March 23, 1948. C. E. McCLELLAN 2,438,343

HIGH-FREQUENCY RADIATION SYSTEM

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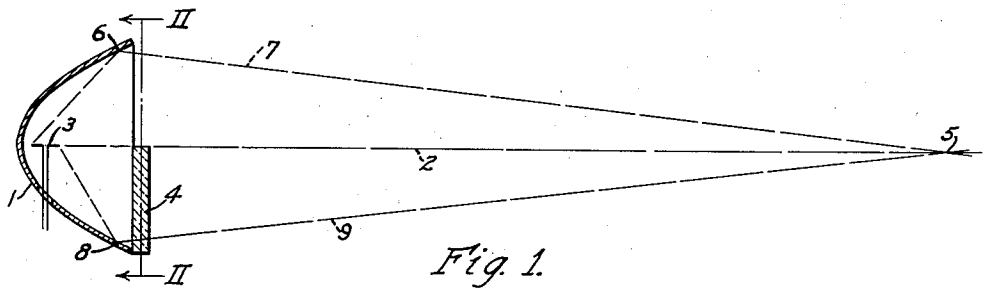


Fig. 1.

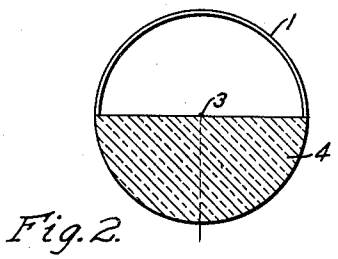


Fig. 2.

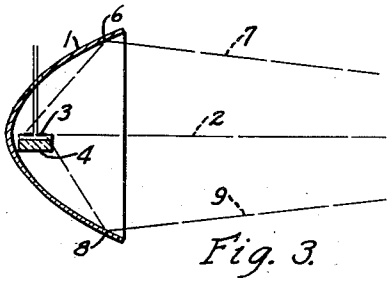


Fig. 3.

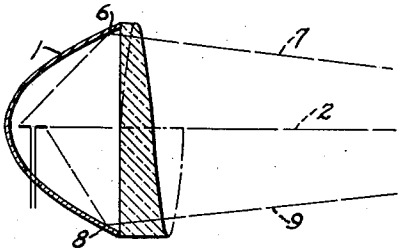


Fig. 5.

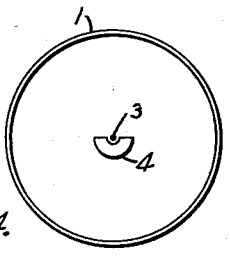


Fig. 4.

WITNESSES:

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HIGH-FREQUENCY RADIATION SYSTEM

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5 Claims. (Cl. 250—33.65)

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My invention relates to arrangements for producing concentrated beams of electromagnetic radiation and, in particular, to arrangements in which a parabolic reflector for electromagnetic waves emanating from a dipole radiator is employed to produce such beams.

One object of my invention is to provide an arrangement of the character described in the preceding paragraph in which the radiation at the central axis of the beam shall be of high intensity.

Another object of my invention is to provide an arrangement of the character above described in which the beam shall be of substantially cylindrical form.

Still another object of my invention is to provide an arrangement in which interposition of a dielectric in the path of the beam is employed to control the phase and distribution of the radiation emanating from the reflector.

Another object of my invention is to provide an arrangement of the above mentioned type in which a plane-polarized beam of radiation may be produced.

Still another object of my invention is to provide an arrangement for producing a circularly-polarized beam of radiation from an arrangement of the type mentioned above.

Other objects of my invention will become apparent upon reading the following description, taken in connection with the drawings, in which:

Figure 1 shows a mid-sectional view of a modification of my invention adapted to produce a plane-polarized cylindrical beam of radiation from a parabolic reflector powered by a dipole;

Fig. 2 shows a sectional view along the line II—II in Fig. 1;

Fig. 3 shows a mid-sectional view of another modification of my invention;

Fig. 4 shows an elevational view of Fig. 3; and

Fig. 5 shows an arrangement adapted to produce a cylindrical beam of circularly-polarized radiation from a reflector of the type just mentioned.

For many purposes, it is desirable to be able to produce a substantially cylindrical beam of electromagnetic radiation, and in the case of radiation having a wave length of the order of a centimeter or so, it is most convenient to attempt this by employing a reflector in the form of a paraboloid of revolution having a dipole radiator fed from some suitable source of alternating current of a wave length of the order of a centimeter and located at the focus of the paraboloid with its axis coincident with that of the paraboloid.

It can be shown that the intensity of the radiation along the axis of the paraboloid is zero if the mid-point of the dipole is positioned at the focal point of the paraboloid. This is a substantial defect from a practical standpoint in the beam from the reflector, since it is usually desirable to have a high intensity along the central axis of the latter.

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In accordance with the form of my invention shown in Figure 1, I interpose a slab of dielectric material which covers one half of a circular aperture of the reflector, this half being the one located on one side of the mid-point of the dipole, and symmetrical to the dipole axis. Referring in detail to Fig. 1, a paraboloidal reflector 1, of which the mid-section is shown and which has an axis 2, has located at its focus a radiator 3 which is positioned with its axis parallel to the axis 2 and with its mid-point at the focus of the paraboloid. Positioned in front of the aperture of the reflector is a semi-circular slab of dielectric 4, such for instance as glass, having a thickness parallel to the axis 2 equal to

$$\frac{\lambda}{2(n-1)}$$

where λ is the wave length of the radiation emananting from the dipole 3 and n is the index of refraction of the dielectric. If we consider a point 5 located along the axis 2 at a distance which is substantial relative to the aperture of the reflector 1, it will be evident that the radiation at 5 may be considered as contributed from a series of small areas positioned upon the surface of the paraboloid 1. Considering any such small area as that located at the point 6, it will emit radiation to the point 5 along the path 7. Now consider a point 8 on the surface of reflector 1 which is exactly homologous to the point 6 on that half of the reflector below the axis 2 in Fig. 1. The small area 8 will emit to the point 5 along the path 9. A moment's consideration of the symmetry of the dipole radiator and the reflector 1 will show that, as has been previously explained, the radiation from the elemental area 6 will be exactly 180 degrees out of phase with the radiation from the elemental area 8, but would otherwise be exactly equal in magnitude to the latter. If the dielectric 4 were removed, the radiation along the path 7 and along the path 9 would arrive with equal intensity but 180 degrees difference of phase at the point 5; hence they would cancel each other. Since the same would be true for any symmetrical pair of points like 6 and 8 on the surface of reflector 1, and would likewise be true regardless of the position of the point 5 along the axis 2, the intensity of radiation along the axis 2 would be everywhere zero, as has already been stated above.

Now let us consider the effect of interposing the slab of dielectric 4. In accordance with well known optical principles, the number of wave lengths of radiation in a path x through a dielectric having an index of refraction of n is increased

over the number of wave lengths of that same radiation in free space by an amount equal to $(n-1)\ (x/\lambda)$. By making the thickness of the dielectric slab 4 just great enough to increase the number of wave lengths between the point 8 and the point 5 by the value one-half, the phase of the radiation arriving at 5 from the point 8 can be switched from 180 degrees out of phase to coincidence of phase with the radiation arriving from the elementary area 6. That is to say, the thickness of the dielectric slab should be such that $(n-1)\ (x/\lambda)$ equals one-half; in other words, the thickness x of the slab 4 should be equal to

$$\frac{\lambda}{2(n-1)}$$

When this is done, the radiation from all points on the lower half of the reflector 1 will reinforce, instead of cancelling, the radiation from all points of the upper half of the reflector 1 incident along the axis 2, and a beam having a high intensity along its central axis will result. This beam will likewise be plane-polarized.

As an alternative form the slab 4 in Fig. 1 may be replaced by a slab positioned inside the reflector at any point where the rays incident upon the lower half, let us say, of the reflector will have to traverse a path through the dielectric of the length

$$\frac{\lambda}{2(n-1)}$$

Figs. 3 and 4 show one example of such an arrangement.

Another way of obtaining a beam of high intensity along its central axis is shown in Fig. 5. Here the dipole and the reflector are of the same type as above described for Fig. 1, but instead of the semi-circular dielectric slab 4, there is placed in front of the reflector aperture a dielectric formed by cutting a cylinder at one end by a plane normal to its axis and having as its opposite end a right-helicoidal surface of one turn having a pitch equal to twice the value determined above for the thickness of the dielectric slab 4.

When a dielectric of the form just described is positioned in front of the reflector, the radiation arriving at any axial point 5 from any given point 8 will traverse a path through the dielectric which is greater by an amount x than will the radiation travelling to the point 5 from the symmetrical diametrically-opposite point 6; hence the two quanta of radiation will arrive at the point 5 in phase with each other just as they do in the case of Fig. 1. Thus the radiation at points on the axis 5 will be of high intensity. However, because of the different form of the dielectric, the waves at 5 will be circularly-polarized.

The reason for this circular polarization is believed to be as follows: If any two planes passing through the axis of the reflector at right angles to each other be considered, it will be seen that the thickness of the dielectric in these planes is such that the electromagnetic vibrations in the

two planes differ in phase by 90°. It is a principle of physics that when any object is subjected to vibrations which are 90° out of phase with each other in two planes perpendicular to each other, a circular movement results. One definition of circularly polarized light is that the particles of the ether or other medium which it is traversing move in circular paths, such as those which have just been shown to be characteristic of the elements of the medium traversed by electromagnetic radiation in the arrangement of Fig. 5.

I claim as my invention:

1. In combination, a paraboloidal reflector, a dipole radiator positioned with its mid-point at the focus of said reflector and parallel to the axis thereof, and a dielectric of uniform thickness normal to the axis of said reflector and covering a portion of the aperture thereof.

2. In combination, a paraboloidal reflector, a dipole radiator positioned with its mid-point at the focus of said reflector and parallel to the axis thereof, and a dielectric of uniform thickness covering a semi-circle constituting half the aperture of said reflector.

3. In combination, a paraboloidal reflector, a dipole radiator positioned with its mid-point at the focus of said reflector and parallel to the axis thereof, and a dielectric of uniform thickness which symmetrically covers one half of the aperture of said reflector.

4. In combination, a paraboloidal reflector, a dipole radiator positioned with its mid-point at the focus of said reflector and parallel to the axis thereof, and a dielectric body disposed about the axis of said reflector in front of the aperture thereof and so distributed in thickness that radiation emanating from said reflector on one side of a plane passing through the reflector axis is changed in phase by 180 electrical degrees relative to radiation emanating from points symmetrically disposed thereto on the other side of said plane.

5. In combination, a paraboloidal reflector, a dipole radiator positioned with its mid-point at the focus of said reflector and parallel to the axis thereof, and a dielectric of uniform thickness which intercepts the path of rays incident upon the part of said reflector on one side of a plane through its axis.

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