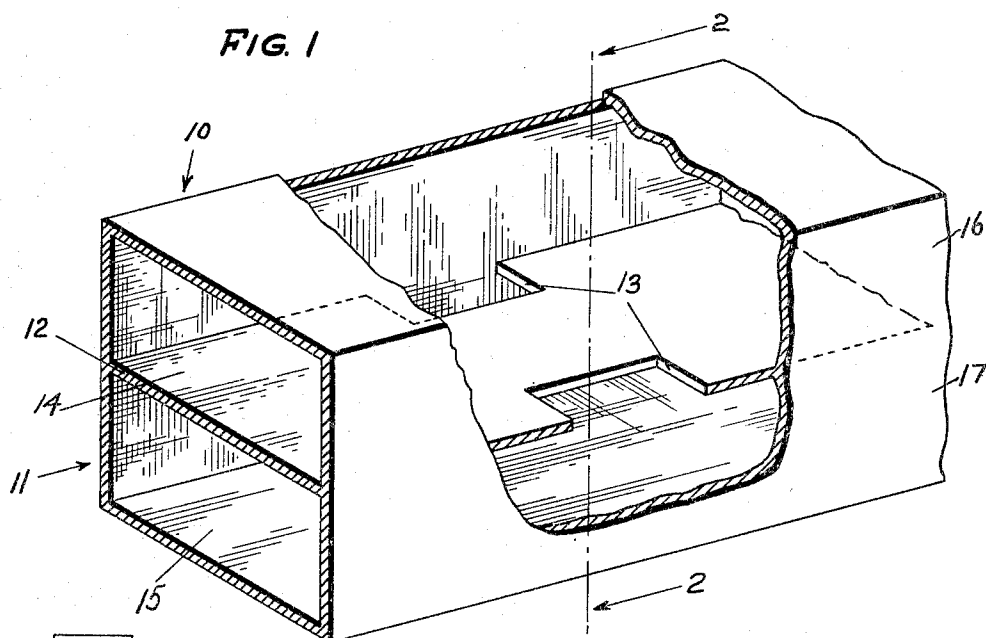
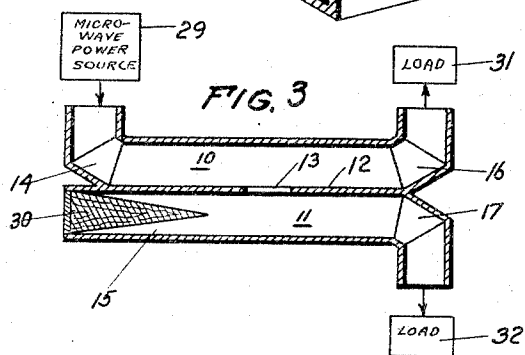
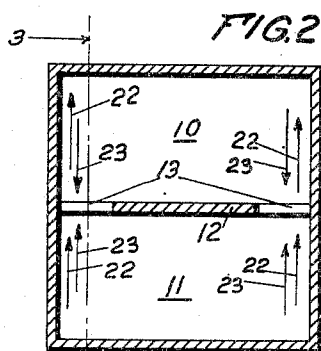
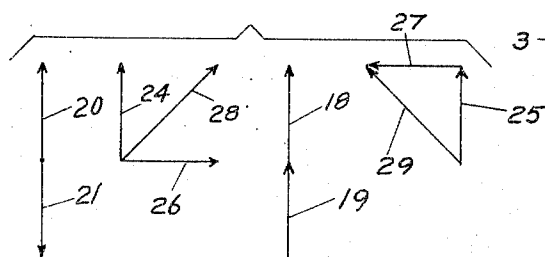


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H. J. RIBLET
HYBRID DIRECTIONAL COUPLER

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HYBRID DIRECTIONAL COUPLER

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4 Claims. (Cl. 333—11)

This invention relates to signal wave translation devices, and more particularly to devices for providing controlled coupling between signaling waves in one channel and signal waves in another channel.

In directional couplers it is desirable to prevent reflection of the signal back to the input of the coupler and thereby reduce the input standing wave ratio. This invention discloses apparatus whereby the reflection of energy from the coupler back to the input is substantially prevented.

This invention further discloses a specific embodiment wherein a directional coupler employs a pair of wave guides having a common wall, said wall having slots therethrough adjacent the edges thereof. The slots in the common wall make the section of the common wall lying between said slots behave as the central conductor of a coaxial type wave translation device for some signals with the walls of the surrounding guide behaving as the outer conductor. A signal in each wave guide which travels down the wave guide through the slotted sections will be unaffected by the slotted common wall section if the signals in each of the guides are of equal magnitude and in phase. However, if the signals are out of phase, said signals, upon passing along the slotted section, will behave as a common signal in a true coaxial conductor.

In a coaxial conductor, the phase velocity of a wave becomes substantially that of a wave in free space. On the other hand, waves traveling down the guides unaffected by the slots still retain the velocity of a wave traveling in a wave guide and, therefore, will travel through the slotted section with a phase velocity somewhat greater than the wave velocity of free space. The result is that a signal in one guide which is out of phase with a signal of equal magnitude in the other guide will shift in phase during passage through the slotted section by a lesser amount than a signal in one guide which is in phase with a signal of equal magnitude in the other guide. Thus, if each guide contains two signals, one of which is in phase with a signal in the adjacent guide and one which is out of phase with the signal in the adjacent guide, the out-of-phase signals will have their phase position retarded relative to the in-phase signals during passage through the slotted section, thereby causing a resultant change in the vector sum of the signals in each guide and resulting in a change in the relative power levels of the two guides. Thus, by varying the length of the slotted section and hence the degree of phase shift occurring between the in-phase and out-of-phase signals, the amount of the power transferred from one guide to the other may be regulated. It has been discovered that, for a hybrid coupling, such as a coupling wherein energy which is introduced into one channel will be equally split by the slots into each channel, the length of the slots may be made on the order of three-quarters of a wave length long.

In addition, since the reflection of waves to the inputs of the guides is caused by the impedance discontinuities produced by the slots in the guides, the reflections due to

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the discontinuity at one end of said slots may be made to substantially cancel the reflection produced by the discontinuity at the other end of the slots for a particular length of the slots by adjusting the slot width.

Thus waves, incident on one end of the slots, which, due to their out-of-phase character, regard the slots as a discontinuity and, therefore, produce reflected waves, will travel down along the slots and see at the other end of the slots a second discontinuity. The waves reflected from the second discontinuity will travel back through the slots and arrive at the first discontinuity in opposition to the signals reflected by the first discontinuity, and thus reflected waves from the second discontinuity will substantially cancel the reflected waves from the first discontinuity.

The invention may be more clearly understood by reference to the accompanying drawing, wherein:

Fig. 1 illustrates a partially cutaway perspective view of a wave guide structure embodying the invention;

Fig. 2 illustrates a transverse, cross-sectional view of the device shown in Fig. 1 taken along line 2—2 of Fig. 1;

Fig. 3 illustrates a longitudinal, cross-sectional view of the device shown in Fig. 1 taken along line 3—3 of Fig. 2; and

Fig. 4 illustrates vector diagrams showing the relation of in and out-of-phase waves in the structure.

Referring now to Figs. 1, 2 and 3, there is shown a pair of wave guides 10 and 11, respectively, having a common wall 12. While these wave guides may be of any desired shape, as shown here, they are of the standard rectangular type, and the common wall is one of the wider walls of the guides.

Wall 12 has therein a pair of rectangular slots 13 positioned adjacent the edges of wall 12. The longer dimensions of slots 13 are parallel to the longitudinal axes of guides 10 and 11, and the shorter sides of each slot are symmetrically disposed on either side of a plane transverse to the axes of guides 10 and 11. The result is that the portion of the common wall 12 lying between slots 13 can behave like the central conductor of a coaxial conductor with the sides of guides 10 and 11 adjacent the slotted section of wall 12 behaving as the outer conductor.

The signals for which the slots 13 cause the section of guides 10 and 11 adjacent thereto to behave as a coaxial conductor may be determined by the following analysis. Assume one end of guide 10 and the end of guide 11 adjacent thereto are the input ends of the device as designated by numerals 14 and 15, respectively, and the other ends of guide 10 and guide 11 are the outputs of the device as designated by numerals 16 and 17, respectively. If a signal is fed into the input end 14 of guide 10 of any given magnitude, an analysis of the operation of the device may be undertaken as follows, reference being had to Fig. 4. If the signal of the end 14 be broken into two vectors which are in phase and of equal magnitude, they may be illustrated, for example, by arrows 18 and 19 in Fig. 4. If no signal is introduced into the end 15 of guide 11, it may be assumed that the resultant signal at end 15 is a plurality of signals whose vector sum is zero. This is shown, for example, by vectors 20 and 21, each of which may be assumed to be equal in magnitude to vector 18 or vector 19. If it be assumed that vector 20 is in phase with vector 18, as is shown in Fig. 3, then vector 21 will be 180 degrees out of phase with respect to vector 19. Thus, signals 20 and 18 constitute a pair of signals, one signal being in each of the guides, respectively, and said signals traveling down the guides 10 and 11 in phase.

If these vectors be considered, for example, currents flowing in the walls of the guides, they may be illustrated,

for example, in Fig. 2 by arrows 22. Since these current arrows 22 are in phase when the wave is passing through the slotted section, the currents 22 in the walls of the lower guide will be equal to the currents in the walls of the upper guide and in phase therewith so that there will be no discontinuity in the current flow between one guide and the other. Therefore, the currents in the walls will have the same phase and magnitude whether the slots are in the common wall or not, and, therefore, the signals will travel down the slotted section as if the slots were not present.

Let us now consider vectors 21 and 19 which are, respectively, out-of-phase signals, signal 21 in guide 11 and signal 19 in guide 10. When these signals reach the slotted section, the currents in the walls adjacent the slots 13 will be in opposition to each other, as shown by arrows 23 in Fig. 2. Since these currents are in opposition, and since there is no common wall conductor at the point of opposition due to the slots, these currents cannot flow in the guide walls in the normal manner. The result is a discontinuity of the wave action as the signals pass into the slotted section of the guides. An analysis of the wave pattern in the slotted section for these out-of-phase signals shows that the signals regard the slotted section as a coaxial conductor, and, therefore, the propagation velocity of these signals is decreased to that of a coaxial conductor which is substantially equal to that of free space. Thus, the pair of out-of-phase signal vectors 19 and 21 will arrive at the other end of the slotted section after the in-phase signal vectors 18 and 20, thereby causing a shift in the relative position between out-of-phase signal vectors 19 and 21 and in-phase signal vectors 18 and 20.

If signal vectors 24 and 25 shown in Fig. 3 represent the phase of vectors 20 and 18, respectively, after passage through the slotted section, then the position of vector 21 will have advanced with respect to the position of vector 24, due to the increased velocity thereof, by a predetermined amount, for example, 90 degrees, as shown by vector 26. Similarly, vector 19 will have advanced in position with respect to vector 18 by a similar predetermined amount, as shown by vector 27. The amount by which the out-of-phase vectors 19 and 21 advance with respect to the in-phase vectors is determined by the length and width of the slots 13. For example, if the guides 10 and 11 are standard guides having inside dimensions of one inch by one-half inch, and the length of the slots be made 1.065 inches, and the width of the slots be made seven thirty seconds of an inch, a 90 degree shift in the phase between in-phase signals 18 and 20 and out-of-phase signals 19 and 21 will occur.

Addition of vectors 24 and 26 produces a resultant vector 28, and addition of vectors 25 and 27 produces a resultant vector 29, vector 29 being equal in magnitude to vector 28 and 90 degrees out of phase therewith. Thus, it may be seen that, at output ends 16 and 17, there will occur resultant vectors of equal magnitude, thereby demonstrating that one-half the power fed into top guide 10 has been split off by slots 13 and fed into guide 11.

Furthermore, the fact that input end 15 of guide 11 has a resultant vector of zero magnitude demonstrates that the power fed through slots 13 has been propagated in guide 11 in the same direction as power propagated into the input end 14 of guide 10, thereby producing a true directional coupling action.

While this invention has disclosed particular dimensions used to produce a hybrid coupling wherein a 90 degree phase shift occurs between the in-phase waves and the out-of-phase waves during passage through the slotted section, adjustment of the dimensions of the slotted section will vary the phase shift between the in-phase and the out-of-phase waves from less than 90 degrees to more than 90 degrees. For example, if the slot length were substantially doubled and the slot width adjusted to produce cancellation of reflections, the out-of-phase waves would be shifted substantially 180 degrees with respect

to the in-phase waves and substantially all the power would be fed from guide 10 through slots 13 into guide 11 and propagated toward the output end 17.

As shown in Fig. 3, input 14 may be, for example, coupled to an impedance matched microwave power source, input end 15 may be terminated by an energy-absorbing matched termination 30 and output ends 16 and 17 may be coupled to separate loads 31 and 32, respectively. With slots 13 adjusted for hybrid coupling energy from source 29 will be equally divided between loads 31 and 32.

While many applications call for both the input ends and the output ends of the guides 10 and 11 to terminate in matched loads, some applications exist where unmatched loads are desirable. Therefore, applicant does not wish to be limited to the particular details of the modification of the embodiment of the invention described herein except as defined by the appended claims.

What is claimed is:

1. A signal wave translation device comprising a pair of wave guides having a common directional coupler wall, said common wall having a pair of slots therein adjacent opposite edges thereof, said slots having their major axes substantially parallel to the axes of said guides, and said slots being dimensioned and arranged to produce hybrid coupling between said guides.

2. A signal wave translation device comprising a pair of wave guides having a common directional coupler wall, said common wall having a pair of slots therein adjacent opposite edges thereof, the centers of said pair of slots lying in a line perpendicular to the longitudinal axes of said slots, said slots having their major axes substantially parallel to the axes of said guides, and said slots being dimensioned and arranged to produce hybrid coupling between said guides.

3. A signal wave translation device comprising a pair of wave guides having a common directional coupler wall, said common wall having a pair of slots therein adjacent opposite edges thereof, the length of said slots being substantially equal to three-quarters of a wave length of a wave propagated in said guide at the operating frequency of said device along said slots, said slots having their major axes substantially parallel to the axes of said guides, and said slots being dimensioned and arranged to produce hybrid coupling between said guides.

4. A signal wave translation device comprising a pair of wave guides having a common directional coupler wall, said common wall having a pair of slots therein adjacent opposite edges thereof, the centers of said pair of slots lying in a line perpendicular to the longitudinal axes of said slots, said slots having their major axes substantially parallel to the axes of said guides, the length of said slots being substantially equal to three-quarters of a wave length of a wave propagated in said guide at the operating frequency of said device along said slots, and said slots being dimensioned and arranged to produce hybrid coupling between said guides.

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