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EXAMINER

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W. E. KOCK

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NONREFLECTIVE RADIO REFRACTOR

Filed March 28, 1950

FIG. 1

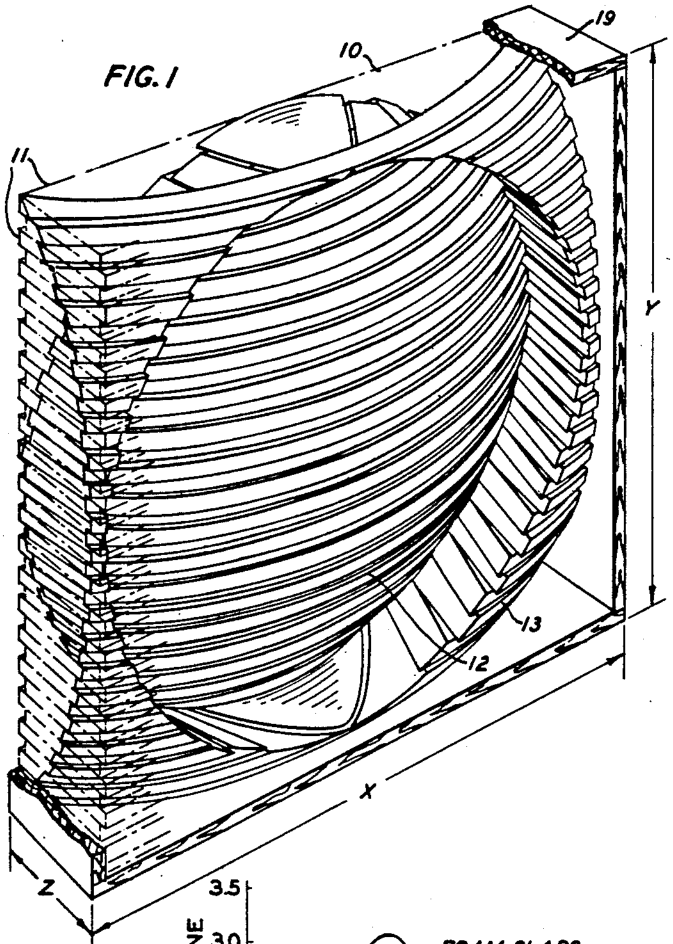


FIG. 2

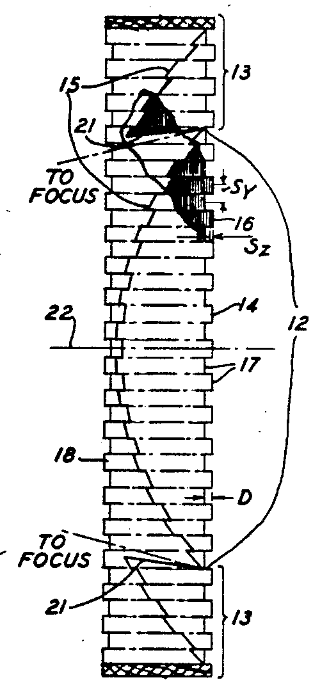


FIG. 3

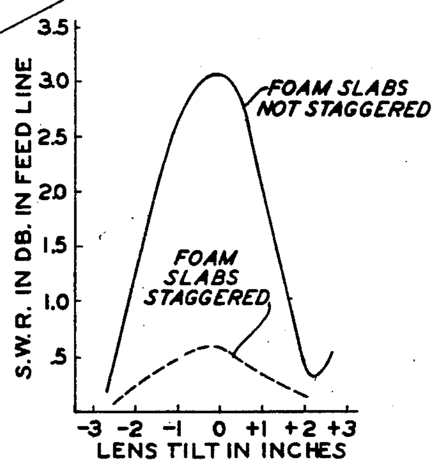
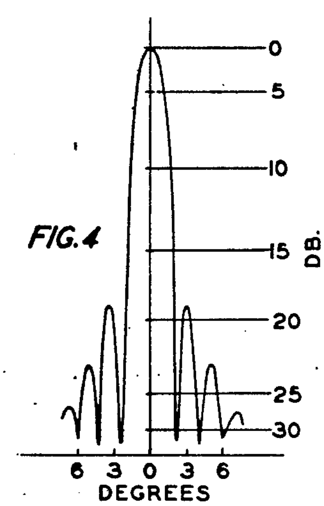


FIG. 4



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NONREFLECTIVE RADIO REFRACTOR

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5 Claims. (Cl. 250—33.63)

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This invention relates to antenna systems and more particularly to improvements in lenses for such systems of the metallic-delay kind.

The metallic-delay lens has distinct advantages not found in other types. Metallic-delay lens can be lightweight and substantially lossless, and are characterized by a high directivity gain. In my copending application, Serial No. 748,448, filed May 16, 1947, now Patent No. 2,577,619, granted December 4, 1951, there is described a metallic-delay lens over which the present invention is an improvement. Therein, there is disclosed a unipolarized metallic-delay structure which comprises a dielectric medium, such as air or polystyrene foam and an array of flat linear conductive members extending parallel to the magnetic polarization, the H vector, of an incoming electromagnetic wave and hence parallel to the X dimension of the structure. The members are spaced in the medium along the perpendicular Y and Z directions which are parallel, respectively, to the vertical electric (E) vector and the horizontal propagation direction of the wave. The linear members are of the "strip" type, that is, each member has a continuous or integral surface and is formed, for example, of sheet metal having a thickness of .005 inch. The flat sides of the strips are parallel to the E vector or dimension Y. The width W or height, that is, the dimension measured parallel to the E vector, of each strip, and the center-to-center spacing of the strips along the Y and Z dimensions are considerably smaller than one-half of the minimum wavelength in the operating band, the width being preferably a quarter of said wavelength or less.

The dielectric constant of the medium is negligible, being very close to unity, and the dielectric constant of the conductive array, for the assumed E vector, is greater than unity. The effective dielectric constant is a function of the electric polarizability of a typical member and the number of members dispersed in a unit area, taken in the YZ plane of the array. Hence the refractive index of the array is greater than unity and the structure functions to decrease the phase velocity of a wave or wave component passing therethrough and having the assumed vertical E polarization. A horizontal E vector is reflected by the horizontal strips and the cut-off orifices between the adjacent strips. Accordingly, only waves having the assumed E polarization are delayed and the structure is unipolarized. A plurality of dielectric slabs of this kind are stacked in horizontal tiers which are arranged to form a refractor of the focussing type.

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However, it has been found that in lenses of this kind a certain amount of energy is reflected from the lens surfaces back into the feed line. In some instances, this reflection can be appreciably reduced by tilting the lens so as to direct the refocussed, reflected energy away from the feed source. Another technique to remedy this fault has been to displace the upper half of the lens longitudinally by one-quarter wavelength with respect to the lower half. Although both of these methods reduce the standing wave in the feed line, there is still a mismatch loss and the reflected energy is reradiated to form a fairly prominent new minor lobe.

It is an object of this invention to improve metallic-delay lenses of this kind.

Other objects of the present invention are, in such lens systems, to reduce the reflections and standing wave ratio in the feed line, to improve the over-all power gain by eliminating mismatch loss, and to minimize minor lobes of the directive characteristic.

In accordance with the invention, these objects are realized by providing a metallic-delay lens structure in which every other dielectric slab which supports the metal conductors is moved forward by a quarter of the mid-band wavelength. The reflections from each slab can thus be considered as cancelling those of the adjacent slabs, and since the individual reflecting surfaces are now less than a mid-band wavelength apart, no reradiation can take place so that the minor lobe and also the loss due to reflection are absent.

As an illustrative embodiment of the invention, a stepped, plano-convex, circularly symmetrical lens is provided in which the adjacent polystyrene slabs are displaced from each other a quarter wavelength.

The invention will be more clearly understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which:

Figs. 1 and 2 are, respectively, perspective and sectional views of a strip-type or metallic-delay lens in accordance with the invention;

Fig. 3 is a graph illustrating the improvement in the standing wave ratio in the feed line effected by the arrangement of Figs. 1 and 2; and

Fig. 4 illustrates the improved directional pattern of this lens arrangement.

Referring to Figs. 1 and 2 which are, respectively, perspective and sectional views of an illustrative embodiment of the invention, reference character 10 is used to denote a large unipolarized, circularly symmetrical strip lens having a square periphery 11. In a manner well-known in the art, in an antenna system, this lens is positioned so that the focal point of the lens is coincident with the center of a square metallic horn which is connected to a translation device such as a super-short wave transmitter or receiver. The lens 10 can be constructed, by way of specific example, for use in the neighborhood of 4000 megacycles and for a six foot square assembly, of 60 rectangular slabs 18, of polyfoam or polystyrene, six feet long, 16 inches wide and 1.2 inches thick piled vertically, to form a rectangular assembly six feet square and 16 inches in depth. Each slab contains in its upper face a plurality of longitudinal slots parallel to the long edges of the slab, the slots being about ¾ inch deep and being spaced .375 inch apart.

Highly conductive metallic strips ¾ inch wide and .005 inch thick are held firmly in the slots and have varying lengths adjusted so that the outermost strips and the ends of all the strips lie in and define the contour of a plano-convex singly stepped lens with a front plane face and a back singly stepped convex face. The portion of each slab not needed to retain the metallic strips in position can be cut away except for such parts of it as may be required for conveniently supporting the slab in its appropriate position in the assembly.

Alternate slabs are then moved forward (normal to the six foot square sides of the lens) one-quarter wavelength (or an odd multiple thereof) of the median frequency of the band of frequencies to be transmitted through the lens and the result is a lens such as the lens 10 illustrated in Figs. 1 and 2 of the drawings accompanying this application. For the specific lens described above, the width X and the height Y are both six feet and the depth Z is 16 inches. The distance between the above-mentioned slots holding the metallic strips in the polyfoam slabs is designated S_Z, i. e., the spacing between strips in the Z plane of the lens. The vertical distance, center to center, between adjacent slabs is designated S_Y, i. e., the spacing of the metallic strips in the Y plane of the lens. The number of vertical strips required for the lens of Figs. 1 and 2 is 1200 for the specific dimensions given above. The vertically stacked slabs 18 are held in position by means of the square wooden frame 19. As described above, alternate polystyrene slabs 18 are displaced from the faces of adjacent slabs by a distance D, approximately equal to one-quarter of the mid-band wavelength, or an odd multiple thereof, to eliminate the reflection, if any, from the front and back faces of the lens into the feed line. This produces corrugated surfaces which consist of alternate series of rectangular ridges and grooves. The diameter or aperture of the circular central section 12 is ordinarily, but not necessarily, sufficiently large so that the central section 12 includes several wavelength zones or steps, whereby this section can be stepped, if desired, for the purpose of reducing the Z dimension of this central section 12. Similarly the diagonal dimension of the square lens is ordinarily sufficiently large so that the outer section 13 includes several wavelength zones, whereby this section can also be stepped, if desired, for reducing the Z dimension of the outer section 13. While, as shown, the outer section 13 is stepped relative to the inner section 12, each of these sections is not itself stepped. The step 21 between the two sections is of the intermediate type disclosed in my copending

application, Serial No. 642,723, filed January 22, 1946. If desired, however, the step 21 can be of the horizontal type or of the focal type, both also being disclosed in the last-mentioned application. As is explained in my copending application Serial No. 748,448, filed May 16, 1947, the convex curvature for the outer section 13 differs from the convex curvature of the central section 12.

In operation, assuming that the lens 10 is used with a transmitter as part of a transmitting antenna, energy is propagated from the feed line and a wave having a vertical polarization and a spherical wave-front is propagated towards the lens 10. The phase of the wavelets passing through the thicker central portion of the lens are retarded a greater amount than the phase of the wavelets propagated through the outer thinner lens portion and the waves arriving at the plane front face 14 are cophasal. Stated differently, the outgoing spherical wave-front is converted by the lens 10 to a plane wave-front extending perpendicular to the axis 22. In reception, the converse operation is obtained, and an incoming plane wave-front having a propagation direction parallel to the axis 22 is transformed by the plane-convex lens 10 into a spherical wave-front converging on the focus. Inasmuch as the lens 10 is circularly symmetrical, focussing action is obtained in all the planes containing the axis 22. Only waves or wave components electrically polarized or with a vertical E vector parallel to the width of the strips are refracted, the waves polarized perpendicular to the aforesaid dimension or with a horizontal E vector being reflected at the faces of the lens 10. By reason of the quarter wave displacements of the alternate polystyrene slabs, the waves reflected from each slab are displaced 180 degrees in phase relative to those reflected in the lower half, so that there is cancellation and substantially no reflected energy enters the feed line.

Fig. 3 graphically illustrates the improvement in standing wave ratio in the feed line resulting from a lens such as that just described. Tests were made of lenses of this kind, as for the specific lens described hereinabove, the X and Y dimensions were each made six feet, the Z dimension sixteen inches, and the focal length about five feet. The lenses were tested at a frequency of 4120 megacycles. The width of the strips 16 and the strip spacing in the Y and Z dimensions were, respectively, about 0.75, 1.31 and 0.375 inches, corresponding to 0.25, 0.46 and 0.13 of the wavelength of 7.2 centimeters; and the strip thickness was 0.005 inch. In the improved lens, the displacement between slabs was about 0.75 inch corresponding to one-quarter of the mid-band wavelength. The measured index of refraction for each lens, with the above characteristics, was about 1.5.

Fig. 4 illustrates the improved directive characteristics of a lens constructed in accordance with the invention. It will be noted that approximately 90 per cent of all the energy is confined within the central lobe.

It is to be understood that the above-described embodiment is illustrative of the principles of the invention. Numerous other embodiments may be devised by one skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A metallic-delay, circularly cylindrical, plano-convex lens for refracting supershort radio

waves, including frequencies within a predetermined band of superhigh frequencies, said lens having a refractive index greater than unity and a focal axis, said lens comprising an inner zone and an outer zone, each zone comprising a plurality of flat conductive strip members having longitudinal dimensions extending parallel to each other and perpendicularly to said focal axis, the width dimension of said members being smaller than one-half the minimum wavelengths in said frequency band and extending perpendicularly to said focal axis and said longitudinal dimensions, said members being arranged in a plurality of tiers extending parallel to said axis, said plurality of tiers being mounted in a like plurality of parallel contiguous dielectric slabs each slab having a thickness smaller than a mid-band wavelength, each slab being displaced from adjacent ones in the direction of the axis of said lens by substantially a quarter of the mid-band wavelength.

2. A lens according to claim 1 in which the dielectric slabs comprise a polystyrene foam medium.

3. A metallic-delay lens for refracting a predetermined band of very high frequency wave energy comprising a plurality of dielectric slabs each having a length and a width substantially exceeding its thickness and a thickness smaller than the mid-band wavelength, each slab including a plurality of metallic strips having their lengths parallel to the length of the slab, their thicknesses perpendicular to the thickness of the slab and being spaced across the width of the slab at uniform intervals smaller than the thickness of the slab, said plurality of slabs being assembled one above the other with their respective corresponding dimensions parallel with each other, alternate slabs being displaced from intermediate ones in the direction of the widths of said slabs by substantially an odd multiple of a quarter of the mid-band wavelength.

4. A lens according to claim 3 in which the dielectric slabs comprise a polystyrene foam medium.

5. In a delay lens having a focal axis, a plurality of rows of metallic strip members each of said strip members having a width substantially exceeding its thickness and a length substantially exceeding its width the width of each member being less than half the minimum wavelength of the wave energy to be transmitted through said lens, the members in each row being spaced in the direction of the axis of the lens the plurality of rows being placed with their major dimensions parallel to each other the spacing between rows being less than a wavelength of the lowest frequency to be transmitted through said lens, alternate ones of the rows being displaced from intermediate ones substantially a quarter of the mid-band wavelength in the direction of the axis of the lens.

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Number	Country	Date
598,493	Great Britain	Feb. 19, 1948

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