. The cells are surrounded by an outer casing 22 internally subdivided by partitions 23 which extend parallel to the direction E of incidence. Each cell 25 is filled with a matrix of foam polymer advantageously of the same composition as the cores 10 of the spheres 1′ imbedded therein; these spheres may be of the type shown either at 1 in FIG. 1 or at 1*a* in FIG. 2. The conductivity of the layers 10 of these spheres advantageously diminishes toward the source of radiation E, i.e., from the bottom tier 15 to the top tier 20, to provide a tapering loss characteristic with minimum reflection. Thus, for example, the concentration of graphite in these layers 10 may vary as follows:

tier 15 — 100 kg per m^3
tier 16 — 80 kg "
tier 17 — 40 kg "
tier 18 — 20 kg "
tier 19 — 10 kg "
tier 20 — 5 kg "

Naturally, the concentration of ferromagnetic particles may be similarly varied in layer 13 if the spheres, or some of them, are of the type shown in FIG. 2.

The skeleton 21 – 23 of structure 24 may consist of the same dielectric material as the cores and the porous matrix, e.g., polystyrene, or of dissimilar material such as, for example, phenol-impregnated paper. Upon omission of this skeleton, the absorber body becomes a continuous sheet or strip of more or less flexible character, depending inter alia upon its thickness.

It is also possible to use different structural elements (e.g. tubes) to hold the spheres in position; thus, the absorber may be given the shape of a mast for naval vessels or of a tube surrounding a radio or television tower. Ribbons or cords of the composition described may be woven into mats. Tapering or wedge-shaped absorber elements, hollow or substantially solid may likewise be formed. Fibers of synthetic resins or glass may be used as internal reinforcements for these elements if required. Nonconductive materials other than natural or synthetic resins, e.g., cellulose (paper, for instance), may also be used as carriers for the coated spheres.

The porous core material need not be of organic character. Mixtures of organic and inorganic materials are, of course, also usable.

There shall now be given, by way of illustration, two examples of a conductive coating designed to form the layer 11 of FIG. 1 or 2. Example I is particularly suitable in combination with a solid or expanded polystyrene core; Example II yields a coating especially adapted to be used with cores of phenolic, polyester and epoxy resins, natural or synthetic rubbers, polyvinylchloride or polyurethane, any of them with or without foaming.

EXAMPLE I

A coating composition is formed from the following ingredients:

19.149 kg of graphite
2.128 kg of carbon black
63.830 kg of shellac dissolved in ethyl alcohol (weight ratio of 1 : 2)
2.128 kg of dimethyldioctadecyl ammonium bentonite (Bentone 34) dissolved in xylene with a weight ratio of 1 : 5
12.765 kg of ethylene glycol.

The carbon black is advantageously of finely comminuted type, with a density of about 1.8 and a particle size of 25 – 50 mμ, e.g., as marketed under the designation A 31.

EXAMPLE II

A mixture is prepared from the following components:

23.196 kg of graphite
2.577 kg of carbon black
12.371 kg of a branched polyester containing hydroxyl groups, such as the one available under the designation Desmophen 1100
5.498 kg of a similar, highly branched polyester such as that available under the designation Desmophen 800, dissolved in 98% butyl acetate with a weight ratio of 2 : 1
12.028 kg of butyl acetate 98%
0.344 kg of Bentone 34 in xylene with a weight ratio of 1 : 5
12.028 kg of ethyl acetate
3.436 kg of chlorinated diphenyl (available as Clophen A60) in xylene with a weight ratio of 4 : 1
17.182 kg of toluol
3.436 kg of methylene glycol acetate
3.093 kg of cellulose-nitrate/collodium wool dissolved in 45% isopropyl alcohol
4.811 kg of xylenepropylene resin (plasticizer).

The foregoing composition is admixed with a polyfunctional isocyanate, such as that available under

the designation Desmodur, whose functional groups react with the hydroxyl groups of the two polyester fractions (Desmophen 800 and 1100). Thus, the equivalent amount of isocyanate marketed as Desmodur L 75 percent is 165 parts by weight per 100 parts of 100 percent Desmophen 800 and 125 parts by weight per 100 parts of Desmophen 1100. The relative proportion of these reactants is, however, not critical.

Each of the foregoing examples yields an air-drying coating of good adhesiveness to its substrate. Naturally, graphite or a graphite/carbon-black mixture could be substituted for the pure carbon black specified therein.

A similar composition may be used as a carrier for the ferromagnetic particles of layer **12** (FIG. **2**).

I claim:

1. An absorber for electromagnetic radiation, comprising a radiation-transparent body with a polymeric matrix incorporating a multiplicity of juxtaposed spheres with diameters on the order of magnitude of the shortest wavelength of radiation to be intercepted, each of said spheres having a nonconductive and nonmagnetizable spherical polymeric core and at least one layer of radiation-responsive material on said core.

2. An absorber as defined in claim **1** wherein said layer is electrically conductive.

3. An absorber as defined in claim **2** wherein said layer incorporates a mass of carbonaceous particles.

4. An absorber as defined in claim **1** wherein said layer is magnetically permeable.

5. An absorber as defined in claim **4** wherein said layer incorporates low-remanence ferromagnetic particles.

6. An absorber as defined in claim **1** wherein each of said spheres further has an electromagnetically inert outer layer adjoining said layer of radiation-responsive material.

7. An absorber as defined in claim **1** wherein said body comprises a compartmented structure accommodating several groups of said spheres in respective compartments filled with said matrix.

8. An absorber as defined in claim **7** wherein said structure has solid walls forming said compartments in a plurality of tiers generally perpendicular to the direction of incidence of said radiation.

9. An absorber as defined in claim **1** wherein said core and said polymeric matrix have substantially the same composition.

10. An absorber as defined in claim **1** wherein said spheres are arrayed in a plurality of strata generally transverse to the direction of incidence of said radiation, said layer of radiation -responsive material having a conductivity which decreases progressively in successive strata toward the source of radiation.

11. An absorber as defined in claim **9** wherein said core and said matrix consist of foam polymer.

12. An absorber as defined in claim **1** wherein said core has a diameter upwards of **1** mm and said layer has a thickness of up to about one-tenth of said diameter.

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