Feb. 6, 1951 G. L. TAWNEY 2,540,148

ULTRA HIGH FREQUENCY POWER-SELECTIVE PROTECTIVE DEVICE

Filed March 22, 1945

Fig. 1.

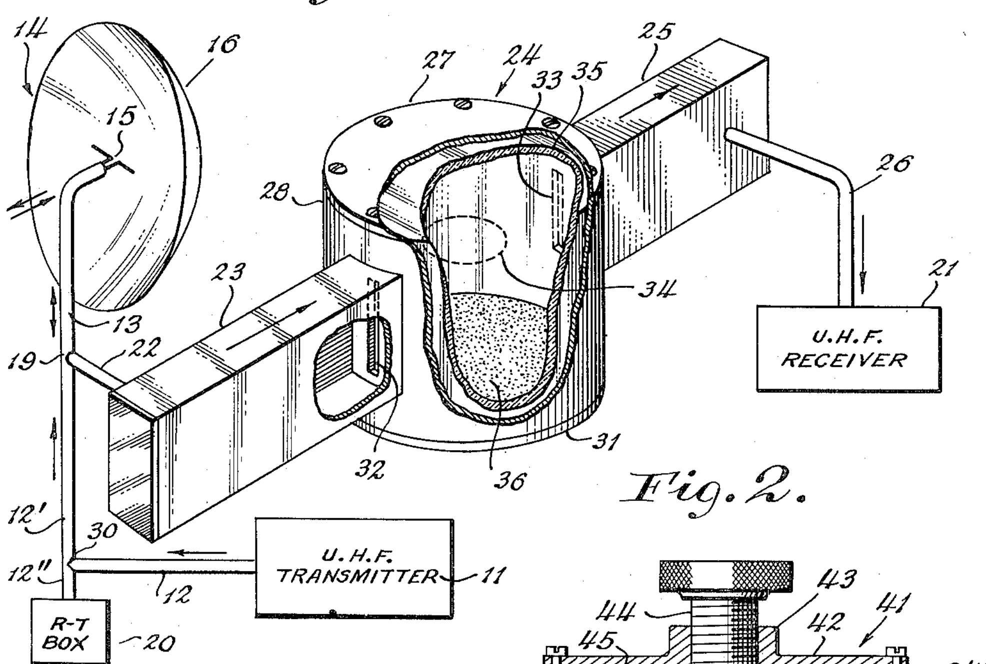


Fig. 2.

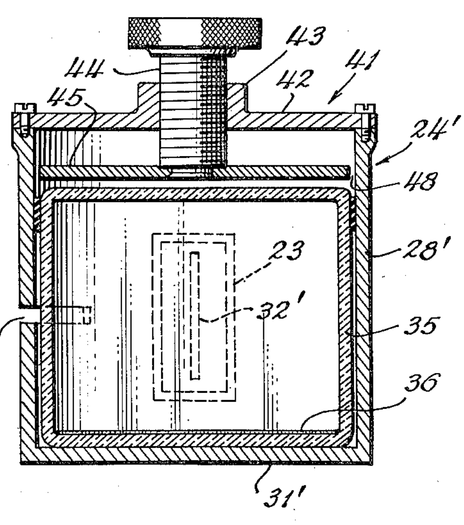
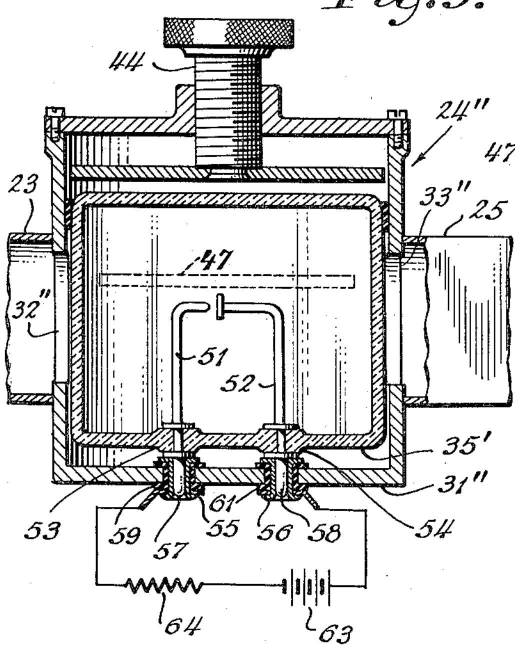


Fig. 3.



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Patented Feb. 6, 1951 2,540,148

UNITED STATES PATENT OFFICE

2,540,148

ULTRA HIGH FREQUENCY POWER-SELECTIVE PROTECTIVE DEVICE

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Application March 22, 1945, Serial No. 584,092

3 Claims. (Cl. 315—39)

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The present invention relates to ultra high frequency apparatus, and particularly to power-selective resonator electric discharge apparatus. Power-selective apparatus may be employed to advantage in various types of high-frequency circuit applications, among which are included radio object detection systems, sometimes referred to as "Radar Systems."

In ultra high frequency radio object detection systems of the type adapted to transmit pulses of ultra high frequency energy toward a remote object and to receive energy pulses reflected therefrom, the position of the remote object is determined in accordance with the direction of energy transmission and reception, and in accordance with the time delay between transmission of an energy pulse and the reception of a corresponding reflected energy pulse. In such systems, a single directive antenna usually is employed alternately for transmission and reception of ultra high frequency energy. The ultra high frequency transmitter may be coupled directly to the antenna so that, during periods of generation of the pulses, energy from the transmitter is supplied to the antenna and is directed toward a remote object. During the intervals between successive transmitter pulses, energy reflected from the distant object and intercepted by the antenna is supplied to the ultra high frequency object detection receiver. Thus, it is readily apparent that the common directive antenna must be coupled to the receiver as well as to the transmitter, and thus, in the absence of a suitable protective device, the sensitive radio object detection receiver would be subject to damage due to the tremendous transmitter output energy during transmission of energy pulses.

In order to prevent excessive power from the transmitter from being conducted to the receiver during the periods of energy pulse generation by the transmitter, a power-selective device such as a "T-R box" usually is connected intermediate the directive antenna and the ultra high frequency receiver. The usual type of "T-R box," or transmitter-receiver ultra high frequency energy blocking device, is a cylindrical cavity resonator having reentrant poles forming a relatively short, high-capacity, high voltage-gradient discharge path. A resonator of the reentrant type which usually forms the basis of the T-R box is illustrated in Fig. 131 (*i*) of section 3, page 265, in the Radio Engineers' Handbook, F. E. Terman, McGraw-Hill, 1943.

The T-R box of the common type usually is filled with readily ionized gas at a relatively low

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pressure, particularly adapted to provide an electric discharge path between the reentrant poles of the resonator so that excitation of the resonator produces a short and relatively straight discharge between the reentrant poles of the resonator. Such a T-R box requires relatively high-intensity excitation for the formation of a discharge and therefore it permits the low-intensity energy reflected from a remote object and intercepted by the antenna to be transferred to the receiver. During the transmission of high-intensity pulses generated by the transmitter, however, an electric discharge occurs within the T-R box. By virtue of this discharge, the Q of the resonator is greatly reduced, and thus its effectiveness as an energy-coupling resonator is similarly reduced. Whereas the resonator serves as an energy coupling device for low-intensity energy, it serves as a greatly mismatched impedance, energy-reflecting device for high-intensity energy, and thus it serves to prevent the receiver from being damaged by high-intensity energy pulses produced by the transmitter.

Usually, a radio object detection system of the type described above includes a second power-selective device, commonly referred to as an "R-T box," which may be similar in form to the T-R box described above. The R-T box may be coupled to the transmitter and to the antenna at a point intermediate the transmitter and the T-R box connection, for preventing an appreciable part of the reflected energy intercepted by antenna 14 from being diverted from the path through the T-R box to the receiver and being dissipated in the transmitter.

A major disadvantage of power-selective devices such as T-R boxes and R-T boxes of the usual type resides in the fact that the tips of the reentrant poles between which the discharge occurs become heated during the discharges due to transmitter pulses. Such reentrant pole tips may be heated to such a temperature as to cause the release of gases which may mix with the readily ionized gas normally used, so changing the nature of the gaseous medium within the device as well as the pressure thereof as to impair the performance of the power-selective device.

Another disadvantage of the reentrant resonator T-R box or R-T box resides in the fact that the maximum Q of the reentrant resonator is relatively low, so that appreciable attenuation of a received signal is produced by the power-selective devices, resulting in a reduction of the range of operation of the object detection system. A further result of the relatively low Q of the reentrant type of resonator is the fact that this type of resonator provides relatively low frequency-selectivity, whereas in some instances it may be desirable to provide appreciable frequency-selectivity in the power-selective devices. A power-selective device capable of high frequency-selectivity aids materially in preventing interference to the radio object detection receiver due to transmitters intended for "jamming," or interfering with radio object detection for military purposes.

Accordingly, it is an object of the present invention to provide an improved power-selective device or transmitter-receiver switch for radio object detection systems and other ultra high frequency radio systems.

Another object of the present invention is to provide a power-selective device of very high frequency-selectivity, and of relatively low insertion loss or attenuation of received signals.

A further object of the present invention is to provide a power-selective device having an ionizable gas medium sealed within a cavity resonator adapted to support an annular electric discharge path.

In a preferred embodiment of the present invention, a cavity resonator adapted to support ultra high frequency oscillations in a generally circular electric field mode is employed as a power-selective device. Preferably, a cylindrical resonator is employed, which may be made tunable, if desired. The resonator is excited by the introduction of an ultra high frequency electric field tangentially at the cylindrical wall of the resonator, so that an annular electric field is formed within the space inside the resonator.

If desired, a cylindrical resonator unit having solid dielectric-filled gas-tight windows for ingress and egress of ultra high frequency energy could be filled with a suitable readily ionized gas, vacuum pumped, and sealed at a relatively low gas pressure. In a preferred form of the present invention, a gas-filled glass or other dielectric envelope is inserted within a cylindrical resonator having no reentrant poles and adapted for excitation in a circular electric mode as by an input wave guide coupled thereto through a slit or window in the cylindrical resonator wall. Such a resonator is characterized by a much higher Q than that of the usual reentrant-type resonator having a discharge path along its axis. Accordingly, the T-R box of the present invention not only affords isolation of the gaseous electric discharge medium from contact with the metal walls of the resonator, but also provides higher Q for increased selectivity and reduced insertion loss.

An advantage of the above-described construction is the freedom from a requirement of ultra high frequency current-carrying connections between the removable gas-filled envelope and the cylindrical resonator. This feature would be realized even if there were provided within the glass envelope an annular discharge electrode having a gap therein defining a relatively short or concentrated voltage breakdown or discharge path. Such an electrode or conductive ring, which could be supported by a glass column extending upwardly from one end of the glass envelope, could be employed in the circular electric mode apparatus; but it is not necessary for the operation of the present invention, since the electric discharge may be formed in an annular path within the resonator remote from any metallic wall or electrode thereof.

The above features will be illustrated and further objects will be made apparent by reference to the following detailed description of the present invention, taken in conjunction with the drawing, wherein:

Fig. 1 illustrates a fixed-tuned circular electric mode power-selective device shown connected in a radio object detection system;

Fig. 2 is a modified form of the present invention including a tuning device and a window through the conductive wall of the cavity resonator whereby light produced by the electric discharge is emitted from the power-selective device; and

Fig. 3 shows a modified form of the present invention including a "keep-alive" electric discharge circuit.

Referring now to Fig. 1, a radio object detection system is shown including an ultra high frequency transmitter **11** coupled through transmission lines such as coaxial lines **12**, **12'** and **13** to a directive antenna **14**. The directive antenna **14** may comprise a dipole antenna element **15** positioned at the focal point of a paraboloidal metallic reflector **16**. The transmitter **11** is adapted to produce ultra high frequency output in recurrent pulses. The antenna **14** may be employed not only for the transmission of energy from transmitter **11**, but also for the interception of energy which may be reflected back toward the object detection system from distant objects. For this purpose, the antenna **14** may be coupled to an ultra high frequency receiver **21** through an energy conducting path comprising a coaxial line **22** connected to transmission lines **12'** and **13** at the junction **19** thereof, a T-R box input wave guide **23**, a T-R box **24**, an output wave guide **25**, and a coaxial line **26**. At the end opposite junction **19**, the coaxial transmission line **22** is coupled to the wave guide **23** in a manner well known in the art, and the coaxial line **26** for delivering energy to the receiver **21** is similarly coupled to the T-R box output wave guide **25**.

The T-R box **24** is a power-selective device for conducting energy to the receiver **21** during periods of quiescence of transmitter **11**, but is characterized by an electric discharge resulting in a great impedance mismatch producing energy reflection during periods of high intensity output from transmitter **11**. The length and characteristics of the coupling elements including the wave guide **23** and the coaxial line section **22** are fixed so that for low-intensity energy intercepted by antenna **14**, an optimum impedance substantially matching the impedance of the antenna **14** and transmission line **13** is presented at the junction **19** by line **22**; while for high-intensity energy from transmitter **11**, the input impedance presented by line **22** at junction **19** is very much larger than the impedance of antenna **14** and transmission line **13**.

A further power-selective device similar to T-R box **24** may be employed as an R-T box **20** coupled through a transmission line section **12''** to the junction **30** of transmission lines **12** and **12'**. The length of the transmission line section **12''** and the coupling to the R-T box **20** is so fixed as to present a very low impedance at junction **30** during periods of low-intensity energization of box **20**, but to present a relatively high impedance at junction **30** during an electric discharge in the R-T box **20** produced by high-intensity energy from transmitter 11. In addition, the length of the transmission line section 12′ between junction 19 and junction 30 preferably is made equal to one-quarter of the wave-length of the energy transmitted and received by the radio object detection system.

During periods of high-intensity energy output from the transmitter 11, the R-T box 20 and the T-R box 24 present very high impedances at junctions 30 and 19 to the transmission line 12, 12′ and 13 through which the energy is conducted to the antenna 14. Accordingly, only a small fraction of the transmitter output energy is diverted to the R-T box and the T-R box, this fraction of the transmitter output energy being sufficient to sustain the electric discharges in the gaseous media within the boxes. During periods of quiescence of the transmitter 11, the very weak signals intercepted by antenna 14 from detected objects is far below the level required to produce electric discharges within the power-selective devices 20 and 24. The R-T box 20 therefore presents a very low impedance at junction 30, so that, by the well-known impedance transformation within a quarter-wavelength transmission line, the section 12′ extending from junction 30 to junction 19 presents a very high impedance at the junction 19 in shunt with the line sections 13 and 22. Accordingly, since the receiver 21 coupled through transmission line section 26, wave guide 25, the T-R box 24, wave guide 23 and transmission line section 22, presents an impedance at junction 19 matching the impedance of antenna 14 and transmission line 13, the greater part of the energy intercepted by the antenna 14 is sent through the T-R box 24 to the receiver 21. From this, it is seen that the R-T box 20 prevents an appreciable part of the energy intercepted by antenna 14 from being diverted through transmission line 12′ and dissipated in the transmitter 11.

Radio object detection systems of the type generally described above are well known and, accordingly, it is not necessary to describe the transmitter and receiver in detail here. The features of the present invention are embodied within the improved power-selective devices 20 and 24. T-R box 24 is shown in detail to illustrate these features.

T-R box 24, constructed in accordance with the present invention, comprises a cavity resonator having a cylindrical conductive wall 28 and conductive top and bottom plates 27 and 31. Two longitudinally extending slits or windows 32 and 33 are provided within the cylindrical wall 28 respectively for coupling energy from wave guide 23 into the cavity resonator 28, 27, 31 and for permitting the exit of energy from the resonator into the output wave guide 25. The internal dimensions of the cavity resonator 28, 27, 31 are determined relative to the wavelength of the transmitter 11 for supporting a circular electric field mode of oscillation. For this purpose, the inside diameter of the cylindrical wall 28 may be determined in accordance with well-known formulae for wave guides operated in any $TE_{0,n}$ mode, and the length thereof between the top and bottom plates may be made equal to an integral number of half-wavelengths at the wave energy propagation rate in the $TE_{0,n}$ mode wave guide. Preferably, this length is made equal to one half-wavelength in the interest of compactness. Preferably, n is unity.

Within the cavity resonator 28, 27, 31 is placed a conformally-shaped envelope 35 of glass or other solid dielectric which is filled with a readily ionized gas and pumped to a predetermined gas pressure usually lower than atmospheric pressure, for facilitating the formation of an electric discharge along annular path 34. A suitable gas is a mixture of hydrogen and water vapor, the former predominating, and the mixture having a pressure of the order of 25 millimeters of mercury.

In order to maintain a supply of ions in the gas within envelope 35, it is desirable that a relatively thin layer 36 of radioactive cobalt, or other radioactive material, be deposited on a surface of the glass envelope 35.

At the initiation of an output pulse from the ultra high frequency transmitter 11, a high-intensity tangential electric field is produced across the slit 32 by the electromagnetic wave energy transmitted through coaxial lines 12, 12′ and 22 and wave guide 23, and a very high-intensity circular electric field is thus produced within the T-R box 24. This results in a voltage breakdown or electric discharge within the annular path 34 within the resonator, with the result that the Q of the resonator is reduced to an extremely low value. As a result of the electric discharge within the T-R box 24, and the sharp diminuation of the Q of the resonator, the resonator becomes greatly mismatched to the wave guide 23, and thus energy arriving through the transmission line section 22 and the wave guide 23 is reflected at the slit 32 back toward the transmission line 22 and the junction 19, producing the very high impedance at junction 19 mentioned above, and the receiver 21 is accordingly protected from damage.

During intervals between high-intensity pulses generated by transmitter 11, reflected energy intercepted by the antenna 14 is transmitted through coaxial lines 13 and 22 and wave guide 23 to the T-R box 24 and, being of extremely low intensity, is insufficient to produce an electric discharge within the resonator. Accordingly, the Q of the resonator remains extremely high, so that efficient energy transfer is provided from the input wave guide 23 to the output wave guide 25, and the receiver 21 is thus provided with an almost unattenuated version of the signal energy intercepted by the antenna 14.

The radioactive material 36 deposited on the inner surface of the glass envelope 35 serves, as mentioned above, to maintain a condition of ionization within the T-R box 24 at all times, and thus to accelerate the formation of an annular electric discharge within the T-R box 24 upon the commencement of a high-intensity, ultra high frequency energy pulse generated by transmitter 11.

For some purposes it may be relatively inconvenient to employ a fixed-tuned power-selective device of the type shown at 24 in Fig. 1. As shown in Fig. 2, a variable tuning structure 41 may be incorporated within a T-R box 24′. The structure 41 includes a fixed top plate 42 having a threaded boss 43 thereon, an adjustable tuning screw 44, and an axially movable tuning plate or disc 45 supported by the tuning screw 44. A glass envelope 35 having therein a deposit 36 of radioactive material such as radioactive cobalt may be used just as in the power-selective device shown in Fig. 1. By rotating the tuning screw 44 in a direction to raise the plate or disc 45, the resonant wavelength of the power-selective device is increased and, accordingly, its resonant frequency is decreased. Conversely, rotation of the screw 44 in the opposite direction increases the resonant frequency of the T-R box 24'.

If desired, an arcuate slit or window 47 may be provided in the cylindrical wall 28' of the resonator 24' so that, during the formation of an electric discharge within the power-selective device, some light generated by the discharge may escape through the slit 47 to serve as an indication of the operation of the device.

An advantage of the circular electric field mode of excitation of the power-selective device is the obviation of low-resistance, high-frequency current-carrying electrical contact between the tuning disc 45 and the inner surface of the cylindrical wall 28'. In fact, since conduction currents on the inner surface of the cylindrical wall 28' should comprise only circular currents, i. e., should be characterized by the absence of any axial components, it may be desirable to provide an annular gap 48 between the inner surface of the wall 28' and the outer edge of the disc 45. Such a gap interferes with the response of the cavity resonator to modes of excitation other than the circular voltage modes, and thus insures best performance of the resonator. For the purpose of providing absorption of any energy which may leak into the space above the tuning disc 45, the upper surface of this disc, as well as the lower surface of the top plate 42, may be thickly coated with ultra high frequency energy dissipative material such as carbon, for example.

Although radioactive material 38 has been shown in the power-selective devices illustrated in Figs. 1 and 2, such radioactive material may be replaced by an electric discharge circuit, if desired, without impairing the high-Q feature of the present invention. As shown in Fig. 3, a power-selective device 24'', generally similar to that shown in Fig. 2, is provided with an electric discharge circuit including "keep-alive" electrodes 51 and 52 supported near the middle of the space within the glass envelope 35' as by seals 53 and 54 therein. Slit 47 serves to transmit light from the device 24'' during the formation of the electric discharge. Suitable sockets 55 and 56 for cooperating with extension pins 57 and 58 of the gas discharge keep-alive electrodes are provided in the bottom plate 31'' of the power-selective device and are insulated therefrom as by insulating bushings 59 and 61. The socket connector elements 55 and 56 may be connected to a keep-alive energization circuit including a source 63 and a series resistor 64 for limiting the discharge current produced within the "keep-alive" glow discharge path between electrodes 51 and 52. A greater number of keep-alive electrodes may be provided within the gas-filled envelope if desired.

From the foregoing description of the present invention, it is seen that a cavity resonator adapted for circular electric field mode excitation is used as a power-selective device, which may take the form of a T-R box for conducting low-intensity energy to a receiver, and for blocking high-intensity energization of the receivers. Another power-selective device of the present invention may be employed as an R-T box. As a result of the use of a circular electric field resonator, it is possible to produce an annular electric discharge within a gaseous medium contained in the resonator, and such a discharge may be made remote from any metal part of the resonator. Along with the elimination of discharge-path-defining electrodes and high-frequency connections thereto, the present invention provides a power-selective device characterized by much higher Q than was formerly obtained, resulting in improved selectivity and decreased insertion loss.

As shown in the drawing, the preferred embodiments of the power-selective devices constructed in accordance with the present invention are made with circular cross-section cylindrical side walls and disc ends. Such a structure probably represents the simplest form of the present invention for manufacture, and is a very efficient type of construction for providing the features for the present invention. However, the generally circular electric field resonator may take other forms, such as a cylinder having an elliptical cross-section. The end plates may be flat or may be curved upwardly or downwardly, or a hollow sphere could be employed for the resonator. The present invention is distinguished from former devices principally in the fact that the high-intensity electric field within the resonator is a continuous field within the gas therein so that it is not required to extend from one wall to another wall of the resonator. Accordingly, as pointed out above, contact difficulties are eliminated, and the Q and the efficiency of the power-selective device are greatly improved.

Thus, where in the appended claims the term "cylinder" is employed, this term is to be construed in its broadest sense as being a surface generated by the extension along an axis of a closed figure, so that the cross-section of the cylinder, as referred to hereinafter, may be circular, elliptical or otherwise, as desired. Similarly, where in the claims the end walls of the resonator are referred to as "discs," it will be understood that these terms are not intended to be restricted to elements characterized by planar surfaces, but may be curved upwardly or downwardly, without departing from the spirit of the present invention. Where a circular electric field mode of oscillation is referred to, it will be understood that this term is meant to define a field characterized by ring-like lines of electric force, the high-intensity lines of force being isolated from the walls of the cavity resonator within which the oscillations are produced. Also, by "annular electric discharge," the claims are intended to refer to an electric discharge which is not necessarily a discharge extending throughout a circular path, but is a discharge along the path of the ring-like lines of electric force referred to above.

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. A device of the character described comprising a conducting body having a cavity resonator characterized by supporting an electromagnetic wave energy mode having an annular electric field component, said resonator having input and output windows coupling electromagnetic wave energy therethrough; and a device for substantially reflecting high-intensity electromagnetic wave energy fields at said input window to prevent high-intensity oscillations in said cavity resonator, said device consisting in its entirety of a sealed vessel in said cavity resonator containing a body of ionizable gas, and means for maintaining ionization of said gas, said gaseous

body supporting an annular electric discharge due to said annular electric field component when said resonator is energized by said high-intensity waves.

2. A transmitter-receiver switch comprising a conducting body having a cavity resonator characterized by supporting an electromagnetic wave energy mode having an annular electric field component, said resonator having input and output windows for coupling electromagnetic wave energy therethrough; and means for substantially reflecting high-intensity electromagnetic wave energy fields at said input window to prevent high-intensity oscillations in said cavity resonator, said means consisting in its entirety of an ionizable gaseous medium, means sealing said gas in said resonator against loss through said windows, and a radio-active material maintaining ionization of said gaseous medium, said gaseous medium supporting an annular electric discharge owing to an increase in the magnitude of said annular electric field component when said resonator is energized by said high-intensity waves.

3. A transmitter-receiver switch comprising a conducting body having a cavity resonator characterized by supporting an electromagnetic wave energy mode having an annular electric field component, said resonator having input and output windows coupling electromagnetic wave energy therethrough; and a device for substantially reflecting high-intensity electromagnetic wave energy fields at said input window to prevent high-intensity oscillations in said cavity resonator, said device consisting in its entirety of a sealed vessel in said cavity resonator containing

a body of ionizable gas, and a radio-active material maintaining ionization of said gas, said gaseous body supporting an annular electric discharge in the presence of said annular electric field component when said resonator is energized by said high-intensity waves.

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