Jan. 4, 1955 G. WILKES 2,698,901

BACK-RADIATION REFLECTOR FOR MICROWAVE ANTENNA SYSTEMS

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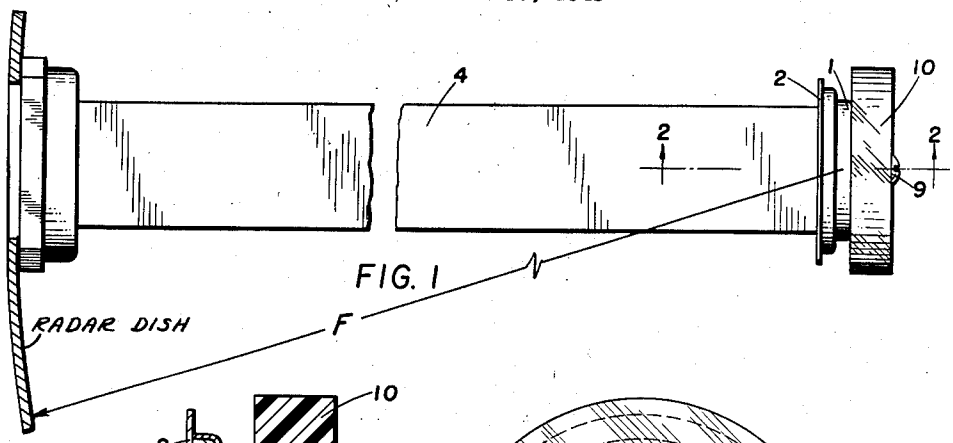


FIG. 1

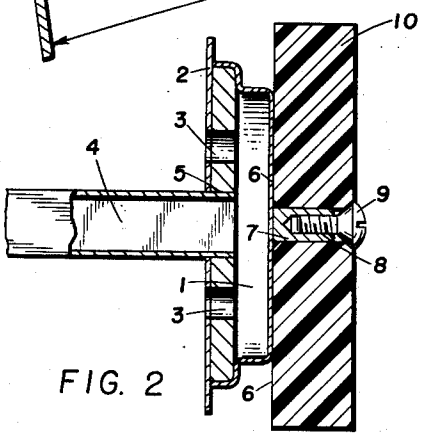


FIG. 2

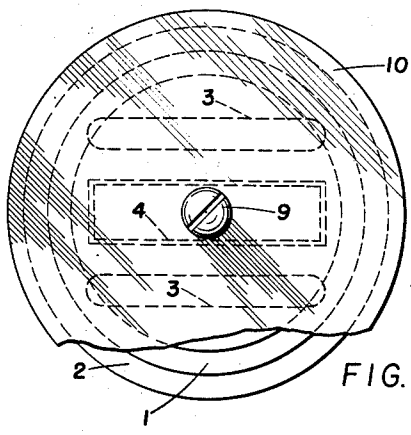


FIG. 3

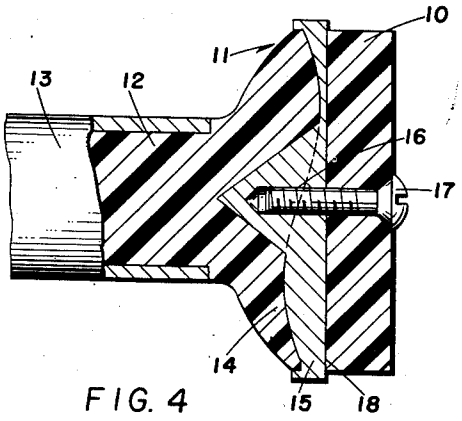


FIG. 4

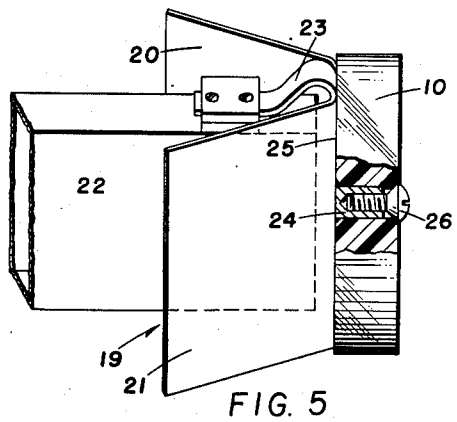


FIG. 5

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BACK-RADIATION REFLECTOR FOR MICROWAVE ANTENNA SYSTEMS

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4 Claims. (Cl. 250—33.63)

The present invention relates to back-radiation reflectors for microwave antenna systems.

An object of the invention is to improve the efficiency of antenna systems of the type wherein the radiating element or feed is supported on a wave guide passing through the center of a dish or reflector.

More specifically, an object is to provide a disc of dielectric material which is designed to be mounted at the extreme end of a conventional feed, remote from the reflector or dish, for the purpose of interposing a high impedance between such end and the free space beyond, into which the radiation flows, such disc preventing a certain amount of the energy loss that would otherwise occur.

For an understanding of the invention, it is disclosed herein, by way of example, as applied to several different forms of antenna systems without thereby in any way implying that no other forms are suitable. In the drawing accompanying the present specification,

Fig. 1 is an elevation of a wave guide having a Cutler feed as its terminus, with the invention applied thereto;

Fig. 2 is a fragmentary section through said feed, on a larger scale, in the plane indicated by line 2—2 of Fig. 1;

Fig. 3 is a corresponding end elevation;

Fig. 4 is a fragmentary axial section showing the invention applied to a feed of the dielectric lens type; and

Fig. 5 is a fragmentary view, partly in axial section, showing the invention applied to a feed of the dihedral-cap type.

In general, present practise in microwave radiating systems provides a terminus of some sort on the end of a wave guide, known as a "feed." This feed is located at or near the principal focus of the reflector, customarily a parabolic reflector, and is nutated by suitable means to provide a scanning beam for irradiating a suitable field, in which a target is believed or known to exist. Obviously, it is desirable that the emitted beam be as powerful as possible, to improve its range and certainty of action, and therefore it is important that needless losses of radiant energy be prevented. Such losses occur with conventional feeds, among other reasons, because the outer face of the feed, directed away from the dish, is itself a fairly powerful source of radiant energy, which is propagated directly into free space, without reflection by the dish, and hence is not directional but spreads or diffuses in the entire hemisphere. Thus its intensity decreases rapidly with distance, and the entire radiation is lost for all practical purposes. The present invention prevents this loss by interposing a high impedance between the outer face of the feed and the free space beyond, and accomplishes this object by the simple expedient of providing a disc of dielectric material of suitable dimensions, determined by the frequency of the microwave energy, on the outside face of the feed.

Referring first to Figs. 1, 2 and 3, there is shown a feed of the well-known Cutler type. This comprises a capsule or pan 1 having a cover 2 with holes 3, 3 therein, here shown as slots. The wave guide 4 enters the capsule through the larger slot shown at 5, and the characteristics of the chamber in capsule 1 are such that it constitutes a suitable resonant cavity that coacts with the wave guide 4 for maximum efficiency.

Secured to the front surface 6 of the capsule is a short tubular stud 7, which may be fastened rigidly in any suitable manner, as by brazing, welding, riveting or the like. This stud 7 is threaded internally as shown at 8, to receive the screw 9.

The disc 10, made of a suitable dielectric such as polyethylene or Teflon, is held in place on surface 6 by means of screw 9. The thickness of the disc 10 is made such that said disc will contain exactly an odd number of half-wave lengths of the radiation in use.

In Fig. 4 is shown a portion of a dielectric lens feed with the disc 10 secured thereto. This feed, which is disclosed and claimed in a co-pending application, filed June 28, 1948 by Gilbert Wilkes, et al., Serial No. 35,776, for "Wave Guide Terminals," includes a dielectric lens element 11 having a stem 12 mounted in the end 13 of the wave guide, said lens having a head 14 backed by a metallic reflector 15, which is suitably secured to said head. A threaded bore 16 in the central portion of fitting 15 receives the screw 17, which holds disc 10 flat against the outer surface 18 of fitting 15, as shown. Disc 10 is identical with that shown in Figs. 1, 2 and 3, provided the wave length in use and the material of the disc remain the same.

Fig. 5 shows a still further type of feed, which is known as the cap feed, and is disclosed in United States Patent 2,455,286 for "Antenna Cap," issued November 30, 1948, to Frank D. Werner. This consists essentially of a metallic element 19 having two flat wings 20 and 21 forming a dihedral angle with each other. This cap feed is held adjacent the open end of the wave guide 22, as by straps 23 of proper length. A tubular stud 24 may be rigidly secured to the blunt apex 25 of the dihedral angle, in any suitable way, and is threaded as shown to receive the screw 26 that holds the disc 10 to the feed 19.

While three different types of feed have been illustrated and described, it will be noted that the dielectric disc 10 is the same in each instance, that is, the characteristics of the said disc are entirely independent of the kind of feed to which it is applied. Obviously the disc is not limited to the particular feeds selected for illustration, but is of general application. It should also be noted that other means than screws may be used to hold the disc in place, for instance, the disc may be cemented in place.

It may be well to discuss here the theory underlying the dimensioning and mode of operation of the dielectric disc:

Most feeds are designed to throw the radiant energy into the dish by causing the energy traveling through the wave guide to reverse its direction of travel as soon as it emerges from the wave guide. This reversal is usually obtained by means of metallic reflectors, mounted in front of the wave guide. Such reflectors may be simple metallic plates, or the back closures of small resonant cavities, with openings directed toward the dish. In still another type of feed, the reflector may be the silvered or metallized back surface of a dielectric element, mounted in the wave guide in such way as to cause the energy in the wave guide to be thrown into the dish.

These metallic reflectors are strongly energized, therefore, on the side facing the dish. As they have dimensions of the order of a wave length, it is evident that their edges then become more or less powerful dipole-type radiators of energy, a large portion of which travels from the feed away from the dish. This energy, called back radiation, is not concentrated into a dense beam by the dish, and being diffuse, is so weak as to be almost totally lost.

It will be understood that the wave length of energy is relatively small, and may be of about the same order of magnitude as the length, width or diameter of the metallic feeds or reflectors shown in Figs. 1–5 of the present case, for example, capsule 1 of Figs. 1, 2 and 3, reflector 15 of Fig. 4 or element 19 of Fig. 5. Thus these metallic members may become strongly excited by the emitted radiation of the transmitter, particularly if their dimensions make them resonant or nearly so, and as they are located in intense fields, they may thus become secondary radiators of considerable power, most of which is wasted for lack of focusing, as just explained.

If a high impedance is interposed between the back surface of the feed and free space, the free radiation of energy from this surface to free space will be impeded, and this radiation, otherwise lost, will be thrown back into the dish. Such an impedance is obtained easily by placing on the back surface of the feed a piece of dielectric

that will contain an odd number of half-wave lengths of the radiation, according to Snell's laws, relating to optical refraction.

The wave length in a dielectric sheet of restricted dimensions (as distinguished from a sheet of indefinite or unlimited extent) is a function of said dimensions and of the index of refraction of the material. The wave length of the radiation in a solid dielectric is well known to differ from that in a vacuum or in air. Since the velocity of the radiation is decreased in the solid, it follows that the wave length therein necessarily is less than in air. However, the electrical wave length in a solid dielectric for waves in the "centimeter" range has been found by experiment to follow a more complex law than that of the very much shorter waves of visible light, and such electric wave length depends not only on the index of refraction at the wave length in question, but also on the physical dimensions or actual size of the dielectric element. The expression "contains an odd number of half-wave lengths" consequently is here used in the sense that the radiation executes exactly an odd number of half cycles in traversing its path through the dielectric element. It may be remarked that as the wave length within the dielectric depends on the diameter as well as the thickness, a larger piece may also be thicker, to contain the same number of wave lengths.

The apparent index of refraction in the dielectric depends not only on the dielectric constant of the material used, but also on its transverse and longitudinal dimensions. The apparent index of refraction can be determined experimentally for a given piece, and when the thickness of the piece has been adjusted so that it will contain an odd number of half-wave lengths, and it is fastened to the back of a feed, for example, by cement or by a screw, the one-way gain of the dish-feed combination is found to be improved by 10% for a metallic feed of the Cutler resonant cavity type, by 17% for a dielectric feed of the type illustrated, and up to 30% for other types of feed, depending on the amount of radiation originally lost.

While the index of refraction of a medium for wave lengths in the optical range, that is, visible light, is approximately a constant there is considerable difference in most cases between this constant and the corresponding index of refraction for electric waves of a wave length of a few centimeters, and sometimes this new value, which is here called the apparent index of refraction, may be of the order of several times as great as the said optical index of refraction of the same material.

As this gain or loss of efficiency due to the interposition of a dielectric element is a cyclic effect, a full wave length dielectric should show a decrease in gain, a dielectric containing one and one-half wave lengths should again show an increased gain, and so forth. This is exactly what experiments prove, and after the measured thickness is corrected for the known variation of the apparent index of refraction, the peaks fall nicely at dielectric thicknesses containing one-half wave length, 3/2 wave length, etc.

It can be shown also from Snell's laws that the dielectric constant of the material used has no effect on the degree of mismatch obtainable, and this is approximately verified by experiment, provided a low loss dielectric material is used.

The expression "mismatch" refers to impedance to the transmission of radiation. If the impedances of two adjacent media are made as widely different from one another as possible, the maximum mismatch is obtained, and corresponds to minimum transmission. For any given medium this condition exists when it contains an odd number of half-wave lengths of the radiation in question.

Having disclosed the invention and described in detail several practical embodiments thereof, it is to be understood clearly that these embodiments are presented merely to illustrate the invention and in no sense as limitations thereof, inasmuch as many other embodiments are possible. The invention is therefore to be defined solely by the scope of the following claims.

What is claimed is:

1. An antenna system including a waveguide and a parabolic reflector, said waveguide terminating near the focus of said reflector, an auxiliary reflector coaxial with said waveguide and positioned beyond the termination thereof for directing energy onto said parabolic reflector, a plate of dielectric material interposed between the auxiliary reflector and free space thereby providing a high impedance between said auxiliary reflector and free space, said plate having a thickness parallel to the axis of the waveguide such that it will contain an odd number of one-half wavelengths of the energy being radiated from the system.

2. An antenna system as claimed in claim 1, wherein the auxiliary reflector comprises a resonant cavity.

3. An antenna system as claimed in claim 1, wherein the auxiliary reflector comprises a dielectric lens having a stem that extends into the waveguide and a metallic reflector backing.

4. An antenna as claimed in claim 1 wherein the auxiliary reflector comprises a dihedral cap fitted over the termination of the guide.

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