Aug. 28, 1956 M. W. P. STRANDBERG ET AL 2,761,141

CONTINUOUSLY VARYING DIELECTRIC CONSTANT ELECTROMAGNETIC LENS

Filed Aug. 28, 1951

Fig 1a

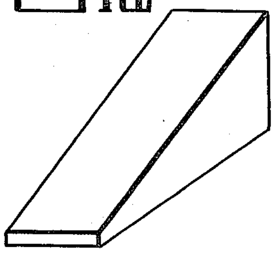


Fig 1b

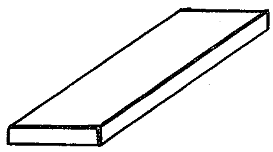


Fig 2a

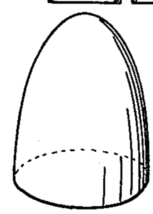
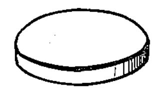


Fig 2b



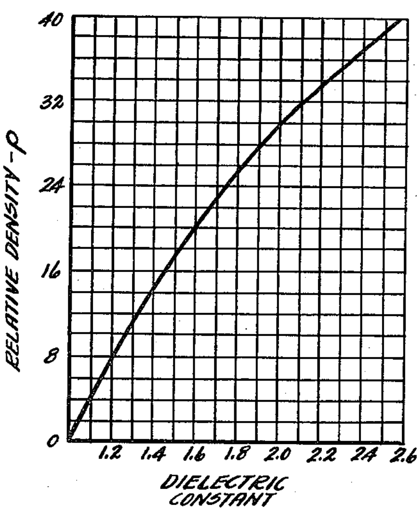


Fig 5

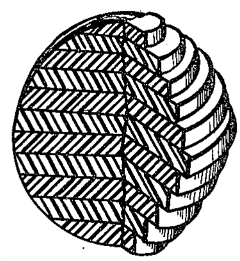


Fig 3

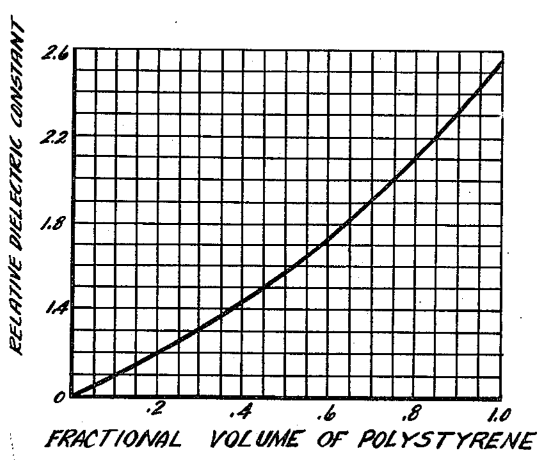


Fig 4

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2,761,141

Patented Aug. 28, 1956

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CONTINUOUSLY VARYING DIELECTRIC CONSTANT ELECTROMAGNETIC LENS

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Application August 28, 1951, Serial No. 244,086

5 Claims. (Cl. 343—911)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described in the foregoing specification and claims may be manufactured and used by or for the Government for governmental purposes, without the payment to us of any royalty thereon.

This invention relates to dielectric materials used as electromagnetic lens and to the method of forming the dielectric materials.

In the art of dielectric materials used to make electromagnetic lens, it is important that the dielectric constant of the lens vary throughout the cross section of the lens. It is old in the art to make a lens of that type by selecting various pieces of material having different dielectric constant and laminating those pieces in such a manner that the dielectric constant of the laminated body varies in cross section. That type of electromagnetic lens is difficult to construct and further has a disadvantage that the dielectric constant of the lens varies in steps rather than uniformly as is desired.

It is an object of this invention to provide a dielectric material in which the dielectric constant varies uniformly in the cross section of the dielectric material.

It is another object of this invention to provide a simple, accurate and effective method of constructing a dielectric material having the dielectric constant which varies uniformly in its cross section.

These and other objects and advantages of this invention will become more clear and will best be understood by the following description taken in conjunction with the drawings wherein:

Figure 1*a* is a perspective view of a piece of dielectric material having a uniform dielectric constant and shaped in a predetermined manner.

Figure 1*b* is a perspective view of the piece of dielectric material showing in Figure 1*a* after it has been deformed by applying pressure.

Figure 2*a* is a perspective view of a piece of dielectric material similar to the piece illustrated in Figure 1*a* except that it is shaped in a different manner.

Figure 2*b* is a perspective view of the piece of dielectric material of Figure 2*a* after it has been deformed by applying pressure.

Figure 3 is a perspective view of the plurality of pieces of dielectric material such as the pieces shown in Figure 2*b* in which the pieces are stacked to simulate a sphere.

Figure 4 is a graph illustrating the dielectric constant of materials having a fractional volume of polystyrene.

Figure 5 is a graph showing dielectric constant relative density of polystyrene.

The material most suitable for use in making the dielectric material of this invention is "Styrofoam" which is a foam of a thermo plastic dielectric synthetic resin such as polystyrene. Other materials which may be used are polymethylmethacrylate and copolymers of vinyl chloride and vinyl acetate, or of methylmethacrylate and styrene. It will be understood however that these are merely examples and that any material may be used which has the characteristic of having a uniform low loss

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dielectric constant and which may be shaped and then deformed by pressure.

The dielectric constant of a material which is a mixture of two dielectric materials is:

$$\epsilon_m = \epsilon_1^a . \epsilon_2^b \quad (1)$$

where ϵ_1 and ϵ_2 are the dielectric constanst of the constituent materials and ϵ_m is the dielectric constant of the mixture. Also, a and b are the fractional volumes of the constituent materials.

For foam material, ϵ_2 is unity; hence Equation 1 reduces to $\epsilon_m = \epsilon_1^a$

For Styrofoam, ϵ_1 is 2.55 (polystyrene). Therefore

$$\epsilon_m = 2.55^a$$

A plot of ϵ_m vs. a is shown in Figure 4.

Referring now to Figure 1*a*, in order to make a piece of dielectric material in which the dielectric constant varies along the length of the material, a block of polystyrene foam is shaped by cutting to a shape such as illustrated in Figure 1*a*. The material is then placed in a press and the slab of uniform cross section is produced such as that as shown in Figure 1*b*. Since the density of the material in the slab of Figure 1*b* varies along its length, the dielectric will also vary along its length. The relationship between the dielectric constant and the density will be such as that shown in the graph of Figure 5.

It will be seen from the graph of Figure 5 that the dielectric constant does not have a linear relationship to the relative density, it will therefore be necessary that this non-linear relationship be taken into account when the material is first cut.

In order to make a circular disk in which the dielectric constant varies radially from the center of the disk, a piece of Styrofoam is first cut or suitably shaped to the shape shown in Figure 2*a*. Pressure is then applied until the material has a flat, disk shape. The resulting piece of dielectric material shown in Figure 2*b* may be referred to as an electromagnetic lens of the two dimensional type.

To make an electromagnetic lens of the three dimensional type, a plurality of disks of the type shown in Figure 2*b* having different diameters are made. The disk having the larger diameter has a dielectric constant at its center which is greater than the dielectric constant at the center of the disk which adjoins it and the next disk has a smaller dielectric constant and so on. The stack of disks thus formed is shown, as noted in the identification of Figure 3 above, as simulating a sphere. As may be seen from Figure 3 the central disc of the stack has a diameter equal to the great circle diameter of the sphere and the other discs have diameters equal to minor circle diameters of the sphere. From Figure 3 it may be seen that each of the discs of the stack which simulates the sphere is of the same thickness at the outer periphery of the disc and in view of the fact noted above that each disc is of the type shown in Figure 2*b* which has been fabricated from pieces of dielectric material of the shape shown in Figure 2*a* but differing only in diameter, it necessarily follows that each disc will have the same density and hence the same dielectric constant at its outer periphery since the density at this point is obviously substantially that of the uncompressed material. The stack of discs may be machined to give the shape of a sphere and fastened together by means of a proper adhesive or by inclosing the sphere in a spherical sheet of thin dielectric material.

While we have, in accordance with the statutes, illustrated and described a particular embodiment of our invention, it will be understood that many modifications, omissions and additions may be made without departing from the spirit and scope of our invention.

What is claimed is:

1. The method of making a variable dielectric constant

lens for electromagnetic waves which comprises shaping a piece of dielectric material having a uniform density and hence a uniform dielectric constant to a shape such that its cross section varies in height in such a manner that the height at any point along the cross section is proportional to the desired magnitude of dielectric constant of the lens at that point, and then applying pressure to cause the material to have a uniform height and hence a variable density and a variable dielectric constant in cross section.

2. A two dimensional electromagnetic lens comprising a disk of a single foamlike dielectric material of substantially uniform thickness, all of the foam forming material being of the same composition, the density of the central portion of said disk being greater than the density of the peripheral portion, the density varying continuously from the center to the periphery whereby said disk has a continuously varying dielectric constant from the center to the periphery.

3. An electromagnetic lens comprising a stack of dielectric disks, the thickness of said stack of disks being substantially equal to the diameter of the center of said stack, each of said disks being constituted of a single dielectric foamlike material, the density of the central portion of each of said disks being greater than the density of the peripheral portion of said disks, said disks varying continuously in density from the center to the periphery.

4. An electromagnetic lens comprising a stack of dielectric disks, the thickness of said stack of disks being substantially equal to the diameter of the center of said stack, each of said disks being constituted of a single dielectric foamlike material, the density of the central portion of each of said disks being greater than the density of the peripheral portion of said disks, said disks varying continuously in density from the center to the periphery, said disks decreasing in diameter from the center to the end of the stack whereby said stack is substantially spherical.

5. An electromagnetic lens comprising a stack of dielectric disks, the thickness of said stack of disks being substantially equal to the diameter of the center of said stack, each of said disks being constituted of a single dielectric foamlike material, the density of the central portion of each of said disks being greater than the density of the peripheral portion of said disks, said disks varying continuously in density from the center to the periphery, said disks decreasing in diameter from the center to the end of the stack whereby said stack is substantially spherical, the density of the central portions of the disks decreasing in proportion to the distance of the disk from the center whereby the dielectric constant along the axial and transverse diameters is substantially equal.

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