March 4, 1947. A. P. KING 2,416,698

RADIATION AND RECEPTION OF MICROWAVES

Original Filed April 29, 1938

FIG. 1.

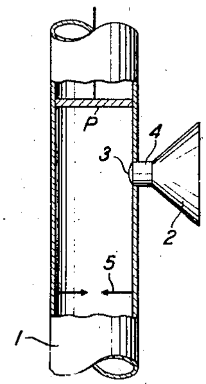


FIG. 2.

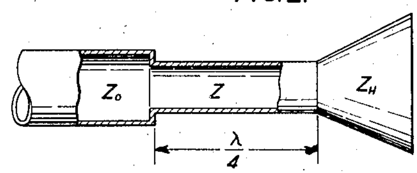


FIG. 3.

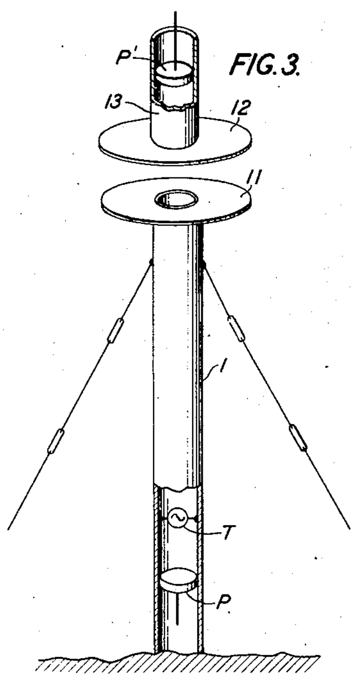


FIG. 4.

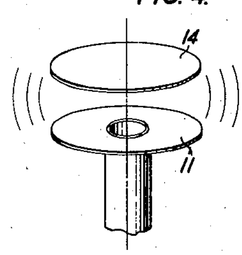


FIG. 5.

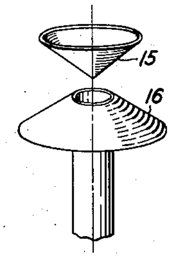


FIG. 6.

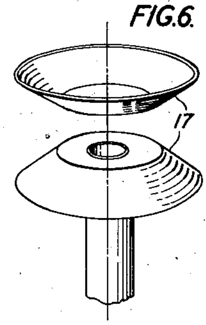
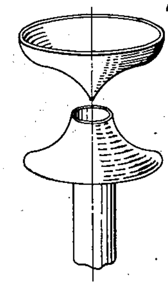


FIG. 7.



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RADIATION AND RECEPTION OF MICROWAVES

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Original application April 29, 1938, Serial No. 204,960, now Patent No. 2,283,935, dated May 26, 1942. Divided and this application May 25, 1942, Serial No. 444,393

6 Claims. (Cl. 250—11)

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This invention relates primarily to systems for the transmission of electromagnetic waves through space and more particularly to apparatus for the launching of hyper-frequency electromagnetic waves into space and for the reception of such waves. This application is a division of my copending application Serial No. 204,960, filed April 29, 1938, which issued May 26, 1942 as U. S. Patent 2,283,935.

A principal object of the present invention is to provide new and improved means for the radiation and reception of radio waves. More particular objects are to increase the efficiency with which guided waves and radio waves are interconverted, to secure directive and otherwise non-uniform space distribution of wave power from a high frequency radiator, to secure similar directionally selective properties in radio wave receiving means and to increase the ratio of received energy level to the energy level of extraneous interference, to effect impedance matching between the radiating or receiving means and free space on the one hand and a connected wave guide on the other, and to secure desired directional properties with impedance matching.

The foregoing objects and various other objects are achieved in accordance with the present invention by the various means hereinafter to be described and illustrated in the accompanying drawings. It will be understood that these specific means are only illustrative examples of practice in accordance with the invention and that the invention includes such other means as come within the spirit and scope of the appended claims. Reference will be made to the accompanying drawings, in which:

Figs. 1 and 2 illustrate arrangements for facilitating an impedance match between a wave guide and a horn adapted for beam transmission; and

Figs. 3 to 7 show systems and structures adapted for broadcast radiation or reception.

By way of introduction I refer to that prior art which has to do with the transmission of hyper-frequency electromagnetic waves through tubular uniconductor guides, i. e., electrically conductive pipes containing only air or some other dielectric medium. It is known that there are many types of electromagnetic waves, each characterized by the spacial distribution of its component electric and magnetic fields, which are capable of transmission through such a guide, and it is known, too, that when the end of the pipe distant from the wave source is left open the

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waves are launched into space and may be received at considerable distances. Conversely, it is known, radio waves of appropriate frequency and polarization impinging on the open end of the pipe can give rise to guided waves therein which can be transmitted to a suitable receiver within the pipe. G. C. Southworth has shown that by suitably flaring the open end of the pipe, that is, by terminating the pipe in some form of horn, one can obtain a better match between the impedance of free space and the characteristic impedance of the pipe guide, so that in the case of a radiator a greater proportion of the guided wave power available within the pipe is converted into radiant wave power, and in the case of a receiver a greater proportion of the intercepted radio wave power is converted into guided wave form. He has found also that such horns serve to modify the directional characteristics of the open-ended pipe, as for example, by largely confining the radiated wave power to a particular direction of transmission or, similarly, by making a receiver selective with respect to the direction of received radio waves.

The transverse dimensions of the various wave guide structures herein disclosed are generally comparable with the lengths of the waves transmitted, and as an example that will be used throughout this specification the frequency of the wave may be 2000 megacycles per second, corresponding to a free space wavelength of 15 centimeters, and the transverse dimensions of the pipe guide may range from 10 to 15 centimeters. Again it is to be remembered that the ratio of wave-length to dimensions is usually more significant than the absolute dimensions, and the latter may be scaled up or down for correspondingly lower and higher frequencies respectively without great effect on the operation of the system. Although air is treated as the dielectric medium throughout this specification, the various radiating and receiving structures disclosed may alternatively enclose a solid or other dielectric medium having a dielectric coefficient greater than unity, in which cases the dimensions may be scaled down in proportion to the index of refraction of the dielectric medium. The transmission cut-off characteristic of the pipe guide is not to to be forgotten, for it is well known that the transverse dimensions of the pipe must exceed a critical value if a dielectrically guided wave of a particular type and frequency is to be sustained within it.

Copper and brass are suitable materials for construction of the horns herein disclosed, but at the high frequencies contemplated many other materials will serve, and iron coated with zinc or tin has been found quite satisfactory.

Referring now to Fig. 1 there is shown a system for the radiation or reception of hyper-frequency radio waves comprising a hollow pipe guide 1 and a conical metallic horn 2 connected in wave energy transfer relation therewith. The connection between the guide and the throat end of the horn is made through an aperture 3 in the guide wall with the axis of the horn normal to the axis of the guide. As shown, the horn 2 strictly is frusto-conical and connection is made to the aperture through a short cylindrical extension 4 of the smaller end. It may be assumed that there is connected to the guide 1 at some distance from the aperture 3 translating apparatus adapted to establish in the guide waves of one type or another susceptible of transmission therethrough, such as for specific example, dielectrically guided waves of the so-called H_{11} or asymmetric magnetic type having lines of electromotive intensity in and roughly parallel to the plane of the paper. For communication purposes, signals may be impressed on the high frequency waves and any suitable modulation means may be provided for this purpose. Alternatively the connected translating apparatus may be arranged to receive guided waves that are established in the guide 1 following interception of radio waves by the horn 2. In other words the system may be used for either radiation or reception without any change except the interchange of source and receiver. The transmission and directional characteristics are the same in both cases, and this is true of all of the embodiments herein disclosed.

Assuming that the Fig. 1 system is to be used as a radiator or transmitter, the guided waves pass up through the guide 1 to the aperture 3. Here they escape into the horn 2 and are radiated therefrom with maximum intensity or directivity along the axis of the horn. To facilitate the transfer of wave power from guide to horn and thereby to increase the radiated wave power, a wave reflector in the form of a longitudinally adjustable metallic piston P is disposed in the guide 1 a short distance beyond the aperture 3. The position of the piston is to be adjusted for maximum radiation.

As a further aid to the matching of impedance between guide and horn a reactance element in the form of an iris 5 of adjustable aperture is disposed in the guide of Fig. 1 near the aperture 3 and on the side away from piston P. Thus the guide 1 is terminated in a chamber bounded by iris 5 and piston P, and the horn branches laterally from the chamber thus formed. By proper adjustment of the longitudinal position of piston P and iris 5 and of the iris aperture, a combination of adjustments will be found for which the wave power radiated or received through the horn is a maximum.

In Fig. 2 the horn and guide are interconnected by a section of guide having an impedance intermediate that of the other two elements and a length approximately equal to a quarter wave-length or an odd multiple thereof at the operating frequency. Preferably the impedance Z of the quarter wave-length section is equal to the geometric means of the impedance Z_H of the horn and the characteristic impedance Z_0 of the guide.

Whereas Figs. 1 and 2 illustrate systems adapted primarily for selective transmission or reception along one direction, that is, for substantially beam transmission, Figs. 3 to 7 illustrate systems in which other directional patterns are obtained, as for example, uniform transmission or reception in all horizontal directions.

Referring to Fig. 3 there is shown a radiating or receiving system comprising a vertical metallic pipe guide 1 surmounted with a circular flange 11 at its upper end, opposite which is disposed an annular plate 12 spaced from the flange 11 a distance, comparable with the diameter of the pipe, that is appropriate for the frequency of operation. Near the base of the pipe is the translating device T and associated piston P for launching or receiving guided waves. For simplicity of illustration the device T is shown as one adapted for waves of the H_{11} type. Where uniform transmission in all horizontal directions is desired, however, it is preferred that E_{01} or H_{01} waves be utilized for transmission through the pipe guide. The same is true of the other broadcoast radiators hereinafter disclosed. In lieu of the annular plate 12, a metallic disc 14 may be employed, as illustrated in Fig. 4. An annular plate is preferred, however, as it permits a metallically bounded cavity to be formed above it for enhancing radiation. The cavity may conveniently comprise, as shown in Fig. 3, a pipe 13 surmounted at its lower end by the plate 12 and terminated at the other end by an adjustable or fixed reflecting piston P'. Piston P' is adjusted to such position that the radiated field is of maximum intensity. From a theoretical standpoint the arrangement is akin to the impedance matching means disclosed in my Patent No. 2,088,749, August 3, 1937, especially when the radiation resistance associated with the spaced plates is considered.

Modified structures as compared with Figs. 3 and 4 are shown in Figs. 5 to 7, inclusive. In Fig. 5 the disc 14 of Fig. 4 is replaced by an inverted metallic cone 15 axially aligned with the pipe, and the flange 11 of Fig. 4 is replaced by a frusto-conical metallic member 16. In Fig. 6 the radiating elements of Fig. 4 are shown surmounted each with a frusto-conical metallic member 17 disposed so that a path of increasing cross-section is obtained as the wave progresses radially outward. Further modification of the contour of the radial path is indicated in Fig. 7 whereby any desired rate of flare is obtainable.

What is claimed is:

1. An antenna system comprising a pair of juxtaposed conductive expanses in the form of surfaces of revolution with common vertical axis, a vertical transmission line comprising a tubular conductor divided into two longitudinally separated portions the proximate ends of which are open, each of said expanses having an opening at the axis of revolution and each being mounted in axial alignment with said transmission line on a respective proximate extremity of said conductor portions, means connected to the lower portion of said transmission line at a point remote from said expanses for launching into said line or receiving therefrom radio frequency waves having a circularly symmetric field configuration, and means for matching the characteristic impedance of said line and the impedance presented by said expanses at the axis thereof comprising a wave reflector disposed in the upper of said conductor portions.

2. An antenna system comprising a pair of juxtaposed conductive expanses in the form of surfaces of revolution with common axis, a transmission line comprising a tubular conductor di-

vided into two longitudinally separated portions the proximate ends of which are open, each of said expanses having an opening at the axis of revolution and each being mounted in axial alignment with said transmission line on a respective proximate extremity of said conductor portions, means for launching waves into one of said portions or for receiving them therefrom, and impedance matching means comprising a reflector disposed in the other of said portions adjacent the open end thereof.

3. An antenna system comprising a pair of vertically separated, laterally extended conductive expanses in capacitive relation, the region between said expanses being open to free space at the outer edges of said expanses, means for energizing said expanses with the waves to be radiated or for receiving intercepted radio waves therefrom, and a conductively bounded chamber apart from and opening into the space between said expanses, said chamber being so proportioned and dimensioned as to enhance the exchange of wave energy between free space and said energizing or receiving means.

4. An antenna system comprising a pair of juxtaposed conductive expanses in the form of surfaces of revolution with common vertical axis, a vertical transmission line comprising a tubular conductor divided into two longitudinally separated portions the proximate ends of which are open, each of said expanses having an opening at the axis of revolution and each being mounted in axial alignment with said transmission line on a respective proximate extremity of said conductor portions, means connected to the lower portion of said transmission line at a point

remote from said expanses for launching into said line or receiving therefrom radio frequency waves having a circularly symmetric field configuration, and a longitudinally adjustable piston disposed in the upper of said conductor portions adjacent the said proximate open end thereof.

5. A system in accordance with claim 2 in which said transmission line is a hollow-pipe guide.

6. An antenna system comprising a pair of juxtaposed conductive expanses substantially in the form of surfaces of revolution with common axis, a tubular uniconductor guide for high frequency electromagnetic waves, said guide being coupled near said axis in wave transfer relation with the space between said expanses for exciting therein the waves to be radiated or for receiving intercepted radio waves therefrom, and a conductively bounded hollow chamber electrically coupled near said axis to the said space between said expanses.

ARCHIE P. KING.

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