June 23, 1953 C. E. ARNOLD 2,643,298

WAVE GUIDE DIRECTIONAL COUPLER

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Fig. 1

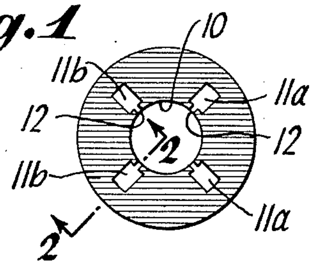


Fig. 2

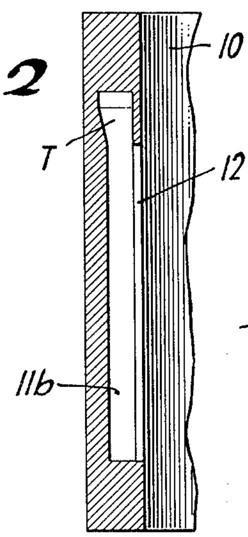


Fig. 3

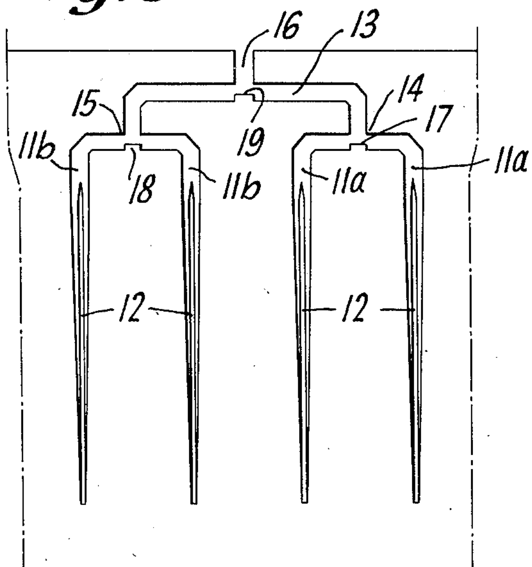
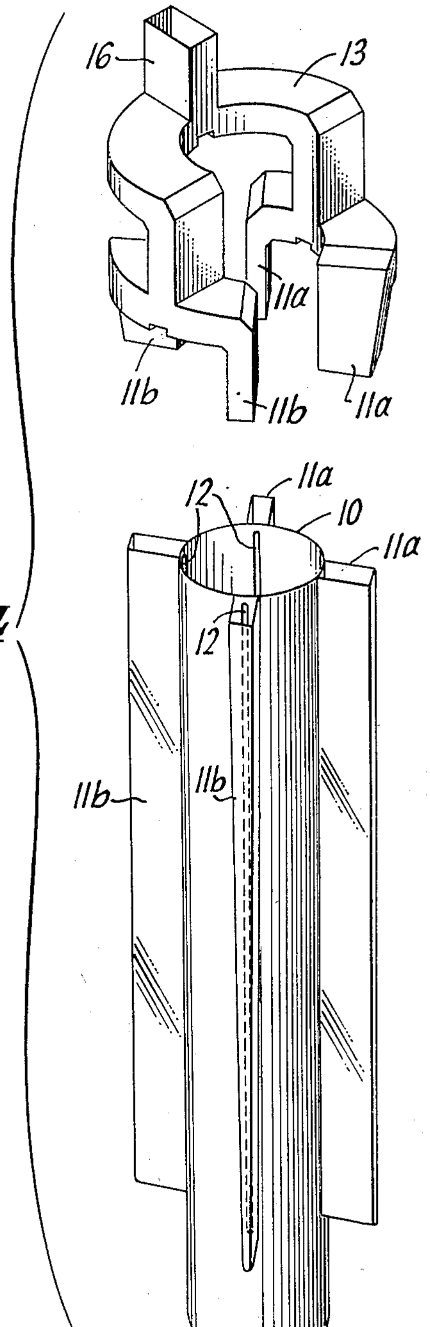


Fig. 4



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WAVE GUIDE DIRECTIONAL COUPLER

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2 Claims. (Cl. 178—44)

1

The present invention relates to wave guide directional couplers and, particularly, to one for intercoupling a circular wave guide operated in the TE_{01} mode and a rectangular wave guide operated in the TE_{10} mode.

In many applications in the ultra-high-frequency radio field, it is desirable to employ rectangular wave guides for convenience in coupling the wave guide to present day magnetrons, mixers, and the like. On the other hand, the circular wave guide may have certain advantages over the rectangular form of wave guide as, for example, the materially lower wave-signal energy loss which is exhibited by the circular wave guide operated in the TE_{01} mode as compared with the rectangular wave guide of the same length. Consequently, it is desirable on occasion to intercouple rectangular and circular wave guides in order to take advantage of the most desirable characteristics of each.

It is an object of the present invention to provide a new and improved wave guide coupler for intercoupling a rectangular wave guide operated in the TE_{10} mode and a circular wave guide operated in the TE_{01} mode, and one which exhibits the characteristic that wave-signal energy coupled from one of the wave guides into the other flows in the same direction in both.

It is an additional object of the invention to provide a new and improved wave guide directional coupler having a substantially uniform wave-signal impedance over the wave propagation paths thereof, and one which not only possesses good directional coupling characteristics but is of relatively simple and inexpensive construction.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring now to the drawings, Fig. 1 is a transverse cross-sectional view of a wave guide directional coupler embodying the present invention in a particular form; Fig. 2 is a longitudinal cross-sectional view taken along the plane 2—2 of Fig. 1; Fig. 3 is a development view showing the interconnections of the rectangular wave guide portions of the coupler; and Fig. 4 is a partially exploded view illustrating the construction of a directional coupler embodying the present invention in a particular form.

Referring now more particularly to Figs. 1 and 2 of the drawings, the wave guide directional coupler of the present invention includes a circular wave guide portion 10 and a plurality of rectangular wave guide portions 11*a* and 11*b* which are spaced in longitudinally juxtaposed position around the circumference of the circular wave guide portion 10, each rectangular wave guide portion being intercoupled electromagnetically with the circular wave guide portion by a longitudinal slot 12 of uniform slot width along the major portion of its length. For purposes of suppression of modes which may tend to be excited other than the TE_{01} mode in the circular wave guide portion and the TE_{10} mode in the rectangular wave guide portions, and to insure approximately unity coupling between the circular wave guide portion and all of the rectangular wave guide portions considered in parallel, the length of the slots 12 preferably is several guide wave lengths. As more clearly seen in Fig. 1 the rectangular wave guide portions 11*a* and 11*b* are so arranged that the longer cross-sectional dimension of each extends radially of the circular wave guide portion 10.

2

Referring now to the developed view of Fig. 3, the wave-signal energy flow through each slot 12 is made uniform along its length by tapering the shorter cross-sectional dimension of each rectangular wave guide portion 11*a* and 11*b* from a value approximately equal to the width of the slot at one end of the slot to the desired rectangular wave guide width at the other end of the slot. The longer cross-sectional dimension is selected such that the wave length in each rectangular wave guide when operated in the TE_{10} mode is equal to the wave length in the circular wave guide when operated in the TE_{01} mode. This equality of guide wave lengths may make desirable the use of a conventional tapered section T, Fig. 2, by which to transform the impedance of each wave guide portion 11*a* and 11*b* to that of the remainder of the rectangular wave guide system presently to be described. Also the end of each slot 12 adjacent the tapered section T may be tapered in width for a length of the slot equal approximately to one-half guide wave length to minimize impedance discontinuities at this end of the slot. These several factors when proportioned as described have the effect that there is maintained a substantially uniform wave-signal impedance along the propagation path of the circular and rectangular wave guide portions with consequent minimized undesirable reflection of wave-signal energy propagated by the desired modes.

It will be apparent from Fig. 3, that the wave guide portions 11*a* and 11*b* are joined at one end in pairs, and the coupler includes a rectangular wave guide portion 13 joined at its ends 14 and 15 to the electrical mid-points of individual pairs of the wave guide portions 11*a* and 11*b*. The coupler also includes an additional rectangular wave guide portion 16 joined at one end to the electrical midpoint of the wave guide portion 13. Metal plates 17 and 18 may be inserted in the rectangular wave guide portions 11*a* and 11*b* in opposing relation to the ends of the wave guide portion 13 for impedance matching purposes in a manner well known, and a similar plate 19 may be used for like reason at the junction of the wave guide portions 13 and 16.

In operation, wave-signal energy flowing in the rectangular wave guide portion 16 toward its junction with the wave guide portion 13 divides at the junction and flows with equal amplitude but opposite phase to the ends 14 and 15 of the latter. At the end 14, the wave-signal energy again divides and flows with equal amplitude but opposite phase into the two rectangular wave guide portions 11*a*, 11*a*. A like division of energy flow occurs at the junction of the wave guide portion 13 and the wave guide portions 11*b*, 11*b*. It will thus be seen that the wave-signal energy coupled through the slots 12 from all of the wave guide portions 11*a* and 11*b* has, at any transverse plane of the circular wave guide, equality of amplitude at each slot and the proper phase relationship to maintain the circular electric-field required for operation of the circular wave guide in the TE_{01} mode. Since the wave length in the rectangular and circular wave guide portions is equal as previously explained, energy coupled from the rectangular wave guide into the circular wave guide flows in the same direction in the latter as it did in the former, and this is likewise true for energy coupled from the circular wave guide into the rectangular wave guide portions. This directional coupling characteristic is enhanced with increasing lengths of the slots 12.

No transverse magnetic modes are intercoupled from the rectangular to the circular wave guide portions, or vice versa, since all wave guide portions of the coupler have only a transverse electric-field. Transverse electric-fields other than the TE_{10} mode in the rectangular wave guide portions and the TE_{01} mode in the circular wave guide portion are suppressed by the symmetry of coupling between the rectangular and circular wave guide portions and by the equality of guide wave lengths in the latter. The four-slot transition shown in Figs. 1, 2 and 3 does not excite any transverse electric modes except the TE_{41}, TE_{81}, etc., if the feeds are maintained equal in phase and amplitude and mechanical symmetry of the feed points is maintained. Certain of the undesired TE modes which may be excited can be suppressed by decreasing the circular guide size beyond cut-off for that mode, and other undesired TE modes are cancelled by the equality of wave lengths in the rectangular and circular wave guide portions if the slots 12 are made several guide wave lengths long.

Since the equivalence of guide wave lengths is not a function of frequency, a wave guide directional coupler embodying the present invention is of the so-called broad band type; that is, its coupling characteristics are exhibited uniformly over a wide range of wave-signal frequencies.

The directional coupler described in connection with Figs. 1, 2 and 3 may be formed by casting or any of numerous well known machining processes. A wave guide directional coupler embodying the present invention in a form suitable for fabrication from conductive sheet material and tubing is illustrated in Fig. 4, elements in Fig. 4 corresponding to similar elements in Figs. 1, 2 and 3 being designated by similar reference numerals. In the Fig. 4 arrangement, the circular wave guide portion 10 is formed of conductive cylindrical tubing slotted longitudinally to provide the coupling slots 12. The rectangular wave guide portions 11*a* and 11*b* may be fabricated as open channel-shaped members formed from conductive material and are secured in position longitudinally of the conductive cylinder 10 by soldering or brazing. The interconnected ends of the wave guide portions 11*a*, 11*b* and the interconnected wave guide portions 13 and 16 may be fabricated as a unit, as shown in Fig. 4, which is secured by soldering or brazing to the unitary structure formed by the circular wave guide 10 and the rectangular wave guide portions which are secured thereto. The operation of this form of the invention is the same as that described above and will not be repeated.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the invention. Consequently, the appended claims should be interpreted broadly, as may be consistent with the spirit and scope of the invention.

What I claim is:

1. A wave guide directional coupler comprising a circular wave guide portion and a pair of rectangular wave guide portions joined at one end and spaced in equidistant longitudinally juxtaposed position around the circumference of said circular wave guide portion with each rectangular wave guide portion coupled electromagnetically to said circular wave guide portion by a longitudinal slot, the longer cross-sectional dimension of each rectangular wave guide portion having a value providing equality of wave lengths in said circular and rectangular wave guide portions and extending radially of said circular wave guide portion and the shorter dimension thereof varying in value at a substantially constant rate along the length of said slot, and a rectangular wave guide portion joined to the electrical midpoint of said one end of said first-mentioned rectangular wave guide portions.

2. A wave guide directional coupler comprising a circular wave guide portion and a plurality of rectangular wave guide portions joined at one end in pairs thereof and spaced in equidistant longitudinally juxtaposed position around the circumference of said circular wave guide with each rectangular wave guide portion intercoupled electromagnetically with said circular wave guide portion by a longitudinal slot, the longer cross-sectional dimension of each rectangular wave guide portion having a value providing equality of wave lengths in said circular and rectangular wave guide portions and extending radially of said circular wave guide over the length of said slot and the shorter dimension thereof varying in value at a substantially constant rate along the length of said slot, a rectangular wave guide portion joined at its ends to the electrical mid-points of individual pairs of said first-mentioned rectangular wave guide portions, and an additional rectangular wave guide portion joined at one end to the electrical mid-point of said last-mentioned wave guide portion.

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