Dec. 6, 1966 L. WESCH 3,290,680

ELECTROMAGNETIC WAVE ABSORBER AND PROCESSES FOR PRODUCING AND USING THE SAME

Filed Aug. 6, 1963

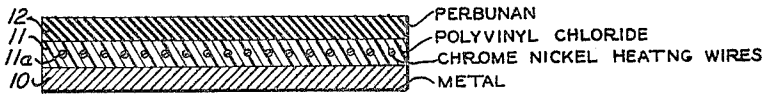


Fig. 1

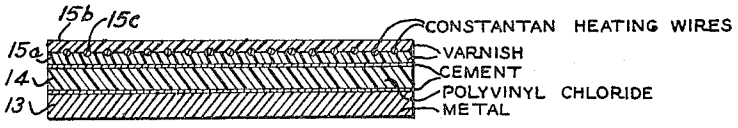


Fig. 2

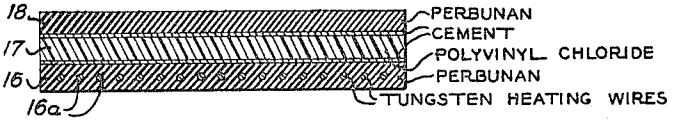


Fig. 3

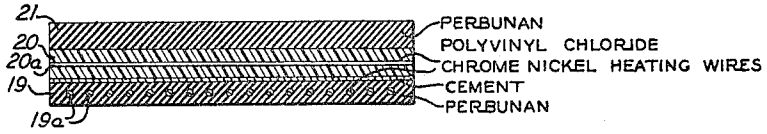


Fig. 4

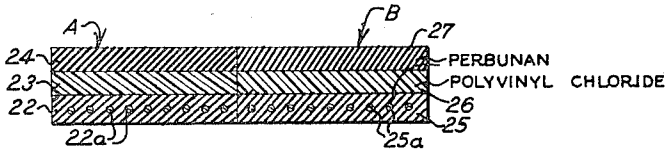


Fig. 5

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ELECTROMAGNETIC WAVE ABSORBER AND PROCESSES FOR PRODUCING AND USING THE SAME

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12 Claims. (Cl. 343—18)

This is a continuation-in-part of the application for Radar Absorber Tunable by Artificial Heating, Ser. No. 855,470, filed Nov. 25, 1959, and now abandoned.

This invention relates to absorbers of electromagnetic wave energy generated from a radar source and to methods of producing such absorbers.

Different kinds of absorbers of microwaves from radar sources have been known for some time. They differ greatly with respect to their theoretical mode of operation as well as in their technological structure. Basically, there are two types of microwave absorbers: those applied in the form of plastics such as varnishes or lacquers, and those applied to the surface of the object to be protected in the form of plastic or rubber layers, such as sheets or films.

It has frequently been observed that the high-frequency constants of the materials used in microwave absorbers vary with temperature as well as with surface wetting such as might be caused by rain or fog, and that the absorbers may become entirely ineffective in case of icing.

It is an object of the invention to provide improved electromagnetic wave absorber constructions and methods permitting the possibility of protecting known absorbers from the danger of icing as well as if keeping them as dry as possible and, in addition, of advantageously utilizing the above-noted temperature variation characteristic of the high-frequency constant.

The basic idea of the process according to the invention resides in the arrangement of heating wires or the like within the absorber layers. Normally, it would be expected that wires such as those used as heat conductors according to the process of the invention would render an absorber thus prepared ineffective due to self-reflection. Contrary to this idea, the insertion of heating grids or structures into absorber materials offers the possibility, not only of displacing to a certain extent the matching maximum by reason of temperature variation of the high-frequency constants, but also of widening the bandwidth of these materials within certain limits.

The heating grids or structures may, for example, be wires made of chrome-nickel, iron and similar resistance wires, having a diameter of less than 0.1 mm. and preferably 0.05 mm. The wires may be arranged in parallel and at a distance from each other which is preferably at least equal to half the wavelength existing in the material. For example, if a heating grid is embedded in a pure material having a dielectric constant of $\epsilon=100$, the distance between the heating wires, adapted to the 5 cm. band, must be at least 2.5 mm. corresponding to

$$\lambda_0/2\sqrt{\epsilon}=5/(2\times 10)$$

wherein λ_0 is the wavelength in free space. The heating grid is thus pervious to a wavelength of less than 5 cm., and the absorber will be fully effective.

Diffraction and interference phenomena on the wires of the heating grid cause a widening of the frequency band. In addition to the widening of the frequency band due to the heating wires, the resistance wires have, to a certain degree, self-absorption characteristics. This means that, giving due consideration thereto, the absorber material itself can be made thinner or lighter, since the self-absorption of the wires, the interference and the diffraction

phenomena permit the reduction of the demands made on the actual absorber material itself.

The temperature gradient of the high-frequency constant of the absorber material can be utilized in that the temperature of an absorber having at 40° C. maximum damping at 5 cm. displays with decreasing temperature a displacement of the optimum damping toward 6 cm. and that, on the other hand, the best matching is obtained with displacement toward 4 cm. with increase of the temperature.

It is further possible to increase the bandwidth by employing zonally different temperatures over the entire surface of the object to be camouflaged so that the damping maxima are spaced corresponding to different prevailing temperatures.

The heating structure may theoretically be arranged in any layer of an electromagnetic wave absorber; i.e., if the absorber is a combination of plastics, the heater may be installed either in one of the lower layers or in the topmost layer. The heater is advisably embedded in a layer which has a low dielectric constant. However, the distance between the wires when embedded in a top layer must be greater than when in the bottom layers. If the electromagnetic wave absorber is positioned on a metallic base, the heating grid should preferably be inserted closely above the metallic base, in which case an insulating intermediate layer should be present between the metallic base and the layer having the heater.

If the electromagnetic wave absorber is one not having a metal wall, a heating grid can be built into the layer which substitutes for the metallic background. Heating grids inserted into absorbers on rubber or plastic bases may, for example, be applied to a plastic plate such as, for example, sheet polyvinyl chloride, and bonded together with another sheet directly in one vulcanizing process. Analogously, it is possible to construct an electromagnetic wave absorber of plastic layers on a carrier sheet for heating grids.

The heating wires themselves can be stretched or clamped on a foil and can be fixed with the aid of a sprayed-on insulating material. The material used for carrier layers may be, but need not be, the same material as that used for the absorber. However, it must have characteristics compatible with the latter and must not change the intrinsic values of the absorber; i.e., the values of the material used for embedding must be taken into consideration when constructing the absorber.

In some cases, it is advantageous to build not only one heating grid into the electromagnetic wave absorber, but two or more. The position of one set of parallel grids would preferably be crosswise or at an angle to the other set or sets, and the grids would have to be insulated from each other. The individual grids can be embedded in the same layer of the absorber, or else, different layers which may also be spaced from each other.

Other objects, features and advantages of the invention will be found in the following detailed description of some preferred embodiments of the invention as illustrated in the accompanying drawing in which:

FIG. 1 is a sectional view of an electromagnetic wave absorber provided in accordance with one embodiment of the invention;

FIG. 2 illustrates in section a second embodiment of the invention;

FIG. 3 is a sectional view of a third embodiment of the invention;

FIG. 4 illustrates in sectional view a further embodiment of the invention; and

FIG. 5 is a sectional view of still another embodiment of the invention.

The electromagnetic wave absorber illustrated in FIG. 1 comprises a metallic base **10** on which is superposed

a phase-shifting layer **11** upon which is further superposed an absorber layer **12**.

The phase-shifting layer **11** is of a material having a low dielectric constant, for example, of about 2.5. Embedded in this layer are a plurality of heating wires **11***a* of, for example, chrome-nickel. The thickness of these wire may, for example, be of the order of 0.5 mm. These wires are arranged in parallel for an effective range of the absorber in the 3 cm. band. The distance between the heating wires is within the range of from 1.5–6 mm. and is preferably 4.5 mm. The thickness of the layer **11** is of the order of 1.5 mm. This layer may, for example be composed of polyvinyl chloride.

The absorber layer **12** is heated by the heating wires **11***a* in the layer **11**. The thickness of absorber layer **12** is of the order of 0.8 mm. Its composition is as follows:

	Parts by weight
Perbunan (a copolymer of butadiene and acrylonitrile. A trade mark of Bayer, Leverkusen, Germany)	19.00
Magnetite	76.00
Isocyanate	0.90
ZnO	0.50
Stearic acid	0.60
Paraffin	0.40
Sulfur	0.40
Coumarone resin	2.00
Diphenylguanidine	0.20

A further example of an electromagnetic wave absorber provided in accordance with the invention is illustrated in FIG. 2. In this figure a plastic sheet **14** is superposed on a metallic layer **13**. The plastic sheet layer may, for example, be of polyvinyl chloride which is about 2 mm. thick. The sheet **14** is cemented on the metallic layer **13** and layers **15***a* and *b* are cemented on the plastic foil **14**.

The layers **15***a* and *b* are composed as follows:

15*a* is a plastic layer composed of 20–50 parts of Desmodur/Desmophen in a weight ratio of 9:1 and 80–50 parts of a ferromagnetic material preferably gamma Fe_2O_3. On this layer are placed heating wires **15***c* of constantan (wire diameter 0.2 mm.) spaced 4–9 mm. and preferably by 6.5 mm. "Desmodur/Desmophen" are condensation products (manufactured by Bayer, Leverkusen, Germany), which condense after application with concurrent elimination of water. The "Desmodur" component is a diisocyanate. A considerable number of chemically different "Desmophen" components are commercially available, the mechanical strength of the lacquer depending essentially on the nature of the latter component. Following is an illustrative list of the Desmophen esters of adipic acid:

"Desmophen" 200=3 adipic acid+phthalic acid+8 1,2, 4-butanetriol

"Desmophen" 300=3 adipic acid+4 1,2,4-butanetriol+1 xylene formaldehyde resin,

"Desmophen" 800=5 adipic acid+1 phthalic acid+8 1, 2,4,-butanetriol

"Desmophen" 900=3 adipic acid+4 1,2,4-butanetriol

"Desmophen" 1100=3 adipic acid+2 1,2,4-butanetriol +2 butylene glycol,

"Desmophen" 1200=3 adipic acid+1 1,2,4-butanetriol +3 butylene glycol (ethylene gylcol monobutyl ether).

The condensation products containing the "Desmophen" components become increasingly softer the higher the characteristics number of the "Desmophen." The reaction betwen the "Desmophen" and "Desmodur" components is a two-step process, the hydroxy radicals first reacting with the isocyanate to form urethanes under elimination of water and the excess isocyanate then reacting with the water formed in the first step to separate CO_2 whereby a foam-like substance is formed. Furthermore, the excess isocyanates may form thermoplastic substances with the glycols.

15*b* is a plastic layer, 1 mm. thick, of the same composition as layer **15***a*.

The effectiveness of this absorber material is in the 5-cm. band.

A third type of electromagnetic wave absorber provided in accordance with the invention is of a structure analogous to that illustrated in FIG. 1 and described above with the difference that the layer **11** consists of a plastic layer combination corresponding to that described for FIG. 2.

In FIG. 2 it is to be noted that layers **15***a* and *b* may consist of: plastic material, Desmodur/Desmophen in a weight ratio of 4:1, filled with 20–40% of barium sulfate, and having effectiveness in the 3-cm. band.

The electromagnetic wave absorber illustrated in FIG. 3 includes heating wires **16***a* which may be, for example, tungsten wires having a diameter of 0.01 mm. and which are spaced at a distance of 2–7 mm. and preferably 4 mm. These wires are positioned in a metal-substitute layer **16** of 3 mm. thickness. The metal-substituting layer **16** may be constituted as follows:

	Parts by weight
Perbunan	28.25
Graphite	30
Conductivity carbon black	28.5
Isocyanate	0.90
Mineral oil softener for rubber such as dibutyl phthalate	6.0
Stearic acid	0.90
Paraffin	0.60
Coumarone resin	2.00
Sulfur	0.60
ZnO	0.75
Dibenzothiacyldisulfide	1.05
Diphenylguanidine	0.45

On layer **16** is cemented a polyvinyl chloride sheet **17** of 2 mm. thickness. On sheet **17** is cemented the absorber sheet **18** of about 1.2 mm. thickness and consisting of the same materials as described above with respect to layer **12**.

This absorber material can be used for a wavelength range of 5 cm.

In the electromagnetic wave absorber of FIG. 4 chrome-nickel heating wires **19***a* of 0.5 mm. thickness are spaced at about 3 mm. These wires **19***a* are positioned in a metal-substitute layer **19** having a thickness of about 3 mm. The composition of layer **19** may be that described with reference to layer **16** of FIG. 3 above.

On layer **19** is cemented a polyvinyl chloride sheet **20** of 2 mm. thickness in which heating wires **20***a* are disposed. Wires **19***a* and **20***a* are disposed crosswise with respect to one another.

Atop the layer **20** is positioned the absorber layer **21** having a thickness, for example, of 1.2 mm. and composed as indicated with respect to layer **12** of FIG. 1 above.

With reference to FIG. 5 the electromagnetic wave absorber shown therein is especially provided so as to increase the effective range thereof. The absorber layer accordingly consists of at least 2 regions which are tuned to different wavelengths.

These regions are preferably juxtaposed and consist, for example, of a region or zone A and a region or zone B.

Zone A includes, for example, a metal substitute layer similar in composition to layer **16** of FIG. 3 in which heating wires **22***a* are positioned. These wires are spaced at a distance, for example, of 2.5 mm. Upon layer **22** is provided a polyvinyl chloride sheet **23** having a thickness of 1.5 mm. and absorber layer **24** having a thickness of 0.8 mm. is positioned on top of the sheet **23**. The absorber layer may have the composition described above with reference to layer **12** of FIG. 1. The A zone is tuned to a 3-cm. band.

Zone B is provided with a metal substitute layer **25** similar to layer **16** of FIG. 3 in which are positioned heat-

ing wires **25***a*. These wires may, for example, be 0.7 mm. thick and may be spaced at a distance of 3.5 mm. Atop layer **25** is positioned a polyvinyl chloride sheet **26** of 2 mm. thickness and on top of the layer **26** is positioned an absorber layer **27** consisting of the same materials as have been described above with reference to layer **12** of FIG. 1. This layer may, for example, have a thickness of 1.3 mm.

The B zone is tuned to the 5.5-cm. band. The lengths of zone A and B may be within the range of 5 to 15 cm., for example, and are preferably 5 cm. for the zone A and 7.5 cm. for the zone B. The zones may be divided and presented as strips or in a checkerboard pattern. Any other desired surface pattern may also be utilized.

In order to obtain a broad-band layer effective between 2.5 and 9 cm., for example, the maxima and minima existing in the layers can be displaced or shifted into the desired range by separate adjustment of the temperatures. For example, it may be advantageous to maintain the temperature of region A at 30° C. and that of the region B at 40° C.

It will be appreciated from the above examples that many different types of constructions are possible within the scope of the invention. Generally, the process of the invention comprises improving the operation of an absorber of electromagnetic waves generated from a radar source by means of heating the material from which the absorber is made.

Preferably, according to the process of the invention heating wires are embedded in parallel in the electromagnetic wave absorber which is improved according to the teachings of the invention. The heating wires embedded in the absorber are preferably spaced by a distance which is greater than one half of the wavelength in the absorber. In the event that the absorber is made of superposed layers having different dielectric constants, the wires are preferably embedded in a layer having one of the lower dielectric constants.

According to the invention the heating wires provided in accordance therewith may be disposed in a combination of plastic layers. The heating wires may be disposed in the uppermost or in the bottom of said layers.

In further accordance with the invention the heating wires may be positioned by stretching the same upon a sheet and affixing the wires to the foil by means of applying an insulating plastic. In another variation of the invention the heating wires may be stretched onto a sheet which is then bonded to a second sheet in a single bonding step.

As has been noted above processes of the invention include providing two or more sets of heating wires which are built into an absorber and are, of course, insulated from one another. The different sets are preferably superposed at right angles to one another or in any event are arranged other than in parallel to each other.

There will now be obvious to those skilled in the art many modifications and variations of the structures and methods set forth above. These modifications and variations will however fall within the scope of the invention as long as they are defined by the following claims.

What is claimed is:

1. For an absorber of electromagnetic wave energy having superimposed layers of different relative dielectric constants, a method of protecting the absorber from icing conditions and adjusting the high frequency constant of the material to thereby tune the damping maximum, said method comprising embedding, in a layer of lower relative dielectric constant, heating wires arranged in spaced parallel relation in the form of a grid and heating the wires to in turn heat the absorber.

2. A method as claimed in claim **1** comprising spacing the wires in said grid apart by a distance which is greater than one-half the wavelength of the electromagnetic wave adapted for being absorbed by the absorber.

3. A method as claimed in claim **1** comprising forming said grid by stretching the heating wires onto a sheet of material and then fixing the wires to the sheet by applying an insulating plastic to the wires.

4. A method as claimed in claim **1** comprising forming said grid by stretching the heating wires onto a sheet of material and bonding the sheet of material to a second sheet of material in a single bonding step.

5. A method as claimed in claim **1** comprising embedding a second grid of heating wires in one of the layers of the absorber in insulated fashion with respect to the first said grid.

6. A method as claimed in claim **5** comprising orienting said grids such that the wires thereof extend at an angle to one another.

7. A method as claimed in claim **5** wherein said first and second grids define separate zones in said absorber for absorbing different wavelengths of electromagnetic waves, and independently heating the grids of each of the zones to thereby heat the absorber in each of said zones to adjust the wavelengths of absorption of each of said zones whereby damping maxima in different wavelength ranges can be obtained in said absorber.

8. In an absorber of electromagnetic wave energy having superposed layers of different relative dielectric constants: a grid of heating wires supported in a layer of lower relative dielectric constant, said wires of the grid extending parallel to one another at a spacing greater than one-half the wavelength of the electromagnetic wave adapted for being absorbed by the absorber, said wires being adapted for being heated to in turn heat the absorber.

9. In an absorber as claimed in claim **8** wherein said layers are plastic layers and the grid is supported in the topmost layer.

10. In an absorber as claimed in claim **8** wherein said layers are plastic layers, and the grid is supported in the lowermost layer which is adapted for being positioned on a metallic base.

11. In an absorber as claimed in claim **10** comprising a second grid of heating wires in one of the layers of the absorber insulated from the first said grid.

12. In an absorber as claimed in claim **11** wherein said grids are isolated from one another and define separate zones in said absorber, each of said grids being adapted for being separately heated to thereby adjust the temperature of each of the zones of the absorber in independent fashion whereby damping maxima in different wavelength ranges can be obtained in said zones.

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