April 9, 1963 R. M. WALKER 3,085,213

CIRCULAR WAVEGUIDE MODE FILTER AND BREAKDOWN SWITCH DEVICE, UTILIZING RESONANT IRIS

Filed Jan. 13, 1960 3 Sheets-Sheet 1

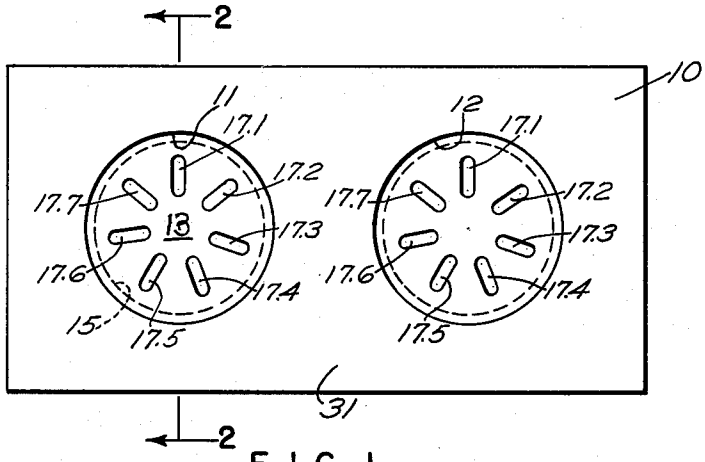


FIG. 1

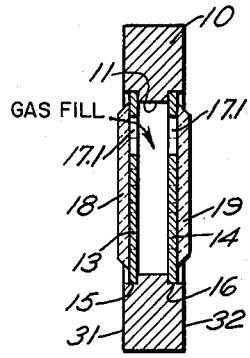


FIG. 2

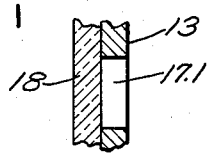


FIG. 3

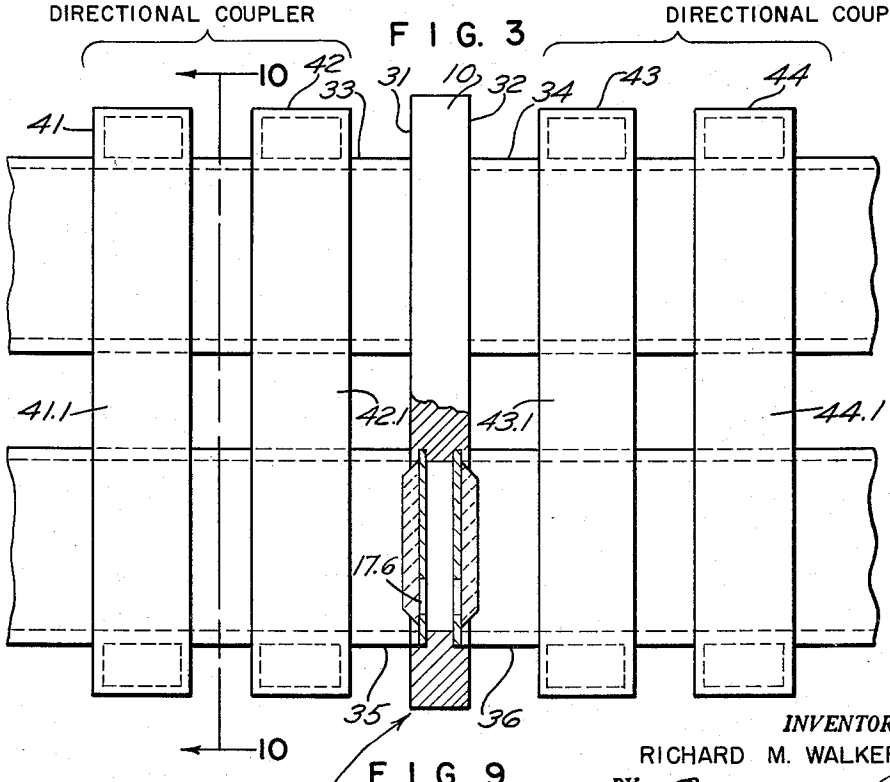


FIG. 9

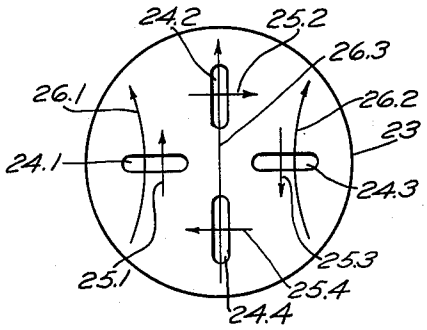
Common Mounting With Separate Iris Mode Filters Which Switch As "T-R" Devices.

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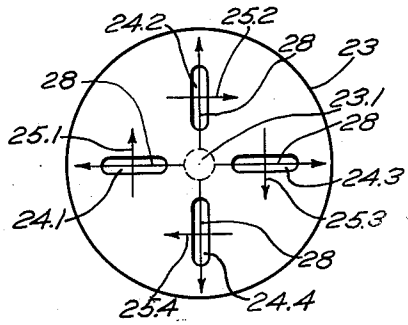
CIRCULAR WAVEGUIDE MODE FILTER AND BREAKDOWN SWITCH DEVICE, UTILIZING RESONANT IRIS

Filed Jan. 13, 1960 3 Sheets-Sheet 2



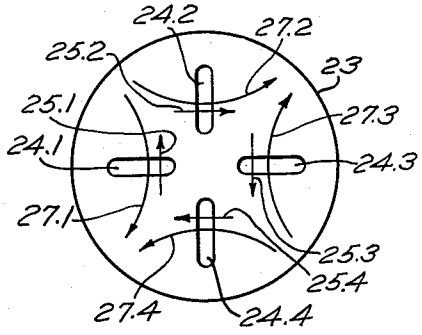
TE_{11}

FIG. 4



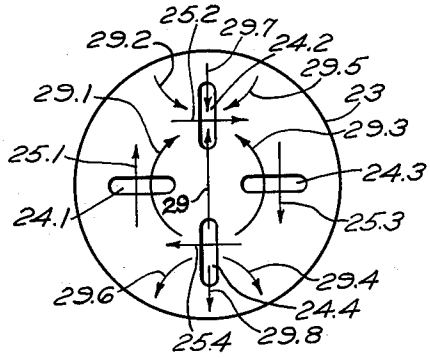
TM_{01}

FIG. 5



TE_{21}

FIG. 6



TM_{11}

FIG. 7

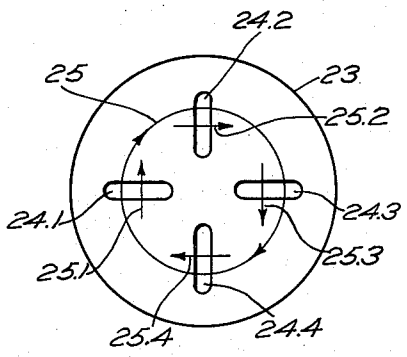
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TE_{01}

FIG. 8

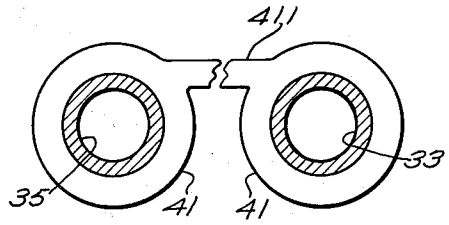


FIG. 10

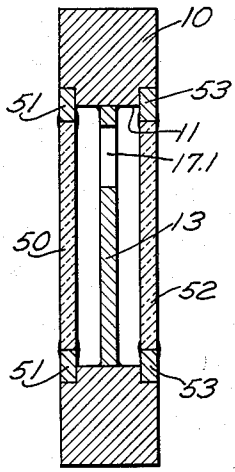


FIG. 11

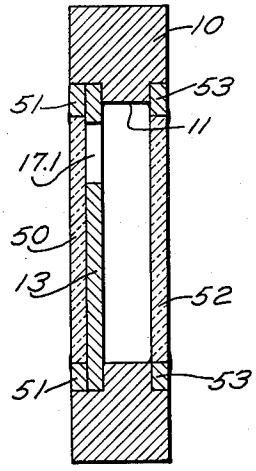


FIG. 12

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United States Patent Office 3,085,213 Patented Apr. 9, 1963

3,085,213

CIRCULAR WAVEGUIDE MODE FILTER AND BREAKDOWN SWITCH DEVICE, UTILIZING RESONANT IRIS

Richard M. Walker, Boston, Mass., assignor to Microwave Associates, Inc., Burlington, Mass., a corporation of Massachusetts

Filed Jan. 13, 1960, Ser. No. 2,217
17 Claims. (Cl. 333—7)

This invention relates in general to circular waveguide switch devices, and more particularly to switch and duplexing devices for circular waveguide systems intended for operation in the TE_{01} mode.

As is well known, a circular waveguide operated in the TE_{01} mode has the unique and important advantage that its attenuation is appreciably lower than that of a rectangular waveguide and decreases with increasing internal diameter of the waveguide. One difficulty, however, is that in a waveguide of diameter just large enough to support the TE_{01} mode four other modes will also propagate, namely, the TE_{11}, TM_{01}, TE_{21} and TM_{11} modes, and in a waveguide of larger diameter additional, higher order, modes will propagate. Due to this difficulty, the adoption and use of circular waveguide systems operated in the TE_{01} mode has been delayed. By contrast, rectangular waveguide systems operated in the TE_{10} mode enjoy the advantage of operation in the fundamental mode, and the design of components for such systems is accordingly less difficult, with the result that rectangular waveguide systems are more extensively used than circular waveguide systems nothwithstanding the recognized advantages of the latter.

It is an object of this invention to provide a circular waveguide switching device for operation in the TE_{01} mode. It is another object of the invention to provide such a switching device which is capable of operation in association with circular waveguides having higher power capabilities and lower loss characteristics than corresponding components in conventional rectangular waveguide form. It is a further object of the invention to provide such a switching device which will be operable over a broad band frequency spectrum. Further objects are to provide such a switching device which is of a readily reproducible design, lends itself to fabrication by known production techniques, is rugged in structure, and requires no unusual material, and is readily adaptable for use in circular waveguide duplexers, balanced duplexers, and other circular waveguide circuits. A general object of the invention is to advance the state of the art of circular waveguide transmission systems operable in the TE_{01} mode.

According to the invention, there is provided in general a TE_{01} mode circular waveguide gas discharge switching device, comprising a section of circular waveguide of internal diameter sufficiently large to propagate the TE_{01} mode, and transversely mounted in this waveguide section intermediate its ends an electrically conductive disc in which at least four radially directed slots are symmetrically arrayed, each slot being located between the center and the edge of the disc, and being effectively hermetically sealed by an electromagnetic wave pervious gas impervious dielectric material. One such disc having its slots disposed in an appropriate gas hermetically sealed in the vicinity of the slots, or two such discs located a known distance apart and having a region filled with such gas surrounding their slots and between them, may comprise a switch cell which is useful, for example, as a TR cell or a Pre TR cell. Each slot is dimensioned to couple through it microwave energy, in a prescribed frequency range, and with like phase and amplitude changes, which energy has a voltage field component transverse to the long slot dimension in the plane of the disc, and to break down electrically by discharge within the gas fill transverse to the long dimension in the plane of the disc when the magnitude of this voltage exceeds a prescribed value. Two such waveguide sections, each provided with such a switch cell, are coupled on each side to a TE_{01} mode circular waveguide hybrid junction or 3 db directional coupler, to comprise a balanced duplexer. In a preferred embodiment of such a balanced duplexer the two waveguide sections are parallel and the switch cells lie in the same plane transverse to both sections. Structurally, the switch cells may be fabricated in a single body and further circular waveguide sections of the same diameter may be attached to this body.

Additional objects and features of the invention will be made apparent in the following description of a preferred embodiment. This description refers to the accompanying drawings, wherein:

FIG. 1 is a plan view of a switch device according to the invention;

FIG. 2 is a section along line **2—2** of FIG. 1;

FIG. 3 is an enlarged fragmentary view showing a detail of FIG. 2;

FIGS. 4 to 8, inclusive, illustrate the operation of switch devices according to FIG. 1;

FIG. 9 illustrates a balanced duplexer;

FIG. 10 is a section along line **10—10** of FIG. 9;

FIG. 11 is a cross-sectional view of a switch device employing only one window disc; and

FIG. 12 is a cross-sectional view of another switch device employing only one window disc.

Referring now to FIGS. 1 and 2, the switch device there illustrated is intended to function as a dual circular waveguide TR or Pre TR cell. A body **10** is circularly apertured at **11** and **12** to provide two short sections of circular waveguide. As is shown in FIG. 2, the first-named short section **11** has first and second window discs **13** and **14** mounted across its ends, resting on shoulders **15** and **16**, respectively, provided at each end. The second-named short section **12** is similarly fitted, and its structure will not separately described, it being understood that the description of the structure of the first-named short section **11** and elements fitted to it is applicable to both sections and the respective elements fitted to them.

As exemplified by the first window disc **13**, each disc is provided with a plurality of radially directed slots, **17.1**, **17.2**, **17.3**, **17.4**, **17.5**, **17.6** and **17.7**. Each slot constitues an iris opening designed to be resonant (i.e., transmit substantially all the incident TE_{01} mode power) at the desired resonant frequency, and to maintain good mode purity in the waveguide in the unfired condition as will presently be described. The number "m" of slots in each window disc is such that the TE_{n1} mode will not be propagated in the circular waveguide being used, where "m"$=2n$, at least, for the highest mode to be suppressed; while seven slots in each window disc are shown in FIG. 1, under certain conditions a minimum number of four slots will suffice, as will be explained below. Preferably, all the slots in a given window disc have equal coupling values, for phase and amplitude, in order to prevent excitation of sub-multiples of the TE_{n1} mode ($m/2$, $m/3$, etc.) and TM modes. The window discs may be made of a metal (such as Kovar) having a coefficient of expansion substantially equal to that of glass, to which a suitable glass for TR cell windows can be sealed. FIG. 2 shows first and second glass discs **18** and **19** sealed over the outer surfaces of the first and second window discs **13** and **14**, respectively. The enlarged fragmentary view in FIG. 3 shows the first glass disc **18** covering the first slot **17.1** in the first window disc **13**. The window discs **13** and **14** are, for example,

suitably plated and soft soldered, and thereby hermetically sealed in the respective openings of the short waveguide section 11. Other forms of hermetically sealed iris diaphragms may be employed, if desired; for example, those constructed according to the techniques disclosed in the copending application of the present inventor and another, Serial No. 657,585, filed May 7, 1957. The interior of each short waveguide section 11 and 12 is evacuated and filled with a suitable gas (not shown) for efficient TR or Pre TR action. The gas fill and pressure are according to known TR tube techniques. Under these conditions, when the magnitude of the voltage across a coupling slot (i.e., transverse to the long dimension of the slot in the plane of the disc) due to incident power exceeds a given value, the slot is fired, and a discharge is formed behind the slot (i.e., on the side away from the glass disc sealing it) to form effectively a short circuit across the waveguide section due to the simultaneous firing of all the slots in a given window disc. The length of each assembly, from the first window disc 13 to the second window disc 14, is approximately one quarter wavelength of the TE_{01} mode in the respective short circular waveguide section, to provide maximum bandwidth for a given window design (for low-level operation—i.e., gas not ionized).

The design and operation of the respective window discs is explained with the aid of the schematic illustrations of FIGS. 4 to 8, inclusive. Each of these figures schematically represents a window disc 23 having four slots 24.1, 24.2, 24.3 and 24.4 radially disposed and symmetrically arrayed in it, the long dimension of each slot lying between the center and periphery or edge of the disc. In such a symmetrical array, the long dimensions of any two successive or adjacent slots (e.g., 24.1 and 24.2) are orthogonally related in the plane of the disc. When the slots are excited by microwave energy incident at one side of the window disc 23 in the TE_{01} mode, the electric field line configuration of which is circular as is illustrated by the circular line 25 in FIG. 8, each slot has impressed across it a component of the electric field of said energy which is directed transversely to the long dimension of the slot in the plane of the window disc 23; furthermore, these components are directed in the same direction around the center of the disc, for example, clockwise, as is indicated by the arrows 25.1, 25.2, 25.3 and 25.4 (hereinafter called "field vectors") drawn across the slots 24.1, 24.2, 24.3 and 24.4, respectively, if the TE_{01} mode field line 25 is directed clockwise. If the slots are designed to couple identical increments of energy applied to them with equal attenuation and phase change effects, the phase front and relative amplitude distribution over the front of a wave incident at one side of the window disc 23 will be reproduced essentially unaltered on the other side of the disc by the energy coupled through the slots, and the four-slot array excited as in FIG. 8 by TE_{01} mode energy applied at one side of the window disc 23 will generate the same mode at the other side of the disc with good mode purity, as will be explained with reference to FIGS. 4 to 7, inclusive.

FIG. 4 shows electric field lines 26.1, 26.2 and 26.3 of the TE_{11} mode, and with their respective arrow heads these lines indicate an instantaneous electric field disposition in a plane parallel to the window disc 23. It is assumed that the four slots have been excited by TE_{01} mode energy as in FIG. 8. The first slot 24.1 is excited in the proper phase to couple with the electric field of the TE_{11} mode, since its field vector 25.1 is in phase with the left-hand field line 26.1. It is apparent, then, that if the disc 23 comprised only one slot 24.1 the incidence of TE_{01} mode energy at one side of it might result in the generation of TE_{11} mode energy on the other side of the disc by energy coupled through this single slot. However, the third slot 24.3 has its field vector 25.3 180° out of phase with the TE_{11} mode field when the first slot 24.1 is in phase with that field, as is indicated by the field vector 25.3 being directed oppositely to the right-hand field line 26.2 of the TE_{11} mode. Thus, the two opposite slots 24.1 and 24.3 cooperate to prevent the generation of TE_{11} mode energy when they are excited by TE_{01} mode energy. The remaining two slots 24.2 and 24.4 have their field vectors 25.2 and 25.4 directed across the maximum TE_{11} mode field line 26.3, so that they do not contribute to the generation of the TE_{11} mode. The same conclusion can be proved from an analysis of other orientations of the instantaneous TE_{11} mode pattern relative to this four-slot configuration.

In FIG. 6 the electric field lines 27.1, 27.2, 27.3 and 27.4 and the respective arrow heads on them represent an instantaneous electric field configuration of the TE_{21} mode in a given plane parallel to the disc 23 (i.e., transverse to a circular waveguide in which the disc 23 may be mounted). Here it is clear from the disposition of the field vectors 25.2 and 25.4 of the two opposed slots 24.2 and 24.4, respectively, in phase with the TE_{21} mode field lines 27.2 and 27.4, respectively, that a single pair of slots having their long dimensions lying along a diameter of the window disc can excite the TE_{21} mode upon being themselves excited by the TE_{01} mode. The addition of another pair of slots 24.1 and 24.3 at right angles to the first pair provides a pair of field vectors 25.1 and 25.3 which are simultaneously 180° out of phase with the electric field of the TE_{21} mode as represented by the field lines 27.1 and 27.3 in the vicinity of these slots. There results a four-slot configuration which, when excited by the TE_{01} mode, is constrained to generate only the TE_{01} mode from the energy coupled through the slots, and does not generate the TE_{11} or the TE_{21} mode.

It should be noted that fewer than four slots will not provide this property, and that if the slots which mutually oppose each other relative to any of these two undesired modes fail to oppose each other equally, a certain amount of the unwanted mode will be generated and propagated in following circular waveguides unless subsequent steps are taken to eliminate it. Hence, a symmetrical array of equally fed slots, having equal coupling coefficients and phase change characteristics with respect to the TE_{01} mode, is a preferred arrangement.

The TM_{01} field would not be excited by the four slots of the disc 23, as is apparent in FIG. 5. In one plane across the TM_{01} mode configuration, the electric field lines 28 are directed radially, as illustrated in FIG. 5, and hence are orthogonally related to all the field vectors 25.1, 25.2, 25.3 and 25.4 of the slots which are due to the TE_{01} mode. In another plane (not shown) across the TM_{01} mode configuration the electric field lines are perpendicular to the disc 23 and concentrated in the center region 23.1 shown by a dotted circle in FIG. 5. Again the electric field of the TM_{01} mode when so disposed will not be excited by the field vectors across the slots due to the TE_{01} mode.

The TM_{11} mode has an instantaneous electric field configuration in a plane transverse to its direction of propagation as is shown in FIG. 7 by the electric field lines 29, 29.1, 29.2, 29.3, 29.4, 29.5, 29.6, 29.7 and 29.8. As in the case of the TE_{11} mode, any pair of opposite and parallel slots, 24.1 and 24.3, for example, lying along the same diameter of the disc 23, serve to inhibit the generation of the TM_{11} mode, due to the fact that their electric field vectors 25.1 and 25.3 resulting from the TE_{01} mode are in phase opposition with respect to the electric field of the TM_{11} mode; where one field vector (e.g., 25.1) tends to favor generating the TM_{11} mode, by being in phase with its field as represented by a field line 29.1 in the vicinity of the first slot 24.1, the other field vector (e.g., 25.3) opposes the establishment of the field of this mode by being opposite to it as represented by the field line 29.3 in the vicinity of the other slot 24.3. The TM_{11} mode electric field is directed perpendicular to the disc 23, or is without direction, in the vicinity of the other pair of

slots 24.2 and 24.4 in the disc, so that these slots cannot contribute to the TM_{11} mode.

It is thus seen that a four-slot configuration in a window disc or partition 23, like the configuration illustrated in FIG. 8, for example, can serve to couple the TE_{01} mode across the partition without exciting any of the lower order modes, (TE_{11}, TM_{01}, TE_{21}) or the degenerate mode (TM_{11}) in a waveguide which is of large enough diameter to propagate the TE_{01} mode. If a larger diameter waveguide is used, additional slots providing an array of slots which are symmetrically arranged and of equal coupling capability with respect to the TE_{01} mode can be used to inhibit the excitation of higher order modes as well. Thus, the seven-slot configuration shown in FIG. 1 will inhibit the generation of the TE_{31} mode as well as the foregoing modes, and will couple the TE_{01} mode with good mode purity. A symmetrical six-slot configuration (not shown) could also accomplish this result. The seven-slot configuration is useful in the case where the slots do not have identical coupling characteristics, in that for such cases this configuration will minimize the possibility of exciting unwanted modes between the TE_{11} and the TE_{71} modes. In such a case, there may also be an unbalance among the slots relative to the TE_{01} mode, which can cause the TE_{11} mode to be excited from incident TE_{01} mode energy, and it will then be required to take other measures to eliminate this single unwanted (TE_{11}) mode. Referring to FIGS. 1 and 2, this can be done by axially staggering the two window discs 13 and 14 by $\frac{1}{14}$ of a revolution, in cases where two window discs are used.

FIGS. 9 and 10 illustrate a circular waveguide balanced duplexer using the TE_{01} mode. The body 10 containing two TR cells as shown in FIGS. 1, 2 and 3 has first and second circular waveguides 33 and 34 collinearly coupled to its opposite sides 31 and 32, respectively, in register with the first circular opening 11 therein, and third and fourth circular waveguides 35 and 36 similarly coupled to it in register with the second circular opening 12 therein. There results a structure comprising two parallel adjacent circular waveguides 33, 34 and 35, 36, in each of which one of the TR cells which is supported in the body 10 is transversely mounted. When TE_{01} mode energy is introduced at one end of either of these waveguides, it is coupled through the TR cell therein with good mode purity to the other end, unless it is of sufficiently high level to fire the iris openings 17.1–17.7, inclusive, in which case it is reflected.

The two elements 41 and 42 on one side 31 of the body 10, and the two elements 43 and 44 on the other side 32 of the body 10 represent hybrid junctions or 3 db directional couplers cross connecting the two circular waveguides 33, 35 and 34, 36 on each side of the TR cells, as is done in known rectangular waveguide balanced duplexer circuits, to provide the complete circular waveguide balanced duplexer circuit. Such couplers per se are not part of the present invention. They can be realized, for example, with pairs of rectangular waveguide coupling links which are wrapped around the circular waveguides, each link being constructed according to U.S. Patent No. 2,766,432 to Walker, the present inventor, or U.S. Patent No. 2,676,306 to Lanciani. If either of these patented configurations is used, the end reflectors there shown in the circular waveguide will be omitted, and two (or more) such coupling links will be employed, spaced along the circular waveguides 33, 35 on one side 31 of the body 10 in the one case, and 34, 36 on the other side 32 of the body 10 in the other case, to provide the desired directivity. The number of coupling links required in either case is determined by the coupling ratio which can be achieved in a single link and the desired bandwidth of the resulting 3 db coupler. As is stated in the patent to Walker, coupling in an individual link can be increased at the expense of bandwidth. The rectangular waveguide sections 41.1, 42.1, 43.1 and 44.1, interconnecting each pair of coupling links will propagate the dominant or TE_{10} rectangular waveguide mode.

While certain patented coupling configurations have been suggested for the 3 db directional couplers required to achieve the circular waveguide balanced duplexer illustrated in FIGS. 9 and 10, it will be apparent to those skilled in the art that other couplers or hybrid junctions may be employed.

Embodiments of the invention employing only one window disc may be constructed according to FIG. 11 or FIG. 12. Each of these figures illustrates an embodiment of the invention in cross section taken as in FIG. 2, showing the body 10 and one of the short sections 11 of circular waveguide therein, and a single window disc 13 mounted in the short section 11. In FIG. 11 the window disc 13 is mounted approximately in the center of the circular waveguide section 11, and glass discs 50 and 52, mounted in suitable metal-to-glass sealing rings 51 and 53, respectively, hermetically seal the respective openings of the waveguide section. In FIG. 12 the window disc 13 is mounted near one of the openings, in contact with one of the windows 50. In either case, a suitable gas fill (not shown) is provided in the cell for efficient TR or Pre TR action.

The embodiments of the invention which have been illustrated and described herein are but a few illustrations of the invention. Other embodiments and modifications will occur to those skilled in the art. No attempt has been made to illustrate all possible embodiments of the invention, but rather only to illustrate its principles and the best manner presently known to practice it. Therefore, while certain specific embodiments have been described as illustrative of the invention, such other forms as would occur to one skilled in this art on a reading of the foregoing specification are also within the spirit and scope of the invention, and it is intended that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

What is claimed is:

1. TE_{01} mode circular waveguide switch comprising a section of circular waveguide of substantially uniform internal diameter sufficiently large to propagate the TE_{01} mode, first and second electrically conductive discs, transversely mounted in said waveguide a known distance apart, at least four radially directed slots each of which is electrically symmetrical about its long dimension and has long edges confronting each other, said slots being symmetrically arrayed in each disc, the long dimension of each slot being substantially smaller than the radius of the disc in which it is arrayed, each slot being located between the center and the edge of the disc in which it is arrayed and being dimensioned to couple therethrough microwave energy in a prescribed frequency range which has a voltage field component transverse to the long slot dimension at said disc, and to break down across said long dimension when the magnitude of said voltage across said slot exceeds a prescribed value the center portion of each disc being free of perforation by any of the slots arrayed in said disc, and electromagnetic wave pervious gas impervious means closing each slot and hermetically sealing the space in said waveguide section between said discs.

2. Switch according to claim 1 in which each of said slots couples an identical quantity of said energy at said frequency.

3. Switch according to claim 1 in which said known distance between said first and second discs is substantially one-quarter wavelength of the TE_{01} mode in said section of circular waveguide.

4. Switch according to claim 1 in which each of said slots is resonant at a frequency in said range.

5. Switch according to claim 3 in which each of said slots couples an identical quantity of said energy at said frequency.

6. TE_{01} mode circular waveguide switch comprising a section of circular waveguide of substantially uniform

internal diameter sufficiently large to propagate the TE_{01} mode, first and second electrically conductive discs transversely mounted in said waveguide a known distance apart, four radially directed slots each of which is electrically symmetrical about its long dimension and has long edges confronting each other, said slots being symmetrically arrayed in each of said discs, the long dimension of each slot being rectangularly disposed relative to the long dimension of each adjacent slot in the same disc and being substantially smaller than the radius of said disc, said slots each being positioned between the center and the edge of the disc in which it is arrayed, each slot being dimensioned to couple therethrough microwave energy in a prescribed frequency range which has a voltage field component transverse to the long slot dimension at said disc, and to break down across said long dimension when the magnitude of said voltage across said slot exceeds a prescribed value the center portion of each disc being free of perforation by any of the slots arrayed in said disc, and electromagnetic wave pervious gas impervious means closing each slot and hermetically sealing the space in said waveguide section between said discs.

7. TE_{01} mode circular waveguide switch circuit comprising first and second circular waveguides each of internal diameter sufficiently large to propagate the TE_{01} mode, an electrically conductive disc transversely mounted in each of said waveguides, at least four radially directed slots each of which is electrically symmetrical about its long dimension and has long edges confronting each other, said slots being symmetrically arrayed in each of said discs, the long dimension of each slot being substantially smaller than the radius of the disc in which it is arrayed, each slot being located between the center and the edge of its disc whereby the center portion of said disc is not perforated by any of said slots, electromagnetic wave pervious gas impervious means closing each slot, each slot being dimensioned to couple therethrough microwave energy in a prescribed frequency range which has a voltage field component transverse to the long slot dimension at said disc, and to break down across said long dimension when the magnitude of said voltage across said slot exceeds a prescribed value, and hybrid coupling means interconnecting said waveguides on each side of said discs.

8. Circuit according to claim 7 in which said first and second waveguides are parallel to each other, and said discs are in a common plane transverse to both of said waveguides.

9. Circuit according to claim 8 in which a single flat body supports said discs, and said waveguides are each in two sections connected collinearly to opposite sides of said body.

10. TE_{01} mode circular waveguide switch circuit comprising first and second circular wave guides each of internal diameter sufficiently large to propagate the TE_{01} mode, first and second electrically conductive discs transversely mounted a known distance apart in each waveguide, at least four radially directed slots each of which is electrically symmetrical about its long dimension and has long edges confronting each other, said slots being symmetrically arrayed in each disc, the long dimension of each slot being substantially smaller than the radius of the disc in which it is arrayed, each slot being located between the center and edge of its disc, electromagnetic wave pervious gas impervious means sealing each slot and hermetically sealing the space between the first and second discs in each of said waveguides, each slot being dimensioned to couple therethrough microwave energy in a prescribed frequency range which has a voltage field component transverse to the long slot dimension at said disc, and to break down across said long dimension when the magnitude of said voltage across said slot exceeds a prescribed value the center portion of each disc being free of perforation by any of the slots arrayed in said disc, and hybrid coupling means interconnecting said waveguides on each side of said discs.

11. Circuit according to claim 10 in which said first and second waveguides are parallel to each other, said first discs in each waveguide are located in a first common plane and said second discs in each waveguide are located in a second common plane, and said planes are parallel to each other and transverse to both of said waveguides.

12. Circuit according to claim 11 in which a single flat body having opposite plane sides spaced substantially said known distance apart and apertured in two places to mate with the internal cross section of said waveguides supports a first and a second of said discs at the opposite sides, respectively, of each aperture, and said waveguides are each in two sections connected collinearly to opposite sides of said body in register with one of said apertures.

13. Circuit according to claim 12 in which the hermetic sealing means are a sealing disc over each of said apertures outside of each of said discs.

14. TE_{01} mode circular waveguide switch circuit comprising first and second circular waveguides each of internal diameter sufficiently large to propagate the TE_{01} mode, first hybrid coupling means interconnecting said waveguides at a first region of each, said coupling means comprising rectangular waveguide coupling links at each said region for interchanging TE_{01} mode energy in a circular waveguide with dominant mode energy in a rectangular waveguide and rectangular waveguide means interconnecting said coupling links between said circular waveguides, second hybrid coupling means similar to said first hybrid coupling means interconnecting said circular waveguides at a second region of each and an iris means in each circular waveguide intermediate said first and second regions, each iris means being adapted to pass TE_{01} mode energy and to prevent passage of lower-order circular waveguide modes, each iris being simultaneously adapted to break down in the presence thereat of TE_{01} mode energy having a voltage exceeding a prescribed value.

15. Switch circuit according to claim 14 in which each of said iris means comprises electrically conductive disc means transversely mounted in said circular waveguide, said disc means having radially-directed elongated slot apertures of length substantially less than the radius thereof located between the center and the periphery thereof so that the center portion is devoid of any aperture, each aperture being electrically symmetrical about its long dimension, the apertures being disposed and dimensioned to pass TE_{01} mode energy through said disc means from one side to the other, each slot being dimensioned to break down electrically across the long dimension thereof in the presence of a voltage exceeding said prescribed value.

16. TE_{01} mode circular wave guide switch comprising: a section of circular waveguide of substantially uniform internal diameter sufficiently large to propagate the TE_{01} mode, an electrically conductive disc transversely mounted approximately in the center of said wave guide section, at least four radially directed slots each having a long dimension which is substantially smaller than the radius of said disc symmetrically arrayed in said disc, each slot being electrically symmetrical about its long dimension and having long edges confronting each other, each slot being located between the center and edge of said disc whereby the center portion of said disc is not perforated by any of said slots, and electromagnetic wave pervious gas impervious means electrically sealing each end of said wave guide section, said slots each being dimensioned to couple therethrough microwave energy in a prescribed frequency range which has a voltage field component transverse to the long slot dimension at said disc, and to break down across said slot when the magnitude of said voltage exceeds a prescribed value.

17. TE_{01} mode circular wave guide switch comprising: a section of circular wave guide of substantially uniform

internal diameter sufficiently large to propagate the TE_{01} mode, an electrically conductive disc transversely mounted across one end of said wave guide section, at least four radially directed slots each having a long dimension which is substantially smaller than the radius of said disc symmetrically arrayed in said disc, each slot being electrically symmetrical about its long dimension and having long edges confronting each other, each slot being located between the center and edge of said disc whereby the center portion of said disc is not perforated by any of said slots, and electromagnetic wave pervious gas impervious means electrically sealing each end of said wave guide section, said disc being in contact with one of said sealing means, said slots each being dimensioned to couple therethrough microwave energy in a prescribed frequency range which has a voltage field component transverse to the long slot dimension at said disc, and to break down across said slot when the magnitude of said voltage exceeds a prescribed value.

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