Sept. 20, 1960 R. H. GEIGER 2,953,713

HIGH SPEED ELECTRONIC R.F. VACUUM SWITCH

Filed March 25, 1958

FIG. 2a.

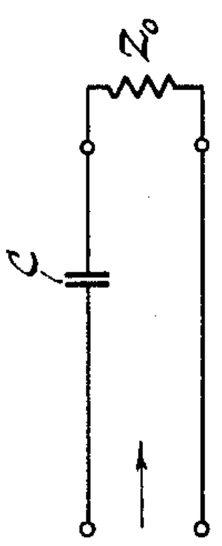
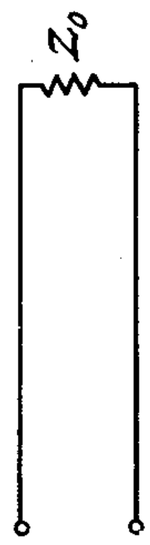


FIG. 2b.



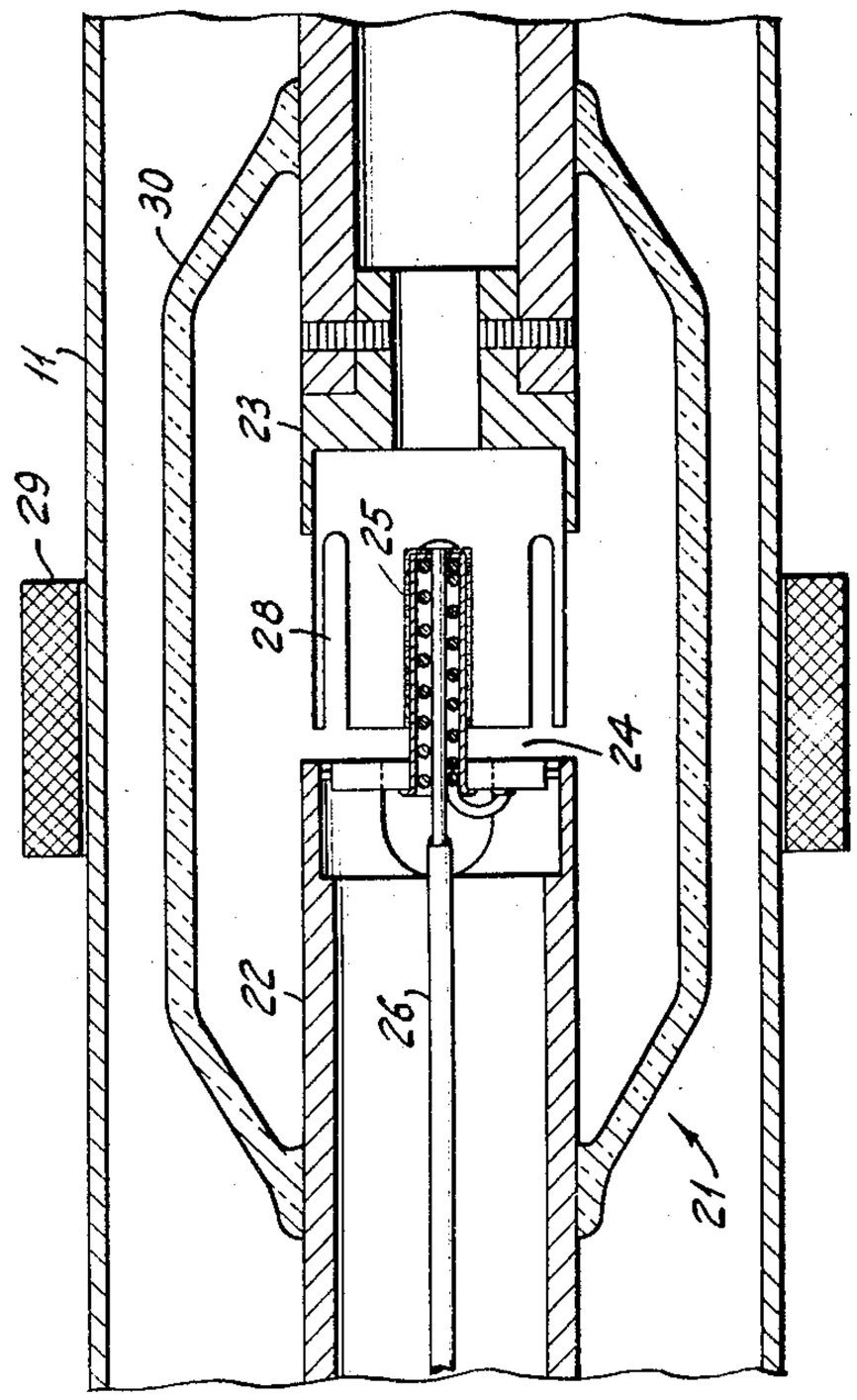


FIG. 1.

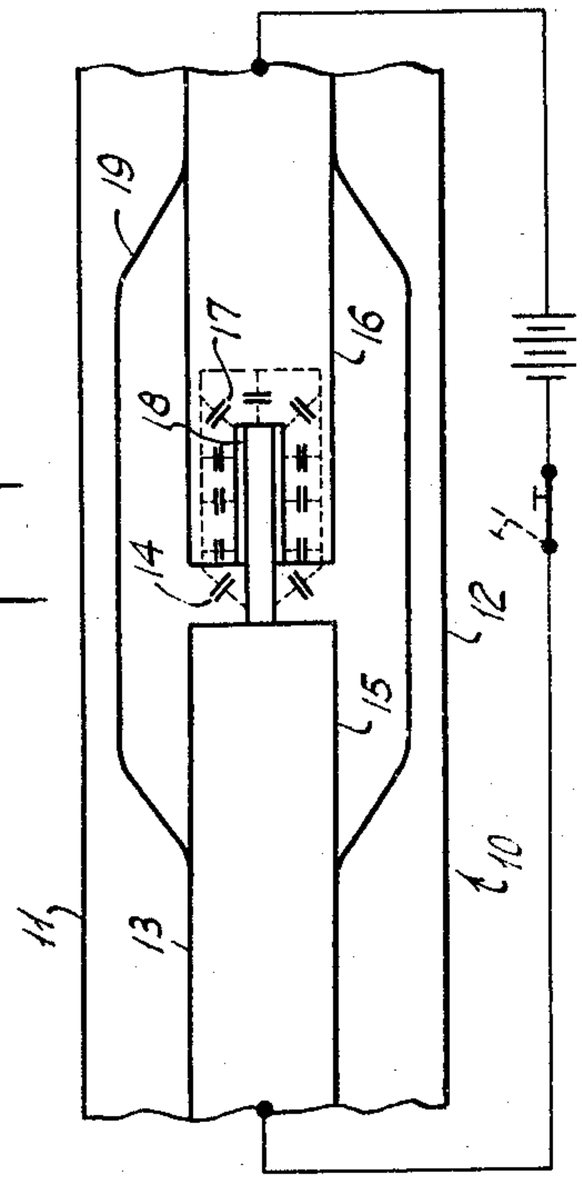


FIG. 3.

INVENTOR
RICHARD H. GEIGER
BY William T. Pease
ATTORNEY

United States Patent Office

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HIGH SPEED ELECTRONIC R.F. VACUUM SWITCH

Richard H. Geiger, Emerson, N.J., assignor to Roger White Electron Devices, Inc., Haskell, N.J., a corporation of New Jersey

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3 Claims. (Cl. 315—39)

This invention relates in general to an electronic switch and is more particularly directed to a transmission line type electronic vacuum switch operable at very high frequencies (VHF) and ultra high frequencies (UHF).

The invention provides a method and apparatus by which rapid switching rates are possible because of the inherent low inertia of the electronic medium.

According to one embodiment of the present invention a coaxial type of transmission line is provided having a gap in the inner conductor. The gap in the line produces a discontinuity and therefore a change in the characteristic impedance normal to the line. This gap makes the line impedance appear capacitive for the particular frequency applicable thereto, the capacitive reactance being substantially greater than the lines characteristic impedance thereby giving the appearance of an open circuit in the line. An electron cloud is introduced into the gap and is so adjusted that its plasma frequency (f_p) is equal to or greater than the signal frequency (f_s). When these conditions have been satisfied the gap provided in the line is effectively shorted to the applied frequency (f_s). The rapidity with which the impedance of the line may be changed provides a means of controlling the impedance characteristics of devices and apparatus having frequency sensitive elements such as filters, tuned circuits and the like.

In another embodiment of the invention disclosed herein a magnetic field parallel to and surrounding the inner conductor of the coaxial line is superimposed on the gap thus producing a cut-off of the anode current in a manner similar to the familiar cut-off of current in magnetrons. This form of operation reduces the power dissipation at the anode and produces a greater electron density across the gap for the same potential difference there-across.

It is therefore an object of the invention to provide a high speed electronic radio frequency vacuum switch sensitive to very high frequency (VHF) and ultra high frequency (UHF) signals.

Another object of the invention is to provide a high speed electronic radio frequency variable impedance switching device for changing the impedance characteristics of frequency sensitive apparatus.

Another object of the invention is to provide an electronic discharge switching device having reduced anode power dissipation and greater sensitivity to switching voltages.

Other objects and advantages will become readily apparent from a study of the specifications and the accompanying drawings wherein:

Fig. 1 is a diagrammatic view showing a portion of a coaxial transmission line partly cut-away with a gap in the line according to the invention.

Figs. 2*a* and 2*b* are schematic diagrams of the coaxial transmission line equivalent circuits in the open circuit state and closed circuit state.

Fig. 3 is a sectional view of a high speed electronic radio frequency vacuum switch having a magnetic field

superimposed on the gap in the inner conductor according to another embodiment of the invention.

Now referring to the drawings and specifically with reference to Fig. 1 there is shown an electronic radio frequency switch according to the invention and generally designated by the reference numeral **10** and comprising a coaxial transmission line **11** having an outer conductor **12** and an inner conductor **13**. The transmission line may be of the air type or of the type having some dielectric medium interposed between the inner and outer conductors common to such type lines. The inner conductor **13** has a gap **14** introduced therein transverse to its axial direction, and is a form of a re-entrant section of a coaxial line. The inner line consequently is composed of two parts or elements **15** and **16** spaced a distance apart which distance defines the gap **14**.

Inner conductor element **16** has a recessed cylindrical portion **17** extending from the gap inwardly some determinable distance and the inner conductor element **15** has centrally protruding therefrom a cylindrical oxide coated indirectly heated cathode **18** extending into and coaxial with the recessed portion of element **16**. Electrons emanating from the cathode **18** are produced by the application of some heater voltage. The potential difference between inner conductors **15** and **16**, conductor **16** being at a positive potential relative to inner conductor **15**, will produce a current flow between the spaced inner conductors. The electron density created in the region defined by the separation of the conductors **15** and **16** is so adjusted as to satisfy the condition that the plasma frequency of the electron cloud, f_p, in the gap region is equal to or greater than the signal frequency, f_s applied between the spaced inner conductors. When these conditions are fulfilled the gap **14** defined by the spaced inner conductor will be effectively shorted for the applied signal frequency, f_s.

Figs. 2*a* and 2*b* show schematically how the control of the electron density in the air gap produces a transition from a line which looks capacitive or open, Fig. 2*a* to a line which looks like it is terminated in its characteristic impedance, Fig. 2*b*.

The inner conductors **15** and **16** and the cathode **18** therebetween are all completely enclosed by a glass envelope **19**, the space enclosed by the envelope being completely evacuated in the manner similar to vacuum tubes. Thus there is produced an electron discharge device which is capable of rendering very rapid switching operations because of the low inertia of the electronic medium.

Fig. 3 shows another embodiment of the invention wherein the gap defined by the spaced inner conductor elements is surrounded by a magnetic field extending in a direction parallel to the inner conductors and coaxial therewith. The inner conductor generally designated by the reference number **21** comprises two separate portions **22** and **23** spaced a distance which defines an air gap **24** in a manner similar to that shown in Fig. 1. An indirectly heated cathode **25** extends from the inner conductor element **22**, at its central portion, inwardly towards the conductor element **23** at the recessed part thereof also in the same manner as shown in Fig. 1. The cathode **25** is heated by filament wires **26** extending within the inner conductor **22** and the cathode **25**. The anode portion **23** of the inner conductors has slotted portions **28** extending axially inwardly to lower the capacity of the gap and increase the open circuit impedance.

A magnetic field extending axially across the gap is produced by a magnet **29** coaxially surrounding the air gap and is so polarized as to cause the field to traverse a path from the cathode part of the inner conductor **22** to the anode portion **23** of the inner conductor. The magnetic field across the gap enables a greater electron density to exist for the same voltage in the absence of

such field, and also produces cut-off of current flow from cathode to anode in a manner comparable to magnetrons thus reducing power dissipation at the anode portion of the inner conductor. A glass envelope **30** surrounds the spaced inner conductors **22** and **23** and the gap defined thereby as well as the magnet **29** associated with the gap. The space portion enclosed by the glass envelope is evacuated as previously explained with reference to Fig. 1 so that an electron discharge device is produced having for its purposes high speed switching at the upper frequencies of the energy spectrum such as at ultra high frequencies and at very high frequencies.

What is claimed is:

1. An electron discharge device operable as a fast acting transmission line switch at high frequencies, said device comprising: a section of a coaxial transmission line having an inner and outer conductor, said inner conductor including two spaced inner conductor elements, the space between said two inner conductors defining a gap therebetween to cause an open circuit in the line simulating high capacitive reactance; envelope means forming a substantially gas free enclosure surrounding the gap between said inner conductor elements; electron emissive means coupled to one of said inner conductor elements; and means for creating an electric field gradient between said inner conductor elements to extract electrons from said emissive means to produce an electron cloud between said elements at a fixed plasma frequency to cause the line to appear as a closed circuit terminated in its characteristic impedance at the operating frequency, said plasma frequency and the frequency of operation being substantially equal.

2. An electron discharge device operable as a high frequency transmission line switch said device comprising: a section of a coaxial transmission line having an outer conductor, and an inner conductor having a gap therein to provide two spaced inner conductor elements, one of said inner conductor elements having a cylindrical recessed portion extending inwardly from the gap, an indirectly heated cathode mounted on and extending from the other inner conductor element at the central portion thereof into the recessed portion of said one inner conductor element; means forming an evacuated envelope surrounding said gap between said inner conductor elements; and means for applying a potential across said inner conductor elements to produce a difference of potential therebetween thereby producing an electron cloud between the said conductors at a fixed plasma frequency to cause the line to appear as a closed circuit at the frequency of operation, said plasma and operating frequency being substantially equal.

3. An electron discharge device operable at high frequencies for fast switching comprising: a section of a coaxial transmission line including an outer conductor, and two spaced inner conductor elements forming an inner conductor having a gap therein, one of said inner conductor elements being provided with slotted portions along the outer periphery thereof to lower the gap capacity and increase the open circuit impedance of the gap whereby said gap normally appears as an open circuit in the line; means for enclosing said gap in a relatively high vacuum; means disposed between the spaced inner conductor elements to produce an electron cloud between said elements at a fixed plasma frequency to cause the line to appear as a closed circuit at the frequency of operation, said plasma and operating frequencies being substantially equal; and magnetic means surrounding the gap to produce an axial magnetic field across the gap from one of the inner conductors to the other of the said inner conductors.

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