Aug. 26, 1952 N. I. KORMAN 2,608,659

ANTENNA FOR MICROWAVE BEACONS

Filed Jan. 10, 1948

Fig. 1

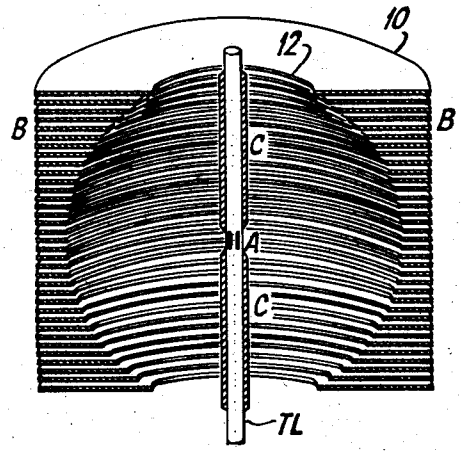


Fig. 2

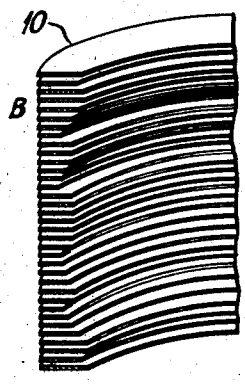


Fig. 3

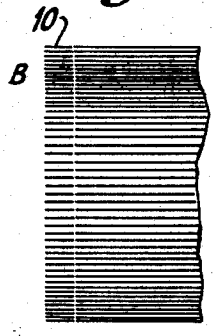


Fig. 4

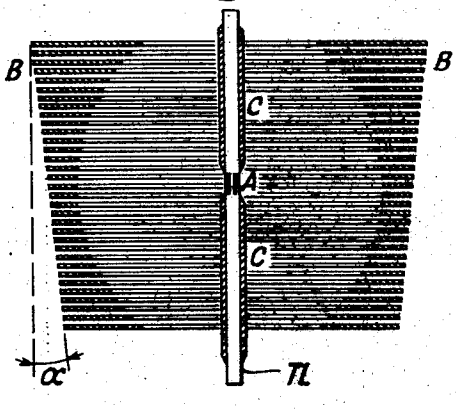


Fig. 5

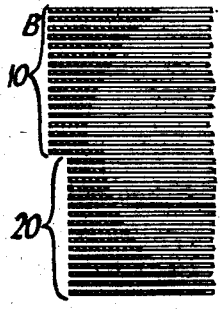
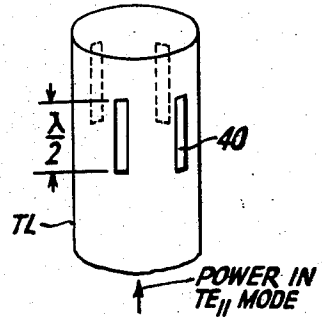


Fig. 6



INVENTOR
NATHANIEL I. KORMAN
BY Harry Purnick
ATTORNEY

Patented Aug. 26, 1952

2,608,659

UNITED STATES PATENT OFFICE

2,608,659

ANTENNA FOR MICROWAVE BEACONS

Nathaniel I. Korman, Camden, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application January 10, 1948, Serial No. 1,634

7 Claims. (Cl. 250—33.63)

1

The present invention relates to microwave antenna and more particularly to such antennas adapted for broadcast service over a wide range of frequency.

An object of the present invention is the provision of a simple antenna structure for microwave use giving high vertical directivity. Another object of the present invention is the provision of an antenna as aforesaid which has substantially no horizontal directivity and which is relatively non-frequency selective. A further object of the present invention is the provision of a microwave antenna for broadcast use which provides essentially a narrow vertical beam of radiated energy with a definite amount of high angle coverage. Still another object of the present invention is the provision of an arrangement for coupling a wave guide or transmission line to free space to radiate horizontally polarized wave energy of equal intensity in all directions in the meridian plane.

The foregoing objects, and others which may appear from the following detailed description are attained by providing a relatively non-directional source of high frequency energy with a slatted lens array which brings into focus the radiation in a narrow vertical beam. The slatted lens is so constructed that there is substantially no focusing in the horizontal plane. Thus the antenna is well suited to broadcast transmission of microwave signals.

For the sake of convenience, in the following detailed description, the antenna will be described as though used for transmission of ultra high frequency energy but it should be clearly understood it may as well be used for reception of ultra high frequency energy.

The present invention may be more fully understood by reference to the following detailed description which is accompanied by a drawing in which Figure 1 illustrates in elevation and partly in section an embodiment of the present invention; while Figure 2 illustrates in section a modification of a portion of the structure of Figure 1; Figures 3, 4 and 5 illustrate in section further modifications of the slatted lens structure of Figure 1; while Figure 6 illustrates in enlarged perspective view a preferred form of non-directional radiant energy source adapted to be used with the slatted antennas of Figures 1 to 5 inclusive.

Referring now to Figure 1, I have shown a relatively non-directional source of high frequency energy A, located on the axis of a cylindrical slatted lens B. The slatted lens B is composed of a large number of flat metallic discs or rings 10, having central apertures 12 of varying sizes. The spacing between the discs or rings 10 is so related to the operating wave length of the system that the electromagnetic waves originating at source A assume, between the plates, a wavelength and phase velocity which is greater than their free space wave length and velocity. Ordinarily this spacing is of the order of, but somewhat greater than one-half of the operating wave length. The plane in which plates or discs 10 lie must be parallel to the electric vector of the wave emitted by source A.

2

The stack of plates or discs 10 thus constitute a refractive medium with an index of refraction less than unity. Since, in a radial direction from source A, the amount of phase advance imparted to the waves by the spaces between the discs 10 at the ends of the cylinder is greater than at intermediate points along the cylinder, the assembly of rings produces a focusing of waves that is similar to that effected by a cylindrical lens about a point source of light. Thus the radiation emitted from source A is compressed in the vertical plane. Due to the fact that the rings are symmetrical about the axis on which source A lies, no focusing effect is obtained in the horizontal plane.

Since the lens of Figure 1 tends to become very thick at the ends of the cylinder a modified form of the invention is illustrated in Figure 2 wherein the diameter of the inner holes in rings 10 vary in steps of multiples of a wavelength. The remainder of the structure used with the lens of Figure 2 is the same as described in Figure 1.

In Figure 3, I have shown in diagrammatic form a further modification of my invention in which, instead of graduating the length along the direction of wave travel, of constant spacing slots, I use a graduated spacing of constant length slots. In this form the rings 10 have constant diameter inner apertures while the spacing between the rings at each end of the cylinder is closer than at intermediate points along the cylinder. Due to the narrower spacing at the ends of the cylinder an increased wave velocity is obtained over that which occurs at intermediate points along the cylinder.

In the lens of Figures 1, 2 and 3 a certain amount of power is reflected from both lens faces. From the standpoint of power efficiency, these reflections are not too important. However, it is important that not much of the reflected power be returned directly to the source A because of the standing waves which would thus be caused to

occur within the transmission line or wave guide TL. The surface of the lens formed by the apertures in rings 10 does not ordinarily cause much trouble on this account, because the reflected power from it is ordinarily scattered and not focused back on source A. However, the outer surface of the cylinder B can reflect a serious amount of power into A. Therefore, in Figure 4, instead of having the outer face cylindrical, the outer surface of lens B is formed as a truncated cone tapering from one end to the other as indicated by the angle marked α in Figure 4.

As a further modification instead of using a truncated cone, a stepped cylinder such as shown in Figure 5 may be employed. Here the lens B has one series of rings 10 having one outside diameter and a second series 20 of a different outside diameter. The diameters of the inside apertures in rings 10 and 20 must be correspondingly adjusted as indicated in the figure.

A further feature of the present invention includes the addition of absorbing material C on the outside surface of the wave guide TL to absorb energy reflected from the outer surface of rings B back toward the source A. This absorbing material may be in the form of a relatively thick coat of poorly conductive material such as conductive rubber.

In Figure 6, I have shown in somewhat enlarged form the relatively non-directional source A of Figures 1 to 5 inclusive. As indicated in Figure 6 a circularly polarized wave of the $TE_{1,1}$ mode is set up in the round wave guide TL by methods well known in the art. Four longitudinal slots 40 each approximately a half-wave in length are cut in the outer surface of the wave guide TL. The slots 40 are uniformly ninety degrees around the circumference of the wave guide.

Radiant energy within the wave guide TL is coupled with surrounding space to radiate a high frequency wave of equal intensity in all directions of the meridianal plane. The vertical directivity of the antenna of Figure 1 energized from a non-directional source such as that shown in Figure 6, is about the same as would be obtained at lower frequencies from a two layer turnstile antenna.

It is to be understood that other non-directional sources known to those skilled in the art may be used in place of that shown in Figure 6.

What is claimed is:

1. An antenna to be operated at a definite operating frequency and comprising a central radiator or receptor for radio waves at said frequency and having a radiation pattern substantially non-directional about a predetermined axis, a stack of more than two substantially parallel metallic plates surrounding and spaced from said radiator or receptor and spaced in the axial direction each from the next adjacent plate by more than a half free-space wavelength at the operating frequency, each said plate having a central aperture and being disc-like with inner and outer edges each substantially a complete circle coaxial with said axis, the space between each adjacent pair of plates being in direct communication with the central space defined by said central apertures and within which said central radiator or receptor is positioned, the axial spacing between plates and the dimension of each plate radially from said inner to said outer edge being selected to cause a relative shift in phase between radio waves at the operating frequency polarized with the electric vector normal to said axis and thus parallel to said plates and propagated radially between one pair of adjacent plates and those similarly polarized and similarly propagated between an adjacent pair of plates, said shift in phase at plates centrally located along said axis being progressively less than and in retardation of those more remote from said central plates, whereby the said antenna is non-directional in a plane normal to said axis, and the directivity in a plane through said axis is increased over that of said central radiator or receptor, said outer edges lying on a truncated conical surface coaxial with said axis, whereby reflections are reduced.

2. An antenna to be operated at a definite operating frequency and comprising a central radiator or receptor for radio waves at said frequency and having a radiation pattern substantially non-directional about a predetermined axis, a stack of more than two substantially parallel metallic plates surrounding and spaced from said radiator or receptor and spaced in the axial direction each from the next adjacent plate by more than a half free-space wavelength at the operating frequency, each said plate having a central aperture and being disc-like with inner and outer edges each substantially a complete circle coaxial with said axis, the space between each adjacent pair of plates being in direct communication with the central space defined by said central apertures and within which said central radiator or receptor is positioned, the axial spacing between plates and the dimension of each plate radially from said inner to said outer edge being selected to cause a relative shift in phase between radio waves at the operating frequency polarized with the electric vector normal to said axis and thus parallel to said plates and propagated radially between one pair of adjacent plates and those similarly polarized and similarly propagated between an adjacent pair of plates, said shift in phase at plates centrally located along said axis being progressively less than and in retardation of those more remote from said central plates, whereby the said antenna is non-directional in a plane normal to said axis, and the directivity in a plane through said axis is increased over that of said central radiator or receptor, said outer edges lying on a truncated conical surface coaxial with said axis, whereby reflections are reduced, the inner edge radii being progressively larger from the plates centrally located along the axial direction with axial distance from the central plates.

3. An antenna to be operated at a definite operating frequency and comprising a central radiator or receptor for radio waves at said frequency and having a radiation pattern substantially non-directional about a predetermined axis, a stack of more than two substantially parallel metallic plates surrounding and spaced from said radiator or receptor and spaced in the axial direction each from the next adjacent plate by more than a half free-space wavelength at the operating frequency, each said plate having a central aperture and being disc-like with inner and outer edges each substantially a complete circle coaxial with said axis, the space between each adjacent pair of plates being in direct communication with the central space defined by said central apertures and within which said central radiator or receptor is positioned, the axial spacing between plates and the dimension of each plate radially from said inner to said outer edge being selected to cause a relative shift in phase between radio waves at the operating frequency

polarized with the electric vector normal to said axis and thus parallel to said plates and propagated radially between one pair of adjacent plates and those similarly polarized and similarly propagated between an adjacent pair of plates, said shift in phase at plates centrally located along said axis being progressively less than and in retardation of those more remote from said central plates, whereby the said antenna is non-directional in a plane normal to said axis, and the directivity in a plane through said axis is increased over that of said central radiator or receptor, said outer edges on one side of the plates centrally located along the axial direction, being all of one radius, and those on the other side axially of said central plates being of the same radius different from said one radius, whereby reflections are reduced.

4. An antenna to be operated at a definite operating frequency and comprising a central radiator or receptor for radio waves at said frequency and having a radiation pattern substantially non-directional about a predetermined axis, a stack of more than two substantially parallel metallic plates surrounding and spaced from said radiator or receptor and spaced in the axial direction each from the next adjacent plate by more than a half free-space wavelength at the operating frequency, each said plate having a central aperture and being disc-like with inner and outer edges each substantially a complete circle coaxial with said axis, the space between each adjacent pair of plates being in direct communication with the central space defined by said central apertures and within which said central radiator or receptor is positioned, the axial spacing between plates and the dimension of each plate radially from said inner to said outer edge being selected to cause a relative shift in phase between radio waves at the operating frequency polarized with the electric vector normal to said axis and thus parallel to said plates and propagated radially between one pair of adjacent plates and those similarly polarized and similarly propagated between an adjacent pair of plates, said shift in phase at plates centrally located along said axis being progressively less than and in retardation of those more remote from said central plates, whereby the said antenna is non-directional in a plane normal to said axis, and the directivity in a plane through said axis is increased over that of said central radiator or receptor, the outer and inner edge radii of any plate on one side axially of a plane centrally located along and normal to said axis, each being less by the same amount than the respective outer and inner edge radii of a plate an equal distance on the other side of said central plane.

5. An antenna to be operated at a definite operating frequency and comprising a central radiator or receptor for radio waves at said frequency and having a radiation pattern substantially non-directional about a predetermined axis, a stack of more than two substantially parallel metallic plates surrounding and spaced from said radiator or receptor and spaced in the axial direction each from the next adjacent plate by more than a half free-space wavelength at the operating frequency, each said plate having a central aperture and being disc-like with inner and outer edges each substantially a complete circle coaxial with said axis, the space between each adjacent pair of plates being in direct communication with the central space defined by said central apertures and

within which said central radiator or receptor is positioned, the axial spacing between plates and the dimension of each plate radially from said inner to said outer edge being selected to cause a relative shift in phase between radio waves at the operating frequency polarized with the electric vector normal to said axis and thus parallel to said plates and propagated radially between one pair of adjacent plates and those similarly polarized and similarly propagated between an adjacent pair of plates, said shift in phase at plates centrally located along said axis being progressively less than and in retardation of those more remote from said central plates, whereby the said antenna is non-directional in a plane normal to said axis, and the directivity in a plane through said axis is increased over that of said central radiator or receptor, the outer edge radii being different to reduce reflections, the spacing and inner edge radii being selected to secure the said relative phase shift.

6. An antenna to be operated at a definite operating frequency and comprising a central radiator or receptor for radio waves at said frequency and having a radiation pattern substantially non-directional about a predetermined axis, a stack of more than two substantially parallel metallic plates surrounding and spaced from said radiator or receptor and spaced in the axial direction each from the next adjacent plate by more than a half free-space wavelength at the operating frequency, each said plate having a central aperture and being disc-like with inner and outer edges each substantially a complete circle coaxial with said axis, the space between each adjacent pair of plates being in direct communication with the central space defined by said central apertures and within which said central radiator or receptor is positioned, the axial spacing between plates and the dimension of each plate radially from said inner to said outer edge being selected to cause a relative shift in phase between radio waves at the operating frequency polarized with the electric vector normal to said axis and thus parallel to said plates and propagated radially between one pair of adjacent plates and those similarly polarized and similarly propagated between an adjacent pair of plates, said shift in phase at plates centrally located along said axis being progressively less than and in retardation of those more remote from said central plates, whereby the said antenna is non-directional in a plane normal to said axis, and the directivity in a plane through said axis is increased over that of said central radiator or receptor, the said radiator or receptor including on its surfaces exposed to said plates radio wave energy absorbent material to reduce multiple reflections.

7. An antenna to be operated at a definite operating frequency and comprising a central radiator or receptor for radio waves at said frequency and having a radiation pattern substantially non-directional about a predetermined axis, a stack of more than two substantially parallel metallic plates surrounding and spaced from said radiator or receptor and spaced in the axial direction each from the next adjacent plate by more than a half free-space wavelength at the operating frequency, each said plate having a central aperture and being disc-like with inner and outer edges each substantially a complete circle coaxial with said axis, the space between each adjacent pair of plates being in direct communication with the central space defined by said

central apertures and within which said central radiator or receptor is positioned, the axial spacing between plates and the dimension of each plate radially from said inner to said outer edge being selected to cause a relative shift in phase between radio waves at the operating frequency polarized with the electric vector normal to said axis and thus parallel to said plates and propagated radially between one pair of adjacent plates and those similarly polarized and similarly propagated between an adjacent pair of plates, said shift in phase at plates centrally located along said axis being progressively less than and in retardation of those more remote from said central plates, whereby the said antenna is non-directional in a plane normal to said axis, and the directivity in a plane through said axis is increased over that of said central radiator or receptor, the inner edge radii being staggered to secure at selected axial plates a full wavelength difference in addition to said phase retardation, thereby to reduce the bulk of the stack of plates from what it otherwise would be.

NATHANIEL I. KORMAN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,206,683	Wolff	July 2, 1940
2,369,808	Southworth	Feb. 20, 1945
2,414,266	Lindenblad	Jan. 14, 1947
2,416,698	King	Mar. 4, 1947
2,433,924	Riblet	Jan. 6, 1948
2,442,951	Iams	June 8, 1948
2,447,549	Willoughby	Aug. 24, 1948
2,452,202	Lindenblad	Oct. 26, 1948

OTHER REFERENCES

Metal-Lens Antenna, Proc. I. R. E., by W. E. Kock.

Metallic Delay Lenses, by W. E. Kock, Bell System Technical Journal, vol. 27, pages 58 to 82, January 1948.

Radio News, November 1947, pages 3, 4, 5 and 20.

Electronics, February 1947, pages 90 to 93.