Feb. 17, 1942. R. S. OHL 2,273,447

UNIDIRECTIVE ENERGY RADIATING SYSTEM

Filed Sept. 7, 1939

FIG. 1

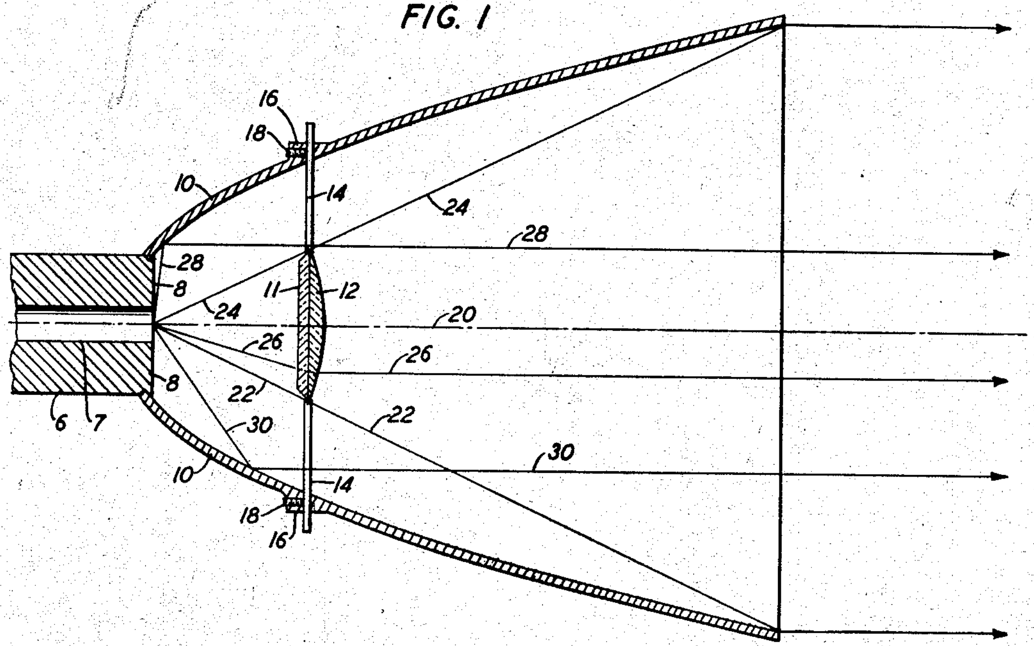
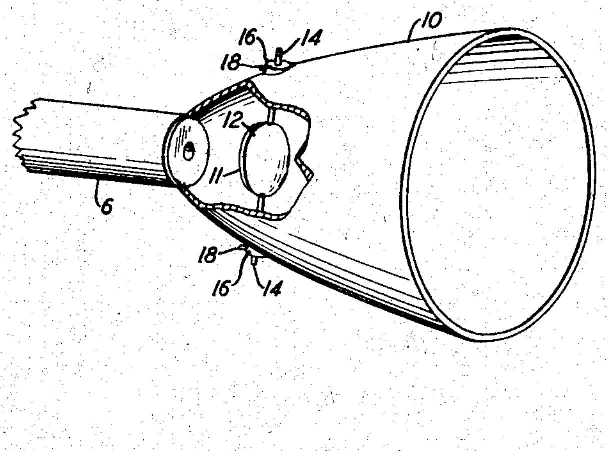


FIG. 2



INVENTOR
R. S. OHL

BY H. O. Wright

ATTORNEY

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UNIDIRECTIVE ENERGY RADIATING SYSTEM

Russell S. Ohl, Little Silver, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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3 Claims. (Cl. 250—11)

This invention relates to an improved system for obtaining unidirective radiation of energy. More particularly, it relates to a novel combination of reflector, lens and radiating means associated to produce a beam of parallel energy rays and to minimize divergence of energy therefrom.

A principal object of the invention is the provision of systems for the production of radiant energy beams in which the component rays are substantially parallel. A further object is the production of a beam of parallel energy rays having an equiphase wave front. Other objects will become apparent during the following description and in the appended claims.

Reflectors and lens systems have long been used to obtain approximately unidirectional radiation of light from a given source. Analogous systems have been proposed for use with ultra-short wave radio systems and other systems employing radiant energy of short wave-length. In an ideal system the source of radiant energy would be a dimensionless point. In practical systems this source obviously always has finite, and frequently has substantial, dimensions. The greater the dimensions of the source the greater will be the tendency toward the divergence of energy from a true unidirectional beam.

The angle of divergence of the beam when using a lens alone can for relatively narrow beams be found from the equation

$$\sin a = \frac{d}{F} \qquad (1)$$

where a is the angle of divergence, d is the diameter of the light source (assuming a round source) and F is the focal distance, or focal length, of the lens.

From Equation 1 it is apparent that though d may be relatively large the divergence of energy from the beam may be made small by making F also relatively large. However, since the source must be located at the focal point of the lens, as F is increased the distance of the source from the lens is correspondingly increased and the angle subtended by the lens with respect to the radiation source is decreased. It becomes desirable, therefore, to supplement the lens by a reflecting member. To reduce the area of the radiating source, in so far as practical considerations permit, it is also convenient and desirable to introduce the energy into the system of this invention through a cylindrical member, as will appear more fully below. As a further refinement the thickness of the lens is increased as may be required to bring the rays passing through the lens into phase with rays directed into the beam by the reflector so that an equiphase wave front is obtained. As an alternative to increasing the lens thickness for the purpose of adjusting the phase, a simple disc of material suitably changing the phase of rays which pass through the lens may be used. The use of materials for adjusting the phase of energy rays is well known in the art.

In accordance with the above desiderata the system of this invention comprises in its simplest form the combination of a cylindrical member through which radiant energy may be transmitted, a parabolic reflector and a lens. The emitting end of the cylindrical member is positioned concentrically in the normal focal plane of the reflector and the lens is placed concentrically within the reflector and normal to its longitudinal axis. The focal point of the lens is made coincident with that of the reflector. Phase adjustment of the rays passing through the lens may be effected by uniformly increasing the effective thickness of the lens or by adding a member of suitable material on either side of the lens to produce the desired phase adjustment of rays passing through the lens.

For many practical uses a truncated conical reflector approximating the dimensions of the parabolic reflector can be substituted for the truly parabolic reflector without greatly increasing the divergence of energy from the beam.

For a system of reasonable physical dimensions the wave-length of the radiant energy must, of course, be relatively very short.

Further, when a lens is employed two effects are operative to produce a beam of parallel rays, namely, refraction and diffraction. Diffraction is objectionable in that it produces some divergence of the beam. However, if the diameter of the lens exceeds four times the wave-length of the radiated energy, refraction becomes almost completely dominant and the absolute sharpness of the beam (absence of divergence) is then determined largely by the focal distance as indicated in Equation 1 above.

The principles of the invention will be more apparent when considered in connection with the accompanying drawing, in which:

Fig. 1 illustrates a preferred embodiment of the combination of the invention in diagrammatic cross-sectional form; and

Fig. 2 shows in perspective the combination of Fig. 1 with the reflector 10 partly broken away to show the method of assembly of the tube and lens within it.

In more detail in Fig. 1, member **6** has a cylindrical passage **7** through its center and the end surface **8** of member **6** is made coincident with the normal focal plane of parabolic reflector **10**, i. e., the plane normal to the longitudinal axis **20** of reflector **10** which contains the focal point of reflector **10**. A lens **12** is supported by members **14** concentrically within reflector **10** and normal to axis **20**. The focal point of lens **12** is made coincident with that of reflector **10**. Members **14** should preferably be constructed of material which will freely transmit the energy to be radiated.

For the purpose of adjusting the phase of energy rays passing through lens **12** so that they will form an equiphase wave front with rays reflected by reflector **10**, a disc of material **11**, its edge being suitably beveled as indicated, may be added to the left of lens **12** or the lens itself may be uniformly increased in thickness.

Rays of energy emanating from the right end of passage **7** if within the angle subtended by lens **12**, as limited by rays **22** and **24** of Fig. 1 which just miss the lens, will be focussed as illustrated by ray **26** by the lens **12** in a beam of rays parallel with axis **20**. Rays not within the angle so subtended, for example rays **22**, **24**, **28** and **30** of Fig. 1, will strike reflector **10** and will be reflected parallel to axis **20**. They will, because of the arrangement of the invention, miss lens **12** and will form with the rays passing through lens **12** a wave front of rays all directed parallel to axis **20**. By the insertion of an appropriate phase adjusting member, such as member **11** of Fig. 1, or by increasing the thickness of lens **12** suitably, an equiphase wave front is obtained.

In Fig. 2 an arrangement of structure substantially as described in connection with Fig. 1 is shown in perspective. In Fig. 2 reflector **10** is partly broken away to show the method of assembling lens **12**, phase adjusting member **11** and member **6** in the combination.

The minimum dimensions for a system of this invention should be determined, as mentioned above, in terms of the wave-length of the energy it is desired to radiate. For example, for a radio system employing waves 5 centimeters long a lens at least 20 centimeters in diameter should preferably be employed. For such a system the passage **7** through member **6** should be approximately 3.3 centimeters in diameter, the axial length of reflector **10** from the focal plane **8** to the right end thereof should be approximately 120 centimeters and the focal length of lens **12** should be at least 38 centimeters for an angle of divergence of $a=5$ degrees.

In general, the larger the dimensions employed, all elements of the combination being in proper proportion, the less the divergence of energy from the beam.

Other embodiments of the principles of the invention will occur to those skilled in the art. The scope of the invention is defined in the following claims.

What is claimed is:

1. Means for producing a unidirective beam of ultra-high frequency radio wave energy comprising a cylindrical wave guide having an internal diameter approximately 0.7 times the wave-length of the energy to be used, a paraboloid reflector having a diameter at its normal focal plane which is large with respect to the internal diameter of the said wave guide, a focusing lens having a diameter substantially equal to the diameter of said reflector at its normal focal plane, said reflector being truncated through its normal focal plane, said wave guide, said reflector and said lens being coaxially aligned, the lens being within the reflector and positioned to have its focal point coincident with the focal point of said reflector, said wave guide being without the reflector, its nearer end lying in the normal focal plane of said reflector.

2. The arrangement of claim 1, the diameter of the lens being at least four times the wave-length of the energy to be used.

3. The arrangement of claim 1, the focal length of said lens being at least 7.6 times the wave-length of the energy to be used.

RUSSELL S. OHL.