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MODULATED BEAM-TYPE ELECTRON TUBE APPARATUS

Filed April 29, 1954

2 Sheets-Sheet 1

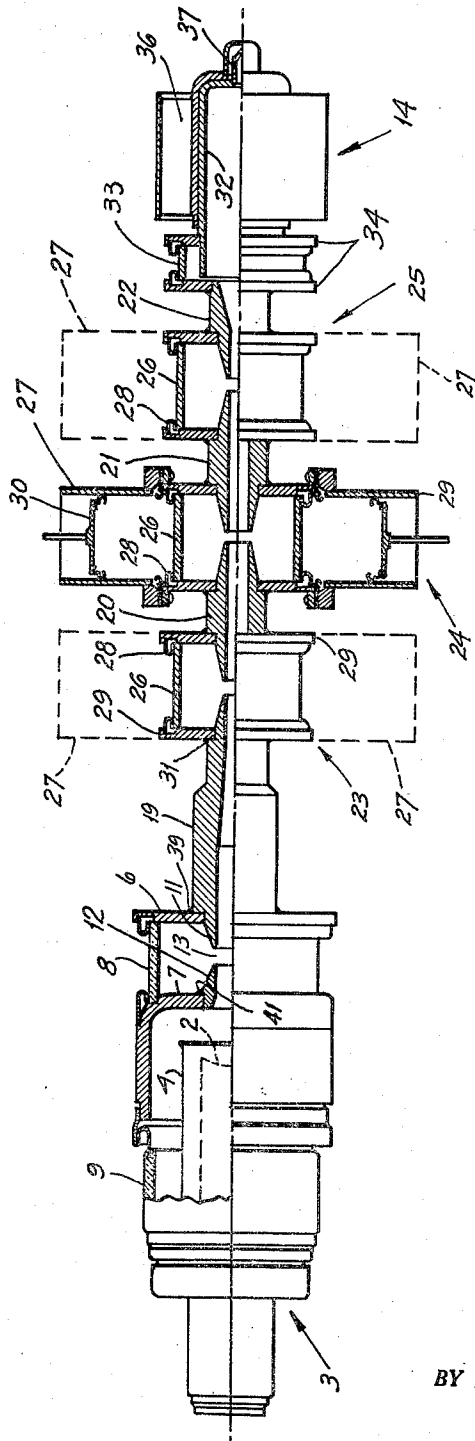


Fig. 1

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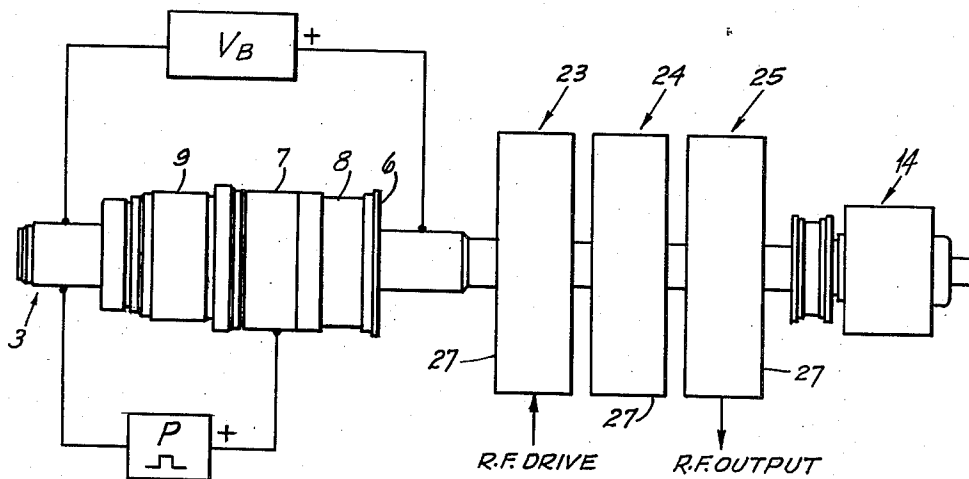


Fig. 2

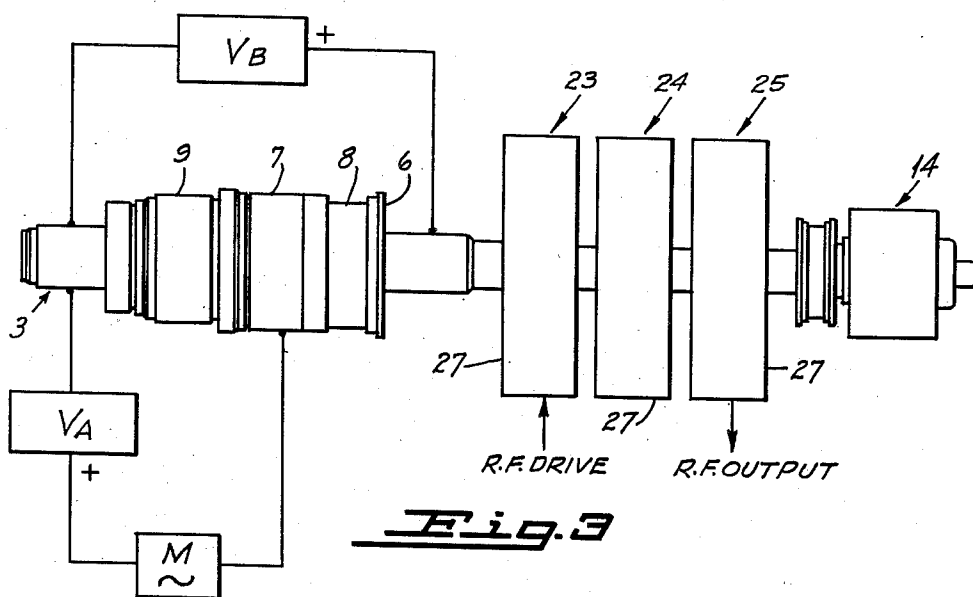


Fig. 3

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MODULATED BEAM-TYPE ELECTRON TUBE APPARATUS

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9 Claims. (Cl. 332-7)

My invention relates to electron tubes of the beam type such as klystrons, traveling wave tubes, and the like.

The principal object of my invention is to provide a tube in which the beam may be modulated in an improved manner.

Another object is to provide a tube wherein a relatively high power beam may be modulated with a low power modulator.

Still another object is to provide such a tube which is adapted for either pulse modulation or modulation by sinusoidal or complex waves.

Another object is to provide a beam-type tube, such as a klystron, operable as an efficient R. F. amplifier adapted for amplitude modulation of continuous waves and delivering a C. W. carrier capable of one hundred percent amplitude modulation.

A still further object of my invention is to provide a tube of the character described which is of simple construction and in which the associated circuitry for modulation purposes is also simplified.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of my invention. It is to be understood that I do not limit myself to this disclosure of species of my invention, as I may adopt variant embodiments thereof within the scope of the claims.

Referring to the drawings:

Figure 1 is an axial sectional view, partly in section and partly in elevation, showing my improvements incorporated in a klystron amplifier.

Figure 2 is an elevational view of the tube with associated circuitry for pulse modulation; and,

Figure 3 is a similar view with the tube connected for amplitude modulation of a C. W. carrier.

With conventional beam-type tubes an electron beam from a cathode passes through an anode and thence into the main body of the tube, such anode being connected to the body and operated at some positive potential with respect to the cathode, which potential is generally referred to as the main beam voltage.

In my improved tube structure there are two anodes; a main anode connected to the body of the tube and a modulating anode interposed between and insulated from the cathode and the first mentioned anode. The main body of the tube may be any suitable structure adapted for interaction with the beam, such as a klystron or a traveling wave structure, a klystron structure with resonant cavities being preferred as hereinafter described.

Referring to Figure 1 and looking first at the left hand or gun end of the tube, I provide a suitable cathode 2 supported by a stem structure 3. Electrons from the cathode are focused into a circular beam by a suitable focusing electrode 4, which beam is adapted to pass through a pair of spaced apertured anodes 6 and 7. A cylinder 8 of insulating material is provided between the main anode 6 and modulating anode 7, and another in-

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insulating cylinder 9 is provided between the modulating anode and the cathode structure. By this arrangement the modulating anode 7 floats electrically free between the cathode and main anode 6.

Anodes 6 and 7 are of metal and have terminal portions exposed externally of the envelope. Insulating cylinders 8 and 9 form wall portions of the evacuated envelope, the envelope of the entire tube being preferably of elongated cylindrical shape. The anodes preferably have tubular projections 11 and 12 at the apertures separated by a gap 13, more about which will be said later.

The beam emerging from anode 6 then passes into the main body of the tube which is preferably a three-cavity klystron amplifier comprising a drift tube terminating at a collector assembly 14. The drift tube is made up of tubular metal sections 19, 20, 21 and 22 having gaps therebetween. These gaps are bridged by cavity resonators generally designated at 23, 24 and 25.

While the cavity resonators may be completely integral with the tube, I prefer to incorporate insulating walls 26 so that portions 27 of the resonators may be applied externally to the evacuated envelope. These external resonator portions may be simple metal boxes engaging the resonator walls on the tube envelope. This permits putting the tuning mechanism 30 in the external portions, which is a great convenience because it is out of the vacuum. Another important advantage of the external resonator structure is that it will accommodate tuning mechanisms which cover a wide frequency range, which is not easily possible if the tuning mechanism is incorporated as a part of the vacuum system.

Suitable magnetic means, not shown, is also provided for confining the electron beam to a path axially of the envelope, which means may comprise simple magnet coils disposed about the envelope in accordance with conventional practice.

In the tube illustrated the insulating walls 26 are preferably ceramic cylinders sealed by flange 28 to metal disks 29 which in turn are secured to the metal drift tube sections at brazes 31. Disks 29 thus form the end walls of those resonator portions which are part of the envelope structure. With the metal boxes 27 in place the drift tubes are all electrically connected together, as will be readily appreciated.

Collector assembly 14 is preferably made up of a cup-shaped metal collector electrode 32 preferably isolated from the body of the tube by an insulating wall cylinder 33, also of ceramic, sealed between supporting disks 34. Suitable heat removal means such as finned cooler 36 is provided about the collector. The collector electrode also preferably carries an exhaust tubulation 37.

Now returning to the gun end of the tube, it is seen that the main anode 6 is mounted directly on drift tube section 19 of the main tube body. This anode is preferably a simple disk-shaped apertured metal piece brazed at 39 to section 19. The tapered end of section 19 provides the tubular projection 11 at the anode aperture. Modulating anode 7 is preferably a cup-shaped metal piece surrounding cathode 2 with an apertured head end facing anode 6. A tapered tubular section brazed at 41 to apertured anode 7 provides the projection 12 which is separated from the projecting end of the drift tube by gap 13. The apertured anodes are thus coaxially aligned with the cathode and with the drift tube of the main body.

The spacing of main anode 6 from the cathode, together with the shielding provided by interposed anode 7, is such that the electrostatic field set up simply by a positive potential on anode 6 does not reach into the surface of the cathode. Such D. C. voltage on anode 6 is the main beam voltage, V_B , applied to the drift tube

of the klystron. Therefore, under conditions of zero potential on anode 7, the beam is cut off. As positive potential is added to modulating anode 7, the electrostatic field is reinforced to a point where it reaches the cathode surface and starts electron current to flow down the beam. Such beam current varies with the voltage on anode 7. This is a case of density modulating the beam current, and in that respect the modulating anode 7 acts like a valve for controlling the current density of the beam. Since the voltage V_B on main anode 6 is a constant, however, the final velocity of the electrons leaving anode 6 and entering the drift tube is a constant.

The location of anodes 6 and 7 adjacent to the cathode and in the structural arrangement shown is important for several reasons. One is the electrostatic field relationships above discussed. Another is that the gap arrangement between the anodes has a beneficial lens effect on keeping the beam properly focused in this portion of the tube. Another reason is that the beam can be initially focused by electrode 4 through the first aperture at anode 7 with few if any electrons landing on the modulating anode. Consequently, the modulating anode draws negligible current and consumes little or no power. It therefore operates as a highly efficient valve device for controlling the beam current.

The main body of the tube functions in the same manner as the radio-frequency portion of a simple klystron amplifier. In other words, R. F. driving power is fed into the first resonator 23 and R. F. output power is taken from the third resonator 25, the interaction with the beam involving bunching and debunching of the electrons in accordance with the well known principle of klystron amplifier operation. Since this part of the tube is thus operating as a simple klystron amplifier (without modulation on the R. F. driving voltage), it is seen that the R. F. drive may be set to give optimum performance and efficiency of the radio-frequency portion of the tube.

Operation of my tube is best illustrated in conjunction with Figures 2 and 3, Figure 2 showing the circuitry for pulse modulation, and Figure 3 illustrating the hook-up for amplitude modulation of a C. W. carrier. In both cases the R. F. drive is adjusted for optimum performance. Both types of operation also include a D. C. supply V_B between the cathode and main anode 6, applying a positive potential on anode 6 and on the tube body. This voltage V_B is the main beam voltage of the tube and is fixed. In both cases, therefore, the main anode 6 is adapted to operate at a steady potential with respect to the cathode.

In the case of pulse operation (Figure 2) the modulating anode 7 is adapted to operate at a varying potential with respect to the cathode for varying the beam current. For this purpose a pulse modulator P providing a positive pulse of desired shape is connected between the cathode and anode 7, so that the pulse voltage is applied to the modulating anode. With this arrangement the voltage on the modulating anode periodically rises and falls to zero, and the beam current accordingly builds up from cut-off to some maximum value in a similar periodic fashion. This is reflected in the output as pulse R. F. power.

Instead of pulse modulator P, it is understood that any other suitable modulator may be inserted at this point for modulating the beam by sinusoidal or complex waves, as will be readily understood by those skilled in the art.

In the amplitude modulated C. W. case (Figure 3) the modulating anode is adapted to operate at some steady potential with respect to the cathode to establish a certain value of beam current and is also adapted to operate at a varying potential to vary the beam current about such value. This circuitry therefore includes a D. C. source V_A between the cathode and anode 7 which puts a steady positive potential on the modulat-

ing anode, the voltage V_A being preferably about half that of the main beam voltage V_B . The steady voltage V_A thus establishes a certain value of beam current which sets the carrier level. A suitable modulating device M, which may be a simple transformer, is placed in series with the supply V_A . The modulation may be of any suitable wave shape, and, when superimposed on V_A , the amplitude of the beam current will vary accordingly. This is then reflected in amplitude modulation of the R. F. output. An efficient high level amplitude modulated R. F. amplifier is thus provided delivering a carrier capable of 100% modulation.

I have found that the R. F. output voltage measured across a constant impedance load varies in accordance with the modulating voltage. Thus, there is a linear relationship between the modulating voltage on anode 7 and the R. F. output voltage. This means that my tube may be used as a high level amplitude modulated R. F. amplifier with a degree of linearity acceptable for applications such as sound broadcasting or video television service.

Another application of interest for which the tube is suitable is in pulse service wherein the shapes or envelopes of the R. F. output pulses have to be precisely controlled, as in a radar system designed for minimum adjacent channel interference. In such an application the shapes of the R. F. pulses follow very closely the shapes of the modulating voltage pulses applied between cathode and anode 7.

I have thus provided a klystron structure which is adapted for modulation in a highly improved manner. This comes about because the beam current can be varied in a very simple and effective manner by varying the voltage on the modulating anode, which is independent of the beam voltage on the main body of the klystron. It is therefore possible to modulate a relatively high power beam with a low power modulator. My improved modulating structure in a klystron amplifier having externally tuned resonators is very versatile in practical applications because it has the modulation features in a tube which also tunes over a wide frequency range.

I claim:

1. A modulating circuit including a klystron comprising an elongated evacuated envelope, a cathode at one end of the envelope for initiating an electron beam, cavity resonators having metal end walls spaced along the envelope axis and forming portions of said envelope, metal drift tube sections connected to said resonator end walls and providing intermediate wall portions of the evacuated envelope, one of the drift tube sections extending towards the cathode and forming a reduced neck portion between a first of the resonators and the cathode end of the envelope, a main anode mounted on the electron receiving end of the last mentioned drift tube section, an apertured modulating anode interposed between the cathode and main anode, and modulating means connected to said modulating anode.

2. A modulating circuit including a klystron comprising an elongated evacuated envelope, a cathode at one end of the envelope for initiating an electron beam, cavity resonators having metal end walls spaced along the envelope axis and forming portions of said envelope, metal drift tube sections connected to said resonator end walls and providing intermediate wall portions of the evacuated envelope, one of the drift tube sections extending towards the cathode and forming a reduced neck portion between a first of the resonators and the cathode end of the envelope, the electron receiving end of the last mentioned drift tube section being spaced from the cathode, a main anode mounted on said receiving end, an apertured modulating anode interposed between the cathode and main anode, a focusing electrode adjacent the cathode and spaced from the modulating anode for directing the electron beam through

the aperture in said modulating anode and a source of modulating signals connected to said modulating anode.

3. A modulating circuit including a klystron comprising an elongated evacuated envelope, a cathode at one end of the envelope for initiating an electron beam, cavity resonators having metal end walls spaced along the envelope axis and forming portions of said envelope, metal drift tube sections connected to said resonator end walls and providing intermediate wall portions of the evacuated envelope, one of the drift tube sections extending towards the cathode and forming a reduced neck portion between a first of the resonators and the cathode end of the envelope, the electron receiving end of the last mentioned drift tube section being spaced from the cathode, a main anode mounted on said receiving end, an apertured modulating anode interposed between the cathode and main anode, the distance between the modulating anode and the electron receiving end of the last mentioned drift tube section being less than the length of said last mentioned section and means including said modulating anode for modulating said beam prior to its entry into the first of the cavity resonators.

4. A modulating circuit including a klystron comprising an elongated evacuated envelope, a cathode at one end of the envelope for initiating an electron beam, cavity resonators having metal end walls spaced along the envelope axis and forming portions of said envelope, metal drift tube sections connected to said resonator end walls and providing intermediate wall portions of the evacuated envelope, one of the drift tube sections extending towards the cathode and forming a reduced neck portion between a first of the resonators and the cathode end of the envelope, the electron receiving end of the last mentioned drift tube section being spaced from the cathode, a main anode mounted on said receiving end, an apertured modulating anode interposed between the cathode and main anode, the distance between the modulating anode and the electron receiving end of the last mentioned drift tube section being less than the length of said last mentioned section, a focussing electrode adjacent the cathode and spaced from the modulating anode for directing said beam through the aperture in said modulating anode, and means including said modulating anode for modulating said beam prior to its entry into the first of the cavity resonators.

5. The method of operating a beam tube having a main body section, a cathode spaced from said body section, a main anode between said cathode and said body section and having an aperture therethrough opening into said body section, a modulating anode between said cathode and said main anode and having an aperture therethrough in alignment with said aperture of said main anode, and a focussing electrode adjacent said cathode, said method comprising the steps of forming the electrons emitted by said cathode into a beam which will pass through the apertures of said modulating anode and said main anode by means of said focussing electrode, applying a constant positive voltage to said main anode with respect to said cathode to accelerate electrons emitted by said cathode, and applying a varying voltage to said modulating anode to control the quantity of electrons in said beam.

6. The method of operating a beam tube having a main body section, a cathode spaced from said body section, a main anode positioned between said body section and said cathode and having an aperture therethrough opening into said body section, a modulating anode between said cathode and said main anode and having an aperture therethrough in alignment with said aperture of said main anode, and a focussing electrode adjacent said cathode, said method comprising the steps of forming the electrons emitted by said cathode into a beam which will pass through the apertures of said modulating anode and said main anode by means of said focussing electrode, applying a constant positive voltage to said main anode with respect to said cathode

to accelerate electrons emitted by said cathode, applying a constant voltage to said modulating anode which is positive with respect to said cathode to establish a given amount of beam current, and simultaneously applying a fluctuating voltage to said modulating anode to vary said beam current about said given amount.

7. The method of operating a klystron having an elongated evacuated envelope, a drift tube axially of the envelope, cavity resonators disposed along the drift tube, a cathode spaced from said drift tube, a main anode located between said cathode and the first of said cavity resonators and connected to said drift tube and having an aperture therethrough aligned with said cathode and said drift tube, a modulating anode between said cathode and said main anode and having an aperture therethrough in alignment with the aperture of said main anode, and a tubular focussing electrode surrounding said cathode and projecting toward said modulating anode, said method comprising the steps of forming the electrons emitted by said cathode into a beam which will pass through the apertures of said modulating anode and said main anode by means of said focussing electrode, applying a constant positive voltage to said main anode with respect to said cathode to accelerate electrons emitted by said cathode, applying a voltage to said modulating anode to control the quantity of electrons in said beam, applying constant wave radio frequency energy to the cavity resonator adjacent said main anode to velocity modulate said beam, and extracting modulated radio frequency energy from said beam through said cavity resonator furthest removed from said main anode.

8. The combination of a beam tube comprising a main body section, a cathode spaced from said body section, a main anode positioned between said cathode and said body section and having an aperture therethrough aligned with said body section and said cathode, a modulating anode interposed between said main anode and said cathode and having an aperture therethrough in alignment with said aperture of said main anode, with a circuit comprising a first power source connected between said cathode and said main anode and supplying a constant positive voltage to said main anode with respect to said cathode, and a second power source connected to said modulating anode and supplying a varying potential to said modulating anode with respect to said cathode.

9. The combination of a klystron comprising an elongated evacuated envelope, a drift tube extending axially of the envelope, cavity resonators disposed along the drift tube, a cathode, an apertured main anode spaced from the cathode and connected to the electron receiving end of the drift tube, an apertured modulating anode interposed between said cathode and said main anode, and a tubular focussing electrode surrounding said cathode, with a circuit comprising a first power source connected between said cathode and said main anode and supplying a constant positive voltage to said main anode with respect to said cathode, a second power source supplying a constant positive voltage, and a third power source supplying a varying voltage, said second and said third power sources being connected in series to said modulating anode whereby said modulating anode is maintained at a voltage varying about a positive value with respect to said cathode.

References Cited in the file of this patent

UNITED STATES PATENTS

2,409,608	Anderson	Oct. 22, 1946
2,409,644	Samuel	Oct. 22, 1946
2,442,662	Peterson	June 1, 1948
2,556,978	Pierce	June 12, 1951
2,758,245	Varian	Aug. 7, 1956

FOREIGN PATENTS

584,452	Great Britain	Jan. 15, 1947
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