

Aug. 9, 1960

H. HONDA
SIGNAL CHANNELING SYSTEM

2,948,863

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2 Sheets-Sheet 1

FIG. 1.

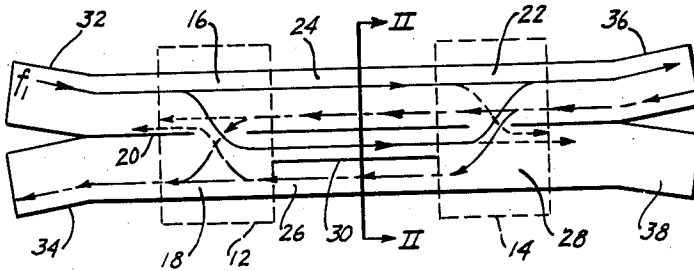
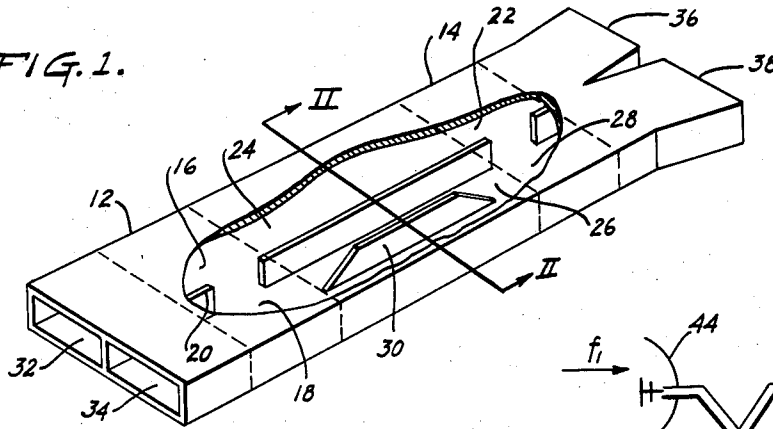


FIG. 1A.

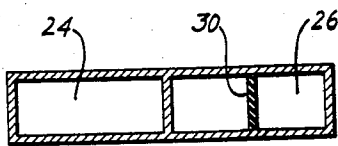


FIG. 2.

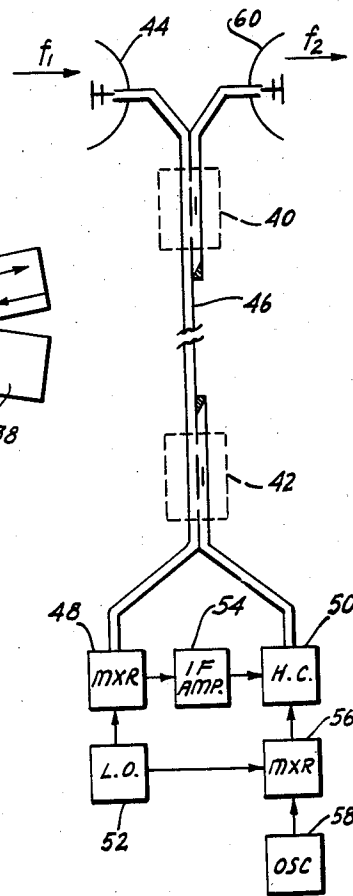


FIG. 3.

INVENTOR.
HAJIME HONDA

BY
Brown, Penk & Lynnestredt
AGENTS

Aug. 9, 1960

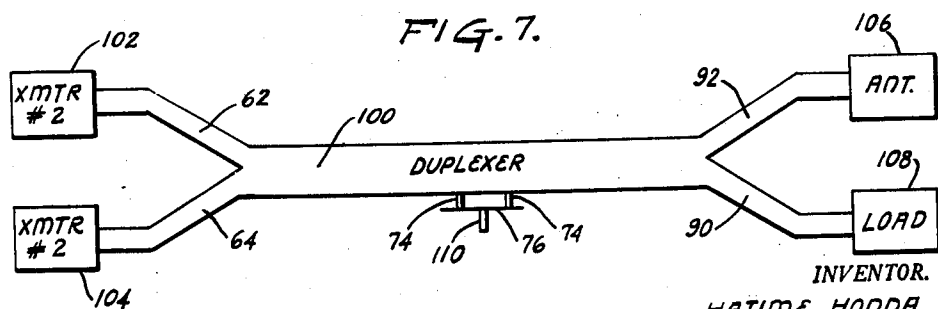
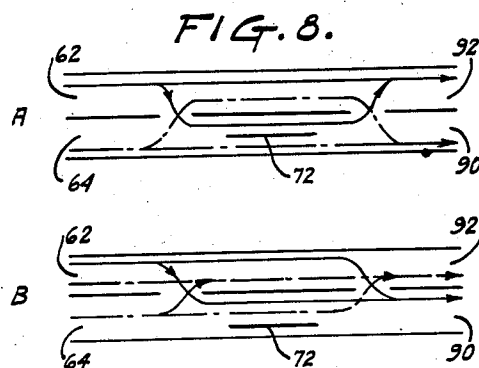
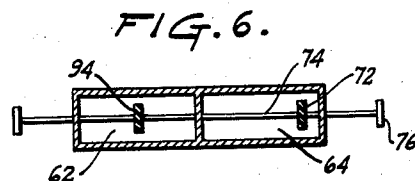
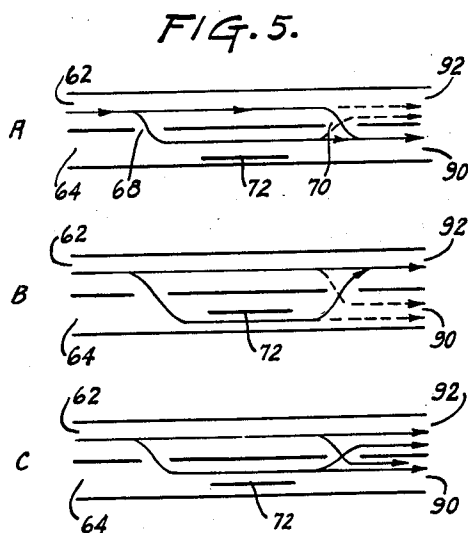
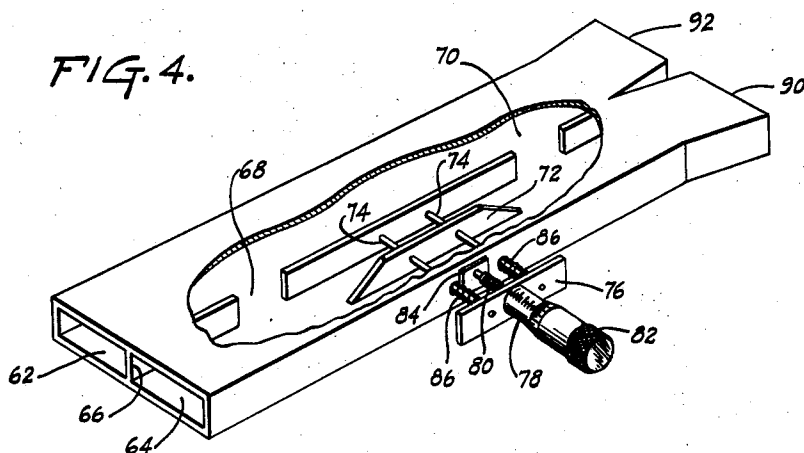
H. HONDA

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2 Sheets-Sheet 2



INVENTOR.

HAJIME HONDA

RY

BY
Brown, Denk & Lynnestredt
AGENTS

AGENTS

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2,948,863

SIGNAL CHANNELING SYSTEM

Hajime Honda, Philadelphia, Pa., assignor to Philco Corporation, Philadelphia, Pa., a corporation of Pennsylvania

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3 Claims. (Cl. 333—10)

This invention relates to waveguide systems and, more particularly, to waveguide systems for channeling a signal from one or more sources to one or more receivers.

In the waveguide art it is often necessary to channel the signal from a generator to two energy receivers such as radiating antennas or the like. In many instances it is desirable to include means for varying the proportions of the energy supplied to the two energy receivers. Waveguide devices for accomplishing this result are known in the art as power dividers. In other instances it is desirable to connect two generators to two antennas or the like and to provide means for interchanging the connection between the generators and the antennas. In still other instances it is desirable to provide a system in which energy at one frequency follows one path through the waveguide system and energy at a different frequency follows a different path through the same system. Systems for accomplishing all of these functions are known in the prior art. However, such systems generally employ waveguide T branches and filters to accomplish the desired channeling of the various signals. These prior art systems suffer from the disadvantages that they are difficult and expensive to construct and that they require considerable space for the various junctions and waveguide filters. Therefore they are not suitable for use in many systems where waveguide space is at a premium. Furthermore, the systems known in the prior art for accomplishing the above results differ substantially from one another and therefore cannot be used interchangeably for accomplishing the results mentioned above.

Therefore it is an object of the present invention to provide a novel and compact waveguide signal channeling system.

It is a further object of the present invention to provide a waveguide system in which the signal may be made to follow a path determined by the frequency of the signal.

It is a further object of the invention to provide a simple, novel waveguide system for connecting one or two generators to one or two loads in a preselected manner.

In general, an embodiment of the invention may comprise two substantially identical directional couplers, each having two input waveguides and two output waveguides. Although there are certain forms of directional couplers which are particularly well suited for use in practicing the present invention, any such couplers may be used which are adapted to supply one-half of the energy received from an input waveguide to each of the two output waveguides and to produce a difference in phase of 90° between the energy in one of the output waveguides and that in the other output waveguide. The output waveguides of one directional coupler are coupled directly to the input waveguides of the other directional coupler by waveguide sections of predetermined length. At least one of these connecting waveguide sections includes a phase shifting device which may or may not be adjustable. Input signals to the waveguide system

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are supplied to the two input waveguides of the first directional coupler and output signals are obtained from the output waveguides of the second directional coupler.

For a better understanding of the invention together with other and further objects thereof reference should now be made to the following detailed description which is to be read in connection with the accompanying drawings in which:

Fig. 1 is a pictorial view, partially broken away, of one preferred embodiment of the present invention;

Fig. 1A is a diagram illustrating the principle of operation of the system of Fig. 1;

Fig. 2 is a cross-sectional view of the system of Fig. 1 taken along the lines II—II of Fig. 1;

Fig. 3 is a schematic diagram of a typical system employing the waveguide coupling system of Fig. 1;

Fig. 4 is a pictorial view, partially broken away, of a second preferred form of the invention;

Fig. 5 with parts A through C, is a diagram illustrating the principle of operation of the system of Fig. 4;

Fig. 6 is a cross-sectional view of still another embodiment of the invention;

Fig. 7 is a schematic diagram of a typical system employing the waveguide system of Fig. 4; and

Fig. 8 with parts A and B, is a diagram illustrating the operation of the system of Fig. 7.

Referring now to Fig. 1, the preferred form of the present invention comprises two short-slot hybrid junctions 12 and 14 of the type described by Henry J. Riblet in an article entitled "The Short-Slot Hybrid Junction," Proceedings of the I.R.E., volume 40, pages 180-184. The short-slot hybrid junction 12 comprises two sections of rectangular waveguide 16 and 18 having a common narrow wall 20. An opening of appropriate dimension is formed in the common narrow wall to permit energy to be transferred from one waveguide to the other. Suitable tuning means, such as capacitive screws or domes (not shown in Fig. 1), may be provided in the vicinity of the slot to provide matching between the waveguides or to correct for errors introduced by the manufacturing process. Directional couplers of this type are commercially available and are currently well known in the art. Waveguide 16 of junction 12 is connected to waveguide 22 of junction 14 by a section of waveguide 24 which is preferably identical in cross-section to waveguides 16 and 22. Similarly a waveguide section 26 connects waveguide 18 of junction 12 to waveguide section 28 of junction 14. A phase shifter 30 is provided in waveguide section 26 for reasons which will appear as the description of the invention proceeds. Phase shifter 30 comprises a dielectric vane extending between and supported by the broader walls of waveguide section 26. The ends of phase shifter 30 are preferably tapered in the manner shown in Fig. 1 to provide a proper impedance match between waveguide 26 and waveguides 18 and 28. Additional waveguide sections 32 and 34 are connected respectively to waveguide sections 16 and 18 of junction 12 to provide means for supplying a signal to and/or receiving a signal from the system. Similarly, waveguide sections 36 and 38 are connected to and form continuations of waveguide sections 22 and 28 of junction 14. As will be obvious to those skilled in the art, waveguide sections 32, 16, 24, 22 and 36 may comprise one continuous waveguide section having two openings formed with one narrow wall at positions corresponding to the slots in junctions 12 and 14. Similarly, waveguide sections 34, 18, 26, 28 and 38 may be formed with a single section of rectangular waveguide.

Fig. 2 shows a typical cross-section of the waveguide system of Fig. 1. Parts in Fig. 2 corresponding to like parts in Fig. 1 bear the same reference numerals. In Fig. 2 the dielectric vane comprising phase shifter 30 is

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shown extending between and supported by the broad walls of waveguide 26. Alternatively this phase shifter 30 may be supported by rods extending parallel to the broad walls of waveguide 26 and suitably supported by the narrow walls of this waveguide. Phase shifters of the type shown in Figs. 1 and 2 are well known in the art and are described in considerable detail in volume 9 of the Radiation Laboratory Series published by the McGraw-Hill Book Company, Inc., New York, N.Y., 1948. The dielectric vane type of phase shifter has been shown in all embodiments of the invention for the reason that it is a simple and highly satisfactory form of phase shifter. However, it will be understood that other forms of phase shifters may be used.

The operation of the system of Fig. 1 will be explained by reference to the diagram of Fig. 1A which is numbered to correspond to Fig. 1. Energy at a frequency f_1 is supplied to waveguide section 32. As shown by the solid line in Fig. 1A, this energy divides equally in junction 12 between waveguide sections 16 and 18. The characteristics of the short-slot junctions are such that the energy in waveguide 18 is 90° out of phase with the energy in waveguide 16. The energy originating in waveguide section 32 passes through waveguide sections 24 and 26 to junction 14. At this point the energy traveling in waveguide section 24 divides equally between waveguide sections 22 and 28. The energy in waveguide section 28 differs 90° in phase from the energy in waveguide section 22. The energy traveling in waveguide 26 is shifted by an odd number of half wavelengths by phase shifter 30. The energy from waveguide section 26 divides equally between waveguide sections 22 and 28 in junction 14. Again the energy in waveguide 22 differs 90° in phase from the energy in waveguide section 28. It will be noted that the energy, traveling in the path including waveguide sections 16, 18, 28 and 22, undergoes a phase shift of an even number of half wavelengths since it is shifted in phase by an odd number of half wavelengths by phase shifter 30 and is shifted in phase by 90° by directional couplers 12 and 14. Therefore this energy will add in phase with energy following the path including waveguide sections 16, 24 and 22. Energy following the path including waveguide sections 16, 24, 22 and 28 will be 180° out of phase with energy following the path including waveguide sections 16, 18, 26 and 28 since these two signals are shifted in phase equally by junctions 12 and 14 respectively, but the latter signal is shifted in phase an additional odd number of half wavelengths by phase shifter 30. Therefore energy following these two paths will cancel in waveguide section 28 so that substantially no energy passes to output waveguide section 38. Perhaps a more accurate method of stating this result is to say that, under the condition assumed above, the impedance of the portion of waveguide 28 leading to output waveguide 38 is such that no energy will enter this branch from waveguides 24 and 26. As mentioned in the above-identified article in the Proceedings of the I.R.E., the characteristics of junctions 12 and 14 are such that substantially no energy is transferred from waveguide 32 to waveguide section 34 through junctions 12 and 14. Therefore, in accordance with the description given above, the energy at frequency f_1 introduced in waveguide section 32 will pass to waveguide section 36 with very little attenuation, and substantially no energy will appear at waveguide sections 34 and 38. The above-mentioned relationship may be expressed in mathematical terms as follows: Let the incoming signal in waveguide 32 equal

$$E/0^\circ$$

where E is expressed in volts. Now if the power divides equally between waveguides 16 and 18, the signal in waveguide 16 is

$$\frac{E}{\sqrt{2}}/0^\circ$$

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and the signal in waveguide 18 is

$$\frac{E}{\sqrt{2}}/-90^\circ$$

- 5 Assuming that the waveguides 24 and 26 introduce a phase shift ϕ determined by their physical length, the two input signals to coupler 14 will be

$$\frac{E}{\sqrt{2}}/-\phi$$

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from waveguide 24, and

$$\frac{E}{\sqrt{2}}/-\phi-270^\circ$$

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from waveguide 26. The signal supplied from coupler 14 to output waveguide 36 will be

$$\frac{E}{2}/-\phi + \frac{E}{2}/-\phi-360^\circ$$

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This may be rewritten as

$$E/-\phi$$

which is the original signal shifted in phase by the angle ϕ in passing through the waveguide.

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Similarly it can be shown that the signal supplied to waveguide 38 is

$$E/2/-\phi-90^\circ + E/2/-\phi-270^\circ$$

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Since these two terms represent two equal signals which are exactly out of phase, the sum is zero.

It can be shown that energy at the frequency f_1 introduced at waveguide section 34 will appear at waveguide section 38, and conversely that energy at frequency f_1 introduced at waveguide sections 36 and 38, respectively, will appear at output sections 32 and 34, respectively.

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Suppose now that energy at frequency f_2 is introduced into a waveguide section 36. Suppose further that the frequency f_2 is such that phase shifter 30 provides a phase shift equal to an integral number of wavelengths at the frequency f_2 . By tracing this signal through the system of Fig. 1, it can be shown that energy will pass from waveguide section 36 to output waveguide section 34 but that substantially no energy will pass from waveguide section 36 to waveguide sections 32 or 38. Similarly it can be shown that energy introduced at waveguide section 34 will appear at waveguide section 36 with substantially no energy being supplied to waveguide sections 32 and 38. This immediately suggests the application of the present invention to systems in which two separate generators are connected to a common load. The generators may be connected to waveguides 32 and 34 respectively and the common load may be connected to waveguide 36. Connected in this manner, the waveguide channeling system of Fig. 1 will provide excellent isolation between the two generators. If no connection is made to waveguide 38, this path should be terminated in its characteristic impedance by a suitable resistive load for the purpose of absorbing any energy that may stray into this branch due to irregularities in the manufacture of the junction, the phase shifter 30 or the like.

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Another application of the waveguide channeling system of Fig. 1 is shown in Fig. 3. The system of Fig. 3 is a typical microwave repeater system which receives signals of one frequency f_1 and retransmits these signals at a second frequency f_2 . The system of Fig. 3 employs two waveguide channeling systems 40 and 42 of the type shown in Fig. 1. In the system of Fig. 3 energy at frequency f_1 is received by antenna 44 and supplied through system 40 to waveguide section 46. Energy traveling down waveguide section 46 passes through system 42 to a suitable mixer circuit 48. As explained in connection with the description of Fig. 1, substantially no energy at frequency f_1 passes down the other branch of the waveguide leading to heterodyne con-

verter 50. A signal from a local oscillator 52 is supplied to mixer 48 to convert the received signals to signals at an intermediate frequency which are amplified in intermediate frequency amplifier 54 and supplied to heterodyne converter 50. A signal from local oscillator 52 is also supplied to a second mixer 56 which receives a second signal from oscillator 58 having a frequency equal to the difference between the frequencies f_1 and f_2 . The signal at the frequency f_2 is supplied by heterodyne converter 50 to channeling system 42 where it passes to waveguide 46 with substantially no energy being coupled back to mixer 48. The energy at the frequency f_2 , traveling up from waveguide section 46, passes through channeling system 40 to transmitting antenna 60 where it is radiated in a desired direction. In a system of the type shown in Fig. 3 the same result can be accomplished by employing separate waveguides from the antenna 44 to mixer 48 and from antenna 60 to heterodyne converter 50. However, one of these waveguides, which may be several hundred feet long, may be omitted as shown in Fig. 3 by including channeling systems 40 and 42 in the system. The advantages of employing a channeling system of the type shown in Fig. 1 in a waveguide system is even more apparent where a single antenna is employed for transmitting and receiving. This antenna may be so arranged that the energy is transmitted in a direction different from that from which it is received by virtue of the fact that it is of different frequency. In such an instance only the junction shown at 42 is required since waveguide 46 would lead to the single antenna. In this latter system, channeling system 42 is necessary in order to isolate the mixer 48 from the heterodyne converter 50. Many other uses for the embodiment shown in Fig. 1 will occur to those working in the waveguide art.

Fig. 4 illustrates a second preferred embodiment of the invention which is similar to the system of Fig. 1 except that the phase shifter which forms part of the invention is made adjustable. The embodiment shown in Fig. 4 comprises two rectangular waveguide sections 62 and 64 which have a common narrow wall 66. Openings 68 and 70 are provided in the common narrow wall 66 to serve as short-slot junctions between waveguides 62 and 64. A dielectric vane phase shifter 72 is supported on rods 74 which extend parallel to the broad wall of waveguide 64. Rods 74 are joined together by a transverse cross member 76 which causes rods 74 to move together and thus maintain dielectric member 72 parallel to the narrow wall of waveguide 64. Motion of rods 74, and hence of dielectric member 72, is effected by means of a micrometer screw of conventional form comprising an internally threaded hub portion 78 which is affixed to transverse member 76 and an externally threaded spindle portion 80 having a sleeve and thimble 82. The end of spindle 80 is biased against pad 84 on the narrow wall of waveguide 64 by tension springs 86 disposed on supporting rods 74. Hub 78 and sleeve 82 may be provided with the usual indicia which indicate the precise position of dielectric member 72. One typical mode of operation of the system of Fig. 4 will be explained by reference to the diagrams of Figs. 5A through 5C. In Fig. 5A it is assumed that dielectric member 72 is so positioned that it introduces an even number of half wavelengths phase shift in the signal supplied to waveguide 62. As explained in connection with the system of Fig. 1, under these conditions energy introduced at waveguide 62 will pass through slots 68 and 70 and continue along waveguide 64 to output waveguide 90. Substantially no energy will pass from waveguide 62 to output waveguide 92. If the position of dielectric member 72 is altered by rotating sleeve 82 so that the phase shift introduced by dielectric member 72 is equal to an odd number of half wavelengths at the frequency of the signal introduced at waveguide

62, energy will pass from waveguide 62 to output waveguide 92 as shown in Fig. 5B. Under these conditions substantially no energy will pass from waveguide 62 to output waveguide 90. If dielectric member 72 is positioned so that it provides a phase shift which lies somewhere between an odd number of half wavelengths and an even number of half wavelengths, energy introduced at waveguide 62 will divide between output waveguides 90 and 92 in a ratio determined by the phase shift provided by dielectric member 72. It should be apparent from the above description that the system of Fig. 4, operated in this manner, constitutes a variable power divider which will divide energy in any desired ratio between output waveguides 90 and 92. It should also be clear that hub 78 and sleeve 82 may be calibrated in terms of power ratio or a suitable calibration chart may be provided relating the particular indicia inscribed on these two members to the power division ratio of the waveguide channeling system.

Fig. 6 is a cross-sectional view of a modified form of the system of Fig. 4. Parts in Fig. 6 corresponding to like parts in Fig. 4 bear the same reference numerals. The system of Fig. 6 differs from the system of Fig. 4 in that rods 74 are extended through waveguide 62 to support a second dielectric member 94 within waveguide 62. Dielectric members 72 and 94 are so positioned on rods 74 that movement of these rods will increase the phase shift in one waveguide while decreasing the phase shift in the other waveguide. The use of two dielectric members in this manner increases the change in power division ratio for a given amount of movement of rods 74. In an alternative form of the invention, dielectric vanes 72 and 94 may be positioned so that movement of the rods 74 produces a change in phase shift in the same direction but in unequal amounts in the two waveguides. In such an embodiment of the invention, the total range of power division ratio may be reduced to a small finite value but the accuracy of establishment of the division ratio is correspondingly increased since a given movement of the rods 74 provides a smaller change in the division ratio. Such an embodiment of the invention is useful where the power division ratio is to be varied over a very limited range.

Fig. 7 illustrates still another application of the system of Fig. 4. In Fig. 7, duplexer 100 corresponds to the waveguide channeling system shown in Fig. 4. A first transmitter 102 is connected to waveguide 62 and a second transmitter 104 is connected to waveguide 64. Transmitter 102 may be the main transmitter in a microwave relay system and transmitter 104 may be the standby transmitter of the relay system. Output waveguide 92 of duplexer 100 is connected to a transmitting antenna 106. An output waveguide 90 is connected to a dummy load 108 which has the same characteristic impedance as antenna 106. In the embodiment of the invention shown in Fig. 7 it is not necessary that the position of dielectric member 72 be micrometrically adjustable. It is sufficient if this member is movable between two accurately determined positions which represent, respectively, an odd number of half wavelengths of phase shift of energy in waveguide 64 and an even number of half wavelengths of phase shift in the same waveguide. Therefore, the micrometer of Fig. 4 has been replaced in Fig. 7 by a simple operating handle 110.

Figs. 8A and 8B illustrate the preferred method of operation of the system of Fig. 7. As shown in Fig. 8A, energy supplied by the main transmitter 102 to waveguide 62 is transferred via output waveguide 92 to antenna 106. Energy supplied by standby transmitter 104 to waveguide 64 is supplied via output waveguide 90 to load 108 with substantially none of the energy from the standby transmitter 104 passing to the antenna 106. However, the operation of standby transmitter 104 will

be substantially the same as if it were connected to antenna 106 since load 104 has a characteristic impedance identical to that of antenna 106. If, for some reason, main transmitter 104 should not function properly, standby transmitter 104 may be placed in operation by moving operating handle 110 to a position that will cause dielectric member 72 to introduce a phase shift of an even number of half wavelengths in waveguide 64. Under these conditions energy from standby transmitter 104 will pass from waveguide 64 to output waveguide 92 and from there to the transmitting antenna 106. Energy from main transmitter 102 will pass from waveguide 62 through output waveguide 90 to the dummy load 108. If transmitters 102 and 104 are supplied with the same input signal, service at the relay station may be continued without interruption, even though a fault develops in transmitter 102, by providing suitable automatic means for shifting the position of operating handle 110.

Many other applications of the novel system shown and described above will occur to those skilled in the art. Therefore the present invention should not be limited in any way by the illustrative examples included above. While I have described what are at present considered to be the preferred embodiments of the invention, the true scope of the invention is pointed out with greater particularity by the hereinafter appended claims.

What is claimed is:

1. A waveguide channeling system comprising first and second waveguide directional couplers, each of said directional couplers having two input waveguides and two output waveguides, the characteristics of said directional couplers being such that energy introduced into either input waveguide divides equally between the two output waveguides with the energy in one output waveguide shifted 90° in phase with respect to energy into the other output waveguide, a first waveguide section coupling an output waveguide of said first directional coupler to an input waveguide of said second directional coupler, and a second waveguide section coupling the other output waveguide of said first directional coupler to the other input waveguide of said second directional coupler, first and second adjustable phase shifting means disposed in said first and second waveguide sections, respectively, and means associated with said two phase shifting means

for simultaneously adjusting said phase shifting means, said adjustment being such as to vary the effective electrical lengths of said two waveguide sections in the same direction and by unequal amounts.

2. A waveguide channeling system comprising first and second juxtaposed rectangular waveguides, said waveguides having a common narrow wall, said common narrow wall being formed with first and second spaced openings therein, each of said openings forming a short-slot hybrid junction between said two waveguides, a first phase shifting means disposed in said first waveguide in a region intermediate said two openings, a second phase shifting means disposed in said second waveguide in a region intermediate said two openings, and means associated with said two phase shifting means for simultaneously adjusting said phase shifting means, said adjustment being such as to vary the effective electrical length of said regions of said first and second waveguides between said two openings in the same direction and by unequal amounts.

3. A waveguide channeling system comprising first and second juxtaposed rectangular waveguides, said rectangular waveguides having a common narrow wall, said common narrow wall being formed with first and second spaced openings therein, each of said openings forming a short-slot hybrid junction between said two rectangular waveguides, a first dielectric vane phase shifter disposed in said first waveguide in a region intermediate said two openings, a second dielectric vane phase shifter disposed in said second waveguide in a region intermediate said two openings, means associated with said two dielectric vane phase shifters for simultaneously moving said dielectric vane phase shifters in directions parallel to the longer transverse axis of said rectangular waveguides, said adjustment being such as to vary the effective electrical length of said regions of said first and second waveguides between said two openings in the same direction but by unequal amounts.

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