

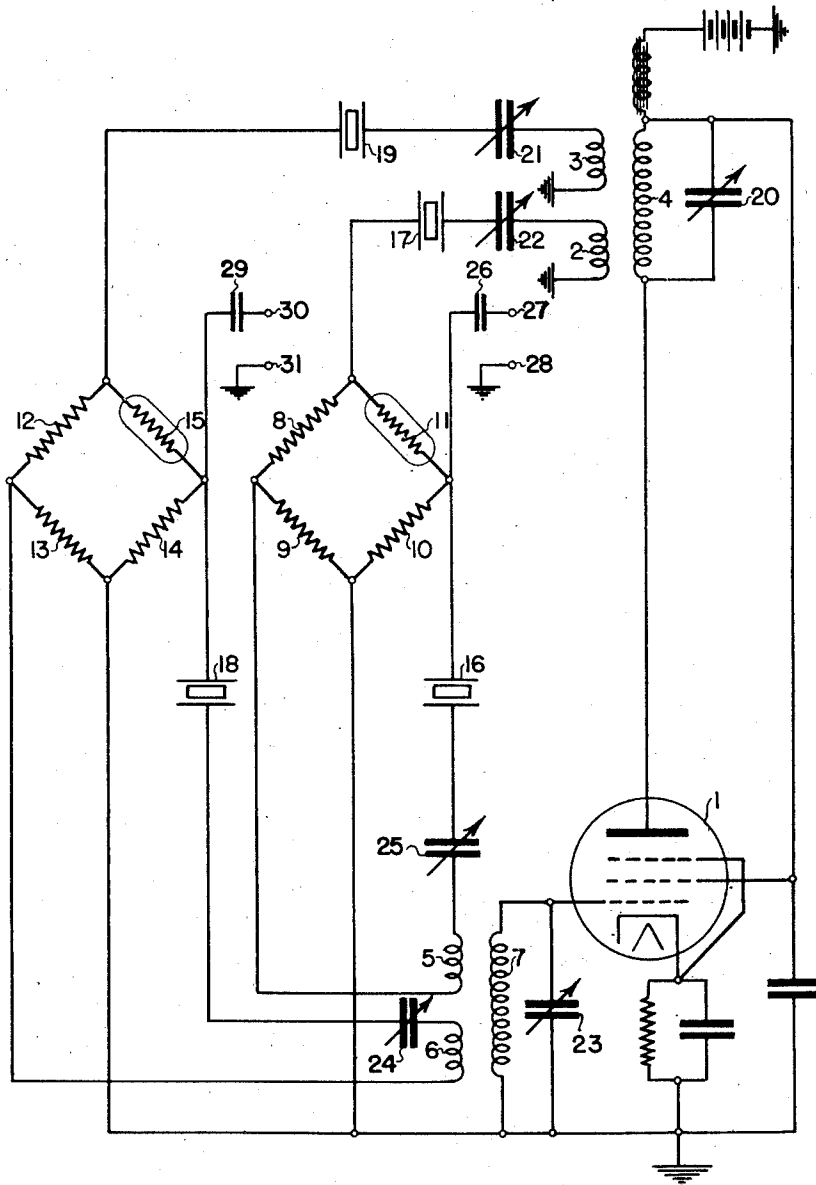
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MULTIPLE-FREQUENCY OSCILLATOR

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MULTIPLE-FREQUENCY OSCILLATOR

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9 Claims. (Cl. 250—36)

This invention relates to an improved vacuum-tube oscillator and, particularly, to an oscillator of the type comprising a vacuum tube and a feed-back circuit containing a tuned element, that is, one having a natural frequency, connecting the input and output circuits of the tube so that in operation oscillations are generated at substantially the frequency of the tuned element between some pair of points on the feed-back circuit.

Great difficulty has heretofore been experienced in simultaneously generating in one vacuum tube oscillations of multiple frequencies with freedom from intermodulation between the generated oscillations. In such of the prior art oscillators as have two or more optimum frequencies, it is found that the oscillator actually oscillates only at the frequency of the generated oscillations of greatest strength due, in large part, to the fact that such oscillations alone drive the tube over the full useful range of its characteristic, thereby developing a form of self-bias so that weaker oscillations cannot appear in the output circuit of the tube.

In certain types of prior art oscillator arrangements, for example, super-regenerative detectors, a single vacuum tube has simultaneously generated oscillations of high frequency and oscillations of relatively low frequency. In such arrangements, however, there is intentionally produced intermodulation between the high-frequency and low-frequency components since the low-frequency components drive the tube to a nonlinear portion of its operating characteristic and the tube periodically blocks at the low frequency. The high-frequency oscillations build up within the tube only during that portion of the low-frequency cycle when the tube is in its unblocked condition.

Another type of oscillator of the prior art is that in which high-frequency oscillations and audible-frequency oscillations are simultaneously generated within a single tube. The tube, however, is specifically so energized that it operates over a nonlinear portion of its characteristic in order that the audible-frequency oscillations shall modulate the high-frequency oscillations, thereby to produce a modulated-carrier signal. In oscillators of this character, freedom from intermodulation between the generated oscillations of different frequency cannot be attained and the oscillator is incapable of generating both frequencies independently and without interaction one on the other.

It has been proposed in the British Patent No. 55

510,379 that a feed-back circuit, including purely resistive circuit elements at the frequency of oscillations to be generated and arranged in the form of a resistive bridge, be coupled between the output and input circuits of the oscillator. One of the resistive elements of the feed-back circuit has a resistance which varies with the magnitude of the feed-back current therethrough, whereby the magnitude of the feed-back energy is limited to a predetermined value and the amplitude of the generated oscillations cannot, therefore, exceed a prescribed upper limit. Feed-back circuits of this nature are termed "stable feed-back circuits." Such oscillators have heretofore been capable of generating oscillations only of a single predetermined frequency.

It is an object of the present invention, therefore, to provide a new and improved multiple-frequency oscillator capable of generating in a single vacuum tube oscillations of different predetermined frequencies with entire freedom from intermodulation between the several generated frequencies.

It is a further object of the invention to provide an oscillator for generating oscillations of predetermined different frequencies and one in which the amplitude of the oscillations of any one frequency is, within limits, independent of the amplitude of oscillations of other frequencies.

In accordance with the invention, a multiple-frequency oscillator comprises a vacuum-tube repeater having input and output circuits broadly responsive to a band of frequencies and having an operating characteristic including linear and nonlinear portions. Means are provided for biasing the repeater normally to operate on the linear portion of its characteristic and a plurality of effectively isolated coupling circuits are provided, each individually sharply responsive to a predetermined different frequency in the above-mentioned band of frequencies, for feeding back oscillations of these predetermined frequencies from the output circuit to the input circuit of the tube. The oscillator also comprises means for limiting the sum of the amplitudes of the feed-back oscillations supplied to the input circuit to a value below that which causes the repeater to operate on the nonlinear portion of its characteristic and a load circuit individually associated with each of the coupling circuits.

The use of stable feed-back circuits as defined above permits the presence between the input and output circuits of a plurality of feed-back circuits, each tuned to a different natural fre-

quency, so that a single tube will generate oscillations of a plurality of different frequencies. Thus, a single tube may generate in this way all the carrier-frequency oscillations required in a system of multichannel telephony. This advantage arises from the limitation in amplitude. If the amplitudes of all the oscillations are limited so that their sum does not exceed the limit above which the valve ceases to operate on the linear part of its characteristic, there will be no intermodulation of the oscillations of different frequencies in the tube. Intermodulation in the feed-back circuits can be prevented by suitable arrangements for preventing the oscillation characteristic of each feed-back circuit from reacting on the others.

The single figure of the drawing is a circuit diagram representing schematically a multiple-frequency oscillator embodying the invention.

Referring now to the single figure of the drawing, there is represented schematically a multiple-frequency oscillator embodying the invention in a preferred form. The oscillator includes a pentode vacuum-tube repeater 1 having input and output circuits broadly tuned or responsive to a band of frequencies and having an operating characteristic including linear and nonlinear portions. There is included in the output circuit the primary winding 4 of a transformer having two secondary windings 2, 3. There are two similar feed-back circuits or coupling circuits each individually sharply tuned or responsive to a predetermined different frequency in the band of frequencies for individually feeding back oscillations of the predetermined frequencies from the output circuit to the input circuit, each feed-back circuit connecting a secondary winding 2, 3 to a respective primary 5, 6 of an input transformer, the secondary 7 of which is coupled to the input electrodes of the pentode vacuum tube 1. The feed-back circuits from windings 2 and 3 include bridge networks of resistors 8, 9, 10, 11 and 12, 13, 14, 15, respectively. The resistors 11 and 15 are of the type in which the value of resistance varies relatively rapidly with the current through it, though not sufficiently rapidly to follow current fluctuations at the frequency of the generated oscillations, as, for example, a variation occurring within a period of the order of several cycles of current. The tuned element in the feed-back circuits from windings 2 and 3 consists of pairs of piezo-electric crystals 16, 17 and 18, 19, respectively, each member of a pair being tuned to the same frequency, but the different pairs being tuned to different frequencies and being serially arranged in their respective feed-back circuit. The crystals are not in the arms of the bridges but are individually connected in series with the two diagonals of their associated bridge network. By placing the crystals in this position, oscillations from one reaction circuit are prevented from reacting upon the other. The variable condensers 20, 21, 22 are used in known manner to obtain the correct phase relations between the main and feed-back circuits. The transformer secondary winding 7 is broadly tuned by a variable condenser 23 to the mid-frequency of a range of frequencies which includes the several different frequencies to which the feed-back circuits are individually tuned. Similarly, the transformer primary winding 4 is broadly tuned by the condenser 20 to the mid-frequency of the same range of frequencies. Condensers 26 and 29 couple individual ones of a plurality of load

circuits 27, 28 and 30, 31 to pairs of points on respective ones of the networks of resistors 8, 9, 10, 11 and 12, 13, 14, 15.

In considering the operation of the invention, it may be stated at the outset that the vacuum-tube repeater 1 has an operating characteristic including linear and nonlinear portions and is self-biased by its cathode-biasing circuit or equivalent normally to operate on the linear portion of its characteristic. When the vacuum tube is first energized, the resistors 11 and 15 are cold and the value of resistance of each is considerably smaller than that required to balance the bridge of which each forms a component. The attenuation of each bridge is relatively small and appreciable energy is fed back through the feed-back circuits from the output circuit to the input circuit of the vacuum-tube repeater 1. As the feed-back energy flows through the arms of each bridge, the resistors 11 and 15 are warmed by the current flowing through each and their resistance changes in a direction tending to establish a balance of the individual bridges and approaches a value for which the loss through each bridge approaches a predetermined value. As the individual resistive bridges approach balance, the magnitude of the feed-back energy decreases and is ultimately limited by suitable choice of the values of the resistors 11 and 15, such that the sum of the amplitudes of the feed-back oscillations applied to the input circuit of the vacuum-tube repeater 1 does not exceed a value above that which causes the repeater to operate on a nonlinear portion of its characteristic. The operation of the vacuum tube on the linear portion of its characteristic prevents intermodulation within the tube between the several generated oscillations of different frequencies. The piezo-electric crystals 16, 17 and 18, 19 prevent interaction between the several feed-back circuits.

The previously mentioned pair of points across which the oscillating voltages are developed may be any pair of ends of arms of the bridge networks. In the event that the load circuits, when coupled individually across such pairs of points, tend to unduly unbalance the bridge networks or should the impedance of the networks be insufficiently large efficiently to couple the output circuits to the oscillator, the output circuits may be inductively or capacitively coupled directly to the anode or grid circuit of the oscillator in known manner.

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A multiple-frequency oscillator comprising, a vacuum-tube repeater having input and output circuits broadly responsive to a band of frequencies, said repeater having an operating characteristic including linear and nonlinear portions, means for biasing said repeater normally to operate on said linear portion of its characteristic, a plurality of effectively isolated coupling circuits each individually sharply responsive to a predetermined different frequency in said band of frequencies for feeding back oscillations of said predetermined frequencies from said out-

put circuit to said input circuit, means for limiting the sum of the amplitudes of said feed-back oscillations applied to said input circuit to a value below that which causes said repeater to operate on said nonlinear portion of its characteristic, and a load circuit individually associated with each of said coupling circuits.

2. A multiple-frequency oscillator comprising, a vacuum-tube repeater having input and output circuits broadly responsive to a band of frequencies, said repeater having an operating characteristic including linear and nonlinear portions, means for biasing said repeater normally to operate on said linear portion of its characteristic, a plurality of effectively isolated coupling circuits each individually sharply responsive to a predetermined different frequency in said band of frequencies for feeding back oscillations of said predetermined frequencies from said output circuit to said input circuit, means in each of said coupling circuits for limiting the sum of the amplitudes of said feed-back oscillations applied to said input circuit to a value below that which causes said repeater to operate on said nonlinear portion of its characteristic, and a load circuit individually associated with each of said coupling circuits.

3. A multiple-frequency oscillator comprising, a vacuum-tube repeater having input and output circuits broadly responsive to a band of frequencies, said repeater having an operating characteristic including linear and nonlinear portions, means for biasing said repeater normally to operate on said linear portion of its characteristic, a plurality of effectively isolated coupling circuits each individually sharply tuned to a predetermined different frequency in said band of frequencies for feeding back oscillations of said predetermined frequencies from said output circuit to said input circuit, means for limiting the sum of the amplitudes of said feed-back oscillations applied to said input circuit to a value below that which causes said repeater to operate on said nonlinear portion of its characteristic, and a load circuit individually associated with each of said coupling circuits.

4. A multiple-frequency oscillator comprising, a vacuum-tube repeater having tuned input and tuned output circuits broadly responsive to a band of frequencies, said repeater having an operating characteristics including linear and nonlinear portions, means for biasing said repeater normally to operate on said linear portion of its characteristic, a plurality of effectively isolated coupling circuits each individually sharply responsive to a predetermined different frequency in said band of frequencies for feeding back oscillations of said predetermined frequencies from said output circuit to said input circuit, means for limiting the sum of the amplitudes of said feed-back oscillations applied to said input circuit to a value below that which causes said repeater to operate on said nonlinear portion of its characteristic, and a load circuit individually associated with each of said coupling circuits.

5. A multiple-frequency oscillator comprising, a vacuum-tube repeater having input and output circuits broadly responsive to a band of frequencies, said repeater having an operating characteristic including linear and nonlinear portions, means for biasing said repeater normally to operate on said linear portions of its characteristic, a plurality of effectively isolated coupling circuits each individually sharply responsive to a predetermined different frequency in said band

of frequencies for individually feeding back oscillations of said predetermined frequencies from said output circuit to said input circuit, means for limiting the sum of the amplitudes of said feed-back oscillations applied to said input circuit to a value below that which causes said repeater to operate on said nonlinear portion of its characteristic, and a load circuit individually associated with each of said coupling circuits.

6. A multiple-frequency oscillator comprising, a vacuum-tube repeater having input and output circuits broadly responsive to a band of frequencies, said repeater having an operating characteristic including linear and nonlinear portions, means for biasing said repeater normally to operate on said linear portion of its characteristic, a plurality of effectively isolated coupling circuits each including serially-arranged therein a piezo-electric crystal individually sharply responsive to a predetermined different frequency in said band of frequencies for feeding back oscillations of said predetermined frequencies from said output circuit to said input circuit, means for limiting the sum of the amplitudes of said feed-back oscillations applied to said input circuit to a value below that which causes said repeater to operate on said nonlinear portion of its characteristic, and a load circuit individually associated with each of said coupling circuits.

7. A multiple-frequency oscillator comprising, a vacuum-tube repeater having input and output circuits broadly responsive to a band of frequencies, said repeater having an operating characteristic including linear and nonlinear portions, means for biasing said repeater normally to operate on said linear portion of its characteristic, a plurality of coupling circuits each individually sharply responsive to a predetermined different frequency in said band of frequencies for feeding back oscillations of said predetermined frequencies from said output circuit to said input circuit, each of said coupling circuits having a first portion coupled to said output circuit and a second portion coupled to said input circuit, and means including a plurality of resistive bridge networks individual to said coupling circuits for interconnecting said first and second portions of said coupling circuits, each of said bridge networks having a resistive arm the resistance of which varies with current through said arm and proportioned to limit the sum of the amplitudes of said feed-back oscillations applied to said input circuit to a value below that which causes said repeater to operate on said nonlinear portion of its characteristic.

8. A multiple-frequency oscillator comprising, a vacuum-tube repeater having input and output circuits broadly responsive to a band of frequencies, said repeater having an operating characteristic including linear and nonlinear portions, means for biasing said repeater normally to operate on said linear portion of its characteristic, a plurality of coupling circuits each individually sharply responsive to a predetermined different frequency in said band of frequencies for feeding back oscillations of said predetermined frequencies from said output circuit to said input circuit, each of said coupling circuits having a first portion coupled to said output circuit and a second portion coupled to said input circuit, and means including a plurality of normally unbalanced resistive bridge networks individual to said coupling circuits for

interconnecting said first and second portions of said coupling circuits, each of said bridge networks having a resistive arm the resistance of which varies with the current through the arm in a direction tending so to balance the bridge network as to limit the sum of the amplitudes of said feed-back oscillations applied to said input circuit to a value below that which causes said repeater to operate on said nonlinear portion of its characteristic.

9. A multiple-frequency oscillator comprising, a vacuum-tube repeater having input and output circuits broadly responsive to a band of frequencies, said repeater having an operating characteristic including linear and nonlinear portions, means for biasing said repeater normally to operate on said linear portion of its characteristic, a plurality of coupling circuits each individually sharply responsive to a predetermined different frequency in said band of frequencies for feeding back oscillations of said predeter-

mined frequencies from said output circuit to said input circuit, each of said coupling circuits having a first portion coupled to said output circuit and a second portion coupled to said input circuit, a piezo-electric crystal serially-connected in each portion of each of said coupling circuits, and means including a plurality of normally unbalanced resistive bridge networks individual to said coupling circuits for interconnecting said first and second portions of said coupling circuits, each of said bridge networks having a resistive arm the value of which varies with the current through the arm in a direction tending so to balance the bridge network as to limit the sum of the amplitudes of said feed-back oscillations applied to said input circuit to a value below that which causes said repeater to operate on said nonlinear portion of its characteristic.

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