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ADJUSTABLE FREQUENCY SWEEP CIRCUIT FOR BACKWARD WAVE OSCILLATOR

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Filed Feb. 4, 1964, Ser. No. 342,579

3 Claims. (Cl. 331-82)

A backward wave oscillator oscillates at the frequency for which the phase velocity of the electromagnetic wave on the slow wave structure, usually a helix, is substantially equal to the average velocity of the electrons in the beam. Therefore, the frequency of oscillation may be changed by changing the electron velocity. This is accomplished by changing the accelerating field to which the electrons are subjected before entering the helix. The electron beam forming device or gun of the tube comprises at least a cathode and an apertured anode through which the beam passes. The anode is normally operated at a fixed positive potential relative to the cathode as determined by the tube design. Consequently, the strength of the accelerating field acting on the electrons between the cathode and the helix is determined by the amount by which the anode is positive relative to the cathode and the amount by which the helix is positive relative to the anode. Usually the helix and the collector electrode, which receives the beam after passage through the helix, are operated at zero or ground direct potential. Consequently, the anode and cathode must be negative relative to the helix. Normally, in a tunable oscillator, the cathode is placed at a fixed negative potential relative to the helix, with the anode positive relative to the cathode by the required amount, to establish the working point at an intermediate frequency in the desired tuning range. Tuning is then accomplished by varying the cathode potential about this working point with a similar variation applied to the anode to maintain its positive potential relative to the cathode at the prescribed value.

Where a backward wave oscillator is to be cyclically swept over a frequency band, such as when used as the local oscillator of a panoramic receiver for cyclically tuning the receiver over a desired frequency band, a driving circuit is used to apply a cyclically recurring waveform, such as a sawtooth of voltage, between the cathode-anode and the helix to effect the desired tuning. As indicated earlier, this circuit must maintain the required direct current relationship between the anode and the cathode. In addition, it is desirable that the circuit provide means for adjusting the direct potential between anode and cathode to accommodate backward wave tubes with different requirements in this respect, and also that it provide means for readily adjusting the average direct potential between cathode and helix to accommodate different tubes and, for any particular tube, to permit establishment of the swept frequency band at various positions in the spectrum. It is the purpose of this invention to provide a simple reliable driving circuit having these features.

The invention will be desired in more detail with reference to single figure of the drawing which illustrates a specific embodiment of the invention as used with a backward wave oscillator employed in a panoramic receiving system.

Referring to the drawing, the backward wave oscillator tube shown schematically at 1 serves as the local oscillator for panoramic superheterodyne receiver 2. A representative commercial tube is the Raytheon QKB 816-A. The essential elements of the backward wave oscillator are an electron gun or beam forming device made up of cathode 3, control grid 4 and anode 5; a collector electrode 6; and a slow wave structure 7 which in this case

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is in the form of a helix. In the specific embodiment shown, the cathode is held at an average direct potential of -700 volts relative to the helix 7, which is at ground or zero potential for direct current, and relative to the collector 6 which is also grounded. The anode 5 may be set at a direct potential relative to the cathode of any value from +75 to +150 volts.

The electron beam 8, generated by the gun structure 3-4-5, passes through the helix along its axis to collector 6. The velocity at which the electrons from cathode 3 enter the helix 7 depends upon the accelerating field to which they have been subjected between the cathode and helix. The amount by which anode 5 is positive relative to cathode 3 largely determines the velocity of the electrons as they pass through the aperture in the anode. A further acceleration occurs between anode 5 and helix 7 depending upon the amount by which the helix is positive relative to the anode. Having entered the helix the electrons are not further subjected to direct current fields and their velocities are no longer influenced from this source. However, they are subjected to the high frequency field of the electromagnetic wave propagated along the helix and interact with this field to cause at first a velocity modulation of the beam which in time results in an alternating current component in the beam travelling at a velocity close to the phase velocity of the propagated wave and transferring energy to the propagated wave derived from the kinetic energy of the electrons. As well known in the art, the phase and group velocities of the propagated wave in a backward wave tube are in opposite directions. Hence, in tube 1, the phase velocity of the wave is from left to right, or the same direction as the electron velocity, whereas the group velocity, or direction of energy flow, is from right to left. Therefore, the radio frequency output of the oscillator is from the end of the helix nearest the cathode. This output may be coupled to the receiver by a suitable wave transmission means such as coaxial transmission line 9.

In the specific embodiment shown, the fixed direct potential of the cathode relative to the helix is -700 volts which establishes the working point of the tube and the position in the frequency spectrum of the band over which the tuning of the oscillator is swept. Superimposed on this direct potential is an alternating negative-going linear sawtooth of 100 volts amplitude peak-to-peak. This causes the cathode potential relative to the helix to vary linearly between -650 volts and -750 volts in a repeating cycle and the frequency of the oscillator to vary continuously in corresponding cycles from a minimum value at -650 volts to a maximum value at -750 volts. The variation of frequency with voltage is exponential in form, becoming less for a unit voltage change as the voltage increases. Therefore, the frequency of the oscillator at the working point potential of -700 volts, which is the center potential of the voltage variation, is not exactly the center frequency of the swept band; however, for small voltage sweeps, such as 100 volts, the frequency at the center voltage is close to the center of the swept band since the characteristic over a small range is nearly linear. At all times, the direct potential of anode 5 relative to cathode 3 is held constant at a selected value between +75 and +150 volts, although this direct potential may have superimposed a small alternating sawtooth component, as will be explained later.

The driving circuit for supplying the above described direct potentials and effecting the above described linear sweep of the cathode voltage relative to the helix constitutes the invention and will now be explained, considering first the direct current aspects of the circuit and then the alternating current aspects.

As a direct current network, the driving circuit oper-

ates to establish cathode 3 at a fixed negative potential of -700 volts, or any other desired value, relative to the helix and to establish anode 5 at a fixed positive potential relative to cathode 3 of any selected value between predetermined minimum and maximum values, in this case between +75 and +150 volts. This is accomplished as follows: Pentode 10 is the amplifying element of a cathode follower circuit. It has its anode directly connected to the positive terminal of a 1000 volt direct current source 11 and its cathode connected through a constant current load impedance to the negative terminal of this source. This load impedance consists of two parallel connected pentodes 12 and 13 which act as constant current devices because of their high amplification factors and the negative feedback to their control grid circuits produced by cathode resistors 14 and 15. Thus, any tendency for the anode current of either tube to change produces a change in control grid to cathode potential that opposes the anode current change. Because of the high amplification factors of the tubes, their anode currents are held substantially constant by this process. The constant current load impedance increases the linearity of the cathode follower circuit.

The control grid bias for tube 10 is provided by a potential divider made up of resistors 16, 17 and 18, the adjustable contact 19 on resistor 17 being connected through normally closed contacts *ab* of relay *K*₁ and grid resistor 20 to the control grid. The cathode 3 of the backward wave tube 1 is directly connected to the cathode of tube 10. Because of the high gain of tube 10 and the cathode follower circuit in which it is connected, the potential of its cathode and that of cathode 3 will be very close to that of the control grid of tube 10. Therefore, the cathode 3 may be established at a direct potential relative to the helix 7 of -700 volts, or any other desired value within the range of the circuit, by adjustment of contact 19.

In order to establish anode 5 of the backward wave tube at the proper positive potential relative to cathode 3, a potential divider consisting of resistor 21, resistor 22 and zener diode 23 is connected between the anode (ground) and cathode of tube 10, the anode 5 being connected to adjustable contact 24 on resistor 22. Zener diode 23 is selected to have a voltage equal the minimum desired anode 5 voltage relative to cathode 3, in this case 75 volts. Resistor 22 is given a value relative to resistor 21 such that the total voltage drop across it added to the diode voltage equals the maximum desired voltage of anode 5 relative to cathode 3, in this case 150 volts. Therefore, the total drop across resistor 22 is 75 volts. A drop of 75 volts across resistor 22 and 75 volts across diode 23 leaves 550 volts across resistor 21. Consequently, resistor 21 is made larger than resistor 22 in the ratio 550/75 or 7.33/1. The combined resistance of 21 and 22 should be such that the current through diode 23 is at about the center of its zener breakdown region. With this arrangement the potential of anode 5 relative to cathode 3 may be set at any desired value between +75 and +150 volts.

Considering now the alternating current operation of the circuit, periodic trigger pulses obtained from synchronizing pulse source 25 are applied to sawtooth wave generator 26 which produces in synchronization therewith a linear negative-going sawtooth voltage wave at point 27 of, for example, 100 volts peak-to-peak amplitude. This wave is applied to the grid of tube 10 through blocking capacitor 28 which removes the direct current component, if any. Although the alternating current wave is applied between the grid and ground it is also effectively applied between the grid and conductor 29 since the alternating current impedance of direct current source 11 is very low relative to the impedance of grid resistor 20. This causes a substantially equal sawtooth to appear at the cathode of tube 10, and consequently at the cathode 3 of tube 1,

since the gain of the cathode follower stage is near unity due to the high amplification of pentode 10. This alternating current sawtooth is superimposed upon the -700 volt direct potential of these cathodes so that the cathode 3 of tube 1 sweeps linearly between -650 volts and -750 volts, sweeping the oscillator frequency between the minimum and maximum frequencies of the swept band.

The 100 volt sawtooth wave applied between cathode 3 and the helix (ground) is also applied across the potential divider 21-22-23. Since the alternating current impedance of zener diode 23 is substantially zero the sawtooth voltage across it is zero and the entire 100 volts is applied across the series combination of resistors 22 and 23. As stated earlier, resistor 21 is larger than resistor 22 in the ratio 7.33/1. Therefore, less than 1/8 of the 100 volts, or about 12 volts, is the peak-to-peak amplitude of the sawtooth across resistor 22. Consequently, the amplitude of the sawtooth voltage between anode 5 and cathode 3 lies in the range 0 to 12 volts depending upon the position of contact 24 on resistor 22.

The presence of the small sawtooth between anode 5 and cathode 3 has no detrimental effect on the operation of the backward wave oscillator since it has no effect on the velocity of the electrons entering the helix. The reason for this is that the amplitude of the sawtooth between the helix and anode 5 is reduced by an amount equal to the amplitude of the sawtooth between anode 5 and cathode 3. Therefore, any increased acceleration of the electrons due to the presence of a sawtooth between anode 5 and cathode 3 is offset by less acceleration of the electrons between anode 5 and helix 7 due to the smaller sawtooth between these electrodes. Consequently, the velocity of the electrons entering the helix when there is a sawtooth voltage present between anode 5 and cathode 3 is no different from what it would have been had the anode 5 potential relative to the cathode been held constant at the direct potential established at contact 24, with the full sawtooth applied between anode 5 and the helix.

The trigger pulses applied to sawtooth wave generator 26 are also applied to the horizontal trigger input of a cathode ray tube indicator 30. This causes a horizontal sweep of the tube to be initiated in synchronism with the start of each sawtooth. The output of receiver 2 is applied to the vertical input of the indicator 30. With this arrangement a vertical mark is produced for each received signal lying within the frequency band over which the tuning of receiver 2 is swept. These marks occur at positions along the horizontal axis of indicator 30 corresponding to their frequencies.

With *K*₁ deenergized the full sawtooth voltage at point 27 is applied through normally closed contacts *de* to the grid of tube 10 as previously explained. As a result, the full sweep voltage is applied to the cathode of backward wave oscillator 1, the tuning of receiver 2 is swept over its full range, and the total swept band of frequencies is displayed along the horizontal axis of indicator 30. In order to resolve signals having a small frequency separation it is sometimes desirable to expand the frequency scale along the horizontal axis of indicator 30, i.e., to spread a fraction of the total frequency band over the full horizontal dimension of the indicator. In the circuit shown a 4× expansion may be effected by closing switch *S*₁ to energize relay *K*₁. Energization of this relay applies a sawtooth of 1/4 the normal amplitude of 100 volts through normally open contacts *ge* to the grid of tube 10, the reduction to 1/4 amplitude being achieved by giving resistor 31 one-third the resistance value of resistor 32. The reduced sawtooth causes the frequency of oscillator 1 to be swept over only 1/4 the full band with a corresponding 1/4 sweep in the tuning of receiver 2. Since a full horizontal sweep of the beam occurs in indicator 30 during the time that the receiver tuning is swept over 1/4 of the full tuning range, only 1/4 of the full frequency band is displayed along the horizontal axis of the indi-

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cator. In order to select the desired $\frac{1}{4}$ of the frequency band to be displayed provision is made to obtain the control grid bias of tube 10 from adjustable contact 33 of resistor 34, rather than from contact 19, when K_1 is energized. The position of contact 33 now determines the fixed direct potential of cathode 3 relative to the helix and therefore the exact $\frac{1}{4}$ of the frequency band to be displayed. Consequently, when S_1 is closed the entire frequency band is displayed along the horizontal axis of indicator 30 and when S_1 is closed only that $\frac{1}{4}$ of the frequency band selected by the position of contact 33 is displayed along the horizontal axis. In the latter case the frequency scale is expanded $4\times$ making easier the resolution of signals closely spaced in frequency.

I claim:

1. A driving circuit for a backward wave oscillator, said oscillator having a helix and an electron beam forming means for directing a beam of electrons through said helix along its axis, said beam forming means having a cathode and an anode, said driving circuit comprising: a direct current source of constant potential having its positive terminal connected to a point of reference potential; a direct current connection between said helix and said point of reference potential; a pentode having its anode connected to said point of reference potential; a constant current impedance connected between the cathode of said pentode and the negative terminal of said source; a direct connection between the cathode of said backward wave oscillator and the cathode of said pentode; means for applying an adjustable biasing potential between the control grid and cathode of said pentode for adjusting the direct potential of the cathode of said backward wave oscillator

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relative to said helix; a potential divider comprising a first resistor, a second resistor and a zener diode connected in series in the order named between said point of reference potential and the cathode of said pentode, said second resistor having an adjustable intermediate contact; a direct connection between the anode of said backward wave oscillator and the adjustable tap on said second resistor; and means for applying a sawtooth alternating voltage wave between the control grid of said pentode and the negative terminal of said source.

2. Apparatus as claimed in claim 1 in which said zener diode has a breakdown voltage equal to the minimum desired direct voltage between the anode and cathode of said backward wave oscillator and in which the ratio of the resistance of said second resistor to that of said first resistor is such that the sum of the direct voltage across said second resistor and the direct voltage across said zener diode equals the maximum desired direct voltage between the anode and cathode of said backward wave oscillator.

3. Apparatus as claimed in claim 1 in which said constant current impedance comprises an additional pentode having its anode connected to the cathode of the first mentioned pentode, its cathode connected through an impedance to the negative terminal of said direct current source and its control grid connected to the negative terminal of said direct current source.

No references cited.

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