

April 1, 1958

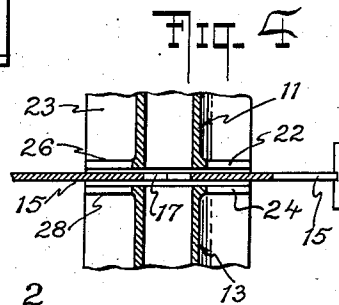
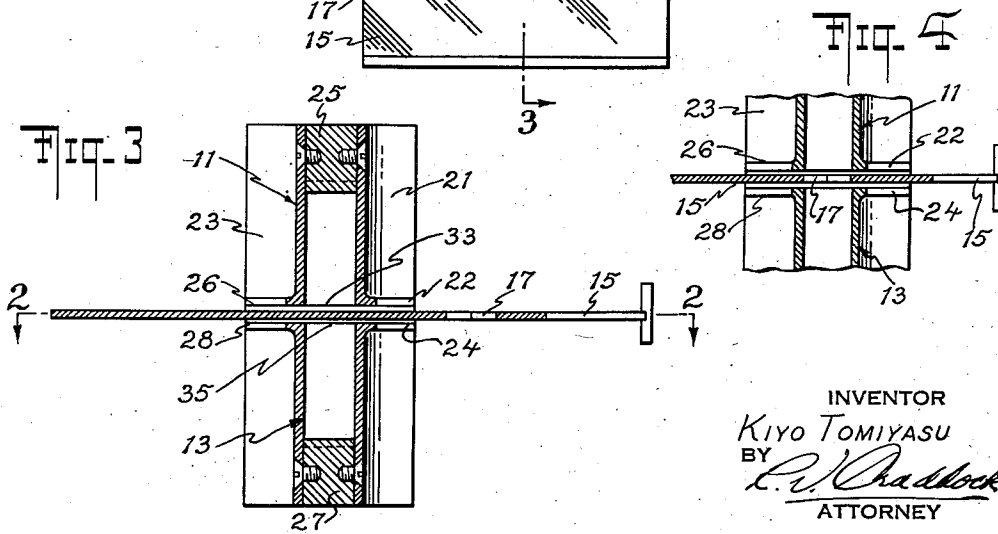
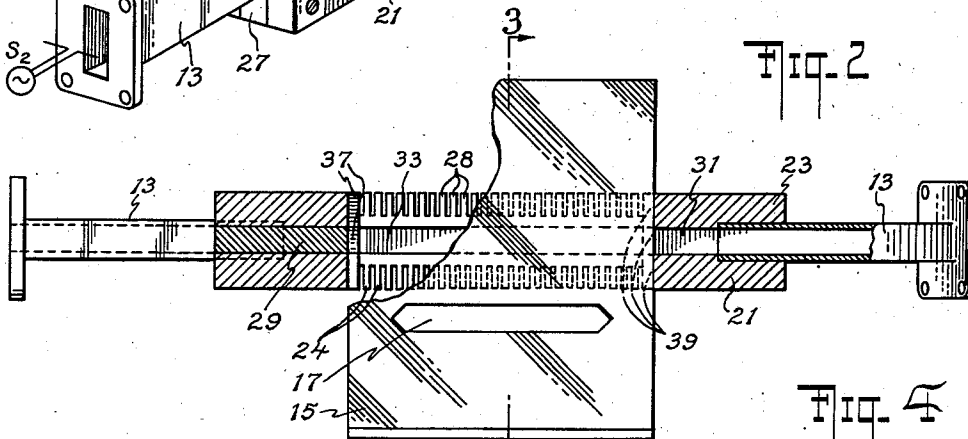
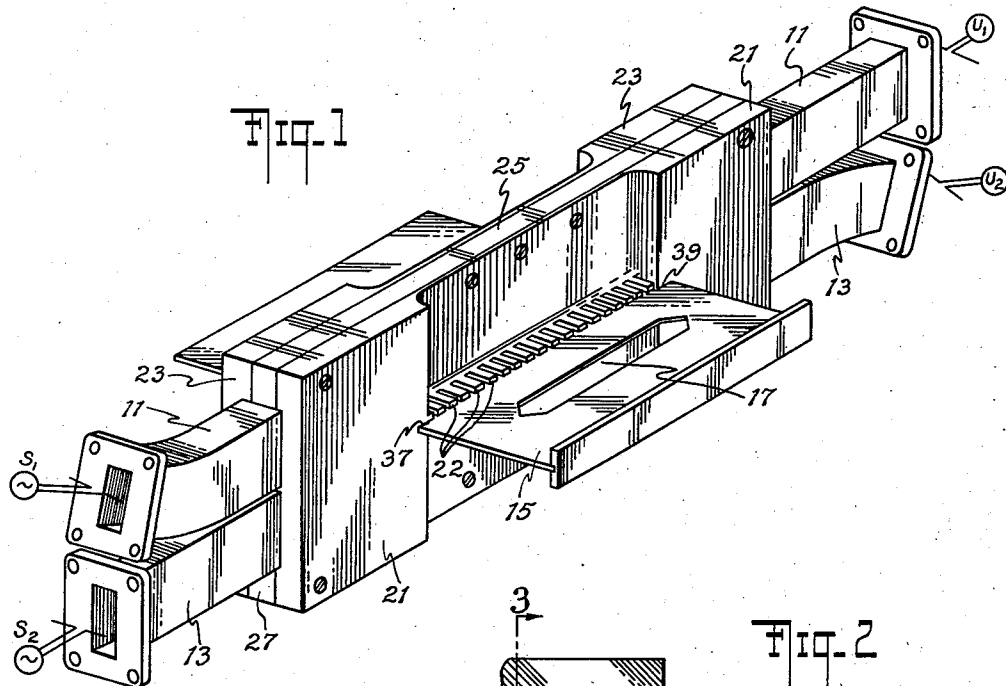
KIYO TOMIYASU

2,829,347

SELECTIVE TRANSFER DEVICE FOR MICROWAVE ENERGY

Filed June 13, 1956

5 Sheets-Sheet 1



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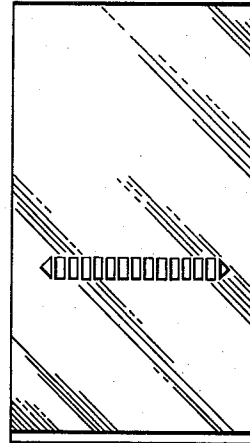
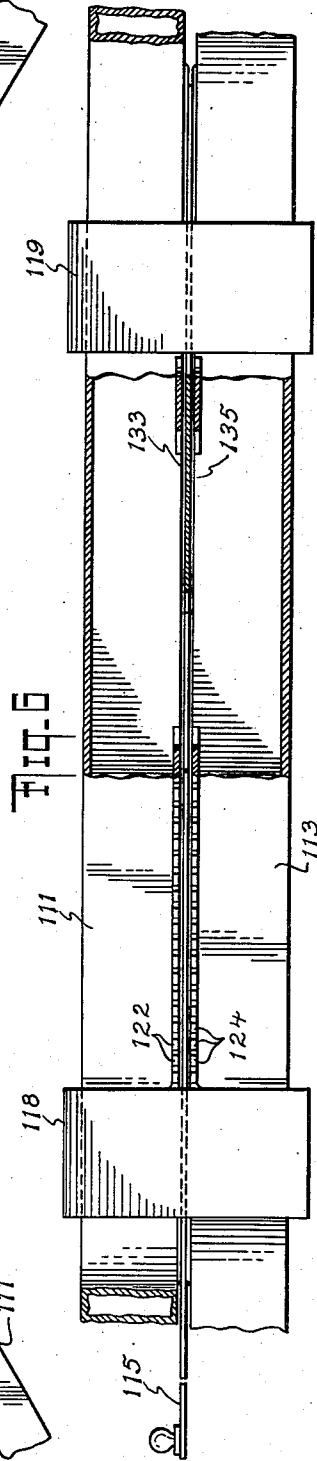
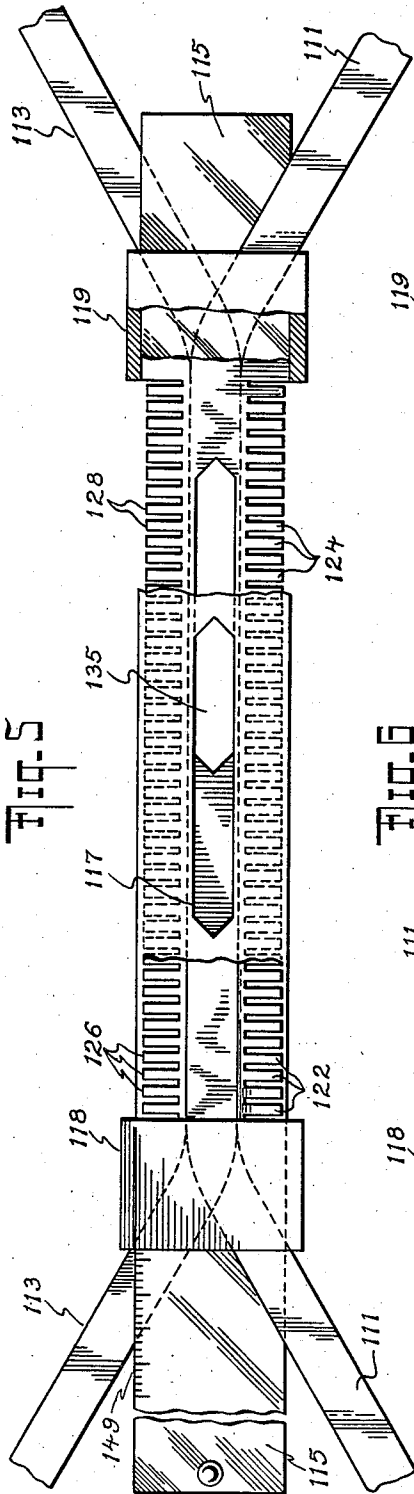
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SELECTIVE TRANSFER DEVICE FOR MICROWAVE ENERGY

Filed June 13, 1956

5 Sheets-Sheet 2



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SELECTIVE TRANSFER DEVICE FOR MICROWAVE ENERGY

Filed June 13, 1956

5 Sheets-Sheet 3

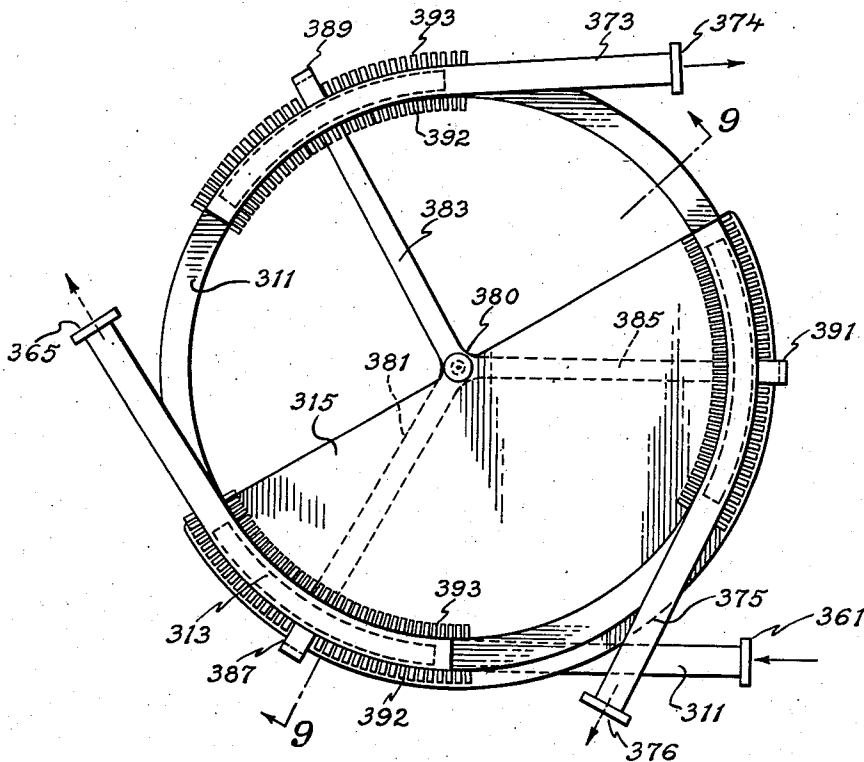


FIG. 8

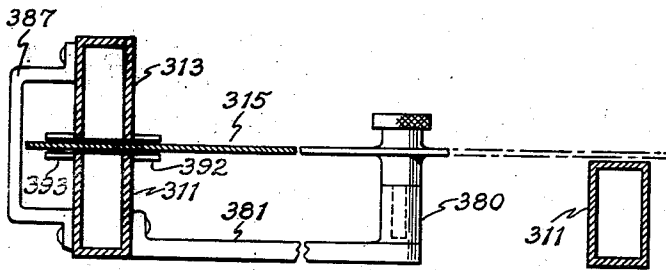


FIG. 9

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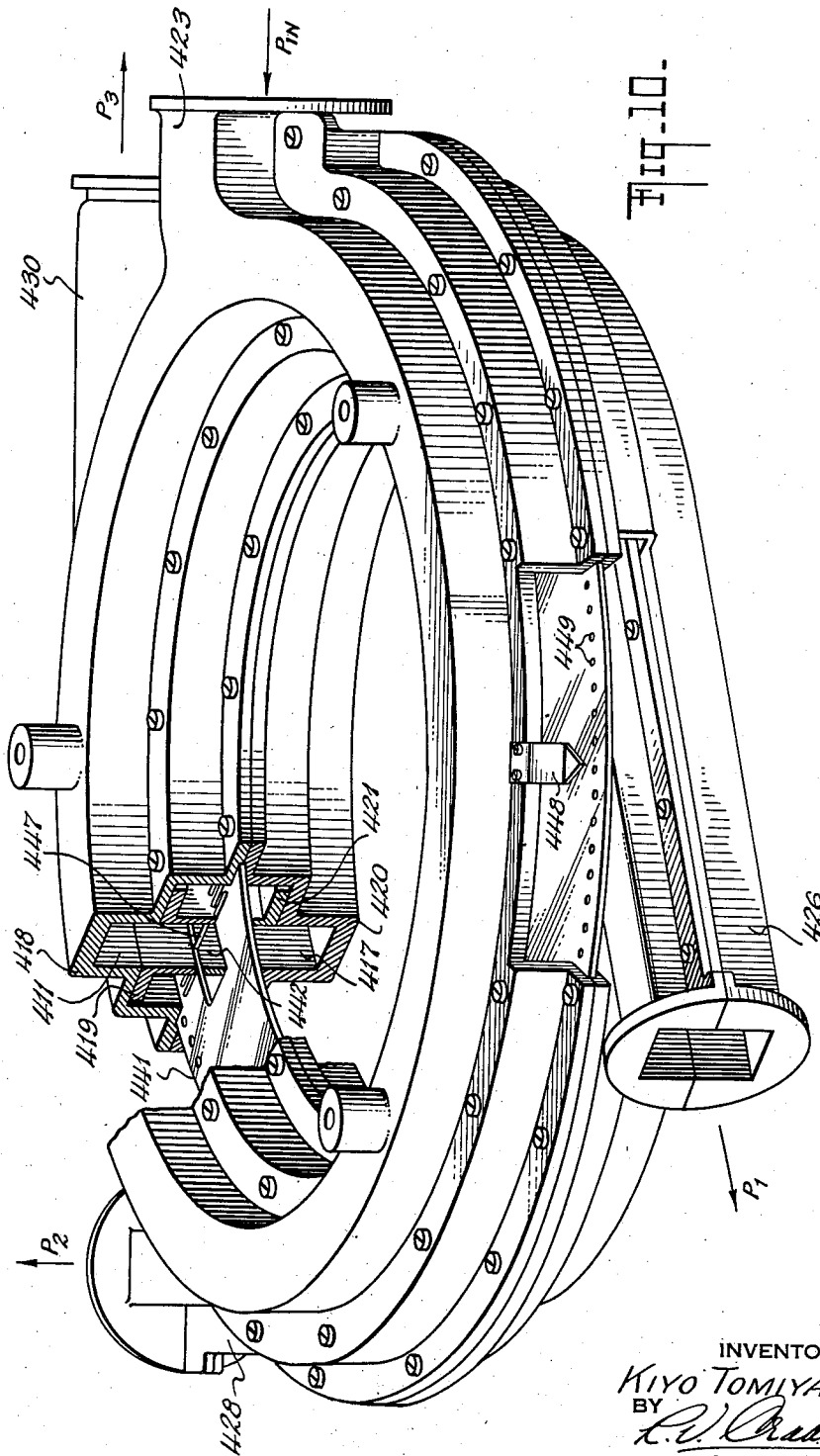
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SELECTIVE TRANSFER DEVICE FOR MICROWAVE ENERGY

Filed June 13, 1956

5 Sheets-Sheet 4



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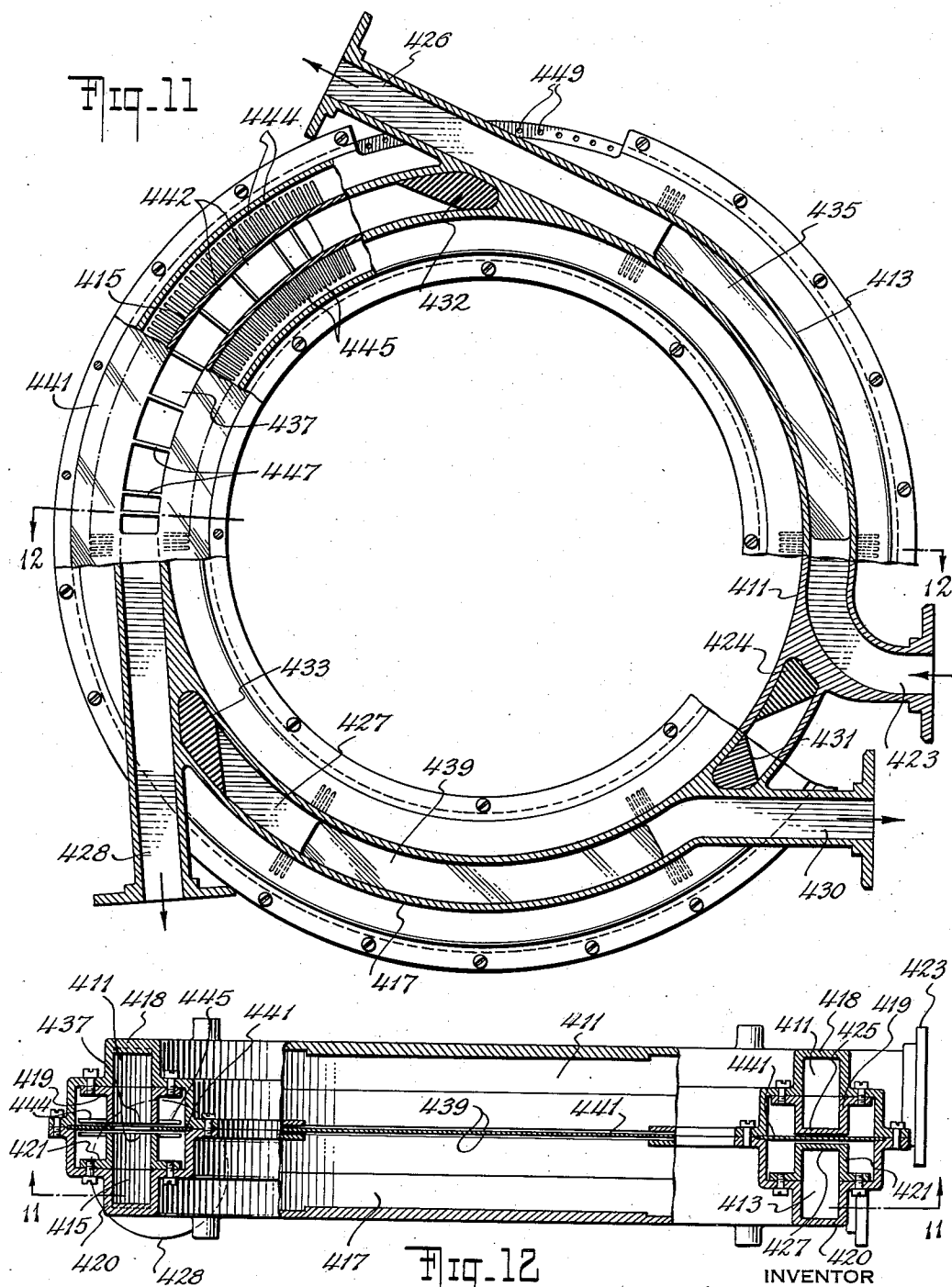
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SELECTIVE TRANSFER DEVICE FOR MICROWAVE ENERGY

Filed June 13, 1956

5 Sheets-Sheet 5



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2,829,347

SELECTIVE TRANSFER DEVICE FOR MICROWAVE ENERGY

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Application June 13, 1956, Serial No. 592,231

10 Claims. (Cl. 333—7)

The present invention relates to waveguide apparatus for microwave energy, and is particularly concerned with energy transfer apparatus for selective transfer of energy between a plurality of waveguides. This application is a continuation-in-part of U. S. patent application S. N. 213,276, by K. Tomiyasu, filed February 21, 1951.

An object of the invention is to provide improved microwave energy path control apparatus.

More specifically, it is an object to provide improved apparatus for selectively transferring energy from one waveguide to another, and for control of the energy transfer.

A further object is to provide improved apparatus for receiving microwave energy through one waveguide and selectively routing it through one or another of plural output waveguide routes.

Another object is to provide improved apparatus for receiving microwave energy through one waveguide and selectively routing it through one and only one of a plurality of output waveguides.

Yet another object is to provide a compact, improved structure for variable directive coupling between first and second waveguides.

These objectives are met by providing two waveguides fixed in adjacent positions with respective waveguide sections thereof parallel, and providing registering openings in the adjacent walls of the parallel waveguide sections for energy transfer therebetween.

These openings are made of such breadth and length as to provide complete directional transfer of the microwave energy from one of the waveguides to the other, in accordance with the principles of patent application Serial No. 197,064, filed November 22, 1950, in the names of Kiyo Tomiyasu and Seymour B. Cohn.

A movable shutter area of conductive material is interposed between the guides to obstruct the region of communication therebetween, e. g. to totally block the registering openings and to insure confinement of an energy component arriving in one of the two waveguides to continuance of propagation in that waveguide. The shutter element is arranged in such a way as to be shiftable to unblock the area of said openings, wholly or partially, and to bring about transfer of all or a substantial part of the microwave energy from one waveguide to the other, or from each supplied waveguide to each other.

Representative embodiments of the present invention are illustrated in the drawings.

Fig. 1 is a perspective view of an energy path control apparatus arranged to serve effectively as a double-throw switch mechanism, for total retention of energy in one wave guide, or for total transfer of energy therefrom to the other of the two waveguides;

Fig. 2 is a longitudinal sectional view of the structure of Fig. 1, taken on the line 2—2 in Fig. 3;

Fig. 3 is a cross-sectional view of the structure of Fig. 1 taken on the line 3—3 in Fig. 2;

Fig. 4 is a fragmentary cross-sectional view illustrating

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the same structure as shown in Fig. 3 but with the shutter element positioned for total energy transfer from one waveguide to the other;

Fig. 5 is a plan view of a longitudinally adjustable shutter embodiment of the present invention, parts being broken away and parts shown in section, for clarity of illustration;

Fig. 6 is a side elevation of the embodiment of Fig. 5, parts likewise being broken away for clarity of illustration;

Fig. 7 is a drawing of a modification of the shutter 15 of Figs. 1—4;

Fig. 8 is a plan view of a multi-circuit switching structure embodying the present invention;

Fig. 9 is a cross-sectional view of the structure of Fig. 8, taken on the line 12—12 therein;

Fig. 10 is a perspective view, partly in cross-section, of a modified multi-circuit switching structure embodying the present invention;

Fig. 11 is a cross-sectional view, partly broken away, looking up at the structure of Fig. 10; and

Fig. 12 is a cross-sectional view, partly broken away, of the structure of Fig. 11.

The embodiment illustrated in Figs. 1—4 basically includes a first waveguide 11 and a second waveguide 13 rigidly fixed together, with sections of appreciable length in the respective waveguides 11 and 13 positioned parallel and adjacent to each other. Registering openings are provided in the adjacent walls of the respective sections of waveguides 11 and 13, and a shutter element 15 is arranged for transverse sliding movement between these sections of waveguides 11 and 13.

The slide or shutter element 15 is provided with a longitudinal opening 17, so located that the shutter 15 may be moved to a position at which the opening 17 is situated directly between the parallel and adjacent sections of waveguides 11 and 13, permitting energy communication from one of the two guides to the other through the openings therein.

The openings in the waveguides and the opening 17 in shutter 15 are so arranged that when the shutter opening and the waveguide openings are in register, complete directional energy transfer occurs through the openings, from one waveguide to the other. When the slide element 15 has been moved to the position with opening 17 remote from the openings in the parallel waveguide sections, the passage between the waveguides 11 and 13 is closed, and accordingly any energy supplied to one end of one waveguide proceeds directly therethrough to the other end thereof with substantially complete freedom from energy transfer over to the other waveguide. The shutter or slide element 15 is illustrated in Figs. 1, 2 and 3 as positioned for this zero-transfer condition.

The construction chosen for the embodiment illustrated in Figs. 1—4 involves rectangular tubing sections at the ends of the waveguides 11 and 13, the relatively long parallel middle sections of the waveguides 11 and 13 being made up as a composite structure including first and second side plates 21 and 23, upper and lower intermediate longitudinal pieces 25 and 27, and partition elements 29 and 31 (Fig. 2). The inside surfaces of said plates 21 and 23, in the space between the left-hand and right-hand rectangular tubular portions of the waveguides as seen in Figs. 1 and 2, serve as the interior side wall surfaces of the two waveguides. The upper and lower intermediate pieces 25 and 27 serve not only to afford a mechanically rigid assembly with the side plates 21 and 23, but also, these pieces serve as continuations of the narrow wall surfaces of the respective waveguides, between the left-hand rectangular tubing sections and the right-hand rectangular tubing sections.

Partition element 29 shown in Fig. 2 serves simultaneously as a portion of the lower interior wall surface of the upper wave guide 11, and a portion of the upper interior wall surface of the lower waveguide 13, reaching to the left-hand ends of the openings 33 and 35 in the upper and lower waveguides 11 and 13, respectively. Similarly, partition element 31 serves as an extension of the adjacent narrow interior wall surfaces of the waveguides, between the ends of the right-hand rectangular tubing sections of waveguides 11 and 13 and the right-hand ends of the openings 33 and 35.

The shutter 15 is supported at its left edge in milled conformal slots 37 in the side plates 21 and 23 and partition element 29, and at its right edge, similarly, in milled conformal slots 39 in the side plates 21 and 23 and partition element 31. These slots accurately position shutter 15 and act as guides for the transverse sliding movement thereof.

Extensive recesses are milled in the middle region of said plates 21 and 23, in such a way as to leave flanges extending along the regions thereof adjacent the operating location of shutter 15. These flanges are provided with a series of transverse cuts, in such a way as to form them into serrated chokes 22, 24, 26 and 28, each comprising a series of transversely extending tines parallel to and spaced slightly from the surface of shutter 15.

The length of the tines of the serrated chokes 22, 24, 26 and 28 is preferably of the order of one-fourth wavelength, and the width and spacing between tines and spacing of the tines from the shutter 15 are preferably much smaller than one-fourth wavelength. As an example, three or more tines may be included within a distance of one-fourth wavelength along the serrated choke (i. e., transverse the direction of extension of the tines).

Such serrated chokes per se are described and claimed in U. S. patent application Serial No. 197,063, filed November 22, 1950, in the name of the present inventor.

The rectangular tubing sections of the ends of the waveguides preferably are recessed within the ends of the composite assembly formed of elements 21, 23, 25, 27, 29 and 31, for full alignment and continuity of the interior waveguide wall surfaces; and good electrical continuity between the tubing ends and the composite structure is provided by soldered junctions thereof. The outer ends of the rectangular tubing sections of waveguides 11 and 13 may be provided with flanges, as illustrated in Figs. 1 and 2, for convenience of connection to further waveguide elements or other microwave apparatus.

In the structure illustrated in Figs. 1 and 2, the openings 33 and 35 in the respective wave guides 11 and 13 are appreciably longer than the opening 17 in shutter 15. Accordingly, the length of the opening 17 determines the effective length of the region of intercoupling between the waveguides 11 and 13 when the shutter is in the position illustrated in Fig. 4 for permitting energy transfer between guides 11 and 13. This effective length of the region of communication is of considerable importance to the operation of the structure; and for a given operating frequency, and given internal dimensions of the wave guides 11 and 13, this length of opening 17 may be arranged to provide complete energy transfer from one waveguide to the other with retention of directional energy transmission. With a greater or lesser length of the opening, partial energy transfer is accomplished between the waveguides, with maintained direction of transmission, the incident energy being thus divided into a transferred component and a component transmitted onward through the guide through which it arrived. Thus, if the structure is to serve primarily as a transfer switch system, the opening 17 must be made to be of that length which provides 100% energy transfer.

The principles of operation of this type of coupler system are closely related to those set forth in detail in patent application Serial No. 197,064, filed November

22, 1950, in the names of the present inventor and Seymour B. Cohn as joint inventors.

As explained in the application above referred to, the operation of this type of coupler system involves the consideration of two modes of wave energy propagation which prevail in the mutually adjacent waveguide portions whose interiors are exposed to each other through the longitudinally extensive openings in the respective guides. It is customary to design a rectangular waveguide for efficient transmission of energy of a known frequency, the mode of transmission being a fundamental mode of the guide usually referred to as the $TE_{1,0}$ mode. This is the dominant transverse electric mode. The "a" dimension of the simple rectangular waveguide ordinarily is such as to prevent it from transmitting energy of this frequency in any of the known higher modes.

When two of such waveguides are juxtaposed with their narrower walls mutually adjacent, and these adjacent narrower walls are opened throughout an appreciable longitudinal extent, the effect is to substantially double the "a" dimension of this waveguide portion. This effectively enlarged waveguide portion is then capable of supporting energy in two modes of propagation, the first being closely related to the simple transverse electric mode $TE_{1,0}$ described in connection with the basic waveguide section, and the second mode being the "asymmetrical" mode designated $TE_{2,0}$. If inductive loading is provided as by the use of a series of spaced cross-bars each extending across the opening in one of the waveguides (or across the opening in the shutter element), such inductive loading brings about a departure of the symmetrical mode from the normal character of a $TE_{1,0}$ energy distribution in the enlarged waveguide section.

Whether or not inductive loading is provided, the symmetrical mode and the asymmetrical mode are propagated along the doubled waveguide section at different phase velocities. At the point of entrance of the energy into the doubled wave guide section, they are in phase in the lower guide (i. e., in waveguide 13), assuming this guide only is supplied with energy at its left-hand end, as by a source S_2 . At the point of entrance into the doubled waveguide section, these components are in phase opposition in the upper waveguide (waveguide 11). Farther along the doubled waveguide section, however, the two components approach cophasality in the upper guide, even as they approach phase opposition in the lower guide. If the effective length of the opening between the guides is sufficient, complete energy transfer takes place from the lower guide to the upper guide with unidirectional propagation being maintained, away from the source end (S_2) and toward the opposite end of the structure, i. e., toward the right-hand end of wave guide 11.

If the effective length of the openings is less or greater than the length for complete energy transfer, then the energy will be divided, part of it being transferred and proceeding outward toward the right-hand end of waveguide 11 to utilization device U_1 , the remaining part of the incident energy from source S_2 being retained in waveguide 13 and delivered to utilization device U_2 .

If inductance cross-bars are provided across the opening in one of the waveguides, or across the opening 17 in shutter 15, as illustrated in Fig. 7, the effective length of the opening for complete energy transfer from one guide to the other must be appreciably greater, for example, three times greater than the effective length of the opening where no cross-bars are employed.

If desired, energy from two or more sources may be handled by the structure shown in Figs. 1-4 simultaneously. For example, a source S_1 may be coupled to the left-hand end of waveguide 11 and a source S_2 may concurrently supply energy to the left-hand end of waveguide 13. These sources need not be of equal frequencies, nor need they be specially related as to their amplitudes. It is only necessary that their frequencies be within the

design frequency range of operation of the structure. With the shutter positioned in such a way as to completely block the openings, as shown in Figs. 1-3, all of the energy from source S_1 proceeds directly through to utilization device U_1 , and all of the energy from source S_2 proceeds directly through waveguide 13 to utilization device U_2 .

A shift of the shutter 15 to situate the opening 17 directly between the wave guides 11 and 13, as illustrated in Fig. 4, brings about a complete interchange of the communication circuits, so that the energy from source S_1 is then delivered to utilization device U_2 and the energy from source S_2 is delivered to utilization device U_1 . Because of the appreciable longitudinal distribution of the coupling between waveguides 11 and 13, the transfer of energy proceeding from source S_1 , over to waveguide 13, is accomplished with negligible leftward propagation (towards source S_2), and likewise, the transfer of energy proceeding from source S_2 , over to waveguide 11, is accomplished with negligible propagation in waveguide 11 toward the left-hand end thereof.

Typical dimensions for an operating frequency of 10,000 megacycles per second are as follows:

	Inches
Width (I. D.) of each waveguide.....	0.40
Height (I. D.) of each waveguide.....	0.90
Width of waveguide openings.....	0.40
Width of opening 17 in shutter 15.....	0.40
Length of waveguide openings.....	3.9
Length of straight sides of opening 17.....	2.62
Length of opening 17.....	3.0

The waveguide walls extend close to the surface of the shutter 15, but are slightly spaced therefrom, substantially equally as the tines of the serrated chokes are spaced from the shutter, as is clearly seen in Fig. 3. Preferably, for providing maximum continuity of transmission through the wave guides and avoiding small energy reflection components which could result from the effectively increased "a" dimension from the lower surface of piece 25 down to the upper surface of shutter 15, and the similarly increased "a" dimension from the upper surface of piece 27 to the lower surface of shutter 15, it is desirable to provide a longitudinally extensive boss or plate on each of pieces 25 and 27 coextensive with the waveguide openings 33 and 35, and of thickness equal to or slightly less than one-half the thickness of partition elements 29 and 31. By this arrangement, the effective "a" dimension throughout each waveguide is substantially uniform when the shutter 15 is positioned as shown in Fig. 3 for preventing energy transfer between the two waveguides.

By making the length of the openings in the waveguides appreciably greater than the effective length for full energy transfer, an advantage of simplified construction is realized in that the constructor is enabled to make an experimental opening 17 in shutter 15, and if such opening proves to be of insufficient length, it may be extended by a relatively simple machining operation, or a series of operations, until the desired result is obtained. Similarly, for a given set of wave guides 11 and 13, various shutters with different lengths of the openings may be provided for complete energy transfer at a plurality of respective wave lengths, or on the other hand, openings of various lengths in the shutters may be provided for various amounts of energy transfer.

In the embodiment shown in Figs. 5 and 6, upper and lower waveguides 111 and 113 are fixed together as by structural elements 118 and 119, and an elongated shutter 115 is provided for longitudinal adjustment of its position between the elongated parallel sections of waveguides 111 and 113.

Serrated chokes 122, 124, 126, 128 are provided for affording the electrical effect substantially equivalent to direct junctions between shutter 115 and the walls of the upper and lower waveguides, without the requirement

of direct friction contact, and for preventing the escape of energy from the confinement within the waveguides.

The elongated shutter 115 is guided in suitable grooves therefor in the structural elements 118 and 119, and is slightly spaced from the tines of the serrated chokes 122, 124, 126, 128 and from the adjacent edges of the waveguides 111 and 113.

Matching openings 133 and 135 are provided in waveguides 111 and 113, respectively, and an opening 117 which may be of similar configuration and of equal size, if desired, is provided in the shutter 115.

These openings are so situated that the shutter 115, shown set for a position of partial power transfer, may be moved to the right to a position of full register of the three openings, for full transfer, or may be moved to the left to a position completely preventing energy transfer from one waveguide to the other.

It is not essential for the length of the opening in the shutter to be exactly equal to the length of the openings in the waveguides since in any event the performance of the system is determined by the length of the effective opening for a given shutter setting.

It will be readily appreciated that the embodiment of Figs. 5 and 6 is usable in the same ways in which the embodiment of Figs. 1-4 may be used, for providing parallel transmission or crossed-over transmission, in two simultaneous communication paths, if desired. The structure of Figs. 5 and 6, however, has the additional feature that the degree of energy transfer may be continuously varied from the condition of substantially complete transmission directly through one waveguide (or in parallel paths through the parallel waveguides), to the condition of complete power interchange between the waveguides. This structure of Figs. 5 and 6 is thus suited for all of the applications for which the coupler of U. S. patent application Serial No. 197,064 is suited.

If desired, a scale of calibrations 149 may be provided on the shutter 115, for indicating the degree of power transfer in percentages, or in decibels, or on such other calibration basis as may be desired.

One of the elongated openings in the waveguides or in the shutter may be provided with a loading element or elements such for example as inductance cross-bars, if desired, as described above in connection with the embodiment of Fig. 1.

The structure illustrated in Figs. 8 and 9 is a selective microwave energy transfer structure involving the same operating principles as in the previous embodiments, but with a ring-like physical arrangement for employment of a rotary shutter system 315, the principal wave guide system 311 being curved into an incomplete ring transmission path. A second waveguide 313 is rigidly positioned above a portion of waveguide 311 and is arcuately conformal therewith over a portion of its length.

Registering longitudinally extensive openings are provided through the upper interior surface of waveguide 311 and the lower interior surface of waveguide 313 for permitting full energy transfer from waveguide 311 to waveguide 313, with directional transmission maintained, to convey substantially the entire energy fed into waveguide 311 through flange 361 thereof, out through waveguide 313 and flange 365 thereof. Such complete energy transfer occurs through the registering openings of waveguide 311 and waveguide 313 when rotary shutter 315 is so positioned as to leave these openings totally unblocked.

A plurality of further wave guides 373 and 375 are similarly rigidly positioned above waveguide 311, and arranged with longitudinally extensive openings adjacent to similar registering openings in waveguide 311.

A spider frame including a hub 380 and arms 381, 383, and 385 may be provided for supporting the shutter bearing and for lending rigidity to the system. The upper waveguides 313, 373 and 375 are supported on

brackets 387, 389 and 391, respectively, extending upward from waveguide 311. These brackets may, if desired, comprise extensions of the spider arms 381, 383 and 385.

Serrated chokes typified by chokes 392 and 393 are provided on waveguide 311, over arcuate regions thereof including and extending beyond the longitudinally extensive openings therein; and corresponding serrated chokes are provided along the sides of the arcuate portions of waveguides 313, 373 and 375, the spacing between the lower waveguide chokes 392, 393 and the chokes of the upper waveguides being slightly greater than the thickness of the shutter 315.

The clockwise end of waveguide 311 beyond the ends of the registering openings of waveguides 311 and 375 is provided with an energy absorber such as a filling of high-loss dielectric material.

With the shutter 315 positioned as illustrated in Fig. 8, blocking the communication path through the registering openings of waveguides 311 and 313, energy entering waveguide 311 at flange 361 is conveyed around to the registering openings of waveguides 311 and 373, and transferred from waveguide 311 to waveguide 373 through these openings, and transmitted outward through flange 374. The registering openings of waveguides 311 and 375 are blocked when the shutter 315 is positioned as seen in Fig. 8, but this is only incidental, since substantially none of the energy supplied through flange 361 remains untransferred and proceeds in waveguide 311 beyond waveguide 373.

Assuming the shutter 315 rotated 120° clockwise from the position seen in Fig. 8, the regions of communication to waveguides 313 and 373 are blocked, and the energy fed into waveguide 311 proceeds on around to the registering openings of waveguides 311, and 375, and is fully transferred to this waveguide, to proceed outward through flange 376.

The complete acceptance of energy by the system of Figs. 8 and 9 is not interrupted even when the energy proceeding clockwise through waveguide 311 first encounters a partially opened transfer system, because this results in partial transfer of the energy through such a transfer system, and complete transfer of the energy through the next open transfer system encountered by the energy continuing clockwise in waveguide 311. For example, assume shutter 315 rotated 90° clockwise from its position illustrated in Fig. 8. As thus repositioned, the shutter would entirely block the registering openings of waveguide 311 and 313, and would reduce by substantially half the effective length of the window or passage comprising the registering openings of waveguides 311 and 373. A partial energy transfer into waveguide 373 would result, the remaining energy proceeding onward in the clockwise direction in waveguide 311, and all being transferred out through fully open waveguide 375.

Like operation prevails if the shutter is so positioned as to block the registering openings of waveguides 311 and 375, and partially unblock the registering openings of waveguides 311 and 313. Such a position is obtained if the shutter 315 is displaced a few degree counter-clockwise from the position illustrated in Fig. 8.

With the arrangement of the shutter 315 and the openings as illustrated in Fig. 8, there is always at least one fully open area of communication between waveguide 311 and another waveguide, and hence the power entering at flange 361 is always communicated to one or at most two of the output waveguide ends.

As in all of the previous forms of the invention, the source and load connections readily may be interchanged, a load device at flange 361 being supplied by one or another of the respective sources connected to guides 313, 373 and 375, or by microwave power contributions from two sources, simultaneously.

The structure illustrated in Figs. 10, 11 and 12 is also a

selective microwave energy transfer structure involving operating principles similar to those of the structure of Figs. 5 and 6. The structure of Figs. 10, 11, 12 differs from the structure of Figs. 8 and 9 in that energy is transferred from the principal waveguide system to one and only one of the output waveguides. The principal waveguide system consists of a waveguide section 411 formed into arcuate shape about a central axis. Waveguide section 411 comprises an annular member 418 and an annular channel member 419. Flanges of annular channel member 419 are joined as by bolting or welding to annular member 418 to form waveguide section 411. A plurality of secondary waveguide sections 413, 415, and 417 are rigidly positioned and fixed to waveguide section 411. Secondary waveguide sections 413, 415, and 417 comprise separate portions of an arcuate waveguide section formed by an annular member 420 and an annular channel member 421. Outwardly projecting flanges on annular members 418 and 420 are joined together to form a rigid structure, whereby plane surfaces 425, 427 of respective channel members 419, 421 are disposed adjacent, but not in contact with each other.

Electromagnetic energy is coupled into waveguide section 411 by means of an input waveguide section 423 which projects into an opening in the wall of each of members 418, 419 of waveguide section 411. Energy coupled into waveguide section 423 travels counter-clockwise in waveguide section 411 as viewed in Fig. 11. The extreme counter-clockwise end of waveguide section 411 is terminated in a non-reflective dissipative termination 424. Electromagnetic energy is received from secondary waveguide sections 413, 415, 417 by means of respective output waveguide sections 426, 428 and 430. Each of sections 426, 428, 430 is coupled to its corresponding secondary waveguide section through openings in the walls of members 420, 421. The extreme clockwise end of each of secondary waveguide sections 413, 415, and 417 of Fig. 11 is terminated with respective non-reflective dissipative terminations 431, 432, and 433.

Arcuate openings 435, 437, 439 are provided through the plane surface 425 of waveguide section 411 and the adjacent plane surface 427 of secondary waveguide sections 413, 415, 417 for permitting 100% energy transfer from waveguide section 411 to any one of waveguide sections 413, 415, and 417. Openings 435, 437, and 439 are of equal arcuate extent. The arcuate spacing between these openings should be at least as great as the arcuate extent of said openings. This is necessary in order that energy be communicated from waveguide section 411 to only one of secondary waveguide sections 413, 415, and 417.

A shutter 441 is supported for rotation between adjacent surfaces 425, 427 in milled slots in the abutting flanges of annular members 418 and 420. Shutter 441 is provided with an opening 442, the arcuate extent of opening 442 being equal to the length of an opening necessary to provide 100% energy transfer between waveguide section 411 and one of sections 413, 415 and 417. In Fig. 11 shutter opening 442 is shown in registration with opening 437. Electromagnetic energy is transferred from waveguide section 411 to one of waveguide sections 413, 415, and 417 when opening 442 registers with the corresponding opening 435, 437 or 439. When no portion of opening 442 is opposite openings 435, 437 or 439, all of the energy supplied section 411 from input section 423 is transferred to termination 424 where it is dissipated. In this manner, energy is delivered to only one of output waveguide sections 426, 428, and 430, or is delivered to termination 424. In no instance is the energy delivered simultaneously to two output waveguide sections. A generator delivering energy to input waveguide section 423 always feeds a matched load, either a load at the end of one of the output waveguide sections 426, 428, 430 or termination 424. Consequently, there are no switching transients or reflections introduced in the system.

Serrated chokes, such as chokes 444 and 445 are provided for affording the equivalent of electrical contact between shutter 441 and the adjacent walls of the upper and lower waveguide sections to prevent escape of energy between the shutter and the waveguide sections and to prevent coupling between the waveguide sections other than through shutter opening 442.

The length of the openings 435, 437, and 439 may be made longer, and correspondingly opening 442, by the employment of inductance cross-bars 447 disposed along opening 442. An indicator 448 may be employed to show the position of the shutter opening. Holes 449 may be utilized in cooperation with a cog wheel, not shown, for moving the shutter opening 442 from registration with one of openings 435, 437, and 439 to registration with another of said openings.

While the arcuate extent of opening 442 should be that required to transfer 100% of the energy from waveguide section 411 to one of secondary waveguide sections 413, 415 and 417, the arcuate extent of openings 435, 437 and 439 may be equal to or greater than that of opening 442. However, the arcuate spacing between openings 435, 437 and 439 should be equal to or greater than the arcuate extent of opening 442. This is necessary in order that energy be transferred to only one of the secondary waveguide sections. In order to provide the smallest possible structure, it is preferable that the length of openings 435, 437 and 439 be made exactly equal to the arcuate length necessary for 100% coupling, and that the length of the arcuate spacing between these openings be made the same arcuate length.

As in all of the previous forms of the invention, the source and load connections may be readily interchanged.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Selective microwave power transfer apparatus comprising first and second waveguides respectively including first and second substantially adjacent wall surfaces, wherein said first waveguide is formed as an arc about a predetermined axis to guide energy therein along a path corresponding to a portion of a circle, said first and second waveguides being rigidly fixed together and said first and second surfaces having longitudinally extensive registering openings therein through which the interior of said first and second waveguides are exposed to each other, said first waveguide including at least one longitudinally extensive opening in said first surface in addition to the opening therein communicating with said second waveguide, and shutter means of conductive material movable substantially along said walls for selectively blocking or unblocking the region of communication between said first and second waveguides for controlling the transfer of microwave power between said first and second waveguides, said shutter means comprising a rotatable shutter supported for rotation about said axis and having a conductive area interposable between said first and second waveguides according to the angular position of said rotatable shutter.

2. Selective microwave power transfer apparatus as defined in claim 1, further including at least one further waveguide adjacent said additional opening in said first surface of said first waveguide, and having a further opening therein in register with said additional opening in said first surface of said first waveguide, said shutter conductive area being selectively interposable between said first waveguide and said further waveguide.

3. A waveguide switching apparatus comprising a first waveguide section adapted for propagating electromagnetic waves along a first axis, said waveguide section

having at least one substantially plane wall parallel to said first axis, said plane wall having at least two openings extending parallel to said first axis, wherein said first waveguide section is formed into arcuate shape about a second axis perpendicular to a plane including said plane wall; further waveguide sections each adapted for propagating electromagnetic waves along further corresponding axes, each of said further waveguide sections having at least one substantially plane wall parallel to the corresponding axis thereof, the plane wall of each of said further waveguide sections having an opening extending parallel to the corresponding axis of said waveguide section, said further waveguide sections being rigidly fixed with respect to said first waveguide section, wherein the opening in the plane wall of each of said further waveguide sections registers with an opening in the plane wall of said first waveguide section, and whereby said first waveguide section communicates with each of said further waveguide sections; and a substantially plane conductive shutter perpendicular to and adapted for rotation about said second axis, said shutter being further disposed from movement between the registered openings of said further waveguide sections and said first waveguide section, whereby said shutter selectively blocks communication between said first waveguide section and said further waveguide sections.

4. A waveguide switching apparatus as in claim 3 wherein the plane wall of each of said further waveguide sections is disposed parallel to the plane wall of said first waveguide section and at least the portion of each of said further waveguide sections containing said opening is formed into arcuate shape about said second axis, the radius of curvature of said arcuate shape being equal to the radius of curvature of said first waveguide section.

5. A waveguide switching apparatus comprising a first waveguide section adapted for propagating electromagnetic waves along a first axis, said waveguide section having at least one substantially plane wall parallel to said first axis, said plane wall having at least two openings of equal extent parallel to said first axis, wherein said first waveguide section is formed into arcuate shape about a second axis perpendicular to a plane including said plane wall; further waveguide sections each adapted for propagating electromagnetic waves along further corresponding axes, each of said further waveguide sections having at least one substantially plane wall parallel to the corresponding axis thereof, the plane wall of each of said further waveguide sections having an opening extending parallel to the corresponding axis of said waveguide section, the extent of the openings of said further waveguide sections being substantially equal to that of the openings of said first waveguide section, said further waveguide sections being rigidly fixed with respect to said first waveguide section, wherein the opening in the plane wall of each of said further waveguide sections registers with an opening in the plane wall of said first waveguide section, and whereby said first waveguide section communicates with each of said further waveguide sections; and a substantially plane conductive shutter disposed perpendicularly to and adapted for rotation about said second axis, said shutter having an opening of arcuate extent not greater than the arcuate spacing between said first waveguide openings, whereby said shutter selectively blocks communication between said first waveguide section and said further waveguide sections.

6. A waveguide switching apparatus comprising a first waveguide section formed into arcuate shape about a predetermined axis to guide electromagnetic energy therein along a path corresponding to a portion of a circle, a plurality of arcuate openings in the wall of said waveguide section and spaced along said path, said path spacing being not less than a predetermined minimum value; a plurality of second waveguide sections, each of said second waveguide sections having an opening in the wall thereof of arcuate extent no less than said predetermined

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minimum value and being rigidly fixed with respect to said first waveguide section, wherein each of the openings in said second waveguide sections registers with an opening of said first waveguide section; and a conductive shutter adapted for rotation about said axis and disposed for movement between the registering openings of said second waveguide sections and said first waveguide section, said shutter having an opening of arcuate extent equal to said predetermined minimum value of spacing, whereby said shutter selectively blocks communication between said first waveguide section and said second waveguide sections, permitting communication from said first waveguide section to no more than one of said second waveguide sections.

7. A waveguide switching apparatus comprising a first waveguide section formed into arcuate shape about a predetermined axis to guide electromagnetic energy therein along a path corresponding to a portion of a circle, a plurality of openings of equal arcuate extent uniformly spaced along said path, the arcuate spacing between said openings being equal to said arcuate extent; a plurality of second waveguide sections, each of said second waveguide sections having an opening in the wall thereof and being rigidly fixed with respect to said first waveguide section, wherein each of the openings in said second waveguide sections registers with an opening of said first waveguide section; and a conductive shutter adapted for rotation about said axis and disposed for movement between the registering openings of said further waveguide sections and said first waveguide section, said shutter having an opening of arcuate extent equal to

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that of said first waveguide openings, whereby said shutter selectively permits communication from said first waveguide section to no more than one of said second waveguide sections.

8. A waveguide switching apparatus as in claim 6 wherein said predetermined minimum value of arcuate extent is equal to the length of an opening necessary to transfer all of the electromagnetic energy from said first waveguide section to a second waveguide section.

9. A waveguide switching apparatus as in claim 6 wherein said first waveguide section includes means to couple electromagnetic energy into said section, said means being connected to said section at one extremity thereof, and wherein each of said second waveguide sections includes means to couple electromagnetic energy out of said second section, each of said further output coupling means being connected to one of said second waveguide sections at one extremity thereof.

10. A waveguide switching apparatus as in claim 6 wherein each of said waveguide sections includes means connected at one extremity thereof for coupling electromagnetic energy to said section, and further includes a non-reflective dissipative termination disposed in the other extremity of said waveguide section.

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