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G. H. ROBERTSON
ELECTRON DISCHARGE DEVICE

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2 Sheets-Sheet 1

FIG. 1

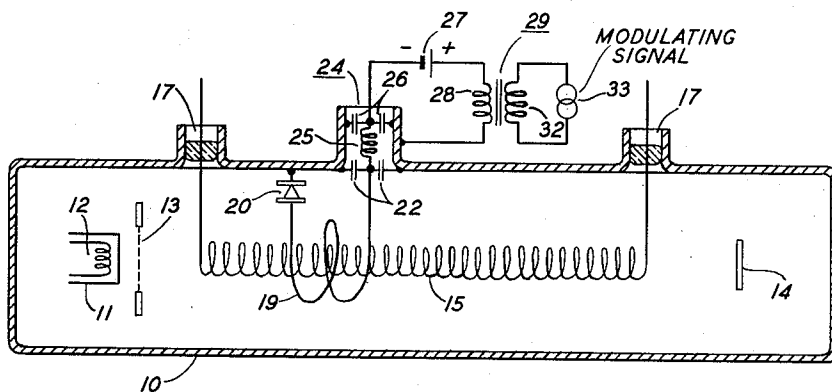


FIG. 2

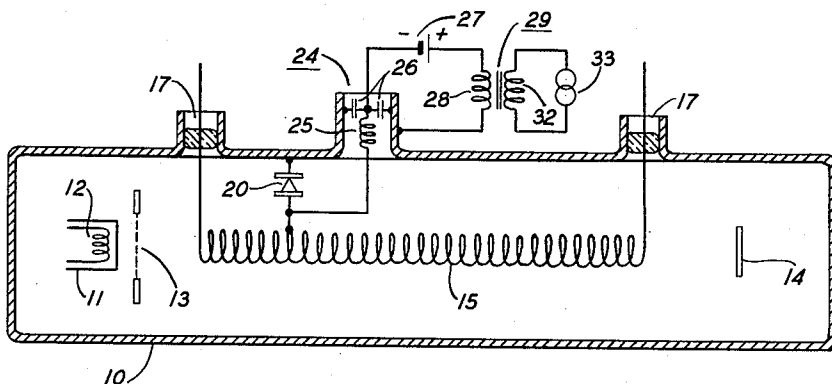
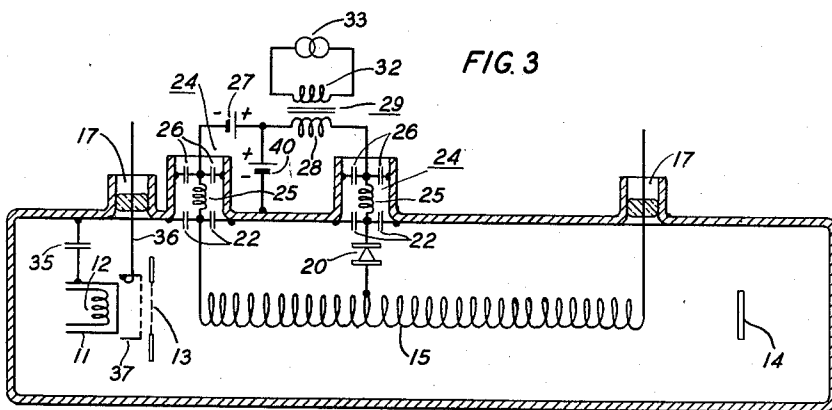


FIG. 3



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ELECTRON DISCHARGE DEVICE

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18 Claims. (Cl. 332-58)

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This invention relates to electron discharge devices and more particularly to such devices of the traveling wave tube type.

Traveling wave tubes generally comprise a transmission line, which defines an interaction circuit, and a means for projecting an electron stream along that interaction circuit. In one known type of traveling wave tube, the interaction circuit comprises a helix to which the high frequency carrier wave is coupled; in other types of traveling wave tubes, the region of interaction may be defined by a filter-type circuit or by resonators. Amplification in these tubes occurs due to the interaction of the electromagnetic waves associated with both the helix and the electron stream in the vicinity of this interaction region. Priorly, the high frequency carrier wave has had the modulating signal applied thereto, external to the traveling wave tube, so that it is the modulated carrier that is introduced to the traveling wave tube and amplified therein. This, of course, requires that the steps of modulation and amplification be distinct, employing separate apparatus and interconnections therebetween.

It is an object of this invention to modulate a carrier within a traveling wave tube after it has been coupled to the interaction circuit of the traveling wave tube. Thus, it is an object of this invention that both the modulation of the carrier wave and the amplification of the modulated carrier be accomplished by a single tube, thereby obviating the necessity for separate apparatus to achieve these results.

In accordance with a feature of this invention, a high frequency carrier wave, such as may be derived from a crystal controlled oscillator, is directly introduced into a traveling wave tube and the modulating signal applied to the carrier within the tube itself. In specific embodiments of this invention, this is attained by varying the attenuation of the interaction circuit under the control of the modulating signal.

The amplification or gain of a traveling wave tube depends on the characteristics of the wave associated with the interaction circuit, e. g., with the helix in one known form of tube, and the interaction of that wave with the electromagnetic wave associated with the electron beam. Priorly, loss has been applied to the helix or positioned adjacent thereto to attenuate the electromagnetic wave associated with the helix so that feedback due to the signal being reflected back from the output will not occur. In accordance with a feature of this invention, additional variable attenuation is applied to the interaction circuit

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under the control of the modulating signal to decrease the amplification in accordance with the modulating signal, whereby the carrier wave is amplitude modulated on passing that point.

5 In one specific illustrative embodiment of this invention, a loop of wire is positioned around the region of interaction in energy coupled relationship therewith. The loss or attenuation introduced into the interaction region by this loop is dependent on the power loss in the loop. A variable impedance element, such as a varistor, is positioned in the loop and forms a portion of a carrier frequency loop circuit. The variable impedance element is also connected in a modulating signal frequency loop circuit so that the impedance of the element is varied in accordance with the modulating signal.

15 In another specific illustrative embodiment of this invention, the variable impedance element is connected between the interaction circuit and ground, the amount of energy being drained off the interaction circuit by this connection depending on the impedance of the variable impedance element which is controlled by the modulating signal.

25 In still another specific illustrative embodiment of this invention, the variable impedance element is connected in series with a portion of the interaction circuit at both the carrier frequency and the modulating signal frequency.

30 In still another specific illustrative embodiment of this invention, the variable impedance element comprises a ring of a dielectric material encompassing a portion of the helix of the traveling wave tube. The ring forms the dielectric of a capacitance defined between the helix, as one plate thereof, and a conducting ring encompassing the dielectric ring, as the other plate thereof. The dielectric loss, and thus the attenuation applied to the helix at that point, is varied in accordance with the electric field across the capacitance, which is controlled by the modulating signal.

40 It is a feature of this invention that a variable impedance element be in energy coupled relationship with the electromagnetic field of the carrier wave associated with the interaction circuit.

45 It is a further feature of this invention that this variable impedance element be subject to control by an external signal or variable voltage, whereby the loss introduced into the interaction circuit by the variable impedance element can be varied in response to the externally applied signal or variable voltage.

55 It is a further feature of this invention that

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the impedance value of the variable impedance element in energy coupled relationship with the electromagnetic field of the carrier wave associated with the interaction circuit be under the control of a modulating signal applied thereto whereby modulation of the carrier wave occurs in response to the modulating signal.

It is a further feature of this invention that this variable attenuation be applied to the interaction circuit in such a manner that amplification of the coupled wave occurs both before and after modulation.

A complete understanding of this invention and of these and other features may be gained from consideration of the following detailed description together with the accompanying drawing, in which Figs. 1, 2, 3 and 4 are sectional representations of traveling wave tubes illustrative of four different specific embodiments of this invention.

Referring now to the drawing, the specific embodiment of this invention depicted in Fig. 1 comprises an envelope 10, which may be of a conducting material and in which are positioned a cathode 11, heater element 12, and accelerating electrode 13, defining an electron gun, an electron receiver 14, and a helix 15. The ends of the helix 15 are brought out through coaxial input and output terminals 17.

Encompassing a portion of the helix 15, advantageously towards the electron gun, is a loop of wire 19. One end of the loop 19 is connected through a variable impedance element 20 to the envelope 10, which is at ground potential. The variable impedance element 20 may advantageously be an asymmetrical varistor, such as of the silicon or germanium diode type, though other variable impedance elements may be employed in the combination of this invention. The carrier frequency circuit defined by the loop 19 is completed by capacitive elements 22 connected between the other end of the loop 19 and the envelope 10, the capacitive elements having a very low impedance for the carrier frequency currents. The modulating signal frequency circuit defined by the loop 19 is completed by a filter element 24, comprising a choke 25 and capacitors 26, a direct current voltage source 27, and the secondary 28 of a transformer 29, the other side of the secondary 28 also being connected to the envelope 10. The primary 32 of the transformer 29 has applied thereto the modulating signal, as from a source 33.

When an electron stream is projected by the electron gun along the interaction region defined by the helix 15, some of the energy of the carrier electromagnetic wave will be coupled to the modulating loop 19. This coupling will produce an electromotive force in the carrier frequency circuit defined by loop 19 dependent on the number of turns of the loop that encompass the helix, the carrier frequency, and the strength of the carrier wave. When the impedance of the variable impedance element 20 is high, the amount of energy dissipated in the loop 19 due to this electromotive force will be small. However, when the impedance of the variable impedance element 20 is lowered, more energy will be dissipated. This dissipation of energy represents attenuation applied to the interaction region and will cause a decrease in the amplitude of the carrier wave as it leaves the portion of the helix encompassed by the loop 19.

The voltage source 27 biases the varistor 20, or other variable impedance element, at a predetermined point on its voltage resistance char-

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acteristic. The electromotive force induced in the loop 19 by the carrier wave will cause an energy loss in the varistor equal to $(E. M. F.)^2 / \text{resistance}$ of the varistor, assuming the total resistance of the loop 19 to be in the varistor 20. This loss is, of course, reflected back into the interaction circuit due to the energy coupling between the loop and that circuit. When the modulating signal is applied to the modulating signal frequency circuit, the resistance of the varistor will vary around the bias point in accordance with the amplitude of the modulating signal. As the loss in the varistor, and thus the attenuation applied to the interaction region, is inversely proportional to the resistance of the varistor, the modulating signal will be superimposed on the amplitude of the carrier as it leaves the portion of the helix encompassed by the loop 19.

In Fig. 2 is depicted another illustrative embodiment of this invention wherein the carrier frequency loop circuit comprises a connection from the helix 15 itself to ground, i. e., to the envelope 10, through the variable impedance element 20. In this embodiment, the variable loss or attenuation is introduced as energy is shunted from the helix to ground through the varistor, the value of resistance of the varistor 20 determining the decrease in the amplitude of the carrier signal at the point of connection of the varistor 20 to the helix 15.

In Fig. 3 is depicted another illustrative embodiment wherein the carrier is applied to the electron stream by employing a capacitor 35 between the cathode 11 and the envelope 10 and connecting the input lead 36 of the input terminal 17 to a control grid 37. In this embodiment, the carrier frequency loop circuit comprises a section of the helix 15 itself, as well as the varistor 20 and two groups of capacitors 22. Thus, one end of the helix 15 is connected directly to ground, though the capacitors 22, and an intermediate point along the helix is connected to ground through the variable impedance element 20 and the capacitors 22. The modulating signal loop circuit also comprises the section of the helix 15 as well as two filter elements 24, the voltage bias 27, and transformer 29. A direct current voltage source 40 may also be positioned between the modulating signal loop circuit and the envelope 10 to apply a direct current voltage bias to the helix 15, if desired.

While the specific variable impedance element employed in each of the illustrative embodiments of Figs. 1, 2 and 3 has been a variable resistance element of the varistor type, various other variable impedance elements may be employed. Thus certain dielectric materials whose dielectric loss changes with applied electric field could advantageously be employed. Fig. 4 illustrates one specific embodiment wherein such a dielectric material, which may be of barium titanate or barium-lead-zirconate, is utilized in the form of a ring 45 encompassing the helix 15 and advantageously having a wedge-shaped cross section to minimize the reflections introduced by the attenuation. A ring 46 of conducting material, such as silver, is secured to the outer circumference of the dielectric ring 45. A capacitance is thus defined in which the conducting ring 46 and the helix 15 are the two plates of the capacitor and the ring 45 is the dielectric thereof. The modulating voltage is applied across this capacitance as by a series circuit comprising a portion of the helix 15, a pair of filter elements 24, a voltage bias 27 and transformer 29. As the di-

electric material 45 is in energy coupled relationship with the carrier wave being transmitted along the helix and its dielectric loss is varied in accordance with the variations in the potential applied across the plates of the capacitance under the control of the modulating signal, modulation of the carrier wave occurs.

Reference is made to my continuing application Serial No. 409,806, filed February 12, 1954, wherein a related invention is disclosed and claimed.

While this invention has been described with reference to modulation of the carrier wave in accordance with a modulating signal, it is to be understood that the impedance value of the variable impedance element in energy coupled relationship may be varied to vary the attenuation at a given point or along the interaction circuit in accordance with other than modulating signals. Similarly, although each of the specific embodiments of this invention described above has incorporated a helix as defining the interaction circuit, this invention is equally applicable to other types of traveling wave tubes wherein the electromagnetic wave may be slowed down in other manners and the region of interaction thus defined by other structures, such as by filter-type circuits or resonators. Nor is this invention to be considered limited to the manner of introduction of the carrier wave into the device, as this will depend on a number of considerations, such as carrier frequency. Thus the carrier wave may be coupled to the interaction circuit not only by coaxial terminals, but by wave guides, resonators, grids, electron streams, or in other manners known in the art.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of this invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An electron discharge device comprising means defining an interaction circuit, means for projecting a stream of charged particles along said circuit, means for introducing a carrier wave to said circuit, the electromagnetic waves of said carrier and said stream interacting within said circuit to amplify said carrier, means defining attenuation associated with said circuit, said attenuation means comprising a variable impedance element in energy coupled relationship with the electromagnetic wave of said carrier, and means for varying the impedance value of said variable impedance element to vary the attenuation associated with said circuit.

2. An electron discharge device comprising a helix, means for projecting a stream of electrons along said helix, means for coupling a carrier wave to said helix, and means for imposing a modulating signal upon said carrier, said last-mentioned means comprising means defining attenuation associated with a portion of said helix intermediate the ends thereof, and circuit means connected to said attenuation defining means for varying said attenuation in accordance with said modulating signal.

3. An electron discharge device comprising means defining an interaction circuit, means for projecting an electron beam along said circuit, means for introducing a carrier wave to said circuit, the electromagnetic waves of said beam and said carrier interacting to amplify said carrier, and means for imposing a modulating signal

onto said carrier, said last-mentioned means comprising a variable impedance element in energy coupled relationship with the electromagnetic field of said carrier and means for varying the impedance of said element in accordance with said modulating signal.

4. An electron discharge device comprising means for introducing a carrier wave to said device, means for amplifying said carrier wave within said device, said amplifying means including means defining a region of interaction and means for projecting a stream of electrons in said device along said region, and means for varying the attenuation associated with said region, said last-mentioned means comprising a variable impedance element in energy coupled relationship with the electromagnetic field of said carrier and means for controlling the impedance value of said element.

5. An electron discharge device comprising means defining an interaction circuit, means for projecting an electron stream along said circuit, means for introducing a carrier wave to said circuit, the electromagnetic waves of said carrier and said stream interacting within said circuit to amplify said carrier, and means for imposing a modulating signal upon said carrier while in said circuit, said last-mentioned means comprising a variable resistance element in energy coupled relationship with the electromagnetic field of said carrier and means for varying the resistance of said element in response to variations in said modulating signal.

6. An electron discharge device comprising means for projecting an electron stream along said device, means for introducing a high frequency carrier to said device, means for amplifying said carrier, said amplifying means comprising means defining a region of interaction for the electromagnetic wave of said stream, and means for imposing a modulating signal onto said carrier, said last-mentioned means comprising a variable impedance element in energy coupled relationship with the electromagnetic field of said carrier and circuit means for varying the impedance of said element in accordance with said modulating signal.

7. An electron discharge device comprising a helix, means for projecting a stream of electrons along said helix, means for coupling a carrier wave to said helix, and means for varying the attenuation associated with said helix, said last-mentioned means comprising a variable impedance element in energy coupled relationship with the electromagnetic field of said carrier and means for controlling the impedance of said element.

8. An electron discharge device comprising a helix, means for projecting a stream of electrons along said helix, means for coupling a carrier wave to said helix, and means for imposing a modulating signal onto said carrier, said last-mentioned means comprising a conductive loop in energy coupled relationship with the electromagnetic field of said carrier, a variable resistance element connected to said loop, and circuit means connected to said loop for varying the resistance of said element in accordance with said modulating signal.

9. An electron discharge device comprising means for projecting an electron stream along said device, means for introducing a high frequency carrier to said device, means for amplifying said carrier, said amplifying means comprising means defining a region of interaction for

the electromagnetic wave of said stream, and means for imposing a modulating signal onto said carrier, said last-mentioned means comprising a conductive loop in the vicinity of said region of interaction and in energy coupled relationship therewith, a variable impedance element connected to said loop, and circuit means connected to said loop for varying the impedance of said element in accordance with said modulating signal.

10. An electron discharge device comprising means defining an interaction circuit, means for projecting an electron beam along said circuit, means for introducing a carrier wave to said circuit, the electromagnetic waves of said beam and said carrier interacting within said circuit to amplify said carrier, and means for varying the attenuation associated with said circuit, said last-mentioned means comprising a conductive loop encompassing a portion of said circuit in energy coupled relationship with the electromagnetic field of said carrier, a variable resistance element connected to said loop, and circuit means connected to said loop for varying the resistance of said element.

11. An electron discharge device comprising a helix, means for projecting a stream of electrons along said helix, means for coupling a carrier wave to said helix, and means for imposing a modulating signal onto said carrier, said last-mentioned means comprising a conductive loop encompassing an intermediate portion of said circuit in energy coupled relationship with the electromagnetic field of said carrier, a variable resistance element connected to said loop and defining a carrier frequency circuit therewith, and circuit means connected to said loop and defining a modulating signal frequency circuit therewith, said circuit means including means for varying the resistance of said element in accordance with said modulating signal.

12. An electron discharge device comprising a helix, means for projecting a stream of electrons along said helix, means for coupling a carrier wave to said helix, and means for imposing a modulating signal upon said carrier, said last-mentioned means comprising a variable impedance element connected to said helix at an intermediate point and between said point and ground potential and means for varying the impedance of said element in accordance with said modulating signal.

13. An electron discharge device comprising means for projecting an electron stream along said device, means for introducing a high frequency carrier to said device, means for amplifying said carrier, said amplifying means comprising conducting means defining a region of interaction, and means for varying the attenuation associated with said region, said last-mentioned means comprising a variable impedance element connected between said conducting means and ground potential and circuit means connected to said element for varying the impedance of said element.

14. An electron discharge device comprising a helix, means for projecting a stream of electrons along said helix, means for coupling a carrier wave to said helix, and means for imposing a modulating signal upon said carrier, said last-mentioned means comprising a variable resistance element connected between one point on said helix and ground potential at said carrier frequency, a modulating frequency circuit including said variable resistance element, and means for introducing said modulating signal to said circuit.

15. An electron discharge device in accordance with claim 14 wherein said modulating frequency circuit includes a portion of said helix.

16. An electron discharge device comprising means defining an interaction circuit, means for projecting an electron stream along said circuit, means for introducing a high frequency carrier wave to said circuit, the electromagnetic waves of said carrier and said stream interacting within said circuit to amplify said carrier, and means for imposing a modulating signal upon said carrier while in said circuit, said last-mentioned means comprising an element of a dielectric material in energy coupled relationship with the electromagnetic field of said carrier, said element having a variable dielectric loss characteristic, and means for varying the dielectric loss of said element in response to variations in said modulating signal.

17. An electron discharge device comprising conducting means defining an interaction circuit, means for projecting an electron stream along said circuit, means for introducing a carrier wave to said circuit, an element having a variable dielectric loss characteristic adjacent said circuit and a conducting member adjacent said element to the other side thereof than said circuit, said conducting circuit, dielectric element, and conducting member defining a capacitance having a dielectric loss characteristic dependent upon the electric field applied across said conducting circuit and said conducting member.

18. An electron discharge device comprising a helix, means for projecting a stream of electrons along said helix, means for coupling a carrier wave to said helix, a ring of a dielectric material having a variable loss characteristic encompassing a portion of said helix, a conducting ring around said dielectric ring, said helix, dielectric ring, and conducting ring defining a capacitance having a loss characteristic dependent upon the electric field between said helix and said conducting ring, and means for applying a potential across said helix and said conducting ring.

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