

Oct. 17, 1967

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3,348,169

CONTROLLABLE MICROWAVE IMPEDANCE UTILIZING MULTIPACTION

Filed April 4, 1962

4 Sheets-Sheet 1

Fig. 1

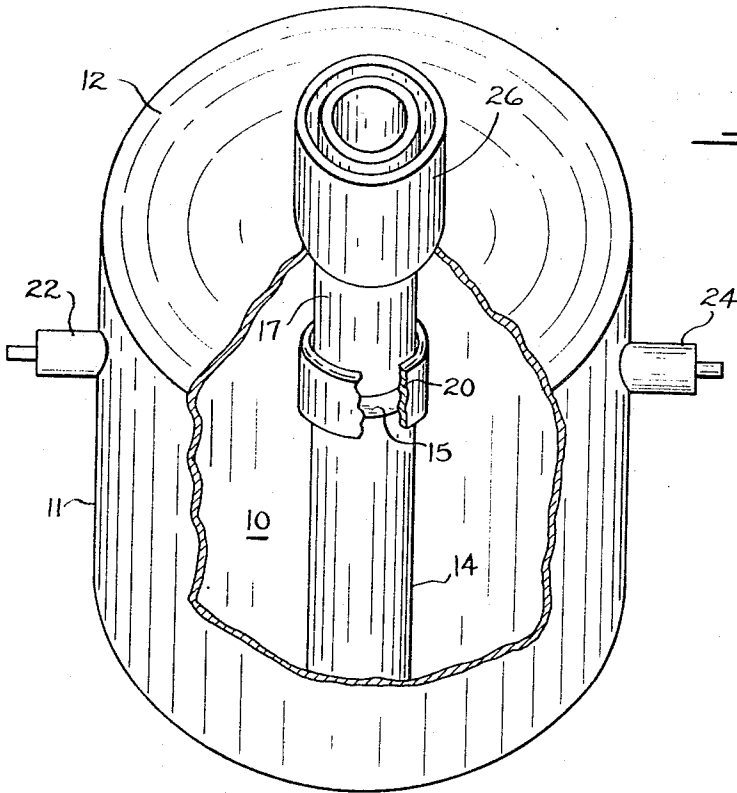
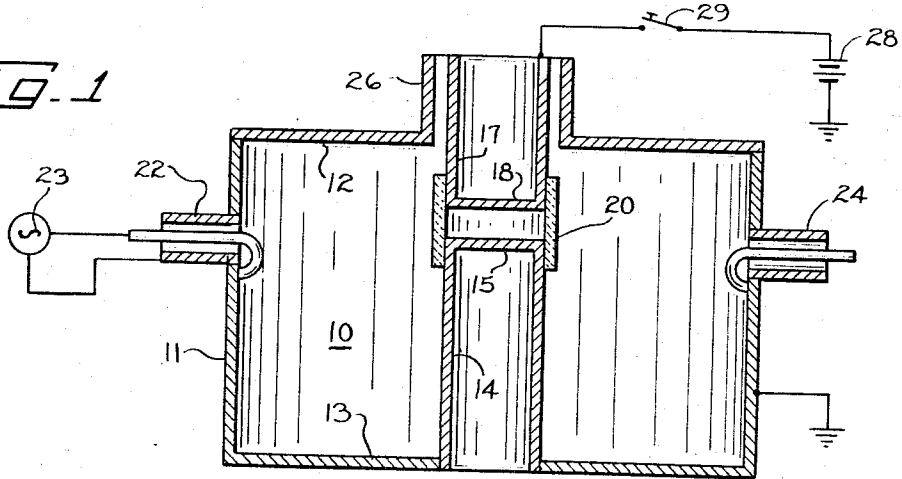


Fig. 2

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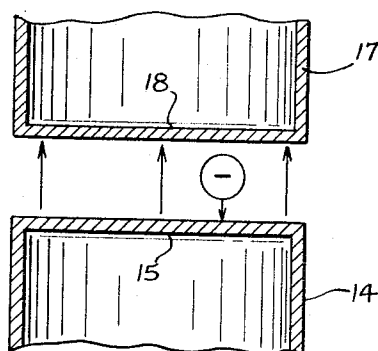


Fig. 3

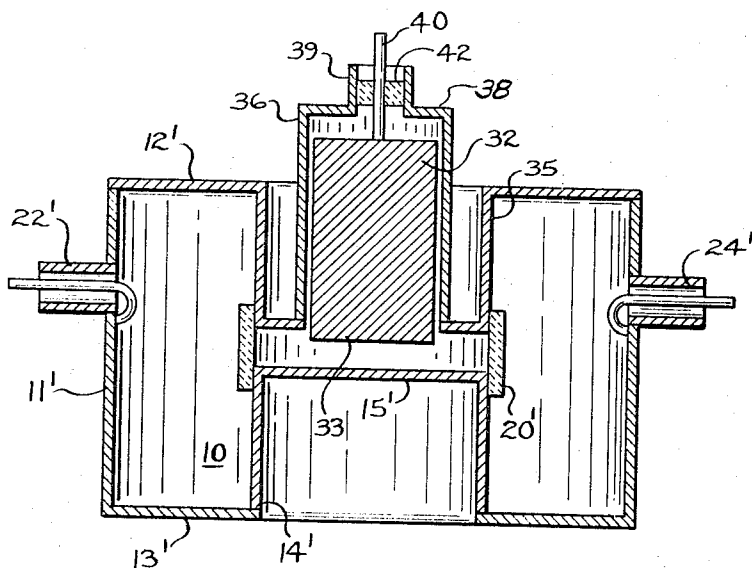


Fig. 4

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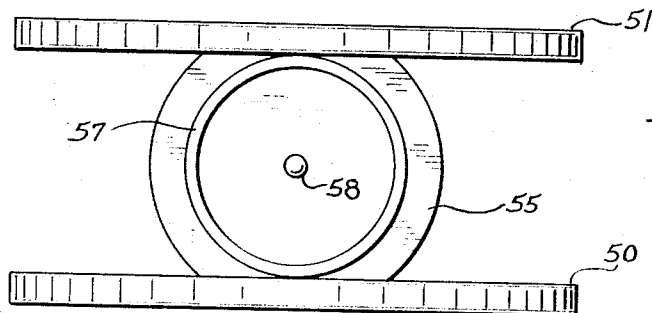


Fig. 5

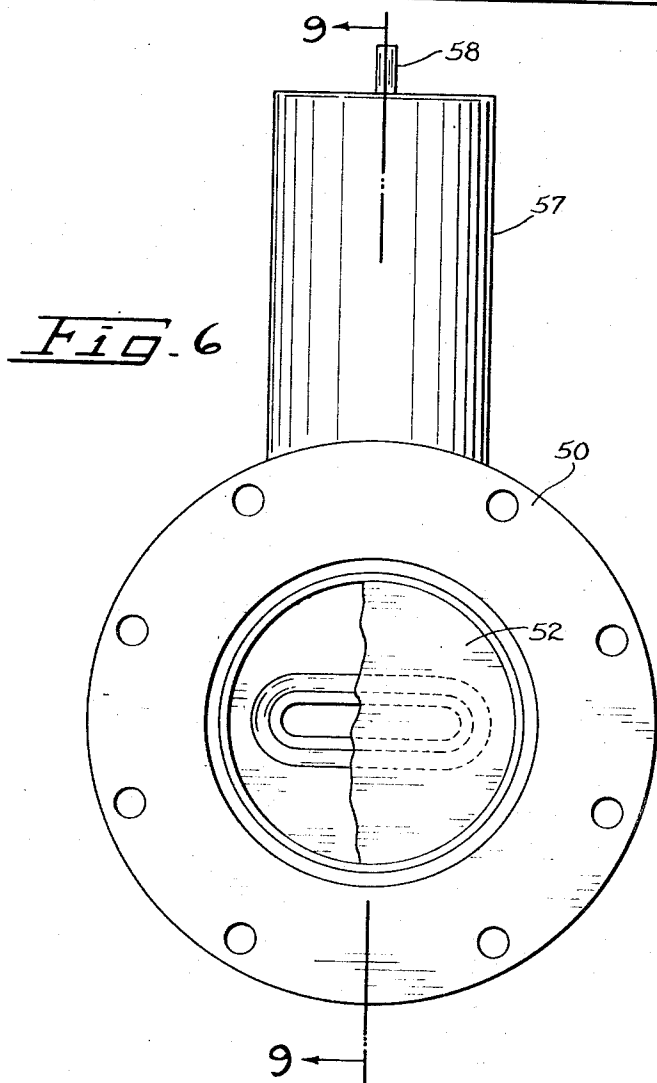


Fig. 6

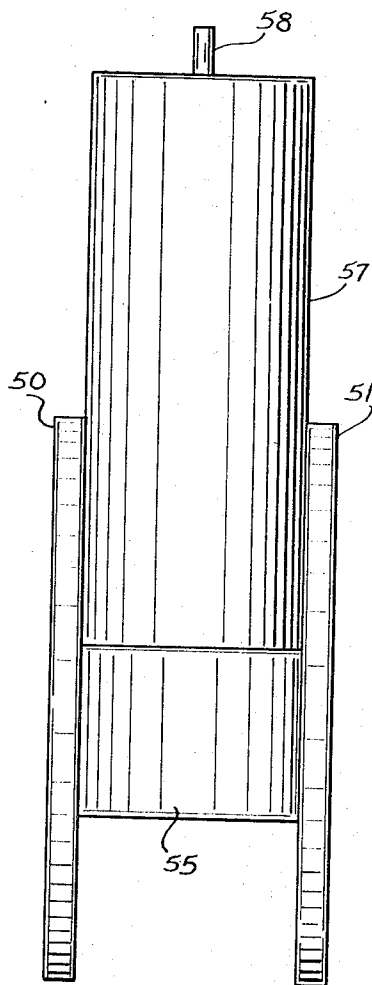


Fig. 7

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CONTROLLABLE MICROWAVE IMPEDANCE UTILIZING MULTIPACTION

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Fig. 8

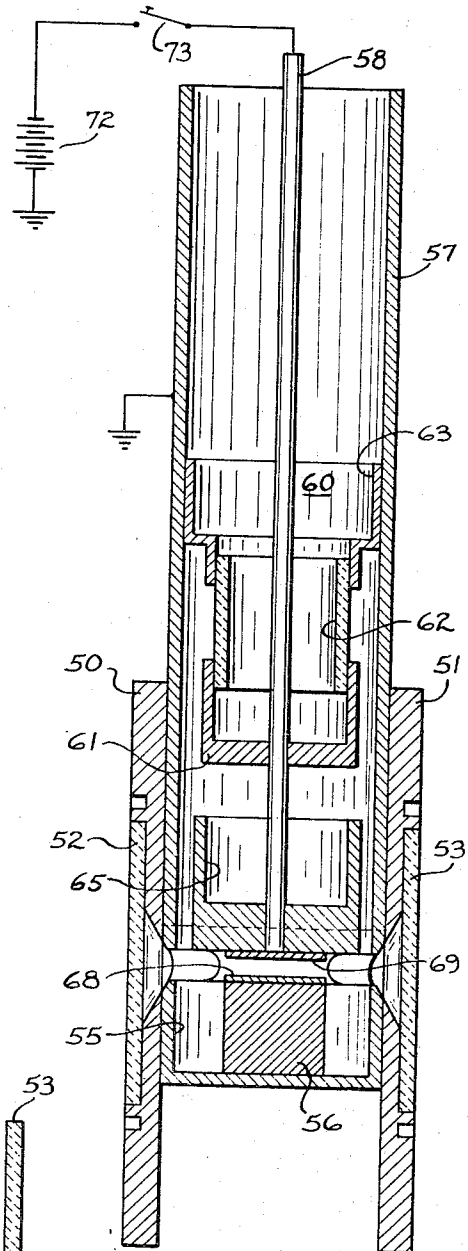
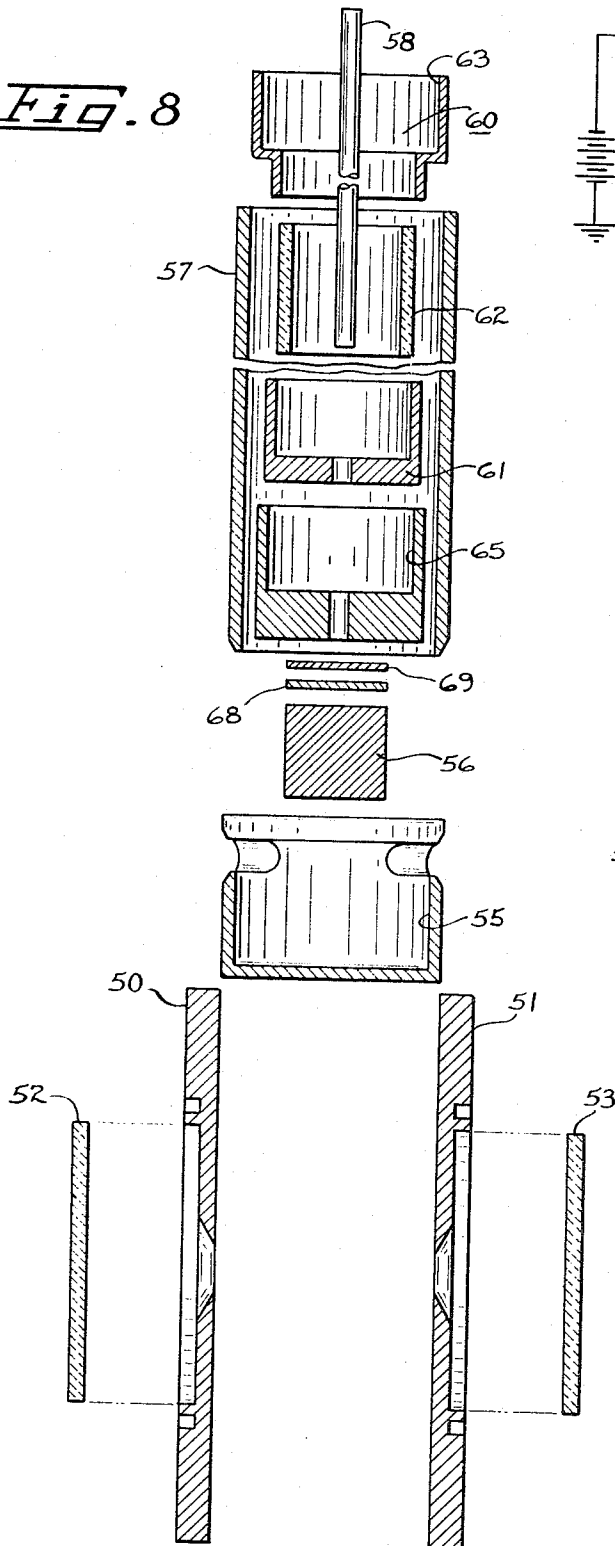


Fig. 9

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3,348,169

CONTROLLABLE MICROWAVE IMPEDANCE UTILIZING MULTIPACTION

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Filed Apr. 4, 1962, Ser. No. 185,907
8 Claims. (Cl. 333-13)

This invention relates to devices providing multipactor discharge and more particularly to a cell employing a controllable multipactor discharge for operation as a variable impedance or switch for microwaves.

In the microwave art, electromagnetic waves having microwave frequencies, termed microwaves, are transmitted from point to point, often through hollow conductive tubes termed waveguides. In systems employing waveguides to transmit waves, the amplitude or phase of the wave flowing in a waveguide are varied by employing controllable devices, termed variable impedances. One form of variable impedance used to selectively permit or prohibit the passage of microwaves through a particular waveguide is known as a waveguide switch.

Prior art variable impedances and switches for microwave transmission and control include mechanical, gaseous, and ferrite devices. In the mechanical devices shutters, plungers, or vanes are selectively positioned within the waveguide to control microwave transmission; i.e., one form of waveguide switch comprises a plate rotatable for closing the waveguide passage to prohibit transmission. In the gaseous devices the microwaves are transmitted through gas-enclosing cells disposed within the waveguide, and a high voltage is applied across the gas cell to produce ionization of the gas molecules and thereby inhibit transmission of microwaves through the cell. In the ferrite devices, various configurations of ferrite material are disposed within the waveguide, and controllable magnetic fields are applied to the ferrite material and thereby prohibit, permit, or restrictively permit the transmission of microwaves through the waveguide.

The common disadvantage of these prior art variable impedances and switches is their relative slowness of operation. In modern microwave technology it is common to transmit microwaves in bursts, known as pulses, spaced but a few millionths of a second (microseconds) apart, the duration of the bursts frequently being substantially less than one-millionth of a second. In the mechanical type variable impedances and switches the inertia of the structure normally prohibits effective control, or change in operation, in less than one-thousandth of a second. In the ferrite variable impedances the difficulty in rapidly changing the magnetic field penetrating the ferrite by adequate amounts in less than many microseconds prevents rapid response to control signals, unless very expensive and bulky current controlling equipment is provided. In the gaseous variable impedances, once the gas has become ionized many microseconds are required for the gas to deionize so as to once again permit unimpeded passage of the microwaves therethrough. However, in this modern microwave technology it is not only desirable to have a variable impedance or switch function in the interval between two successive pulses, which may be spaced only a few microseconds apart, but it is sometimes advantageous to provide for altering the value of the impedance or state of the switch within the duration of an individual pulse; i.e., within a period considerably less than a microsecond.

Accordingly, it is the principal object of this invention to provide an improved controllable microwave impedance.

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Another object of this invention is to provide an improved microwave switch.

Another object of this invention is to provide a microwave device whose impedance may be varied at extremely rapid rates.

Another object of this invention is to provide a controllable microwave impedance whose value may be altered within the duration of a microwave pulse.

The foregoing objects are achieved, according to one embodiment of the invention, by providing a hollow conductive chamber, known as a cavity resonator, in the path of the microwaves, and by providing a variable impedance element in the form of a controllable multipactor discharge across the resonator. The cavity resonator is provided with first and second opposed walls, the first wall having an aperture therein. A conductive plate is disposed opposite the second wall in the aperture. A portion of the resonator is evacuated and sealed to maintain the region between the plate and the opposing portion the second wall evacuated. Coupling to the resonator is provided for delivering electromagnetic energy to the region between the plate and the second wall. The opposing surfaces of the plate and the second wall are comprised of material characterized by a secondary emission ratio greater than unity for the energy level of electromagnetic energy supplied. The spacing between the plate and the second wall is adjusted to support multipactor discharge therebetween, multipactor discharge being a sustained secondary emission discharge between opposed surfaces as a result of the motion of secondary electrons produced at the surfaces in synchronism with the alternating field of electromagnetic energy existing between the surfaces. The plate is electrically insulated from the first wall and filtering means is coupled between the plate and the first wall to prevent escape of electromagnetic energy therebetween. A control voltage of variable level is coupled between the plate and the second wall. In operation, when such control voltage is at zero level, electromagnetic energy applied to the region between plate and second wall induces a multipactor discharge therebetween, the discharge thereby simulating a short-circuit, or relatively low impedance, between plate and second wall. When the control voltage level between plate and second wall is increased the multipactor discharge is rendered less intense, or is extinguished, whereby a controllable impedance or switching action is simulated. A rapid application of the control voltage provides an equally rapid extinction of the multipactor discharge, whereas a sudden reduction of the control voltage provides an equally rapid initiation of the multipactor discharge. Thus, an extremely rapid response controllable impedance is provided by the cavity resonator with controllable multipactor discharge.

The invention will be described with reference to the accompanying drawings wherein:

FIGURE 1 is an elevational view, in cross section, of one embodiment of the invention;

FIGURE 2 is a perspective view, partly in cross section of the embodiment of FIG. 1;

FIGURE 3 is an enlarged partial sectional view of the embodiment of FIG. 1, illustrating the principle of operation thereof;

FIGURE 4 is an elevational view, in cross section, of a second embodiment of the invention;

FIGURE 5 is a top view of a third embodiment of the invention;

FIGURE 6 is a side elevational view of the embodiment of FIG. 5;

FIGURE 7 is a front elevational view of the embodiment of FIG. 5;

FIGURE 8 is an exploded view, in cross-section, of the embodiment of FIGS. 5, 6, and 7; and

FIGURE 9 is a cross-sectional view of the embodiment of FIGS. 5, 6, and 7.

The variable impedance cell of FIGS. 1 and 2 comprises a cavity resonator 10, having conductive walls, in the form of a figure-of-revolution. Resonator 10 comprises a cylindrical wall 11 and a pair of opposed plane walls 12 and 13. Wall 13 is provided with a cylindrical reentrant portion 14 having a plane circular end member 15 on one end thereof. An aperture is provided centrally in wall 12, and supported within the aperture is a cylindrical member 17. A plane circular end member 18 is affixed to the end of cylindrical member 17 opposing end member 15. The opposing surfaces of end members 15 and 18 comprise material characterized by a secondary emission ratio greater than unity for a predetermined level of electromagnetic energy, as will be described in greater detail hereinafter.

A cylindrical dielectric window 20 is affixed and sealed to the outer surface of reentrant portion 14 near one end thereof and to outer surface of cylindrical member 17 near one end thereof. Window 20, composed of a material such as glass, functions as a gas seal, transparent for passage of electromagnetic energy, but impervious to the passage of gas molecules. Accordingly, while the region between the opposed surfaces of end members 15 and 18 is evacuated and this region is maintained evacuated by window 20, the window permits passage of electromagnetic energy into the region.

A coaxial coupler 22 is affixed in cylindrical wall 11 and functions to transmit electromagnetic energy generated by a source, or generator, 23 to resonator 10. An additional coupler 24 functions to extract electromagnetic energy transmitted through resonator 10 to a utilization device, not shown.

A cylindrical member 26 is affixed to plane wall 12 surrounding the aperture therein, and is disposed coaxially with respect to and spaced from cylindrical member 17. Cylindrical member 26 is approximately one-quarter wavelength in height at the operating frequency of source 23. Member 26 and the opposing surface of cylindrical member 17 functions as an open-ended quarter-wavelength choke, or as a filter which prohibits the transfer therethrough of electromagnetic energy at the frequency of source 23. In this manner electromagnetic energy in resonator 10 will not escape from the cavity resonator by leaking by the circular gap between the cylindrical member 17 and wall 12.

A voltage source 28 has one pole thereof coupled through a ground connection and through the walls of resonator 10 to end member 15. The other pole of source 28 is coupled through a switch 29 to end member 18. The form of the controllable voltage applied between end members 15 and 18 is not limited to that shown. For example, an alternating modulating voltage may replace source 28 and switch 29 and yet be consistent with the principles of the instant invention. Additionally, switch 29 may be an electronically controlled switch rather than the device shown.

The manner of operation of the variable impedance cell, as presently understood, will now be described. In FIG. 3 the long vertical lines with arrows thereon represent, at a given instant, the distribution of the electric field component of the electromagnetic energy in the region between the opposed surfaces of end member 15 and 18. For electromagnetic energy of microwave frequencies, the electric field illustrated reverses its direction at thousands of megacycles each second. Thus, at one moment the electric field will be directed upwardly, as illustrated in FIG. 3, and one-half cycle later it will be directed downwardly.

The electric field represents the force on positive electric charges, and the direction of the electric field represents the direction of this force. Thus, at the moment illustrated in FIG. 3, positive charges will experience an upward force and, therefore, will be accelerated toward

end member 18. Conversely negative charges, such as the one shown, at the same moment will experience a downward force and, therefore, will be accelerated toward end member 15.

It is well known that the entire region immediately above the earth's surface is continually subjected to radioactive emissions from materials in the earth's surface and from cosmic rays. A significant portion of the matter receiving these radioactive emissions and cosmic rays will be ionized thereby; in other words, such matter will be broken into positive and negative charges wherein the negative charges are electrons. The interior of the evacuated region of resonator 10 is therefore always subjected to those radioactive emissions and cosmic rays. Since a perfect vacuum can never be attained, this evacuated region always contains a small number of residual gas molecules. Consequently, ionization of a small fraction of these residual gas molecules will continually be occurring, so that a number of electrons are always present in the evacuated region of resonator 10. These residual electrons will be accelerated by the electric field of the microwave energy and many will strike one of the end members 15 and 18.

When electrons strike a surface, other electrons are driven from the surface by the energy of impact. The electrons striking the surface are termed primary electrons and the electrons driven from the surface are termed secondary electrons. The ratio of the number of secondary electrons created to the number of primary electrons striking a surface is defined as the secondary-emission ratio. The secondary-emission ratio varies with the velocity of the primary electrons and the material of the surface. For many types of surface materials secondary-emission ratios greater than unity are provided for a wide range of electron velocities; for example, see K. R. Spangenberg, "Vacuum Tubes," pages 48-57, McGraw-Hill Book Company, Inc., New York, 1948. However, these surface materials do not provide a secondary-emission ratio greater than unity for very slow or very fast primary electrons.

End members 15 and 18 are provided with such a surface material adapted to yield a secondary-emission ratio greater than unity for primary electrons having a wide range of velocities. One such surface material particularly suitable for employment for this purpose is an alloy of silver and magnesium, such as that described by V. K. Zworykin, J. E. Ruedy, and E. W. Pike, "Silver-Magnesium Alloy as a Secondary Electron Emitting Material," J. Appl. Phys., vol. 12, pages 696-698, September 1941.

Consequently, if the strength of the electric field component of the electromagnetic energy in the region between end members 15 and 18 is sufficiently great, a number of residual electrons formed in the evacuated region will be accelerated to strike end members 15 and 18 with sufficient energy to create a greater number of secondary electrons. Providing that the electric field reverses direction immediately after creation of these secondary electrons they will be accelerated in a direction away from the surface at which they were created and toward the opposing end member. Thus, consider the instant depicted in FIG. 3. Residual electrons created in the region between end members 15 and 18 will be accelerated toward end member 15. If the electric field persists in the direction shown sufficiently long for the residual electrons to strike end member 15, secondary electrons will be emitted therefrom greater in number than the primary electrons, provided the electric field strength is sufficiently great. If, now, the electric field reverses direction immediately after creation of these secondary electrons, they will be accelerated toward end member 18. Once again, if the electric field provided in this reverse direction persists sufficiently long for this group of secondary electrons to travel from end member 15 to end member 18, a new group of secondary elec-

trons will be impelled from end member 18, this new group being greater in number than the original group of electrons striking end member 18. Again, if the electric field reverses immediately after formation of this new group, the new group will be accelerated toward end member 15. Thus, with sufficient electric field strength and an appropriate frequency of the electromagnetic energy secondary electron groups travel back-and-forth between the opposed surfaces of end members 15 and 18. With such favorable conditions the size of each secondary electron group grows after each reversal until a sheet of electron current is created across the gap defined by the opposed surfaces of members 15 and 18. The current flowing in the manner described is termed a multipactor discharge and, therefore, is defined as a sustained secondary-emission discharge existing across the gap as a result of the motion of secondary electrons in synchronism with a strong rapidly alternating electric field applied to the gap. Accordingly, the height of the gap in resonator 10 is adjusted by design or by experiment so that synchronism of the secondary electrons with electromagnetic energy of appropriate strength and frequency provides a multipactor discharge.

As described thus far, and assuming that the switch 29 of FIG. 1 is open, resonator 10 will provide a multipactor discharge between end members 15 and 18 when electromagnetic energy is received in the gap from source 23. This multipactor discharge will function as an equivalent short circuit across the gap defined by members 15 and 18, thereby attenuating or preventing transmission of electromagnetic energy to output coupler 24. Consider now, the operation when switch 29 is closed. The voltage of source 28 is coupled directly across the gap between end members 15 and 18 and serves to superpose a steady electric field on the rapidly alternating electric field of the electromagnetic energy. The electric field so created by voltage source 28 aids the microwave field when it is directed upwardly in the gap, but opposes such field when it is directed downwardly. Therefore, an augmented electric field appears across the gap of FIG. 3 during the alternate half-cycles of the microwave energy and a diminished electric field appears across the gap during the remaining half-cycles. With a stronger upward than downward force on secondary electrons created in the gap, the time required for secondary electrons to cross the gap will be less for one set of half-cycles of the microwave energy than for the other set of half-cycles. Therefore, synchronism between secondary electrons and a constant frequency electromagnetic field cannot be maintained and the multipactor discharge will either be extinguished or substantially reduced in intensity. If the voltage of source 28 is of sufficient strength, the velocity of secondary electrons striking end member 18 will be too great for the surface of member 18 to provide a secondary-emission ratio greater than unity. Accordingly, immediately upon application of such an intense voltage, by the closing of switch 29, the multipactor discharge will terminate. This termination is very rapid and will occur within approximately one-half cycle of the microwave frequency. Additionally, if the voltage of source 29 is of sufficient strength, the velocity of secondary electrons striking end member 15 will be too small for the surface of member 15 to provide a secondary-emission ratio greater than unity. Therefore, a very rapid switching action, normally occurring in less than one-half cycle of the microwave frequency, may be effected by rapid application of a large steady voltage across the gap defined by end members 15 and 18. On the other hand, if source 28 and switch 29 are replaced by a large alternating voltage, resonator 10 will function as a modulator wherein the multipactor discharge is alternately starting and extinguishing at the frequency of modulation; therefore, the microwave energy transmitted by coupler 24 will be modulated at the frequency of the alternating voltage. If the amplitude of the alternating

voltage is not sufficiently great to extinguish, but only to decrease the intensity of the multipactor discharge, the discharge will function as variable impedance and a smaller level of modulation will take place. Accordingly, the instant invention, by providing a controllable voltage across a gap supporting a multipactor discharge, provides an extremely rapid-acting switch or a modulator operative at very high modulation frequencies.

In the embodiment of this invention illustrated in FIG. 4, elements corresponding to those of the embodiment of FIGS. 1 and 2 have been numbered with similar primed reference numerals. The variable impedance cell of FIG. 4 comprises a cavity resonator 10', having conductive walls, in the form of a figure-of-revolution. Resonator 10' comprises a cylindrical wall 11' and a pair of opposed plane walls 12' and 13'. Wall 13' is provided with a cylindrical reentrant portion 14' having a plane circular end member 15' on one end thereof. An aperture is provided centrally in wall 12' and supported within the aperture is a cylindrical member 32. The end of cylindrical member 32 opposite end member 15' is designated by the reference number 33. The opposing surfaces of end member 15' and end 33 comprise material characterized by a secondary-emission ratio greater than unity for the energy level of electromagnetic energy to be received therebetween during operation.

A reentrant cylinder 35 is affixed to wall 12', surrounding the aperture therein, and extends toward reentrant portion 14'. A cylindrical dielectric window 20' is affixed and sealed to the outer surface of the reentrant portion 14' near one end thereof and to the outer surface of cylinder 35 near one end thereof. Window 20' functions as a gas seal, transparent for the passage of electromagnetic energy, but impervious to the passage of gas molecules. Accordingly, while the region between the opposed surfaces of end member 15' and end 33 is evacuated and this region is maintained evacuated by window 20', the window permits passage of electromagnetic energy into the region.

A coaxial coupler 22' is affixed in cylindrical wall 11' and functions to transmit electromagnetic energy generated by a source, not shown, to resonator 10'. An additional coupler 24' functions to extract electromagnetic energy transmitted through resonator 10' to a utilization device, not shown.

A cylindrical wall 36 is affixed at the lower end thereof to cylinder 35 and is disposed concentrically within cylinder 35. An apertured end wall 38 encloses the upper end of cylindrical wall 36. Surrounding the aperture in wall 38 is a small hollow cylinder 39. A conductive rod 40 is disposed concentrically within cylinder 39 and is affixed to one end of cylindrical member 32. Rod 40 functions to support member 32 concentrically with cylindrical wall 36 and spaced from end member 15'. Rod 40 also functions as an electrical connection for the switching or modulating voltage, which is not shown. An insulator support 42 is disposed between cylinder 39 and rod 40 and serves as a spacing and supporting member for rod 40. Additionally, insulator support 42 is sealed in a gas-tight manner to the inner surface of a cylinder 39 and the outer surface of rod 40 to form a gas seal to maintain the vacuum in the region between end member 15' and end 33. Cylindrical member 32 is approximately one-quarter wavelength long, at the operating frequency of the electromagnetic energy to be supplied. Accordingly, the outer surface of member 32 and the spaced, but opposing inner surface of cylindrical wall 36 function as an open-ended quarter wavelength choke, or as a filter which prohibits the transfer therethrough of electromagnetic energy, as described in the theory of operation of FIGS. 1 and 2. Thus, the cell of FIG. 4 may function as a high-speed controllable impedance or switch, according to the nature of the voltage applied to rod 40.

An additional embodiment of the invention is illustrated in FIGS. 5-9. This embodiment is adapted to be

inserted in a waveguide transmission system, or in a cavity resonator of the types shown in FIGS. 1, 2, and 4. A pair of apertured end plates 50 and 51 are disposed on opposite sides of the switch and are employed to couple the switch to a waveguide system or to a cavity resonator. A pair of disc-shaped dielectric windows 52 and 53 function as a gas seal to permit the transfer of electromagnetic energy therethrough, but to maintain a vacuum in the region between the windows. Disposed between plates 50 and 51 is a hollow member 55 having opposing apertures for transmission of microwaves. A cylinder 56 is supported on the bottom portion of member 55 and extends upwardly therefrom. An elongated cylinder 57 abuts the upper surface of member 55 and extends upwardly between plates 50 and 51. Supported concentrically with cylinder 57 is a rod 58.

A support member, denoted generally by the numeral 60, is affixed to the interior wall of cylinder 57 and functions to support rod 58 therein. Support member 60 comprises a cup-shaped member 61, a cylindrical window 62, and an annular member 63. The outer surface of the upper portion of annular member 63 is sealed, as by brazing, to the inner surface of cylinder 57 in a gas-tight manner and supports member 60 within cylinder 57. The outer surface of cylindrical window 62 is sealed at one end thereof to the inner surface of annular member 63 and at the other end thereof to the inner surface of cup-shaped member 61. Cylindrical window 62 thereby functions as an insulating support member for rod 58 and simultaneously serves to maintain a gas seal. Cup-shaped member 61 is provided with an aperture in the lower portion thereof to receive rod 58, and is thereby sealed to rod 58 to maintain the requisite vacuum seal, provided generally by supporting member 60.

A cup-shaped member 65 is affixed to the lower end of rod 58, with the lower portion thereof facing the upper surface of cylinder 56. The upper portion, or skirt, of cup-shaped member 65 is approximately one-quarter wavelength in height and functions, in cooperation with the spaced opposing inner surface of cylinder 57, as a choke, or filter, to prevent leakage of microwave energy into cylinder 57.

Although, cylinder 56 and cup-shaped member 65 may comprise a material having a satisfactory secondary-emission ratio to sustain multipactor discharge therebetween, in the instant embodiment a separate secondary emitting material is employed. A secondary emitting disc 68 is affixed to the upper surface of cylinder 56 and a secondary emitting disc 69 is affixed to the lower surface of cup-shaped member 65. Discs 68 and 69 comprise materials having high secondary-emission ratios, such as the silver-magnesium alloy previously described.

The region between discs 68 and 69 is maintained evacuated by disc-shaped windows 52 and 53 and cylindrical window 62. The spacing between discs 68 and 69 is adjusted to provide a multipactor discharge thereacross in the presence of the microwave energy to be supplied.

A variable amplitude or control voltage, to quench the multipactor discharge for switching or to vary the intensity of the discharge for modulation is connected to rod 58. This voltage is shown symbolically as being provided by a voltage source 72 and the switch 73.

For the embodiment of FIGS. 5-9, the following typical characteristics have been determined. The cell was designed to operate at approximately 2800 megacycles. The spacing between discs 68 and 69 was approximately one-quarter inch. Upon application of 9500 control volts between pulses, multipactor discharges due to microwave pulses up to 70 kilowatts were extinguished. For 70 kilowatt microwave pulses, the intensity of the discharge was found to decrease as the electrode voltage was increased from 220 volts to 9500 control volts. On the other hand, one-half microsecond, 8300 volt control pulses were adequate to extinguish the discharge when applied during the duration of a microsecond, 70 kilowatt pulses. The

total time for the discharge to terminate was less than one one-hundredth of a microsecond. With microwave pulses of 2.1 megawatts, 9600 control volts, or greater, would extinguish a discharge, once started. If the control voltage were applied prior to application of the microwave energy, the discharge for 2.1 megawatt pulses would still take place for control voltages less than 2700 volts, would sometimes occur for ranges of control voltages between 2700 and 7800, but would not occur for greater than 7800 control volts.

Accordingly, there has been described herein three embodiments of a device operable as a very rapid action microwave switch or as a high frequency modulator for microwaves, wherein the switching or modulation function is accomplished through the vehicle of a multipactor discharge, the multipactor discharge taking place in an evacuated region between a pair of mutually insulated electrodes and the switching or modulating voltage being applied across the electrodes.

While the principles of the invention have now been made clear in an illustrative embodiment, there will be immediately obvious to those skilled in the art many modifications in structure, arrangement, proportions, the elements, materials, and components used in the practice of the invention, and otherwise, which are particularly adapted for specific environments and operating requirements, without departing from those principles. The appended claims are therefore intended to cover and embrace any such modification, within the limits only of the true spirit and scope of the invention.

What is claimed is:

1. A microwave system comprising a source of microwave energy, load means to utilize the microwave energy from said source, waveguide means interconnecting said source and said load means, a microwave switching device disposed in the path of said microwave energy between said source and said load and comprising a pair of opposing electrodes having an evacuated region therebetween, each of said opposing electrodes so spaced that upon the incidence of microwave energy of a given frequency, oscillatory motion of electrons occurs between said electrodes with a transit time from one to the other of said pair of electrodes of substantially one-half the period of the incident microwave energy and with sufficient energy to cause secondary electron emission from at least one of said electrodes at a ratio with respect to incident primary electrons of greater than unity, a direct current potential source connected across said electrodes and means to apply a direct current potential from said direct current potential source across said electrodes to permit the passage of the microwave energy through said switching device and to prevent the establishment of a discharge between said electrodes.

2. A microwave system comprising a switching device having a pair of opposing electrodes with an evacuated region therebetween, said electrodes so spaced that upon the incidence of microwave energy of a given frequency, oscillatory motion of electrons occurs between said electrodes with a transit time from one to the other of said pair of electrodes of substantially one-half the period of the incident microwave energy and with sufficient energy to cause secondary electron emission from at least one of said electrodes at a ratio with respect to incident primary electrons of greater than unity, a direct current voltage source electrically coupled across said opposing electrodes, wave guide means disposed to direct microwave energy between said opposing electrodes and through said evacuated region, means to disconnect said direct current voltage source from said electrodes, and means for the introduction of electrons into said evacuated region to permit a discharge to occur in said evacuated region between said opposing electrodes and to substantially prevent the transmission of microwave energy therethrough.

3. A cell for providing a variable impedance comprising: a pair of opposed spaced conductive elements adapted

to support a multipactor discharge therebetween, means for electrically insulating one of said elements from the other, means for maintaining the region between said elements substantially evacuated, means for coupling said region to a source of electromagnetic energy, said source being adapted to supply electromagnetic energy to said region at an energy level inducing multipactor discharge between said elements, the spacing between said elements being adjusted in relation to the frequency of said electromagnetic energy to support said multipactor discharge, and means for selectively applying a voltage between said conductive elements, said voltage having a magnitude sufficient to present a multipactor discharge between said elements for electromagnetic energy having said energy level.

4. The cell of claim 3 wherein each of the opposed surfaces of said elements comprises a material characterized by a secondary-emission ratio greater than unity for electromagnetic energy in said region having said energy level.

5. A cell for providing a controllable multipactor discharge comprising: a pair of opposed spaced conductive members, each of the opposed surfaces of said member comprising a material characterized by a secondary-emission ratio greater than unity for a predetermined energy level of electromagnetic energy in the region between said opposed surfaces, means for electrically insulating one of said members from the others, means for maintaining said region substantially evacuated, means for coupling electromagnetic energy having said predetermined level to said region, said electromagnetic energy providing a sustained secondary-emission discharge between said surfaces as a result of the motion of secondary electrons produced at said surfaces in synchronism with the alternating field of said electromagnetic energy, and means for selectively applying a voltage between said members, said voltage having a magnitude sufficient to prevent said sustained secondary-emission discharge between said surfaces for electromagnetic energy having said predetermined energy level.

6. A cell for providing a variable impedance comprising: a first metallic member having an aperture therein, a second metallic member disposed within said aperture

and spaced from said first member, a third metallic member disposed opposite said second member, means for maintaining the region between said second and third members substantially evacuated, means for coupling said region to a source of electromagnetic energy, said source being adapted to supply electromagnetic energy to said region at an energy level inducing multipactor discharge between said second and third members, the spacing between said elements being adjusted in relation to the frequency of said electromagnetic energy to support said multipactor discharge, filter means coupled to said first and second members to prevent the escape of said electromagnetic energy therebetween, and means for selectively applying a voltage between said second and third members, said voltage having magnitude sufficient to prevent multipactor discharge between said second and third members for electromagnetic energy having said energy level.

7. The cell of claim 6 wherein said aperture and said second members are circular.

8. The cell of claim 7 wherein said filter means comprises coaxially disposed inner and outer conductors, said outer conductor being affixed at one end thereof to said first member and said inner conductor being affixed at one end thereof to said second member.

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