Jan. 1, 1957 L. GOLDSTEIN 2,776,409

COMBINED T.-R. AND LOW POWER SWITCHING GAS DISCHARGE DEVICE

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Fig. 1

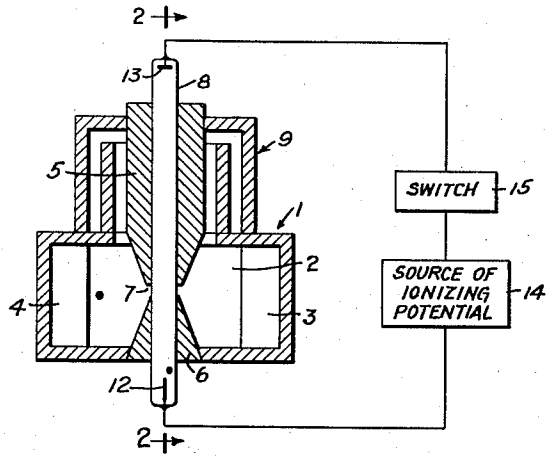
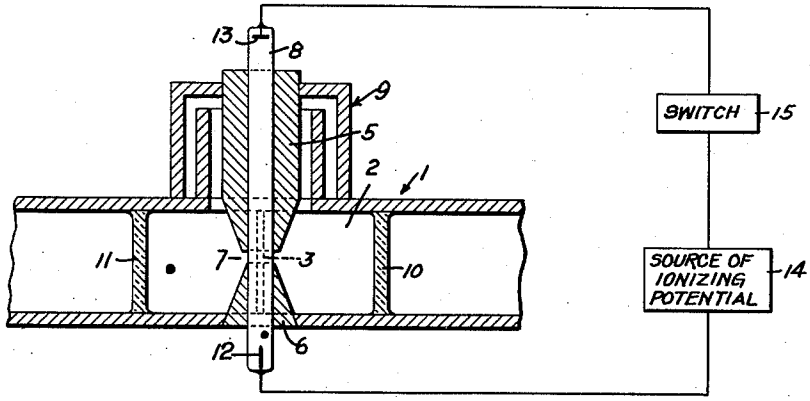


Fig. 2



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COMBINED T.-R. AND LOW POWER SWITCHING GAS DISCHARGE DEVICE

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This invention relates to a gas discharge device for use at ultra-high freqeuncies 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.

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 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 at the initiation of a discharge. 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 from the foregoing discussion that the nature of the gases required in T-R tubes and low power switching tubes are quite different. In the past it has been necessary to perform these functions by utilizing different gas filled electron discharge devices. However, I have found that the difference in the optimum operation of a T-R tube and low power switching tube does not exclude the possibility of utilizing different gaseous mediums in one structure to form a dual purpose tube. In view of the required short time for T-R action, one of the gas fillings must be electronegative in character while the other gas filling must provide a gas discharge plasma of adequate electron density for the required low power operation without affecting the useful life of the tube.

One of the objects of this invention, therefore, is to provide a combined T-R and low power switching gas filled electron discharge device.

A feature of this invention is the use of a gas discharge device comprising a body portion having a resonating chamber therein. Discharge elements are formed by a pair of truncated cone-shaped electrodes through which a capillary tube is inserted. The cones are located with their slightly truncated apex ends opposed and in alignment. The resonating chamber is filled with a T-R type gas mixture and T-R action is obtained by a discharge

between the truncated cones ionizing the gaseous mixture in the chamber. The capillary tube divides the device into a second region permitting the introduction of a gas for low power switching purposes into the capillary which is surrounded by a T-R type gas. Thus within a single structure the separation of the switch is obtained enabling its simultaneous use as a low power switch and T-R tube.

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 drawings, in which:

Fig. 1 is a view in elevation partly in section in schematic form of one embodiment of this invention; and

Fig. 2 is a view partly in section of the embodiment of Fig. 1 taken along line 2—2.

Referring to Figs. 1 and 2 of the drawing, a combined T-R and low power switching tube is shown in accordance with the principles of this invention which is adapted for use in hollow waveguide transmission line 1. The embodiment shown comprises a resonant chamber 2 having inductive irises 3 and 4 therein. Contained within the resonant chamber 2, between irises 3 and 4, are a pair of cone-shaped electrodes 5 and 6 arranged with their slightly truncated apex ends in alignment and slightly separated to form a gap 7. Electrodes 5 and 6 are hollow having axial openings extending therethrough in which is inserted capillary tube 8. The tube 8 is inserted through waveguide 1 into resonant chamber 2 through R. F. choke 9. The resonant chamber 2 is provided with walls 10 and 11 which are composed of a material, such as glass, which is impervious to gas but will permit the free passage of electromagnetic energy therethrough and which are sealed in a gas type union with the walls of waveguide 1. Contained within the resonant chamber 2 is an ionizable medium, such as an appropriate mixture of gases that will be readily ionized by the passage of R. F. energy. One mixture of gases found satisfactory for use in the resonant chamber comprises a 99% neon and 1% argon or 100% xenon at approximately 10 mm. mercury pressure. Capillary tube 8 is provided with a second ionizable medium, such as a mixture of 98% neon, 1% argon, and 1% hydrogen at 30 mm. Hg, between cathode 12 and ring anode 13.

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 system 1. When a high intensity radio-frequency energy pulse is propagated through waveguide system 1 to the resonant cavity 2, it will cause the ionization of the medium contained within the chamber 2, thus detuning the resonant chamber for the operating frequency of the radio-frequency energy whereby the output side of waveguide 1 is isolated from the input radio-frequency energy. At the conclusion of the propagated radio-frequency pulse, the resonant chamber will again be tuned for the operating frequency. The operation of the device as a T-R box depends on the fact that the ionization of the gaseous medium occurs when the radio-frequency energy enters the resonant chamber. This ionization of the gas causes the highly tuned resonant chamber to be detuned, thus preventing the transmittal of energy.

In order to function as a low power switching device, an ionizing potential from source 14 is applied to the gas contained within capillary tube 8 by the cathode 12 and anode 13 when switch 15 is closed. As switch 15 is closed, the gaseous medium contained within capillary tube 8 will ionize, detuning resonant chamber 2. This function does not depend upon the transmittal of a radio-frequency energy pulse through waveguide 1 but is independently controlled by means of switch 15 and the source of ionizing potential 14.

Thus the gas mixture within resonant chamber 2 performs a T-R function while the ionization of the gas contained within capillary tube 8 performs a low power switching function all within one electron discharge device contained within the waveguide system 1.

While I have described above the principles of my 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 my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. In a waveguide system, a gas discharge device comprising means defining a resonant chamber, means to contain a first ionizable medium within said chamber, means to contain a second ionizable medium in said chamber separated from said first medium, first electrode means in contact with said first medium to control the ionization thereof, and second electrode means in contact with said second medium to control the ionization thereof, said means to contain a second ionizable medium including a capillary tube axially disposed in an opening in said first electrode means and extending through said resonant chamber.

2. A device according to claim 1, wherein said waveguide system further includes a radio-frequency choke through which said capillary tube is extended into said resonant chamber.

3. A device according to claim 1, wherein said second electrode means includes a pair of electrodes axially disposed within said tube and wherein a source of ionizing potential is coupled to said electrodes.

4. A device according to claim 3, which further includes a switch for selectively applying said source of ionizing potential to said electrode means.

5. A combination T-R and attenuating gas discharge device comprising means defining a resonant chamber, a first ionizable gaseous medium contained within said chamber, a capillary tube extending through said chamber, a first pair of electrodes in said capillary tube, a second ionizable gaseous medium contained within said capillary tube and separated from said first medium, and a second pair of electrodes in axial juxtaposition within said resonant chamber whereby a high power radio-frequency pulse propagated through said waveguide system will cause the ionization of said first gaseous medium and said second gaseous medium may be ionized by applying a source of ionizing potential to said first electrodes within said capillary tube.

6. A device according to claim 5 which further includes switching means for selectively applying said source of ionizing potential to said first electrodes to cause said tube to discharge and detune said chamber whereby during the on period of operation of said switching means low-power radio-frequency energy propagating through said chamber will be attenuated, said low-power radio-frequency energy propagating through said chamber being insufficient to cause said first gaseous medium to be ionized during the off period of operation of said switching means.

7. A device according to claim 5 wherein said first ionizable gaseous medium comprises an electronegative gas and said second ionizable gaseous medium comprises a non-electronegative gas.

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