Jan. 5, 1943. G. E. PRAY ET AL 2,307,074

MODULATING CIRCUIT FOR HIGH FREQUENCIES

Filed Jan. 22, 1941

Fig. 1.

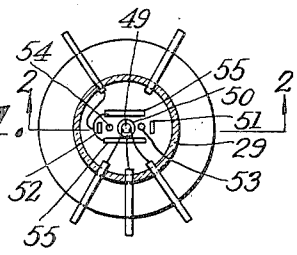


Fig. 2.

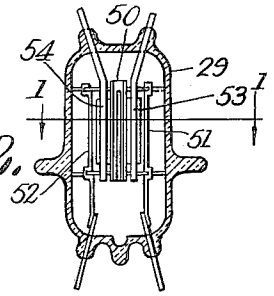


Fig. 3.

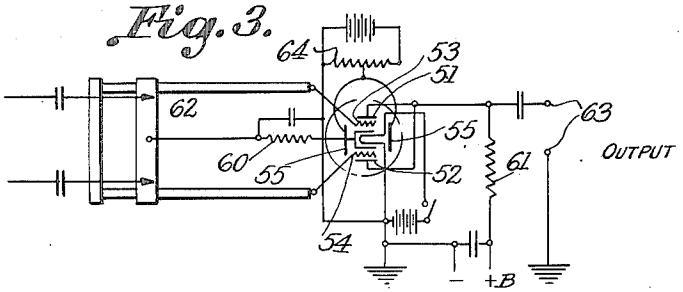


Fig. 4.

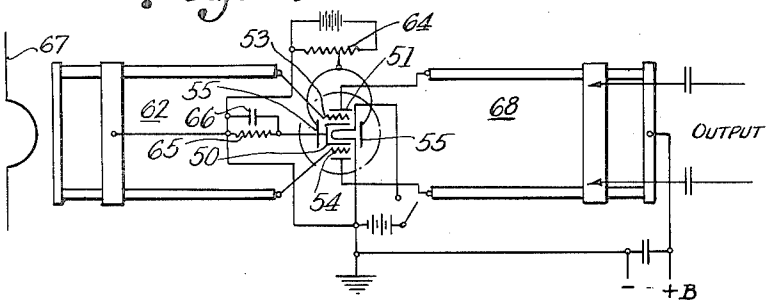
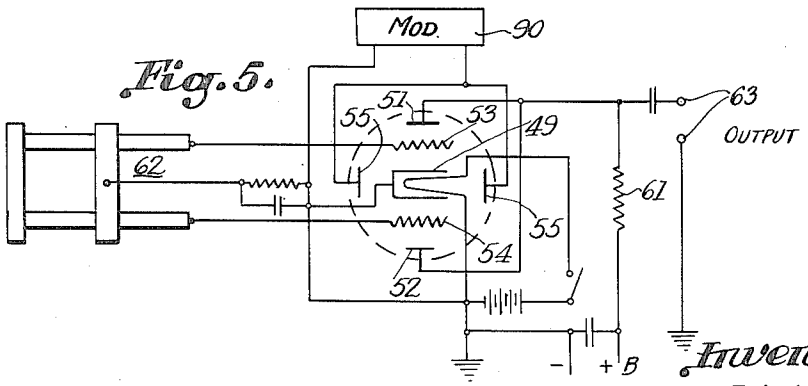


Fig. 5.



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MODULATING CIRCUIT FOR HIGH FREQUENCIES

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Original application September 22, 1938, Serial No. 231,215, now Patent No. 2,251,951, dated August 12, 1941. Divided and this application January 22, 1941, Serial No. 375,416

4 Claims. (Cl. 179—171)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates to circuits particularly adapted for use with ultra high radio frequencies, for example, in the range above 500 megacycles.

The principal object of this invention is to provide radio circuits that will efficiently handle the very high frequencies now coming into use.

In the drawing:

Fig. 1 is a transverse section of a tube particularly useful in circuits of the type herein described;

Fig. 2 is a longitudinal section of the tube shown in Fig. 1;

Figs. 3, 4, and 5 are schematic showings of circuits embodying the present invention.

This application is a division of our co-pending application Ser. No. 231,215, filed September 22, 1938, Patent No. 2,251,951, August 12, 1941.

For amplification, detection, or oscillation at frequencies of the order of 100 megacycles per second and upward, the vacuum tube input impedance and the cathode to grid electron transit time are the most important factors limiting the efficiency of the tube or circuit. If the input elements of the tube present a low capacitive reactance, then the resonant input circuit must have a low value of inductance, with consequent sacrifice in the resonant gain of the circuit. If the input elements of the tube also present a low shunt resistance, the resonant impedance of the circuit is greatly reduced, with further loss in sensitivity and loss of selectivity.

This low shunt resistance is due to transit time effect as is well known in the art. In explanation, we will consider a vacuum tube triode, with an electron emitting cathode or filament, an anode whose potential is positive with respect to the cathode, and a control electrode or grid whose potential is varied sinusoidally from positive to negative with respect to the cathode. The cathode will emit a supply of electrons with nearly zero initial velocity, building up a space charge layer around the cathode. As electrons are drawn from the space charge layer, they are replenished by further cathode emission. Since the anode is maintained positive, the potential gradient in the tube places the space charge layer so close to the cathode that it may be considered as being at the surface of the cathode. Then an electron which receives velocity due to positive grid or anode potentials must traverse the distance from the cathode to the grid before the grid curernt is affected, and from cathode to anode before the anode curent is affected. The grid potential is always low compared to the anode potential, so the velocity imparted to an electron in the cathode-grid space is very small compared to the velocity in the grid-anode space. Thus, the cathode-grid transit time is many times greater than the grid-anode transit time for a normal spacing of the electrodes, and is the important factor to consider.

In the vacuum tubes commercially available for use at frequencies above 100 megacycles, with rated negative grid and positive anode (or screen if using a tetrode or pentode) potentials, the time required for an electron to go from the cathode or filament to the grid is of the order of 10^{-9} seconds. At low frequencies this time is negligible compared to the period of one oscillation, but as the frequency is incraesed this transit time becomes a larger portion of an oscillation. Thus when the grid is driven positive an increase of electron flow is induced, but no grid current flows until these electrons reach the grid. Then as the grid is driven negative, some of the electrons accelerated during the positive portion of the cycle will still produce current in the grid until the grid bias becomes sufficiently negative to overcome the velocity of these electrons, deflecting them toward the anode or turning them back toward the cathode. Thus the grid and anode currents are shifted in phase from their normal relations to the grid voltage, this phase shift being called the "transit angle." The component of current in phase with the negative grid voltage has the effect of greatly reducing the input impedance of the tube and consuming power from the input circuit.

The tube depicted in Figs. 1 and 2 is so constructed as to avoid the difficulty above-mentioned, and the circuits wherein this tube is used are designed to retain the full benefits of the tube construction for high frequency use.

Figs. 1 and 2 illustrate a novel type of electron beam tube for ultra high frequencies. Mounted within the glass envelope **29** are the cathode support **49** bearing activated coating **50**, two anodes **51** and **52** on diametrically opposite sides of the cathode, single straight wire control electrodes **53**, **54** respectively disposed between the anodes and the cathode, and the focusing plates **55**. The emissive coating on the cathode may completely encircle the cathode support or may be in a narrow band facing each anode, and the anodes **51** and **52** may be either flat strips or transversely curved to be concentric with the cathode. The control electrodes **53** and **54** are parallel to the cathode and disposed in the electron stream between the cathode and the anodes.

Focusing plates **55** may be flat rectangular

plates and are disposed parallel to the common axial plane of the cathode and the other electrodes. The electrodes are placed very close together. The anodes 51 and 52 are maintained at a relatively high positive potential while the focusing plates 55 are maintained at a negative potential of 0.5 to 5.0 volts, depending upon the spacing from the other elements, thus repelling the electrons that leave the cathode and restricting the electron stream to a narrow beam not substantially wider than the width of the anodes. The control electrodes 53 and 54 have impressed upon them radio frequency potentials from an external source, such as a resonant circuit, to change the potentials of the control electrodes to be alternately positive and negative with respect to the cathode and thus the electron stream is directed first to one anode and then to the other.

In the operation of the tubes depicted in Figs. 1 and 2, the anodes 51 and 52 will always attract the electrons while the focusing plates 55 will always repel them, thus forming the electron stream into a definite beam. When the control electrode 54 is positive and 53 is negative there will be a large flow of electrons to anode 52 and very little electron flow to anode 51 and when the radio frequency potentials on the control grids 53 and 54 are reversed, the electron stream will be diverted to electrode 51 and there will be extremely little current passing to anode 52. As the control electrode potentials are varied the currents in the tube will vary and thus it is seen that a push-pull triode action is obtained with short and relatively uniform electron paths, and with stray fields and large transit time losses eliminated.

Fig. 3 illustrates a tube of the type shown in Figs. 1 and 2 used as a grid-leak detector. Grid resistor 60 on the order of 20 megohms has been satisfactorily used in this circuit, while the plate load resistor 61 may be of the order of one megohm. The input radio frequency is applied to control grids 53 and 54 by means of a resonant frame 62, while the anodes 51 and 52 have a common output circuit that includes resistor 61, the output energy being taken off between the terminals 63. The potentiometer 64 applies suitable negative potential to the focusing plates 55. Due to the design of these tubes, the anode impedance is inherently high, values of 100,000 ohms to 1.5 megohms having been obtained.

Fig. 4 shows a tube of the type above disclosed, used as a radio frequency amplifier. The control grids 53 and 54 are biased slightly negative with respect to the cathode 50 due to cathode current through resistor 65. The use of such bias tends to increase the cathode-grid transit time, which is undesirable when working near the upper frequency limit of the tube. However, under such conditions, it is possible to operate without grid bias with no damage to the tube, due to the high anode impedance of these tubes. In such a case, resistor 65 and the shunting capacitor 66 would be replaced by a conducting wire. It has also been found practical under most conditions of operation to maintain the focusing plates 55 at cathode potential, in which case the potentiometer circuit 64 would also be replaced by a conducting wire. The output may be coupled either capacitively or inductively to the load. The antenna indicated at 67 may of course be replaced by the output of a preceding stage.

The circuit of Fig. 4 may be used as an oscillator by applying sufficient anode potential and coupling the resonant frames 62 and 68 by placing them close to each other physically. In some cases, it may be desirable to change the circuit from cathode bias to grid-leak bias in the conventional manner.

Electron beam tubes such as above disclosed have an additional feature of some value. If a varying potential be applied between the cathode and the focusing electrodes, it may be used to control the anode current to some extent. Thus the tube may be modulated in that manner for use as a mixer tube in a superheterodyne receiver, as a modulated oscillator, or as a modulated amplifier.

One system for practicing this type of modulation, utilizing the tube shown in Figs. 1 and 2, is schematically illustrated in Fig. 5. The reference characters that are common to this figure and the preceding figures denote the same elements. A modulating potential derived from conventional modulator 90 is applied between cathode 49 and focusing electrodes 55, producing a narrowing and widening of the electron stream which modulates the density of the electron flow impinging upon anodes 51 and 52 and consequently varies the anode current in conformity with the modulating potential.

Wherever in this specification definite values are stated, they are given by way of illustration and not of limitation.

The invention herein described and claimed may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

We claim:

1. A method of modulating an electron stream in a tube having an electron emissive cathode, narrow strip anode means, control electrode means between said anode means and said cathode, and electrostatic focusing means to restrict the electron stream between said cathode and said anode means to a zone not substantially wider than the width of said anode means, comprising the step of applying between said cathode and said focusing means modulating potentials differing in frequency from the potentials applied to said control electrode means and derived from a source independent of the source of the potentials applied to said control electrode means.

2. A method of modulating an electron stream in a tube having an electron emissive cathode, narrow strip anode means, control electrode means between said anode means and said cathode, and electrostatic means to restrict the electron stream between said cathode and said anode means to a zone not substantially wider than the width of said anode means, comprising the steps of applying a first varying potential between said cathode and said control electrode means and applying between said cathode and said electrostatic means a modulating second potential of a frequency different from said first potential and derived from a source independent of said first potential.

3. An electron discharge device network, comprising a tube having an electron emissive cathode, two narrow strip anodes disposed on opposite sides of said cathode with all parts of any longitudinal element of the surface of each substantially equidistant from the corresponding parts of a longitudinal element of the surface of said cathode, separate control electrode means disposed between said cathode and each said anode,

two electron-repelling focusing plates disposed on opposite sides of said cathode extending parallel to the common plane of symmetry through said cathode and said control electrode means to carry a potential to restrict the movement of electrons from said anode to a zone not substantially wider than said anodes, the transverse dimension of each said anode not being greater than the distance between said focusing plates; a high frequency resonant input circuit having its terminals respectively connected to said control electrodes, biasing means including a resistor of the order of twenty megohms and a capacitor in parallel therewith connecting said cathode to a point of electrical symmetry in said input circuit, a common output circuit for said anodes including an anode load resistor of the order of one megohm, and means to apply a suitable negative potential to said focusing plates.

4. An electron discharge device network, comprising a tube having an electron emissive cathode, two narrow strip anodes disposed on opposite sides of said cathode with all parts of any longitudinal element of the surfaces of each substantially equidistant from the corresponding parts of a longitudinal element of the surface of said cathode, separate control electrode means disposed between said cathode and each said anode, two electron-repelling focusing plates disposed on opposite sides of said cathode extending parallel to the common plane of symmetry through said cathode and said control electrode means to carry a potential to restrict the movement of electrons from said cathode to either said anode to a zone not substantially wider than said anodes, the transverse dimension of each said anode not being greater than the distance between said focusing plates; a resonant input circuit having its terminals respectively connected to said control electrodes, a resonant output circuit having its terminals respectively connected to said anodes, and means connecting said cathode to a point of electrical symmetry in said input circuit, to a like point in said output circuit, and to said focusing plates.

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