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HIGH FREQUENCY POWER AMPLIFIER

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Fig. 1.

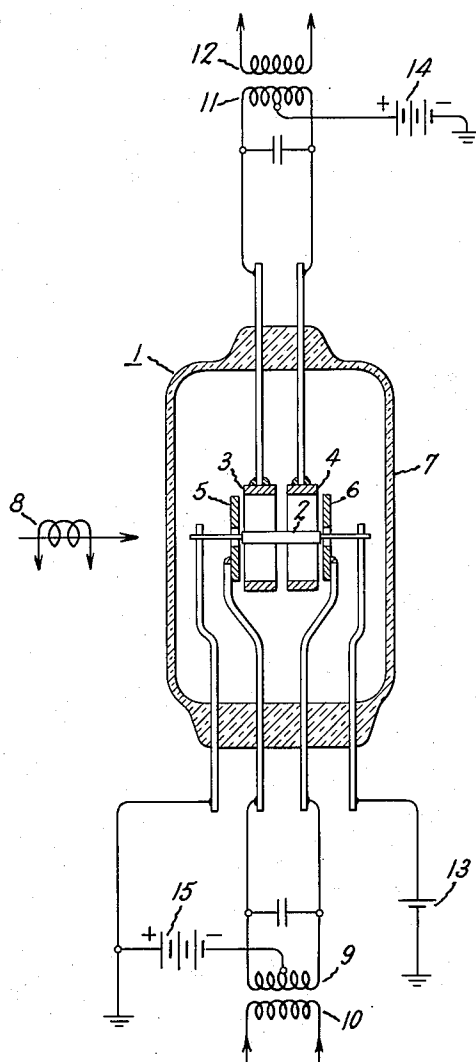
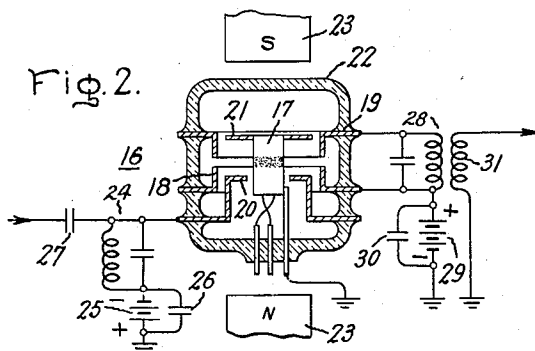


Fig. 2.



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HIGH FREQUENCY POWER AMPLIFIER

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8 Claims. (Cl. 179—171)

This invention relates to high frequency power amplifiers utilizing magnetron principles.

Since magnetron oscillators have proved very successful as high power high frequency oscillators, similar devices in which a magnetic field and an electric field at right angles to each other react upon an electronic space charge have been investigated for use in power amplification. To operate successfully as amplifiers, such magnetron type devices must be arranged to prevent feedback from the output to the input circuit while at the same time preferably providing both substantial power gain and relatively high power output of high frequency energy.

Accordingly, it is a primary object of my invention to provide a high frequency power amplifier utilizing magnetron principles.

It is a further object of my invention to provide an amplifying device for producing a high power output at high frequencies.

It is another object of my invention to provide a magnetron type of amplifying device in which feedback between the output and input circuits is minimized.

It is yet another object of my invention to provide an improved frequency multiplying power amplifier.

According to my invention, a control voltage is employed to axially deflect a rotating space charge in a magnetron type of discharge device and thus divide the electron current from the cathode between a pair of axially spaced anodes according to the amplitude of the control voltage. The anodes surround an elongated cathode and are coaxial with it, and either one or two input control electrodes having facing surfaces transverse to the cathode axis are axially spaced from the gap between the anodes.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 is a cross sectional view of a magnetron type of discharge device with external circuits therefor incorporating my invention, and Fig. 2 is a modification.

Referring now to Fig. 1, there is shown connected in circuit a discharge device 1 whose essential elements are an elongated cathode 2, a pair of cylindrical anodes 3 and 4 coaxial with the cathode, and a pair of input or control electrode disks 5 and 6 near the respective ends of the cathode and transverse to it. An envelope 7 which may suitably be made of glass, surrounds the electrode assembly, and the various electrodes are supported by conductive support wires or rods which are sealed through the envelope to provide external terminals for circuit connections. A magnetic field parallel to the axis of the cathode is established within the space between the cathode and the anodes, the means for producing this field being indicated schematically at 8 as a solenoid posi-

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tioned outside the envelope 7 and whose terminals may be connected to a suitable direct current voltage source.

Referring now more particularly to the details of construction of the device 1, the cathode 2 may suitably comprise a cylindrical nickel sleeve surrounding a heater coil and coated with an alkaline earth oxide mixture for copious emission of electrons when the cathode is heated. The heater coil is connected to the cathode support rods and also at one point to the cathode sleeve. The anode cylinders 3 and 4 which surround the cathode are of the same diameter and axially spaced to thus define a gap between them transverse to the cathode axis. The cylinders are preferably of the same length. The control electrode disks 5 and 6 substantially enclose the ends of the space charge chamber between the cathode and the anodes and are shown as centrally apertured to permit the passage of the cathode heater leads therethrough. The control electrodes are thus on opposite sides of the gap between the anodes and are preferably equidistant from the gap.

As shown in Fig. 1, the disks 5 and 6 have a diameter substantially equal to the inside diameter of the anode cylinders 3 and 4 and are positioned near the ends of the anode cylinders. While this placement of the disks is provided in order to maintain the effectiveness of the control electrodes without unduly increasing the capacitance between them and the anodes, it is obvious that other arrangements may be utilized if desired, such as decreasing the diameter of the control disks 5 and 6 and moving them inwardly toward the gap. However, the active or effective surfaces of the anodes 3 and 4 and of the cathode 2 are only those portions between the facing surfaces of the control electrodes 5 and 6. To prevent distortion of the magnetic field, each of the various electrodes is made of a non-magnetic conductive material, such as molybdenum.

An input circuit 9, schematically represented as a parallel resonant circuit with lumped capacitance and inductance elements, is connected between the terminals of the control electrodes 5 and 6, and a source of amplitude modulated signals to be amplified is coupled by coupling means 10 to the input circuit. It should be understood, of course, that while lumped constant circuits are shown, various high frequency equivalents may be employed, such as tuned transmission line sections. A tuned output circuit 11, schematically represented as is the input circuit 9, is connected between the terminals of the anodes 3 and 4, and suitable output coupling means 12 couples the amplified power from the output circuit 11 to the desired load. While the input and output circuits 9 and 11 have been illustrated as outside the envelope of the discharge device 1, equivalent circuit arrangements within the envelope may be substituted as may be desired for higher frequency operation.

To provide the conditions for operation of the amplifier, the cathode 2 is heated to provide thermionic emission, a source of heating current 13 being connected between the cathode terminals, one of which is preferably grounded for convenience. A radial electric field is established between both anodes 3 and 4 and the cathode 2 by connecting a source of unidirectional voltage 14 between them. In order to prevent interference with the desired operation of the output circuit 11, the common connection to the anodes is made from the positive terminal of the source 14 to the mid-point or high frequency neutral point of the output circuit, as represented by a midtap on its inductance element. The negative terminal of the source 14 is suitably returned to ground. The radial electric field in conjunction with the axial magnetic field imparts an average angular velocity about the cathode to the emitted electrons which constitute the space charge, and the intensities of the electric and mag-

netic fields are adjusted to provide a substantial electron current flow to the anodes.

In order to shape the space charge envelope for effective axial modulation, a negative bias voltage is supplied to the input electrodes 5 and 6. This is suitably achieved without interfering with the signal input circuit connected between these electrodes by connecting the negative terminal of a source of bias voltage 15 to the high frequency neutral point of the input circuit and grounding the positive terminal of the source. In this way, both input electrodes 5 and 6 are negative with respect to the cathode and the cathode space charge, thus tending to repel the space charge axially toward the center of the space charge chamber. The space charge is thus bunched or compressed and is believed to take the form of a disk of relatively high charge density, since electrons in the disk are supplied from the entire active length of the cathode.

When the electron disk radius is sufficiently great, current flows between the cathode and the anodes, being divided between the anodes according to the position of the disk. The axial magnetic and the radial electric fields are adjusted to provide the desired total collection current. The steady state collection current is readily adjusted over a large range without difficulty, and very high density space charge currents are easily handled. For example a 10 milliamperere disk of current at one thousand volts on the anode may be obtained for a given magnetic field density, or a 1 ampere current can be obtained at 100 volts in the same device by adjusting the magnetic field.

The space charge disk representing the bunched space charge of the device 1 is axially deflected to change the terminus of the electron space charge current from one to the other of the anodes 3 and 4 by the modulating voltage applied between the control electrodes 5 and 6 from the signal source previously mentioned. The power to switch the space charge disk across the anode gap is negligible and hence the input circuit is not loaded, as is generally desired for amplifier operation. The output circuit 11 is preferably tuned, more or less broadly as desired, to the frequency of the input circuit 9 so that the alternate switching of current from one anode to the other at the input frequency excites the output circuit at the same frequency. An output amplitude limiting action which occurs when the drive input is either more than sufficient to transfer the current all to one anode or less than sufficient to create any differential current between anodes may also be utilized. Whether the tube is employed for amplifying a modulated or unmodulated signal, the power output is derived from the voltage source 14 and the power to switch the bunched charge across the gaps is negligible.

If desired, the output circuit 11 may be tuned to any desired harmonic of the frequency of the input circuit for utilization of the power amplifier as a frequency multiplier.

Referring now to Fig. 2, a modification of the arrangement of Fig. 1 is employed in which the input and output circuits are single-ended to provide potentials with respect to a common reference point instead of being arranged for balanced or push-pull operation as in Fig. 1.

There is shown a discharge device 16 having a cylindrical sleeve cathode 17, a pair of hollow cylindrical anodes 18 and 19, and a pair of annular electrodes 20 and 21, electrode 21 being conductively supported from the cathode. An envelope 22, which may be suitably made of glass, surrounds the electrode assembly. In order that the device 16 be readily adaptable for coupling to concentric line input and output circuits, the electrode 20 and the anodes 18 and 19 are provided with radial flanges which extend through the envelope to provide external terminals. Conductive support wires for the cathode 17 and for a cathode heater assembly inside the cathode sleeve also extend axially through the en-

velope wall past the input electrode 20. A magnetic field parallel to the cathode axis is established within the space between the cathode and anodes, the means for producing this field being indicated as magnet pole pieces 23 respectively positioned at either end of the device 16.

An input circuit 24 schematically represented as a parallel resonant circuit with lumped capacitance and inductance elements is coupled between the cathode 17 and control electrode 20. As shown in Fig. 2, one side of the input circuit 24 is connected to the input or control electrode 20 and the other side is coupled to ground through a negative bias voltage source 25 which may suitably be bypassed by a capacitor 26. The cathode 17 is directly returned to ground. A suitable input coupling means such as a capacitor 27 supplies the biased electrode 20 with a signal voltage from a signal source. The bias voltage is selected as previously described to axially compress the cathode space charge by repelling at least a portion of the space charge toward the cathode 17 and the electrode 21 to compress the space charge axially.

An output circuit 28, similarly schematically represented as is the input circuit 24, is coupled between one of the anodes and ground. As shown in the drawing, one terminal of the output circuit is connected to the output anode 19 and the other terminal to the output anode 18, that anode being coupled to ground through a source of positive voltage 29 by-passed by capacitor 30. A suitable output coupling means 31 is coupled to the output circuit 28 to transmit the amplified power to the desired load.

Except for the fact that it is arranged for single-ended input and output circuits, the amplifier arrangement of Fig. 2 corresponds to that of Fig. 1. Accordingly, when the input signal on the input electrode 20 is negative going, the space charge is forced across the gap between the anode cylinder 18 and 19 toward the other electrode 21, which may also be considered as a control electrode at cathode potential. The space charge current accordingly is transferred from the anode 18 to the anode 19 thereby to provide amplified signals across the output circuit 28.

Direct capacitive coupling between the input and output circuits is minimized in view of the fact that the input electrode 20 upon which the high frequency input signal is impressed is under the anode cylinder 18 which is at ground potential for high frequency signals. Similarly, input and output circuit coupling between the electrode 21 and the other anode 19 is avoided, since the electrode 21 is at ground potential. Accordingly, while the full advantages of the space charge bunching and axial displacement of the balanced input system of Fig. 1 are not realized when one of the transverse disk electrodes is connected to the cathode, the latter embodiment is preferred in installations where capacitive coupling between input and output systems is to be minimized.

While the present invention has been described by reference to a particular embodiment thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electron discharge device of the magnetron type comprising an evacuated envelope containing an elongated electron emitting cathode extending along a given axis, first and second cylindrical anodes spaced along said axis and coaxial therewith and each presenting a continuous cylindrical surface facing said cathode, the spaced facing ends of said anodes being transverse to said axis and defining a gap between them, means for coupling an output circuit between said anodes and first and second control electrodes having facing surfaces transverse to said axis and spaced from said gap on

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opposite sides thereof, said electrodes being surrounded by and located within the axial extent of said anodes, for deflecting electrons in the space between said cathode and said anodes across said gap.

2. An electron discharge device comprising an evacuated envelope containing an elongated electron emitting cathode extending along a given axis, first and second cylindrical members spaced along said axis and coaxial therewith and each presenting a continuous cylindrical surface facing said cathode, the spaced facing ends of said members being transverse to said axis and defining a gap between them, means for coupling an output circuit between said members and first and second control electrodes having facing surfaces transverse to said axis and spaced from said gap on opposite sides thereof, at least one of said electrodes being surrounded by and located within the axial extent of said members, and means for producing a static magnetic field parallel to said axis in the space between said cathode and said cylindrical members.

3. An electron discharge device of the magnetron type comprising an envelope containing an elongated electron emitting cathode extending along a given axis, a pair of anodes each surrounding said cathode and having an inner cylindrical surface coaxial therewith and each presenting a continuous cylindrical surface facing said cathode, said anodes having facing end surfaces transverse to said axis spaced from each other along said axis to define a gap between them means for coupling an output circuit between said anodes, and first and second annular control input electrodes surrounding said cathode near the opposite ends thereof and having facing surfaces transverse to said axis, said control electrodes being spaced from said gap on opposite sides thereof and being located within the axial extent of said anodes.

4. A power amplifier comprising an electron discharge device having an envelope containing an elongated electron emitting cathode extending along a given axis, a pair of cylindrical anodes surrounding said cathode and coaxial therewith, said anodes having facing end surfaces transverse to said axis spaced along said axis to define a gap between them and each presenting a continuous cylindrical surface facing said cathode, and a pair of control electrodes having facing surfaces transverse to said axis and spaced from said gap on opposite sides thereof, means providing a static axial magnetic field in the space between said cathode and said cylindrical members and means providing a static radial electric field between said cathode and said anodes to establish a generally rotating space charge around said cathode between said cathode and said anodes, means for applying a negative bias to at least one of said control electrodes with respect to said cathode to axially compress the rotating space charge, and means for applying signal voltage between said control electrodes to axially move the compressed space charge across the gap between said pair of anodes.

5. A high frequency power amplifier comprising an electron discharge device having an envelope containing an elongated electron emitting cathode extending along a given axis, a pair of cylindrical anodes surrounding said cathode and coaxial therewith, said anodes having facing end surfaces transverse to said axis spaced along said axis to define a gap between them and each presenting a continuous cylindrical surface facing said cathode, and a pair of control electrodes having facing surfaces transverse to said axis and spaced from said gap on opposite sides thereof, means providing a static axial magnetic field in the space between said cathode and said cylindrical members and means providing a static radial electric field between said cathode and said anodes to establish a generally rotating space charge around said cathode between said cathode and said anodes, means for applying a negative bias to said control electrodes with respect to said cathode to axially compress the

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rotating space charge, tuned input circuit means coupled to said control electrodes for applying an alternating input voltage therebetween to move the compressed space charge across said gap, and tuned output circuit means coupled to said anodes.

6. A high frequency power amplifier comprising an electron discharge device having an envelope containing an elongated electron emitting cathode extending along a given axis, a pair of hollow anodes each surrounding said cathode and having an inner cylindrical surface coaxial therewith, said anodes having facing end surfaces transverse to said axis spaced along said axis to define a gap between them and each presenting a continuous cylindrical surface facing said cathode, and a pair of control electrodes having facing surfaces transverse to said axis and spaced from said gap on opposite sides thereof, means for establishing an axial magnetic field in the space between said cathode and said cylindrical members, means for supplying a positive potential to said anodes with respect to said cathodes to establish a radial electric field between said cathode and said anodes whereby a generally rotating direction around said cathode is imparted to the space charge flowing between said cathode and said anodes, means for applying a negative bias to at least one of said control electrodes with respect to said cathode to axially compress the rotating space charge, means for applying a signal voltage of a given frequency between said control electrodes to switch the compressed space charge across the gap between said pair of anodes, and an output circuit tuned to said frequency coupled to said anodes.

7. A power amplifier comprising an electron discharge device having an elongated electron emitting cathode extending along a given axis, a pair of hollow anodes surrounding said cathode to define a space charge chamber coaxial therewith, said anodes having facing end surfaces transverse to said axis spaced along said axis to define a gap between them and each presenting a continuous cylindrical surface facing said cathode, and a pair of control electrodes each having a surface transverse to said axis facing said gap and each spaced therefrom on opposite sides thereof, means providing a static axial magnetic field and a static radial electric field in said space charge chamber to establish a generally rotating space charge current around said cathode between said cathode and said anodes, means for applying a negative bias to said control electrodes with respect to said cathode to axially compress the rotating space charge, and means for applying an alternating input voltage between said electrodes and said cathode to switch the space charge current between said pair of anodes.

8. A power amplifier comprising an electron discharge device having an elongated electron emitting cathode extending along a given axis, a pair of hollow anodes surrounding said cathode and coaxial therewith, said anodes having facing end surfaces transverse to said axis and spaced along said axis to define a gap between them and each presenting a continuous cylindrical surface facing said cathode, and a pair of control electrodes having facing surfaces transverse to said axis spaced from said gap, one of said electrodes being connected to said cathode, means for providing a static axial magnetic field and a static radial electric field in the space between said cathode and said anodes to establish a generally rotating space current around said cathode, means for applying a negative bias to the other control electrode with respect to said cathode and said one electrode to axially compress the rotating space charge, and means for applying an alternating input voltage between said other control electrode and said cathode and said one electrode to switch the compressed space charge between said pair of anodes.

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