

Dec. 30, 1958

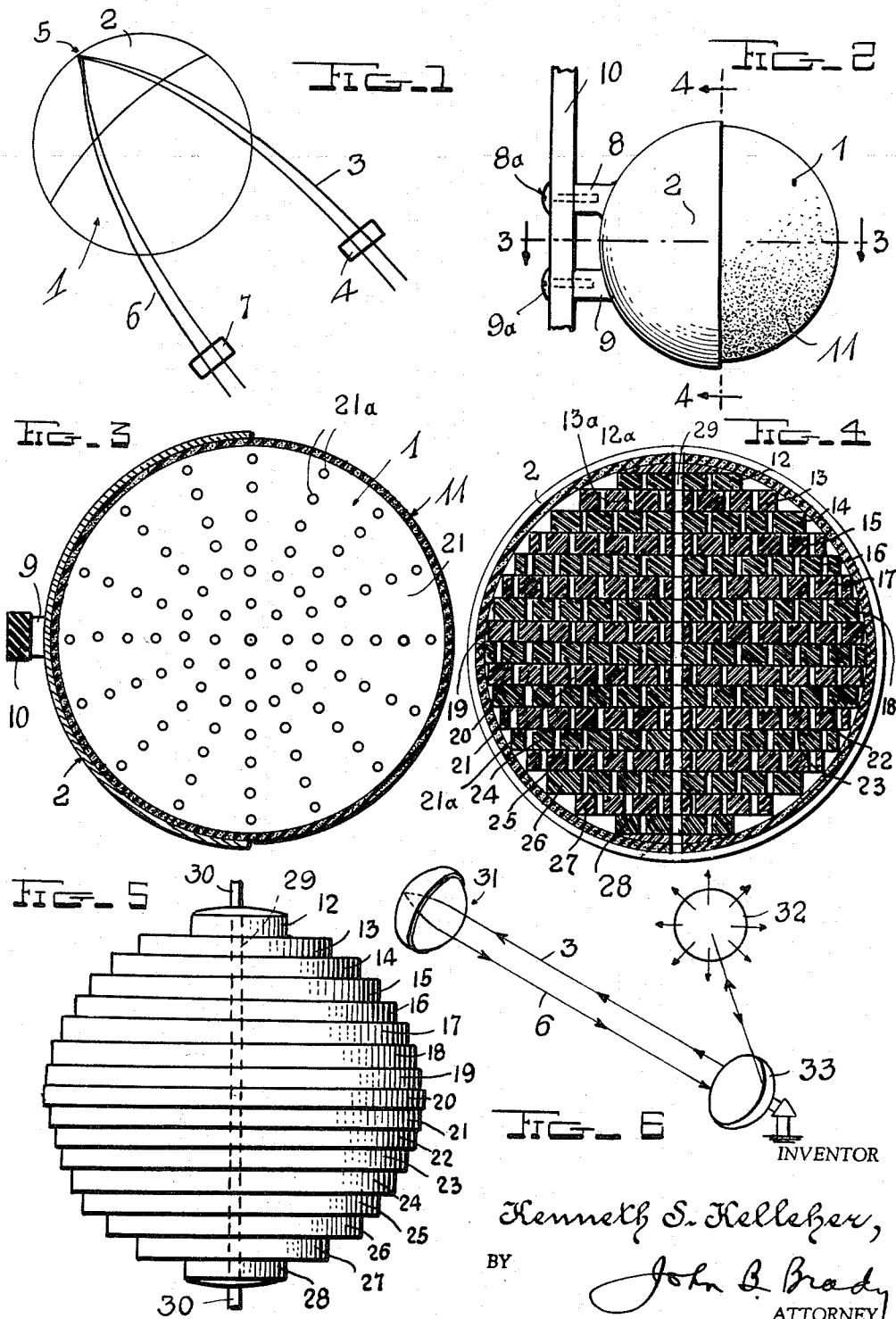
K. S. KELLEHER

2,866,971

RADIANT ENERGY REFLECTOR

Filed Sept. 5, 1956

2 Sheets-Sheet 1



Kenneth S. Kelleher,
BY John B. Brady
ATTORNEY

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2 Sheets-Sheet 2

FIG. 7

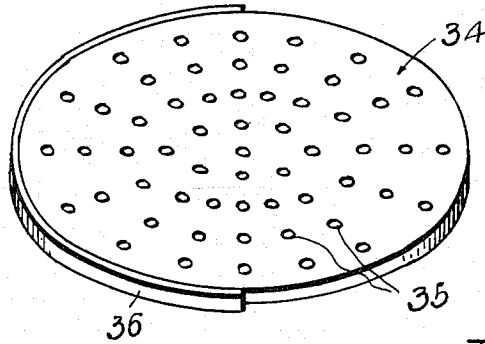


FIG. 8

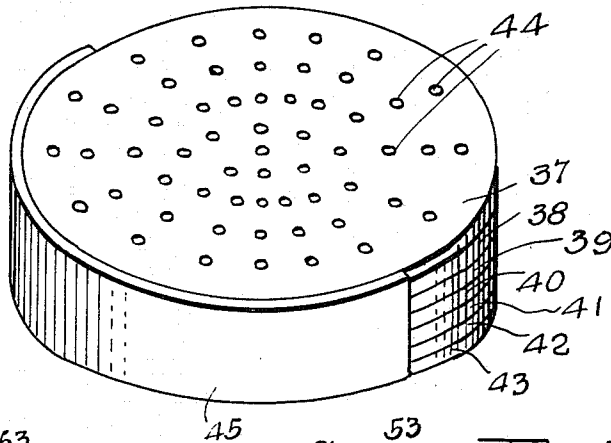


FIG. 10

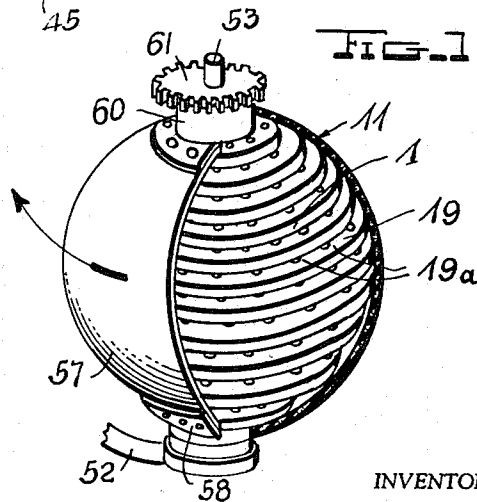
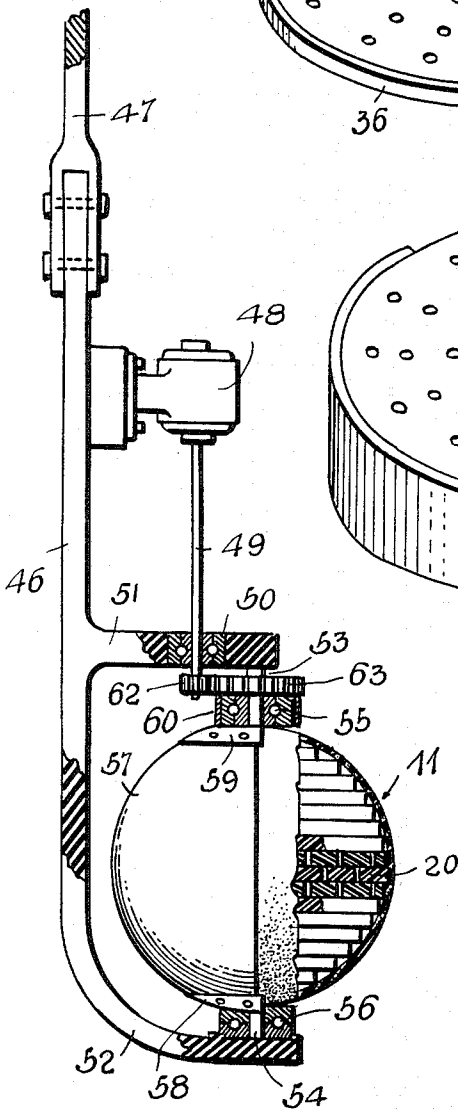


FIG. 9



INVENTOR

Kenneth S. Kelleher,

BY

John B. Brady

ATTORNEY

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2,866,971

RADIANT ENERGY REFLECTOR

Kenneth S. Kelleher, Alexandria, Va.

Application September 5, 1956, Serial No. 608,091

10 Claims. (Cl. 343—755)

My invention relates broadly to radiant energy reflectors and more particularly to a radiant energy reflector having a variable index of refraction lens together with a metallic reflecting material.

One of the objects of my invention is to provide a construction of radiant energy reflector having extremely accurate focussing properties as a radiant energy lens where the locus of the focal points are all located on the surface of a sphere.

Another object of my invention is to provide a construction of radiant energy reflector employing a dielectric sphere in association with a metallic reflector where the sphere constitutes a variable index of refraction lens so associated with a metallic reflecting surface in such manner that radiant energy transmitted to the sphere from a plurality of directions is reflected along a path which emerges from the sphere in a direction of the incoming waves.

Another object of my invention is to provide a combination structure for a radiant energy reflector consisting of a substantially semi-spherical metallic reflector and a spherical dielectric lens for receiving incident, nearly-plane waves arriving from a plurality of directions and reflecting waves of the same type with a high degree of efficiency.

Other and further objects of my invention reside in a composite structure of spherical dielectric lens and semi-spherical cap metallic reflector associated therewith as set forth more fully in the specification hereinafter following by reference to the accompanying drawings, in which:

Fig. 1 is a theoretical view showing the composite spherical lens and semi-spherical metallic reflector associated in accordance with my invention and illustrating the symmetrical paths of incident and reflected radiant energy;

Fig. 2 is a side elevational view of the composite lens of my invention illustrating a fragmentary portion of the support for mounting the structure;

Fig. 3 is a horizontal sectional view on an enlarged scale, taken substantially on line 3—3 of Fig. 2;

Fig. 4 is a vertical sectional view taken substantially on line 4—4 of Fig. 2;

Fig. 5 is a side elevational view showing one method of assembling dielectric plates for forming the dielectric sphere of my invention;

Fig. 6 is a theoretical view showing the application of the structure of my invention as a radar target and illustrating the accuracy with which incident waves are focused and reflected in the structure of my invention;

Fig. 7 shows a modified form of my invention where the lens is in the shape of a disc;

Fig. 8 is a perspective view of a further modified form of my invention showing the arrangement of the void dielectric in the form of a multiplicity of stacked discs;

Fig. 9 is a schematic view showing the application of my invention to a radar target operative through a sweep path of 360°; and

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Fig. 10 is a perspective view of the assembly illustrated in Fig. 9 with parts broken away to illustrate the arrangement of the sphere having dielectric voids therein where certain parts are broken away and shown in section and illustrating particularly the manner in which the semi-spherical metallic reflector is controlled for 360° sweep about the dielectric sphere.

My invention is directed to a construction of radiant energy reflector which is highly accurate and precise in its focusing characteristics. The lens of my invention is spherical having void dielectric characteristics and density correction. The density of the dielectric material forming the spherical lens is changed by reducing the dielectric structure by removal of the dielectric material, leaving voids in the dielectric structure. The spherical lens is assembled by stacking circular plates of void dielectric material where the plates vary in diameter from a maximum at the middle of the structure toward each end thereof. The voids in the dielectric plates are staggered or offset with respect to each other except at the centers of the plates where the voids are aligned to facilitate the passage of an assembly member on which the plates may be temporarily maintained in position. After assembly of the plates on the temporary aligning means the assembly is subjected to a pressure molding process by which a spherical foam plastic or rubber binding is formed around the plates for maintaining the plates in position and forming the spherical dielectric lens. The spherical dielectric lens bound within the foam plastic or rubber housing is assembled with a semi-spherical cap or metallic reflector. Such reflector may be fixed with respect to the spherical dielectric lens or the semi-spherical metallic reflector may be mounted to revolve about the stationary spherical lens for operating the lens through a field of 360°.

Referring to the drawings in more detail, reference character 1 designates the spherical dielectric lens which is capped by the metallic semi-spherical reflector 2. The incident waves are represented at 3 originating at locations 4 and being propagated through the dielectric spherical lens 1, where they impinge upon the interior of the metallic surface of the metallic semi-spherical reflector 2. The locus of all focal points, such as 5, are on the surface of the sphere and are very definitely fixed. The wave energy is reflected from the interior surface of the metallic semi-spherical reflector 2 along the paths indicated at 6 to the location represented at 7. The spherical dielectric lens 1 has a variable index of refraction giving increased efficiency and accuracy in operation not obtainable with the use of simple metallic reflectors or reflectors with constant index lens. Waves arriving over a broad angle are uniformly reflected by the structure of my invention. The assembly as illustrated in Fig. 1 receives an incident nearly-plane wave and reflects a wave of the same type. The substantially dielectric lens is capable of accepting incident waves arriving from a plurality of directions.

In Fig. 2 I have illustrated one manner of mounting the composite structure of my invention. The semi-spherical reflector 2 is provided with a pair of rearwardly extending bosses 8 and 9 through which fastening screws 8a and 9a extend for fastening the reflector 2 to the depending support 10 of insulation material. The spherical lens 1 is supported in a position directed generally toward the radiant energy transmitting source.

In Fig. 3 I have illustrated the association of the semi-spherical metallic reflector 2 with the spherical lens 1. A jacket or binder of foam plastic or rubber, represented at 11, serves to maintain the position of the dielectric discs from which the spherical dielectric lens 1 is formed.

Fig. 5 more clearly explains the construction of the spherical dielectric means which is formed from a plurality

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of dielectric plates of varying diameters and which I have represented at 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27 and 28. These dielectric plates 12-28 vary in diameter, one with respect to the other, except that plates 19, 20 and 21 adjacent the center of the sphere have substantially the same diameters. That is, the discs vary in step-by-step formation from a maximum diameter at the center of the assembly to a minimum diameter at opposite ends of the assembly. The plates are formed from dielectric material and each contains dielectric voids or cavities. The voids along the central axis of the plates are all aligned diametrically through the sphere, as represented more clearly in Fig. 4 by reference character 29. These aligned voids are adapted to receive a diametrically extending pin 30 as represented in Fig. 5 on which the discs 12-28 are assembled. Such pin 30 enables the discs to be suspended in a spherical pressure mold into which liquid foam plastic or rubber is introduced and allowed to solidify forming a foam plastic or rubber spherical binding 11 around the discs 12-28. The spherical unit consisting of the plates 12-28 constitutes a variable index of refraction lens. The individual dielectric plates contain cavities or voids which I have designated for example at 12a and 13a in plates 12 and 13 and at 21a in plate 21. These voids or cavities are produced by drilling holes in the dielectric plates but these holes are not aligned, but are offset or staggered from the holes in an adjacent plate. Thus, a non-communicating labyrinth of cavities is disseminated through the dielectric structure of the spherical lens, represented for example in Fig. 4. This labyrinth of dielectric voids provides an artificial molecular structure by which the radiant energy waves are retarded and establish a field in each of the cavities. Thus obstacles are artificially introduced into the path of the advancing waves which serve to control the direction of the wave path. By proper distribution of these voids a very accurate control is obtained over the incident waves for assuring the reflection of the waves along a very precise and accurately directed path. The molecular interference produced through the structure of the voids in the spherical dielectric lens provides for precision in the refractive control of the waves which enables the reflected waves to be pin-pointed upon a target with an accuracy not obtainable in conventional structures. In other words, I provide means for manipulating the dielectrics artificially within a field of uniform refraction characteristics.

Fig. 6 is illustrative of the advantageous results obtainable by the application of my invention to radar targets which I have represented at the location 31. Reference character 32 designates a normal obstacle capable of reflecting radar waves from a transmitting source in association with the radar reflector 33 from which incident waves emanate along path 3 to the radar target 31 and from which reflection waves 6 pass to the reflector 33.

In Fig. 7 I have shown a modified form of reflector constituted by a disc lens 34 of dielectric material. The disc lens 34 comprises a variable-index refraction lens containing dielectric cavities or voids indicated generally at 35. A short metallic cylinder 36 is associated with the disc 34 and serves as a reflector for waves advancing into the disc 34.

In Fig. 8 I have shown a lens comprising a plurality of flat dielectric discs 37, 38, 39, 40, 41, 42 and 43, superimposed upon each other and provided with voids or cavities 44 forming obstructions for controlling the incident and reflected waves through the lens. The obstructions 44 are staggered as in the case of the spherical lens. A semi-spherical reflector 45 extends adjacent all of the discs 37-43 for reflecting incident waves directed through the dielectric material of the discs 37-43.

My invention is applicable to systems operating over a range of 360° where the variable index of refraction lens is maintained fixed and where the metallic reflector revolves about the lens as shown in Figs. 9 and 10. In this arrangement a bracket of insulation material represented

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at 46, and which may depend for example from the chassis of an aircraft, is supported through a suitable hanger 47. Bracket 46 provides a mounting for motor 48 which drives vertical shaft 49 the lower end of which is journaled in bearing 50 carried in the arm 51 projecting from bracket 46. The bracket 46 terminates in a downwardly extending arm 52 vertically aligned beneath arm 51. Between these arms 51 and 52 the spherical lens of Figs. 1-5, coated by the foam plastic or rubber binder 11, is fixedly mounted through stub shafts 53 and 54. I provide ball-races 55 and 56 around the stub shafts 53 and 54 which constitute bearings. The semi-spherical reflector shown at 57 is journaled for rotation. The semi-spherical reflector 57 connects at its bottom with a seat 58 which forms part of the bearing constituted by a ball-race 56. The upper end of the semi-spherical reflector 57 connects through the seat 59 with the sleeve 60, which in turn connects to the gear 61. Gear 61 is driven by pinion 62 operated by shaft 49 driven through motor 48. Sleeve 60 thus transmits the turn torque from gear 61 to the reflector 57 which revolves about the ball-races 55 and 56, thereby cyclically exposing the variable-index refraction lens 1 to incident waves over a range of 360°. A periodic sweep of the surrounding area is thus obtained enabling the variable index refraction lens to be continuously effective upon radial waves incident from directions throughout a range of 360°.

The precision operation obtainable with the variable index of refraction lens is thus usefully employed over the entire 360° range about the lens.

Certain rules may be developed for the production of the structure of my invention. A typical design involves the spherical Luneberg lens whose index varies with radius as $n^2 = 2 - r^2$. At this point, it should be observed that the index squared is equal to the dielectric constant, so it is possible to relate the design equation directly to dielectric-constant values. The design technique found most practical uses the void dielectric of Equations 1 and 2, as follows:

The dielectric constant K of an artificial medium comprised of a cubical lattice of spherical voids is

$$K/K_1 = (1 + 2FC) / (1 - FC) \quad (1)$$

Fractional volume F is the volume of the voids in unit volume; thus, F involves the void diameter and the void density in number per unit volume. Constant C is characteristic of the base medium,

$$C = (1 - K_1) / (1 + 2K_1) \quad (2)$$

where K_1 is the dielectric constant of the base medium. It has been found experimentally that Equation 1 is valid even when the diameter and spacing of voids exceed $\lambda/4$. (λ is wavelength.)

The desired sphere is formed from a collection of discs of varying radius, placed one above the other, to approximately a spherical form similar to that in Figs. 4 and 5.

There are four steps in the design.

(1) Select base material of dielectric constant K_1 and obtain the coefficient $C = (1 - K_1) / (1 + 2K_1)$; using polystyrene with $K_1 = 2.52$, $C = -0.252$; (2) write Equation 1 using values of K_1 and C to obtain a relationship between void-dielectric constant and fractional volume;

$$K = 2.52(1 - 0.504F) / (1 + 0.252F);$$

(3) combine the lens equation relating dielectric constant to coordinate value with Equation 1 to obtain a relationship between coordinate value and fractional volume; $2 - r^2 = 2.52(1 - 0.504F) / (1 + 0.252F)$. (4) Compute fractional volume as a function of the position within the lens.

To use the disc assembly technique, note that $r^2 = d^2 + a^2$ where d is the distance of the disc from the lens center and a is the radius coordinate within the disc. The fractional volume is then given by

$$F = 3.97 \left\{ \frac{0.52 + a^2 + d^2}{7.04 - a^2 - d^2} \right\}$$

For a disc at a given distance d from the lens center, the fractional volume at any disc radius is known.

In practice, each disc is divided into annular rings of width less than $\lambda/4$ so no void will be large in terms of a wavelength. The desired fractional volume in each annular ring is determined from the above equation. This void volume is then obtained by drilling the correct size and number of holes.

While I have described my invention in certain of its preferred embodiments, I realize that modifications may be made, and I desire that it be understood that no limitations upon my invention are intended other than may be imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A reflector for radiant energy comprising a dielectric sphere having a variable index of refraction and a semi-spherical metallic reflector disposed adjacent one side of said sphere.
2. A reflector for radiant energy comprising a semi-spherical metallic reflector and a spherical dielectric body disposed within said semi-spherical metallic reflector, said dielectric body having dielectric voids distributed through the structure thereof.
3. A reflector for radiant energy comprising a dielectric sphere consisting of a labyrinth of variable index of refraction members and a semi-spherical metallic reflector arranged adjacent said members.
4. A reflector for radiant energy comprising a dielectric sphere consisting of a multiplicity of layers of dielectric material having a variable index of refraction and a semi-spherical metallic reflector arranged adjacent said layers.
5. A reflector for radiant energy comprising a dielectric sphere consisting of a plurality of flat members contacting each other face to face, each having a variable index of refraction and a semi-spherical metallic reflector disposed adjacent one side of said members.
6. A reflector for radiant energy comprising a dielectric sphere having a variable index of refraction, a resilient casing extending around said sphere and a semi-spherical metallic reflector arranged around said resilient casing.
7. A reflector for radiant energy comprising a spherical dielectric body having a variable index of refraction and

consisting of a plurality of flat layers of dielectric material, a resilient casing enclosing said layers of material and maintaining said layers of material within the contour of said spherical electric body and a semi-spherical metallic reflector located adjacent one side of said resilient casing.

8. A reflector for radiant energy comprising a semi-spherical metallic reflector and a spherical dielectric body mounted within said semi-spherical metallic reflector in spaced relation to the reflecting surface of said semi-spherical metallic reflector, said spherical dielectric body comprising a plurality of layers of dielectric material each containing density correction means for predetermining the index of refraction of the reflector.

9. A reflector for radiant energy comprising a semi-spherical metallic reflector and a spherical dielectric body mounted within said semi-spherical metallic reflector in spaced relation to the reflecting surface of said semi-spherical metallic reflector, said spherical dielectric body comprising a plurality of layers of dielectric material each containing dielectric voids staggered in one dielectric layer with respect to the dielectric voids in the adjacent dielectric layer for predetermining the index of refraction of said reflector.

10. A reflector for radiant energy comprising a semi-spherical metallic reflector and a spherical dielectric body mounted within said semi-spherical metallic reflector in spaced relation to the reflecting surface of said semi-spherical metallic reflector, said spherical dielectric body comprising a plurality of layers of dielectric material each containing a centrally aligned aperture and a multiplicity of distributed apertures, the distributed apertures in one layer being offset with respect to the distributed apertures in an adjacent layer for predetermining the index of refraction of the reflector.

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