

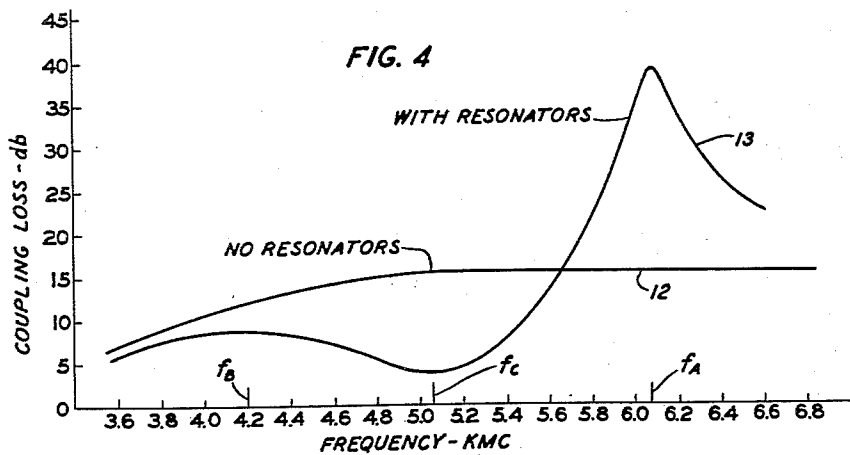
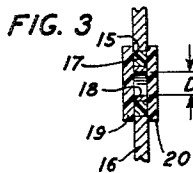
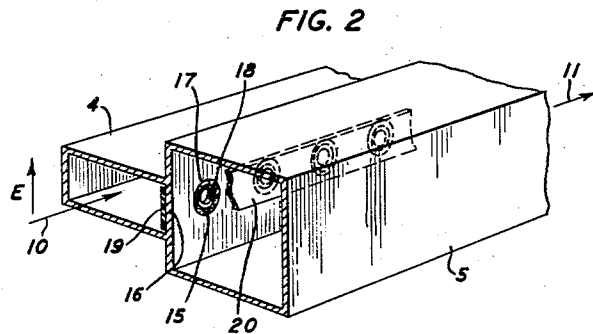
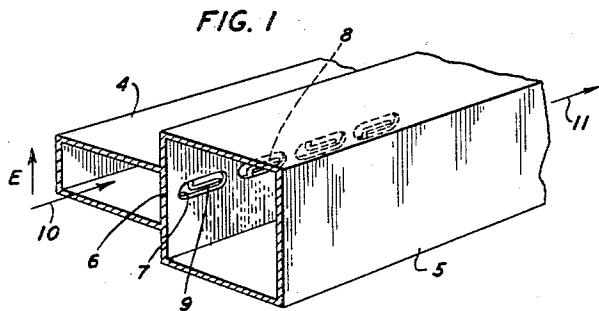
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WAVE-GUIDE COUPLER

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## WAVE-GUIDE COUPLER

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This invention relates to wave transmission and more particularly to wide-band directional couplers for wave guides.

An object of the invention is to flatten the transmission band of a wave-guide directional coupler. Another object is to reduce the transmission loss in the band of such a coupler. A further object is to discriminate against another selected band of frequencies.

In microwave systems, it is sometimes desired to connect two wave guides through a directional coupler which has a wide, flat transmission band and a selected rejection band. Such a coupler is useful, for example, in an arrangement for connecting two wave guides, carrying different frequency bands, to a single guide which feeds a common antenna.

The directional coupler in accordance with the present invention is well suited to meet these requirements. It comprises two wave guides which have a common wall with a series of coupling apertures therein. A resonator is associated with each aperture. This resonator is dimensioned to be antiresonant at a frequency  $f_A$  in the band to be excluded and is so coupled to the electromagnetic field in the aperture that the transmission loss is lowered and flattened over one or more transmitted bands. When the coupling aperture is circular, the resonator may be a conductive ring having an outer circumference approximately equal to an integral number  $n$  of free-space wavelengths  $\lambda$  at  $f_A$ . The inner diameter is chosen to make the desired transmission band as flat as possible. For a coupling slot, the resonator is preferably a bent, conductive rod having a length approximately equal to  $n\lambda/4$  at  $f_A$ . One or both ends of the rod are connected to a side of the slot. The point of connection and the diameter of the rod largely determine the flatness of the transmitted band.

The nature of the invention and its various objects, features, and advantages will appear more fully in the following detailed description of the typical embodiments illustrated in the accompanying drawing, of which:

Fig. 1 is a perspective view of two wave guides coupled through apertures with rod-type resonators in accordance with the invention;

Fig. 2 shows a modification in which the resonators are conductive rings;

Fig. 3 is a cross section of the ring used in Fig. 2; and

Fig. 4 shows typical loss characteristics of the coupler obtainable, respectively, with and without the resonators.

In the coupling arrangement shown in Fig. 1, the two wave guides 4 and 5 are arranged side by side and have a common wall 6. Each of the guides is rectangular in cross section. The guide 5 is square. The guide 4 has unequal transverse dimensions, with the wall 6 forming one of the narrower side walls. Either or both of the guides may have a cross section of other suitable shape. For maximum energy transfer, both guides will have the same velocity of propagation in the transmission band.

In accordance with the invention, means are provided for transferring a wide band of electromagnetic waves

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from one of the guides to the other. These means comprise one or more apertures, such as 7, in the common wall 6. Four such apertures are shown, but it will be understood that any number may be employed, depending upon the amount of energy to be transferred. If directional properties are desired in the coupler, the centers of the apertures preferably have a spacing approximately equal to an odd integral number of quarter-wavelengths in the guide at a frequency to be transmitted. This spacing will provide a good input impedance and high directivity, but is not critical.

In Fig. 1, the aperture 7 is in the form of a slot with its length parallel to the longitudinal axis of the guides 4 and 5. Associated with each slot 7 is a resonator coupled to the electromagnetic field therein. As shown, the resonator is a conductive rod 9, with a right-angle bend therein, conductively attached at one end to a wider side of the slot 7. These rods project, alternately, from the top of the slot, as does the rod 9, and the bottom, as does the rod 8, to provide mechanical and electrical symmetry and thus avoid conversion from vertical to horizontal polarization in the square guide 5.

Electromagnetic waves may, for example, be fed into the guide 4 at one end, as indicated by the arrow 10. The electric field of these waves is perpendicular to the wider walls of the guide, as shown by the arrow E. It will be assumed that it is desired to transfer a wide band, centered at the frequency  $f_B$ , from the guide 4 to the guide 5 and to propagate these waves in the latter in the direction of the arrow 11. It will also be assumed that it is desired to exclude a higher band of frequencies, centered at  $f_A$ , from the guide 5.

If the resonators are omitted, the coupling loss, in decibels, from the guide 4 to the guide 5 over the frequency range from 3.6 to 6.8 kilomegacycles will, in a typical case, be of the form shown by the curve 12 in Fig. 4. In the region of interest, this loss increases with frequency, and the slope is steepest at the lower end, near the cut-off frequency of the guide 4.

To suppress the band centered at  $f_A$ , the length of the rod 9 is made approximately equal to an integral number  $n$  of free-space quarter-wavelengths at this frequency. The width of the rejection band and the shape of the loss characteristic at other frequencies are determined by the diameter of the rod 9 and by the point at which it is connected to the slot 7. The closer this point of connection is to the center of the slot 7, the wider is the rejection band. Decreasing the diameter of the rod 9 reduces the width of the band. If the length of the rod is equal to an integral number of half-wavelengths, both ends may be connected to the slot 7.

The point of connection and the diameter of the rod 9 may be so chosen that the transmission loss through the slot 7 is made lower and more uniform in the band centered at  $f_B$ . The curve 13 in Fig. 4 shows a typical characteristic obtainable. This is a measured characteristic for a directional coupler having 16 coupling slots, each 0.715 of an inch in length, and 16 resonant rods, each 0.032 of an inch in diameter and 0.445 of an inch in length and offset from the side of the slot by 0.125 of an inch. A comparison of the curves 12 and 13 shows that, for a band of 0.4 kilomegacycle centered at a frequency  $f_B$  of 4.2 kilomegacycles, the addition of the resonators reduces the loss by approximately three decibels and the deviation to a quarter of the amount. It will also be noted that there is a second quite flat band centered at the frequency  $f_C$  over which the loss is even lower than at  $f_B$ .

Fig. 2 shows a modified form of directional coupler with circular coupling holes 15 in the common wall 16 between the wave guides 4 and 5. As shown more clearly

in the cross-sectional view of Fig. 3, a dielectric ring 17 fits into each of the holes 15. Inside of the ring 17 is a conductive ring 18. The rings 17 and 18 are held in place by two strips of insulating material 19 and 20 placed on opposite sides of the wall 16 and fastened thereto by any suitable means. In Fig. 2, part of the strip 20 has been broken away to show the first hole 15 and the rings 17 and 18. In order to provide a coupling characteristic such as curve 13, with high loss at  $f_A$ , the outer circumference of the ring 18 is made approximately equal to  $n\lambda$  at that frequency. The width of the rejection band and the shape of the characteristic at other frequencies are determined largely by the inner diameter  $D$  of the ring 18. As the inner diameter  $D$  is made smaller, the rejection band becomes wider. The presence of the dielectric ring 17 and strips 18 and 19 in effect slightly increases both the inner and the outer diameter of the conductive ring 18, and thus affects the shape of the curve to an extent depending upon the dielectric constant of the material used.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In a wave-guide coupler, two sections of wave guide positioned side by side and having a common wall, a longitudinal slot in the common wall, and a bent, conductive rod having a length approximately equal to an integral number of quarter-wavelengths in free space at a selected frequency, the rod being attached at one end at least to a wider side of the slot at a point chosen to lower and flatten the transmission loss through the slot over a band of frequencies below the selected frequency.

2. In a wave-guide coupler according to claim 1, a conductive rod as defined and having a length approximately equal to an odd number of quarter-wavelengths in free space at a selected frequency and being attached at one end only to the wider side of the slot.

3. A wave-guide coupler comprising two sections of wave guide positioned side by side and having a common wall, a series of slots in said common wall spaced apart longitudinally therealong and each having a longitudinal dimension greater than the transverse dimension, and a

bent conductive rod for each slot having a length approximately equal to an integral number of quarter-wavelengths in free space at a selected frequency and each rod being attached at one end at least to a wider side of the slot at a point chosen to provide a low and substantially uniform transmission loss in the coupling between said sections of wave guide over a band of frequencies below said selected frequency.

4. A wave-guide coupler according to claim 3 in which the rods in alternate slots are attached to the opposite sides of the respective slots.

5. In a wave-guide coupler, a wave guide of square cross section, a wave guide of rectangular cross section having one dimension larger than the other and positioned side by side with said wave guide of square cross section, a wall of said wave guide of square cross section being common to a narrow wall of said wave guide of rectangular cross section and being provided with a series of slots interconnecting said wave guides and spaced apart longitudinally along the common wall, the longitudinal dimension of each slot being greater than the transverse dimension, and a conductive rod mounted in each of such slots, the length of each rod being approximately equal to an integral number of quarter-wavelengths in free space at a selected frequency, and each rod being attached at one end at least to a wider side of its respective slot at a point chosen to provide a low and approximately uniform loss in the coupling between said wave guides over a band of frequencies lying below said selected frequency, the rods in alternate slots being attached to the same side of their respective slots and those in the remaining slots being attached to the opposite sides of their respective slots.

6. A wave-guide coupler according to claim 5 in which the length of each rod is approximately equal to an odd number of quarter-wavelengths in free space at said selected frequency and each rod is attached at only one end to a wider side of its respective slot.

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