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J. L. CLARKE

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FREQUENCY CONTROL SYSTEM

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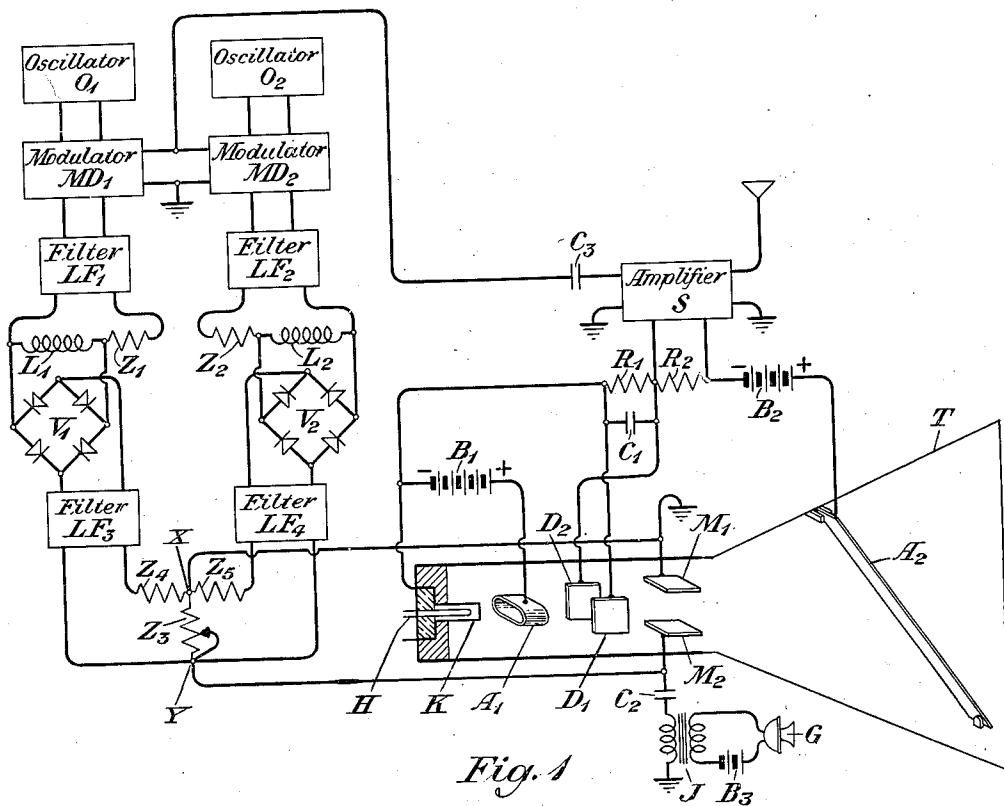
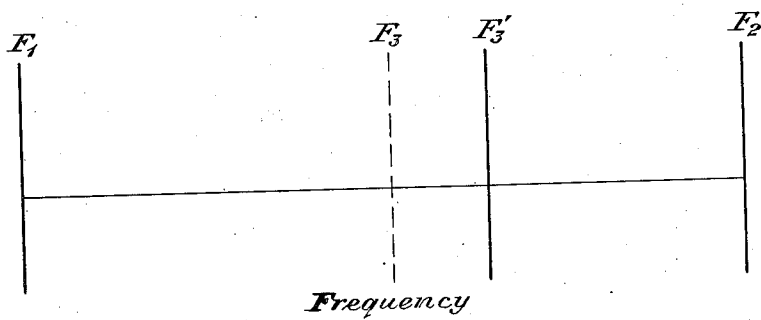


Fig. 1



Frequency

Fig. 2

INVENTOR
J. L. Clarke
BY *Jefferson Eholich*
ATTORNEY

UNITED STATES PATENT OFFICE

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FREQUENCY CONTROL SYSTEM

John L. Clarke, Lachine, Quebec, Canada, assignor to American Telephone and Telegraph Company, a corporation of New York

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11 Claims. (Cl. 179-171.5)

This invention relates to oscillation generators and especially to oscillation generators of the electron beam type. Still more particularly this invention relates to oscillation generators of the electron beam type which include means for maintaining the frequency of the generated oscillations substantially constant.

This is a continuation in part of my application Serial No. 350,227, filed August 3, 1940, entitled "Frequency modulator."

In the prior application just referred to, there is disclosed a circuit including an electron beam tube for generating oscillations and for varying the frequency of the generated oscillations in accordance with signals or other effects. The electron beam tube includes a plurality of electrodes one of which is positioned at a predetermined angle with respect to the mean path of the electron beam. As the electron beam is deflected along different paths which strike the inclined anode at different points along its surface, the frequency of the generated oscillations will be correspondingly varied as, for example, in accordance with signals or other effects.

In the circuit arrangement of the prior application there will be some fluctuations of the mean or base frequency of the generated current. These fluctuations will be due either to changes of the battery voltage, or to changes in the condenser capacity, or to changes in the magnitudes of the resistors, or to deformations of the beam forming anode A₁, as would be the case with variations in temperature, weather conditions, or the like. According to the present invention a modified arrangement has been evolved for maintaining the mean or base frequency of the generated current of the electron beam tube substantially constant. This may be accomplished by obtaining a small D. C. voltage from the fluctuations of the mean or base frequency and causing this D. C. voltage to act as a bias which may be applied to the electrodes upon which the signals or other effects may be impressed. The effect of this bias will be to maintain the mean or base frequency of the electron beam tube oscillator substantially constant. This bias may be controlled automatically, that is, the bias will have a polarity which will correspond to the direction of change in the mean or base frequency and its magnitude will increase or decrease by an amount which will correspond to the shift in the mean frequency from its assigned value.

According to this invention two additional electrical oscillators of highly constant frequency and amplitude are provided, the frequencies of these

two additional oscillators being such that their mean or average frequency equals the desired mean or base frequency desired for the system. The outputs of these two additional oscillators are heterodyned with the output of the electron beam tube and, after removing the additive products of modulation, the two components of the difference frequencies are passed respectively through networks which rectify the two currents and thus yield two voltages which are proportional to the two difference frequencies. These two voltages are then caused to oppose each other in a suitable network, and the difference between the rectified voltages will yield a resultant D. C. voltage which will be impressed upon the circuit of the modulating electrodes of the electron beam tube. There the resultant D. C. voltage will bias the tube in such a way as to maintain the mean or base frequency generated by the electron beam tube at a substantially constant value.

This invention will be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawing in which Figure 1 represents the general layout of one form of circuit arrangement suitable for carrying out the principles of the invention and Fig. 2 shows a frequency diagram used to explain the operation of the invention.

Referring to Fig. 1 of the drawing, the electron beam tube designated T includes a heater H, a cathode K, a first anode of annular shape designated A₁, which is maintained at a suitable potential with respect to the cathode by battery B₁, two plates D₁ and D₂ positioned on opposite sides of the emitted cathode beam, two additional electrodes M₁ and M₂ of similar construction which are displaced 90 degrees with respect to the other two plates D₁ and D₂, and an inclined anode A₂. The cathode K is connected to the anode A₂ by a circuit which includes two resistors R₁ and R₂ and a battery B₂ which is used to maintain the anode A₂ at a suitable positive potential with respect to the cathode K. A condenser C₁ is connected not alone in shunt with the resistor R₁ but also across the deflecting plates D₁ and D₂. The arrangement already described will generate oscillations of a desired frequency as already explained in the prior application referred to, and the current of the desired frequency so generated will be amplified by amplifier S and radiated through space over a suitable antenna circuit. A telephone microphone or other equivalent device upon which signals may be impressed is connected in series with a battery B₃ and the primary winding of a transformer J, the secondary

of which is connected to the modulating plates M_1 and M_2 through a condenser C_2 . Hence signals reaching the microphonic device G will be impressed upon the modulating electrodes M_1 and M_2 , the electron beam will be deflected in accordance with these signals, causing the beam to move up and down along the inclined surface of the anode A_2 , and hence vary the frequency of the oscillations generated by the tube T in accordance with these signals.

Some of the current generated by the electron beam tube T may be transmitted through the amplifier S over a circuit which includes the condenser C_3 , this circuit extending to the input circuits of two modulators, MD_1 and MD_2 which have identical characteristics. These modulators are also supplied with alternating currents generated by two oscillators O_1 and O_2 which may be of any well known type, for example, oscillators maintained constant in frequency by piezoelectric crystals, and maintained constant in amplitude in any well known manner as, for example, by interposing current limiters between the oscillators O_1 and O_2 and the modulators MD_1 and MD_2 . The modulator MD_1 , therefore, has impressed upon its input circuit current of the frequency generated by the electron beam tube T as well as current generated by the oscillator O_1 . Likewise the modulator MD_2 receives both the current generated by the tube T and that obtained from the oscillator O_2 . The products of modulation which include, among other things, the sum and difference components of the beating frequencies, are transmitted to the filters LF_1 and LF_2 , respectively, which act to substantially suppress all components except the difference frequencies resulting from modulation. Thus the filter LF_1 will transmit only current of a frequency $F_3 - F_1$, where F_3 is the frequency of the current obtained from the electron beam tube T and F_1 is the frequency of the current produced by oscillator O_1 . Likewise the filter LF_2 will transmit only current of the frequency $F_2 - F_3$, where F_2 is the frequency of the current supplied by oscillator O_2 , all other components being suppressed by the latter filter.

The output of the filter LF_1 includes a circuit having a non-reactive resistor Z_1 and an inductance L_1 connected in series relationship. A similar series circuit of resistance Z_2 and inductance L_2 is connected in the output circuit of the filter LF_2 . In these two series circuits the resistances Z_1 and Z_2 form impedances which are very large with respect to the impedances of the two corresponding inductances L_1 and L_2 , respectively, in which case the resistances Z_1 and Z_2 will for all practical purposes determine the magnitudes of the currents flowing from the filters LF_1 and LF_2 . The voltages across the inductances L_1 and L_2 will correspond to the frequencies of the low frequency components passed by the filters LF_1 and LF_2 , that is, the voltages across coils L_1 and L_2 will be proportional to the frequencies of the beating currents flowing through the output circuits of the respective filters LF_1 and LF_2 . The inductances L_1 and L_2 are connected to corresponding full wave rectifiers V_1 and V_2 which may be of any well known type, and the rectified currents are transmitted through low pass filters LF_3 and LF_4 , respectively, to a T network which comprises two equal resistors Z_4 and Z_5 and a shunt resistor Z_3 . The latter resistor Z_3 —which may be adjusted to have any predetermined magnitude—is connected between points X and Y , point X being

common to the two series resistors Z_4 and Z_5 of the T network. The terminals X and Y are connected to the modulating electrodes M_1 and M_2 of the electron beam tube T . In this arrangement the filters LF_3 and LF_4 act to substantially suppress all alternating currents and merely freely transmit only the fluctuating direct current voltages resulting from rectification by the devices V_1 and V_2 , respectively.

It will be observed that the rectified voltage obtained from the rectifier V_1 is poled in such a direction that positive current will flow through the filter LF_3 so as to render the terminal Y positive with respect to the terminal X of the T network. Likewise the rectified voltage obtained from the rectifier V_2 will be poled in such a direction that the flow of positive current through the filter LF_4 will render the terminal X positive with respect to the terminal Y . Thus two opposing voltages will be simultaneously impressed upon the resistor Z_3 . When these voltages are equal they will fully neutralize each other and consequently no biasing voltage will be supplied to the modulating electrodes M_1 and M_2 of the tube T . However, if the rectified voltage from device V_1 exceeds that obtained from rectifying device V_2 , then resistor Z_3 will have a resultant voltage impressed thereon such that the point Y will be positive with respect to the point X and consequently the modulating plate M_2 will be biased at a corresponding positive potential with respect to the modulating plate M_1 . Similarly when the voltage obtained from the rectifying device V_2 exceeds that obtained from the rectifying device V_1 the resultant voltage across the resistor Z_3 will be such as to render the terminal X positive with respect to the terminal Y . Consequently the plate M_1 of the tube T will be rendered positive with respect to the plate M_2 . Thus a biasing voltage is obtained by this arrangement and applied to the modulating electrodes M_1 and M_2 of the tube T , the biasing voltage being of such polarity and magnitude as to correspond to the shift in the frequency F_3 of the tube T with respect to the fixed frequencies of the oscillators O_1 and O_2 .

This latter feature may perhaps be better explained in connection with Fig. 2. Here the frequencies of the oscillators O_1 and O_2 are designated F_1 and F_2 respectively and these frequencies are equally spaced from the mean or base frequency obtained from tube T which is designated F_3 and is shown in dotted lines. When the mean or base frequency is at the value shown by the dotted lines, the differences in frequency between F_1 and F_3 and F_2 and F_3 are equal. In this event the rectified currents obtained from rectifiers V_1 and V_2 will be equal and the bias applied to the modulating electrodes M_1 and M_2 will be zero. However, when the frequency of the current generated by tube T rises to a value such as F'_3 , for example, then the frequency difference $F'_3 - F_1$ will exceed the frequency difference $F_2 - F'_3$. In the latter case the rectified current obtained from rectifier V_1 will exceed that obtained from rectifier V_2 and hence the plate M_2 will be biased to a positive potential with respect to the plate M_1 . Obviously when the current generated by tube T is lower than the value shown by the dotted lines F_3 , the bias upon the modulating electrodes M_1 and M_2 will be reversed, thereby bringing the electrode M_1 to a positive potential with respect to electrode M_2 .

It will be apparent that the current supplied by the tube T to the input circuits of the modu-

lators MD₁ and MD₂ need not be passed through the amplifier S. If desired the current obtained from the tube T may be tapped across the resistor R₂. The condenser C₂ is employed primarily to prevent any direct currents obtained from the T network from flowing through the secondary winding of transformer J.

The electron tube T includes two pairs of deflecting plates D₁ and D₂ and M₁ and M₂, the deflecting plates D₁ and D₂ being supplied with voltage which is also impressed upon the condenser C₁ for initially fixing the frequency of the current generated by tube T. The voltage applied to the plates M₁ and M₂ varies the path of the electron beam in order to change the generated frequency in accordance with signals or other effects. The biasing voltage obtained in accordance with this invention is applied to the modulating electrodes M₁ and M₂ of the electron beam T to control the deflections of the electron beam along the anode A₂ and in effect this maintains the electron beam in its normal or mean path. The mean or base frequency obtained from the tube T will thus always be maintained substantially constant and independent of temperature and weather conditions and the frequency may be varied only when the signal modulating voltage acts to deflect the electron beam in accordance with that voltage. The modulating electrodes M₁ and M₂ are thus supplied with two voltages acting simultaneously, (1) the biasing voltage obtained from the T network to maintain the mean or base frequency of beam tube oscillator substantially constant, and (2) the voltage obtained from the signal source G which varies the frequency of the beam tube oscillator in accordance with the signals as is the practice in frequency modulation.

One of the oscillators, such as O₁ and the circuit directly connected thereto, that is, the circuit interconnecting oscillator O₁ and the T network, may be omitted, if desired, within the spirit of this invention. In that case the frequency of oscillator O₂ is set at some value which will always be lower than the frequency F'₃ of the beam tube oscillator so that when the two currents are impressed on modulator MD₂ there will always be a difference frequency. The latter frequency is passed through filter LF₂, through resistor Z₂ and inductance L₂, rectified by V₂ and the rectified output passed through filter LF₄ as before. The output of filter LF₄—a fluctuating voltage proportional to the difference between frequencies F₂ and F'₃—is then impressed on a resistor such as Z₃. A portion of the voltage developed in the resistor Z₃ is then impressed on plates M₁ and M₂ of tube T. The circuit constants are so chosen that frequency F'₃ is at the correct mean frequency when the voltage across Z₃ is at some median value in its range of fluctuations. Then, if the frequency F'₃ is low, that is, below its assigned value, the voltage developed across Z₃ is also low and acts upon electrodes M₁ and M₂ in such a way as to raise the frequency F'₃ to its correct mean or assigned value. If, on the other hand, the frequency F'₃ is high, the voltage difference on resistor Z₃ is high and in turn reacts on electrodes M₁ and M₂ in such a way as to depress the frequency F'₃ to its correct mean or assigned value. In other words, whereas in the arrangement making use of two oscillators as shown in the drawing, the condition for correct mean frequency was attained when the voltage across resistor Z₃ was zero and deviations from the correct frequency

were made manifest as positive or negative voltages on resistor Z₃ depending on whether the frequency was too high or too low, in the arrangement now described using only one oscillator the condition for correct mean frequency is attained when some predetermined voltage exists across the resistor. Deviations from the correct mean frequency are made manifest by changes in the magnitude of the voltage across resistor Z₃ upward and downward from the value which determines the correct frequency depending on whether the frequency is too high or too low.

While this invention has been shown and described in certain particular arrangements merely for the purpose of illustration, it will be understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. The combination of an electron beam oscillator having a pair of spaced electrodes parallel to each other upon which variable voltages may be impressed to correspondingly change the path of the electron beam and the frequency of oscillations sustained by said oscillator, the planes of said electrodes being substantially parallel to the direction of travel of the electron beam, and means responsive to fluctuations in the mean frequency of said oscillator for producing a biasing voltage for application to said spaced electrodes to maintain the mean frequency of said oscillator substantially constant.

2. The combination of an electron beam oscillator for generating current of a predetermined frequency, a pair of parallel spaced electrodes enclosed within the tube of said oscillator, the planes of said electrodes being substantially parallel to the direction of travel of the electron beam, means responsive to variations in the frequency of the current produced by said oscillator for obtaining a bias voltage, and means for applying said bias voltage to said spaced electrodes to maintain the frequency of the generated current at its predetermined value.

3. The combination of an electron beam oscillation generator, a signal circuit coupled to said oscillation generator to vary the frequency of the current produced thereby in accordance with signals impressed upon said signal circuit, said signal circuit including a pair of parallel spaced electrodes which are enclosed within the tube of said oscillation generator, the planes of said electrodes being substantially parallel to the direction of travel of the electron beam, and means responsive to variations in the mean frequency of said oscillation generator for impressing a bias voltage on the signal circuit to maintain the mean frequency of the generated current substantially constant.

4. The method of maintaining substantially constant the mean frequency of an electron beam oscillator having a pair of parallel spaced electrodes between which the electron beam passes, the planes of said electrodes being substantially parallel to the direction of travel of the electron beam, which consists in generating a bias voltage proportional to any change in the frequency of the generated current, and modifying the path of the electron beam between said parallel electrodes in accordance with the bias voltage so as to maintain the mean frequency of said oscillator substantially constant.

5. A frequency control system for an electron beam oscillation generator, comprising a pair of parallel electrodes the planes of which lie in the general direction of travel of the electron beam, means responsive to any variations in the mean frequency of the current generated by the electron beam tube to produce a direct current voltage proportional to the change in the mean frequency, said direct current voltage being poled so as to correspond to the directional change of said mean frequency and being applied to said parallel electrodes, and means responsive to said direct current voltage for correspondingly deflecting the electron beam of said tube so as to maintain the mean frequency thereof substantially constant.

6. The combination of an electron beam tube having a cathode, an anode electrode inclined at a predetermined angle with respect to the electron beam emanating from the cathode, and first and second pairs of spaced electrodes displaced 90° from each other, a circuit interconnecting said anode and said cathode for applying a variable voltage to the electrodes of said first pair to generate alternating current, a signal circuit connected to the second pair of electrodes for modulating the frequency of the generated current, and means responsive to changes in the mean frequency of the current generated by said electron beam tube to obtain a voltage which is proportional to said frequency change, and means for impressing said latter voltage upon the signal circuit.

7. An oscillation generator comprising an electron beam tube including a cathode, first and second pairs of spaced electrodes which are displaced 90° from each other and an inclined anode, a circuit interconnecting the anode and cathode of said tube for applying voltage to the first pair of spaced electrodes to generate current of a predetermined frequency, and means responsive to fluctuations of the predetermined frequency of the current generated by said tube for producing a bias voltage proportional to said fluctuations of frequency, and means for impressing the bias voltage upon the second pair of spaced electrodes.

8. The combination of an electron beam tube

oscillation generator having a pair of parallel spaced electrodes between which the electron beam travels, an anode circuit in which the generated current flows, the planes of said electrodes being in the direction of travel of said electron beam, and means responsive to fluctuations in the mean frequency of said current to deflect the electron beam of the tube by an amount which is proportional to said mean frequency fluctuation.

9. The combination of an electron beam tube oscillation generator having an anode circuit in which the generated current flows, a pair of spaced electrodes within the tube of said generator on opposite sides of the electron beam of said tube, and means for continuously producing a voltage which is proportional to any change in the frequency of the generated current, and means for applying said voltage to said spaced electrodes to deflect the electron beam to maintain the frequency of the generated current substantially constant.

10. The combination of an electron beam tube, means for deflecting the electron beam of said tube back and forth in one direction, means responsive to said electron beam deflections to generate oscillations of a predetermined frequency, means responsive to changes in the frequency of said oscillations to deflect the beam in a different direction in order to maintain the frequency of the generated oscillations substantially constant.

11. The combination of an electron beam tube oscillation generator having a pair of electrodes which control the frequency of the generated oscillations, two oscillators generating currents which are constant in frequency and amplitude, means for separately modulating the current of the beam tube generator with the currents of the two constant frequency oscillators, means for producing two direct current voltages which are proportional to the frequencies of said separately obtained products of modulation, and means for applying to the control electrodes of said beam tube generator a voltage corresponding to the difference of said two direct current voltages.

JOHN L. CLARKE.