

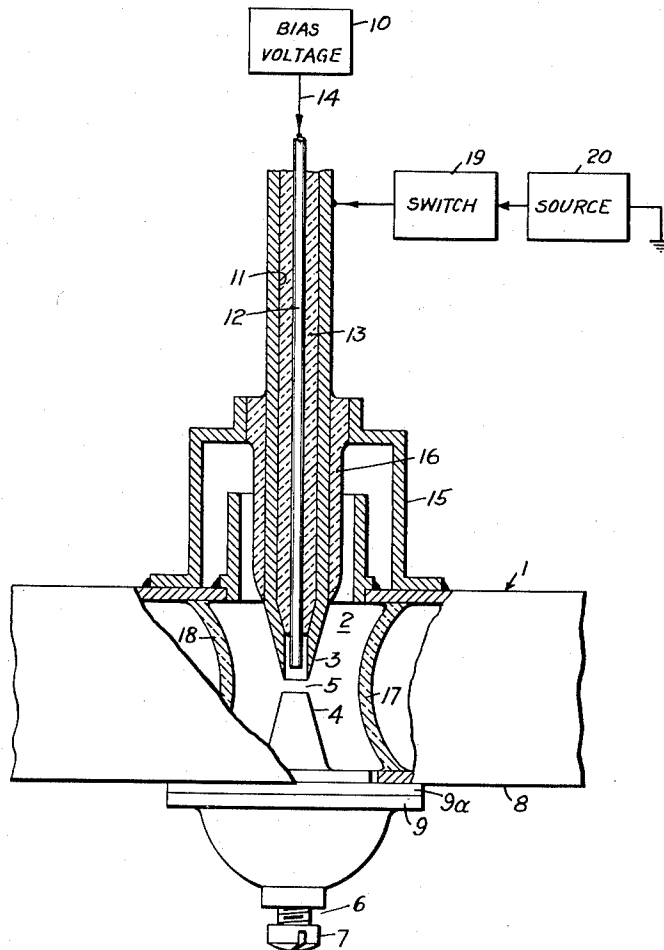
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WAVE GUIDE WITH DUAL PURPOSE GAS DISCHARGE DEVICE

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WAVE GUIDE WITH DUAL PURPOSE GAS DISCHARGE DEVICE

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This invention relates to a gas discharge device for use at ultra-high frequencies and more particularly to a gas discharge device which performs the dual function of a T-R box and attenuating switch. By the abbreviation "T-R" as used, for example, in "T-R box," I refer to the well-known abbreviation for the term "transmission-reception." This will be the meaning of this abbreviation where used in the specification and claims.

In order to be able to control the flow of guided electromagnetic energy, a variation in circuit elements must be produced in the guiding system. Such variations can be achieved mechanically, but in general the time duration involved in mechanical operations is very limited, and if a very rapid control of the energy flow is desired, other means must be provided.

The controlling circuit elements must have adequate electrical conductivity at the frequency of the low or high intensity microwave fields to be controlled. The ideal inertialess controlling circuit element for microwave energy is a pure electron gas created in an appropriate volume of the waveguide system. It is known from the free electron model of the electrical conductivity in metals that conductivity is proportional to the density of the electrons responsible for it. For this reason to obtain high electrical conductivities in an otherwise non-conducting medium by the creation of an electron gas in that medium, the density of such a gas must be very high. It is also known that because of the space charge forces which arise in a pure electron gas, only limited densities can be obtained. It is necessary that the controlling circuit element constituted by an electron gas have the required minimum density for reasonable conductivities, and this can only be obtained if the electron gas is space charge compensated. A simple way to produce a high electron density, space charge compensated, free electron gas is to produce a discharge in a non-electronegative gaseous medium. There, under certain conditions, space charge compensation occurs, the positive ions being produced with the electrons in equal numbers. Under these conditions, however, the electron gas is not a pure gas but has certain partial pressures in the gas mixture in which it is produced.

T-R box operation and control of low power, high frequency, energy flow in switching operations are both dependent on the complex conductivity of a non-pure, space charge compensated electron gas. The specific requirements, however, are different in the two operations.

As the main purpose of a T-R tube is to connect the antenna to the transmitter while effectively protecting the receiver from possible damage due to the high power, radio-frequency pulse of the transmitter, the T-R tube is generally operated by the leading edge of high power, radio-frequency pulse of short duration (less than 1 microsecond). This device operates, therefore, at high power levels. It must perform its function in a very

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short time and recover during the shortest possible time after the cessation of the transmitter radio-frequency pulse.

The discharge in the gas of a T-R cavity is produced by the dissipation of a fraction of the energy of the transmitter power pulse. In a T-R tube a gas or gas mixture is needed in which a discharge will be started with the lowest possible radio-frequency field at the operating frequency, so as to minimize spike energy transmitted through the T-R tube to the receiver before a discharge takes place. Furthermore, in order to obtain short recovery times, the free electron removal from the radio-frequency gap is obtained through electron attachment by electronegative components of the gas mixture used. In order to obtain very rapid recovery, the electronegative gas vapor in the T-R tube should have fairly high pressure, which gives to the whole gas mixture a strong electronegative character. In order to build up very rapidly the electron density necessary to detune the cavity sufficiently by means of the radio-frequency pulse, the mean free path of the electrons should be relatively large so that they can be accelerated to inelastic collisional levels in the gas in a mean free path. This requires a relatively low total gas pressure (5 to 15 mm. mercury).

An attenuator switch for radio-frequency energy flow, as opposed to the T-R function, should attenuate low power radio-frequency signal echoes during predetermined time, relatively longer than the transmitter pulse (several hundred microseconds or longer). The amplitude of the radio-frequency field is small and entirely insufficient to maintain an adequate electron density in the radio-frequency gap. It is not possible to operate the discharge by the radio-frequency power of the transmitter either. An appropriate electron density, whose magnitude depends on the attenuation required and can be easily calculated, is produced and/or maintained in the switching tube by external means. One requirement of a good switching device is that the attenuation must be mostly reactive. No large dissipation of the low power radio-frequency energy in the gas can be tolerated. In view of the fact that high free electron density for long durations is needed which can be obtained and maintained with low power sources (direct-current or the low frequency alternating-current), the electron removal process in such a switch should be minimized. In particular no electronegative gases or mixtures thereof should be utilized for this purpose.

It is seen that the nature of the gases in T-R tubes and switching tubes as defined above are very different. However, we have found that this difference in the optimum operation of a T-R tube and a switching tube does not exclude the possibility of using the same gas mixture in a dual purpose tube, provided appropriate electron densities can be readily produced in an electronegative gas mixture used in T-R tube geometries. In view of the required short time in T-R action, the gas mixture should have an electronegative character; means must therefore be provided to produce a gas discharge plasma of adequate electron density for required switching operation without affecting the useful life of the tube.

One of the objects of this invention, therefore, is to provide a combination T-R and attenuating switch gas discharge device.

Another object of this invention is to provide a combination T-R and attenuating switch gas discharge device for use at super-high frequencies utilizing a single gas mixture within a single envelope.

A feature of this invention is the use of a gas discharge device comprising a body portion having a resonating chamber therein. The discharge elements of the device

are formed by a pair of truncated cone-shaped electrodes, one of which is hollow. The cones are located with their slightly truncated apex ends opposed and in alignment. The hollow cone is insulated from the remainder of the structure and has a keep-alive electrode inserted in the hollow portion coaxial with said hollow cone and insulated therefrom. The tube is coupled in a waveguide system and functions in a manner to be described hereinafter.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawing in which:

The figure of the illustration is a partial cross-sectional view of one embodiment of a gas discharge device of this invention.

Referring to the figure of the drawing, a combined T-R and attenuator tube is shown in accordance with the principles of this invention which is adopted for use in a hollow waveguide transmission line 1. The device comprises a space charge chamber or cavity resonator 2 within a section of the hollow waveguide transmission line 1. Contained within the chamber are a pair of cone-shaped electrodes 3 and 4 arranged with their slightly truncated apex ends in alignment and slightly separated to form a capacitance gap 5. The cone 4 is adjustable along its axis to vary the frequency at which the resonator functions. The cone 4 is connected to an adjusting screw device 6 capable of operation by means of a screw driver placed in slot 7. A flexible hermetic seal is maintained between the electrode 4 and waveguide wall 8 by means of a thin diaphragm 9 sealed to a shoulder 9a on the waveguide wall 8 along its peripheral edge and sealed to the electrode 4 at its center. The cone-shaped electrode 3 is hollow having an axial opening 11 extending therethrough and emerging at the small end of the electrode 3 communicating with the chamber 2. Contained within the opening 11 is a rod of uniform diameter functioning as "keep-alive electrode" 12. The keep-alive electrode 12 is insulated from the cone-shaped electrode 3 by a sheath 13 constructed of an insulated material, such as glass, and may be coupled to a source of electric current 10 through lead 14. The cone 3 is inserted into the space charge chamber 2 through a radio-frequency choke 15 and is electrically isolated from the remainder of the transmission system by insulating walls 16 composed of any suitable material, such as glass.

The resonant cavity 2 is provided with walls 17 and 18 composed of an appropriate substance which permits the free passage of electromagnetic energy therethrough and is sealed in a gas tight union with the walls of waveguide 1. An appropriate mixture of gases is introduced into the space charge chamber 2 by means well-known to those skilled in the art. We have found that a suitable gas mixture comprises argon at 10 mm. mercury pressure and water at 6 millimeters mercury pressure.

The T-R tube functions of the device of this invention are performed in the usual manner well-known to those skilled in the art. The T-R tube comprises the highly tuned resonant cavity 2 within and forming a part of the waveguide transmission line 1. A direct-current bias potential 10 is coupled to the keep-alive electrode 12 to sustain an electric field within the tube at a value just below that at which conduction through the gas can take place. When a high intensity energy pulse is transmitted through waveguide 1 to the resonant cavity 2, the field is sufficiently increased that a gaseous discharge occurs, and as a result the resonant chamber 2 is detuned for the operating frequency, whereby the output side of the waveguide is disconnected from the system. At the conclusion of the pulse conduction, the resonator again becomes tuned for the operating frequency. The operation of the device as a T-R box depends upon the fact that a gaseous discharge will occur at a predetermined small potential above the

direct current bias potential applied to the keep-alive electrode 12.

In order to function as an attenuating switch device for low peak voltages, the insulated cone-shaped electrode 3 is connected through an appropriate switch 19 to a source of electric energy 20 so that when switch 19 is closed, a discharge will occur which detunes the resonant cavity 2. When the resonant cavity 2 is detuned, the output side of the waveguide transmission system 1 will be isolated from any radio-frequency energy coupled to the input side. We have found that this gas tube switch, when supplied with a striking potential of approximately 400 volts resulting in a current of 0.75 milliamperes will provide 35 decibels of attenuation. The gas tube discharge was pulsed at a 1 kilocycle rate of a 50 percent duty cycle.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. A combination T-R and attenuating switch gas discharge device system providing selective T-R action and attenuation of low-power radio-frequency energy comprising means defining a resonant chamber, an ionizable gas filling said chamber, first and second electrodes disposed within said chamber and insulated from one another for direct currents and electrically connected to the means defining a resonant chamber at radio frequency, means to couple a source of biasing voltage between said first and second electrodes whereby said electrodes serve as keep-alive electrodes, and a third electrode spaced from said first and second electrodes and insulated therefrom, said first and third electrodes being so disposed that high-power radio-frequency energy propagating through said chamber will cause ionization of said gas and a discharge directly between said first and third electrodes, low-power radio-frequency energy being insufficient of itself to cause said discharge, a source of voltage, and switching means operable independently of high-power radio-frequency energy propagating through said chamber to couple said source of voltage between said first and third electrodes whereby during the on period of operation of said switching means low-power radio-frequency energy propagating through said chamber will cause a discharge directly between said first and third electrodes thereby attenuating said energy in its passage through the chamber.

2. In a waveguide system, a waveguide section, a combination T-R and attenuating switch gas discharge device providing selective T-R action and attenuation of low-power radio-frequency energy disposed crosswise of said waveguide section, said device comprising means defining a resonant chamber as an extension of the wall structure of said waveguide section, an ionizable gas in said chamber consisting of a mixture of a non-electronegative gas and an electronegative gas, a first electrode disposed in said gas discharge device insulated from said waveguide section for direct currents and electrically connected to the means defining a resonant chamber at radio frequency and having an axially extended opening therein, a second electrode insulated from said first electrode and having a source of voltage applied thereto and to said first electrode whereby said first and second electrodes serve as keep-alive electrodes, means disposing said second electrode coaxially in said first electrode, a third electrode disposed in axially spaced relation to said first and second electrodes and insulated therefrom, a source of voltage, independently operable switching means to couple said source of voltage to said first and third electrodes to attenuate low-power radio-frequency energy propagating through said chamber, said low-power radio-frequency energy being insufficient to cause said tube to discharge during the off period of operation of said switch, and wherein high-power radio-frequency energy propagating through said chamber will cause an electric discharge within the

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gas to detune said cavity and prevent passage of the high-power radio-frequency energy therethrough.

3. In a waveguide system, a waveguide section, a combination T-R and attenuating switch gas discharge device providing selective T-R action and attenuation of low-power radio-frequency energy disposed crosswise of said waveguide section, said device comprising means defining a resonant chamber as an extension of the wall structure of said waveguide section, an ionizable gas in said chamber consisting of a mixture of a non-electronegative gas and an electronegative gas, an opening in said waveguide section, a sleeve of insulating material disposed within said opening, a tubular first electrode disposed coaxially in said sleeve in said gas discharge device insulated from said waveguide section for direct currents and electrically connected to the means defining a resonant chamber at radio frequency and having an axially extended opening therein, a second electrode insulated from said first electrode and having a source of voltage applied between said second and said first electrodes whereby said first and second electrodes serve as keep-alive electrodes, insulating means disposing said second electrode coaxially in said first electrode, a third electrode disposed in axially spaced relation to said first and second electrodes and insulated therefrom, said first and third electrodes being of a truncated conical shape having their apexes in juxtaposition thereby forming a capacitance gap, said third electrode only being directly attached to a conductive wall of said chamber and including a mounting having means to ax-

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ially adjust said third electrode relative to said first electrode to vary the capacitance gap, a pair of oppositely spaced windows in said waveguide section to retain said gaseous medium within said resonant chamber while permitting radio-frequency energy to be passed therethrough, a source of voltage, independently operable switching means to couple said source of voltage between said first and third electrodes to attenuate low-power radio-frequency energy propagating through said chamber, said low-power radio-frequency energy being insufficient to cause said tube to discharge during the off period of said switch, and wherein high-power radio-frequency energy propagating through said chamber will cause an electric discharge within the gas directly between said first and third electrodes to detune said cavity and prevent passage of the high-power radio-frequency energy therethrough.

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