May 20, 1952 R. E. CLAPP 2,597,144

ELECTROMAGNETIC WAVE CONTROL STRUCTURE

Filed Sept. 14, 1945

FIG. 1

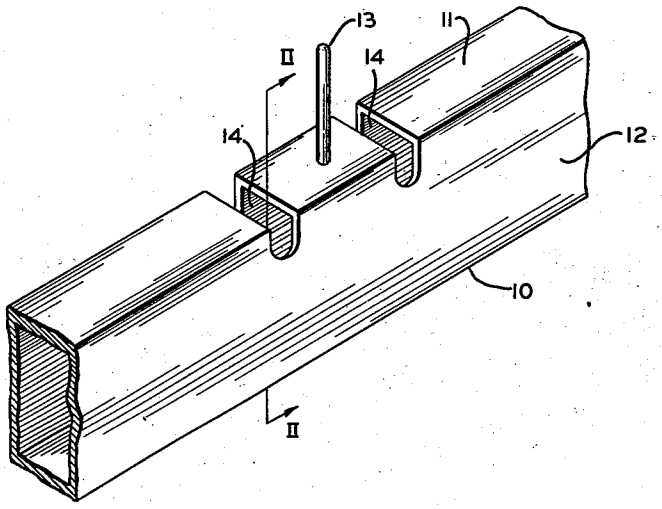


FIG. 2

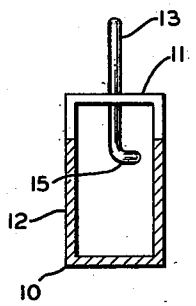


FIG. 3

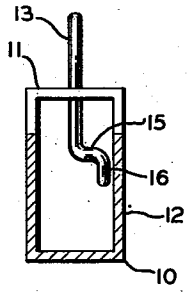
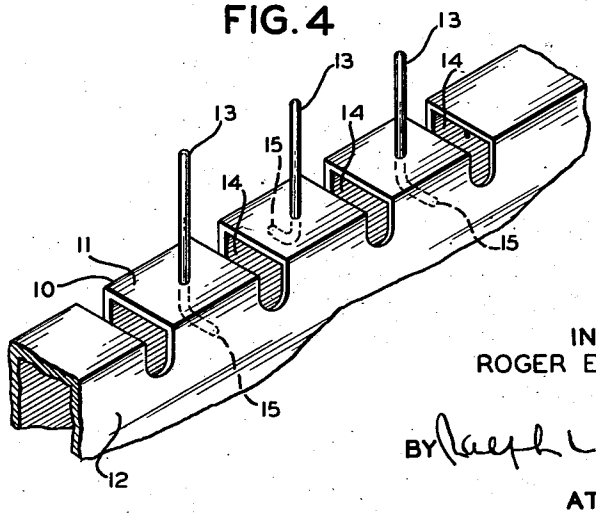


FIG. 4



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ELECTROMAGNETIC WAVE CONTROL STRUCTURE

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15 Claims. (Cl. 250—33.63)

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This invention relates to systems for the interchange of radio energy between wave guides and free space, and more particularly to the mounting of antenna elements in a wall of a wave guide.

In my copending application, S. N. 504,638, filed October 1, 1943, which matured into Patent No. 2,574,433, November 6, 1951, and that of Luis W. Alvarez, S. N. 509,790, filed November 10, 1943, both assigned to the same assignee as my present invention, a number of arrangements for the interchange of energy between wave guides and free space are disclosed. My present invention is a novel structure for converting a section of wave guide to a radio antenna, but susceptible, however, of the same useful applications as the systems disclosed in the above-mentioned copending applications.

When it is sought to transmit and receive radio energy of the lower frequencies and correspondingly longer wave lengths, the problem of connecting a transmission line to an antenna is relatively simple due to the large sizes of the mechanical parts involved, thus permitting the use of ordinary tools and practices. The problem is also simple in such cases due to the tolerably low energy losses at the points of connection. However, when frequencies sufficiently high to make desirable the use of wave guides as transmission lines are used, antenna elements become quite small, due to the corresponding reduction in size of the wave lengths encountered. The problems involved in coupling a wave guide to one or more antennas of small size are complex, and the energy losses encountered at the coupling points sufficiently great to justify the development of even more complex electrical joints in an effort to minimize such losses. Obviously a structure which will provide a radio antenna that can be operated directly from a wave guide without complex coupling joints will eliminate many of these problems and have improved electrical efficiency. In my present invention I provide such a simplified structure, wherein a wave guide has mounted directly on a wall thereof, without insulation, a rod-shaped antenna member that extends through the wall and is bent in appropriate fashion to form a coupling probe inside the wave guide, the whole structure being simple and easy to construct.

It is an object of my invention to provide a structure for the interchange of radio energy between a wave guide and free space that will have no mechanical couplings and no moving parts.

It is a further object of my invention to provide

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such a structure that will have high radiating efficiency and will have minimum energy transfer losses.

It is a still further object of my invention to provide such a structure that will be simple in design, easy to construct, and inexpensive.

Other and further objects and features of my invention will become apparent upon a careful consideration of the following detailed description when taken together with the accompanying drawings, the figures of which illustrate typical embodiments of the invention.

In the drawings:

Fig. 1 illustrates a system constructed in accordance with the teachings of my invention.

Fig. 2 is a cross section of Fig. 1 taken along line II—II, showing a typical probe construction;

Fig. 3 is a cross section corresponding to that of Fig. 2, showing an alternative probe construction; and

Fig. 4, showing a partly broken away wave guide, illustrates an arrangement of antenna elements in an array.

Referring to Fig. 1, a wave guide 10 has an antenna rod 13 mounted in a wall 11 thereof. The rod 13 extends through the wall 11 and is bent to form a coupling probe 15 inside the wave guide 10 as shown in Fig. 2. At least one slot 14 is cut transversely in the wall 11 in which the rod 13 is mounted and near the rod 13 to permit that portion of the wall 11 in which the rod 13 is mounted to undergo radio-frequency variations in voltage. The probe 15 is bent and oriented in such a direction as to couple the rod 13, with the electrostatic field of the energy being carried within the wave guide 10, in a known and usual fashion. As shown in Fig. 3, the probe 15 may have an additional projection 16 thereon, at an angle, for impedance matching purposes. When the rod 13 is placed in the center of a narrow wall 11 of a rectangular wave guide 10, as shown, the probe 15 will efficiently couple energy into the rod 13 from waves being carried by the wave guide 10 in various modes, such as for example, the TE_{01} or the TE_{02} mode. A second transverse slot 14 is provided in the wall 11 on the opposite side of the rod 13 from the first slot 14, and serves to eliminate undesired radiation and reception at the first slot 14, as will be explained hereinbelow.

With any one of the hereinabove mentioned modes of transmission along the wave guide 10, TE_{01}, or TE_{02}, electrostatic lines of force will exist transverse to the wave guide 10 and parallel to a narrow wall 11, as is well known. The probe 15 is preferably oriented in such a direc-

tion that its bent end will point in a direction that is substantially parallel to the direction of the electrostatic lines of force, and therefore in Fig. 1 substantially transverse to the wave guide 10, in order to provide efficient electrical coupling between the energy in the wave guide and the antenna rod 13. The rod 13 may be of any desired length, except that lengths in the neighborhood of one-half a free-space wave length are to be avoided. I have found that a length equal approximately to one-quarter of a free-space wave length is desirable, but this is not critical, and considerable variation is permissible, except for the undersired length hereinabove mentioned. The slots 14, while permitting that portion of the wall 11 to undergo voltage changes as hereinabove stated, would not normally be adapted alone to permit or facilitate the interchange of energy between the wave guide 10 and free space. However currents will occur due to the presence in the wave guide 10 of the probe 15, and these currents will excite the slots 14. If there is only one slot 14, it will then act along with the antenna rod 13 to facilitate the interchange of energy between the wave guide 10 and free space. It is desirable to avoid this, and to confine the radiation and reception of energy to the antenna rod 13. The second slot 14 is used to cancel out the effect of the first slot 14. The slots 14 can be so spaced that they will be approximately resonant at the operating frequency being used, or somewhat off-resonance in order to match such susceptance as the probe 15 may introduce into the wave guide 10. Thus the use of two slots 14 permits the better matching of the impedances of the wave guide 10 and the antenna rod 13. The rod 13 acts as a rod antenna that takes energy from and introduces energy into the wave guide 10, and correspondingly radiates or receives energy. The rod 13 may be termed a "half-dipole," and has a radiation pattern similar to that of a conventional dipole antenna. The configuration of the radiation pattern of a half-dipole 13 may be altered however, if desired, by directing the probe 15 in a direction other than transverse to the wave guide 10. Thus, by directing the probe 15 so that it makes an angle of, for example, 10 or 20 degrees with a line transverse to the wave guide 10, radiation from the half-dipole 13 will continue, but the radiation pattern will be altered.

In Fig. 3 is illustrated an alternative form of probe 15, which is the same as the probe 15 as illustrated in Figs. 1 and 2 except that there is added a projection 16 for impedance matching purposes.

In Fig. 4 is illustrated an arrangement of half-dipoles 13 of my invention in an array. The rods 13 are spaced apart by a distance equal to one-half the wave length in the wave guide of energy at the operating frequency. The probes 15 are alternately reversed in direction, so that the coupling of each with energy in the wave guide 10 differs from that of its nearest neighbor by 180 electrical degrees. A phase difference of 180 electrical degrees being equal to the phase difference resulting from one-half wave length of physical spacing, the rods 13 are each the equivalent electrically of one wave length in the wave guide 10 apart from their nearest neighbors. The radiation from each of the half-dipoles 13 is then in phase with that from all the others and a directional beam will result after the fashion of a similar arrangement of conventional dipole antennas. The slots 14 shown in Fig. 4 function as in Fig. 1 to permit the portion of the wall 11 in which each rod 13 is mounted to undergo radio frequency variations in voltage. Probes 15 having projections 16, as shown in Fig. 3, may be used with the array of Fig. 4 if desired.

Although I have shown and described only certain specific embodiments of my invention, I am fully aware of the many modifications possible thereof. Therefore my invention is not to be limited except insofar as is necessitated by the prior art and the spirit of the appended claims.

What is claimed is:

1. A system for the interchange of radio energy between a wave guide and free space comprising a wave guide, an antenna rod mounted perpendicularly through a wall thereof and extending outwardly a distance other than one-half the free space wave length of energy at the operating frequency and being bent within said wave guide to form an electrical coupling probe, said antenna rod being conductively joined to said wall at the point at which said antenna rod passes therethrough, and at least one transverse slot cut in said wall on at least one side of said rod, said slot being excited solely by currents resulting from the presence of said probe in said wave guide.

2. A system for the interchange of radio energy between a wave guide and free space comprising a rectangular wave guide, an antenna rod mounted perpendicularly through a narrow wall thereof and extending outwardly a distance substantially equal to one quarter of the free-space wave length of energy at the operating frequency and being bent within said wave guide substantially transversely to said wave guide to form an electrical coupling probe, said antenna rod being conductively joined to said narrow wall at the point of passage therethrough of said antenna rod, and a pair of slots cut across said wall one on each side of said rod, said slots being excited solely by currents resulting from the presence of said probe in said wave guide.

3. The invention of claim 2 wherein said slots are spaced apart a distance of an odd number of free space half wave lengths of the energy at the operating frequency, whereby energy is interchanged with free space substantially only by said rod.

4. A system for the interchange of energy between a wave guide and free space comprising a rectangular wave guide, a plurality of antenna rods mounted perpendicularly through a narrow wall thereof in a centered linear array, each of said rods extending outwardly a distance substantially equal to one quarter of the free-space wave length of energy at the operating frequency and being bent within said wave guide substantially transverse to said wave guide to form an electrical coupling probe, and a plurality of slots cut across said wall, there being at least one slot on each side of each of said rods.

5. The invention of claim 4 wherein said probes are directed alternately to opposite sides of said wave guide and said rods are spaced apart on said wall by a distance equal to one-half the free space wave length of energy at the operating frequency.

6. A system for the interchange of radio energy between a wave guide and free space comprising a wave guide, and an antenna rod mounted through a wall thereof, said antenna rod being

conductively joined to said wall at the point at which said antenna rod passes therethrough, said guide being formed with a slot in said wall at a point displaced from said antenna rod.

7. A system for the interchange of radio energy between a wave guide and free space comprising a wave guide, and an antenna rod mounted through a wall thereof, said antenna rod being conductively joined to said wall at the point at which said antenna rod passes through said wall, the portion of said rod within said guide being of a configuration adapting it to serve as an electrical coupling probe, said guide being formed with a pair of slots in said wall at points displaced from said antenna rod.

8. Apparatus of claim 7 wherein said slots are transverse of said wave guide and spaced apart by an odd number of free space half wave lengths of energy at the operating frequency.

9. Apparatus of claim 7 wherein said slots are parallel and spaced apart by an odd number of free space half wave lengths of energy at the operating frequency.

10. A system for the interchange of radio energy between a wave guide and free space comprising a wave guide, a rod mounted to the exterior of a wall of said guide, a second rod mounted to the interior of said wall substantially opposite said first rod, said wall being formed with a slot, said slot being excited by currents resulting from the presence of said second rod within said wave guide.

11. A system for the interchange of radio energy between a wave guide and free space comprising a wave guide, a rod mounted to a wall of said guide at the exterior of said guide, said wall being formed with a pair of slots, said slots being spaced from one another by an odd number of free space half wave lengths and an electrical coupling probe mounted to said wall at the interior of said guide, said rod and said probe being mounted to said wall at points between said slots.

12. An antenna system comprising a rectangular wave guide having one narrow wall thereof formed of a series of longitudinally spaced plates, the adjacent edges of adjacent plates defining a plurality of slots extending substantially transversely across said narrow wall, a plurality of antenna rods each conductively and mechanically joined at one end thereof to the outer surface of a separate one of said plates, said antenna rods extending outwardly from said narrow wall in a direction substantially perpendicular to said narrow wall, and means disposed within said wave guide for causing excitation of said slots by energy propagated within said wave guide.

13. An antenna system comprising a rectangular wave guide having one wall thereof formed of

a series of longitudinally spaced plates electrically joined to the broad walls of said wave guide, the adjacent edges of adjacent plates defining a plurality of slots extending substantially transversely across said narrow wall, said slots further extending substantially transversely across the two broad walls of said wave guide for a distance small compared to the transverse dimension of said broad walls, a plurality of antenna rods each conductively and mechanically joined at one end thereof to the central region of the outer surface of a separate one of said plates, said antenna rods extending outwardly from said narrow wall in a direction substantially perpendicular to said narrow wall, and a plurality of probes each extending inwardly from the inner surface of a separate one of said plates, said probes being positioned to cause excitation of said slots by energy propagated within said wave guide.

14. An antenna as in claim 13 wherein each of said probes is formed with at least a first arm conductively joined to said plates and extending substantially perpendicular thereto, and a second arm conductively joined to said first arm and extending in a direction parallel to said narrow wall.

15. A system for the interchange of energy between a wave guide and free space comprising a rectangular wave guide formed with a plurality of equispaced slots extending transversely across a narrow wall thereof, a plurality of antenna rods conductively and mechanically secured to the central regions of the plates bounded by adjacent slots and the broad walls of said wave guide, each of said rods extending outwardly a distance substantially equal to one-quarter of the free-space wavelength of energy at the operating frequency, and a plurality of probes extending inwardly from the central regions of said plates, said probes having a portion thereof bent to extend substantially parallel to said narrow wall, said slots being longitudinally spaced approximately one-half wavelength apart at the operating frequency.

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