Aug. 14, 1945. W. P. BOLLINGER 2,382,198

OSCILLATOR STABILIZING CIRCUIT

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Fig. 1.

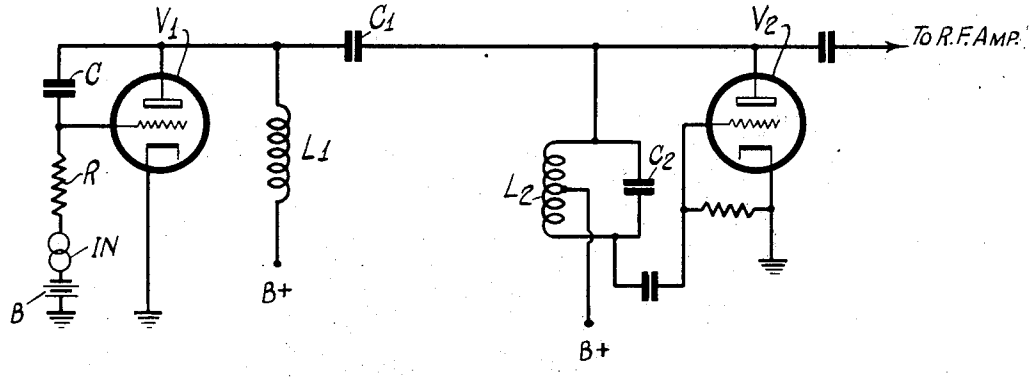


Fig. 2.

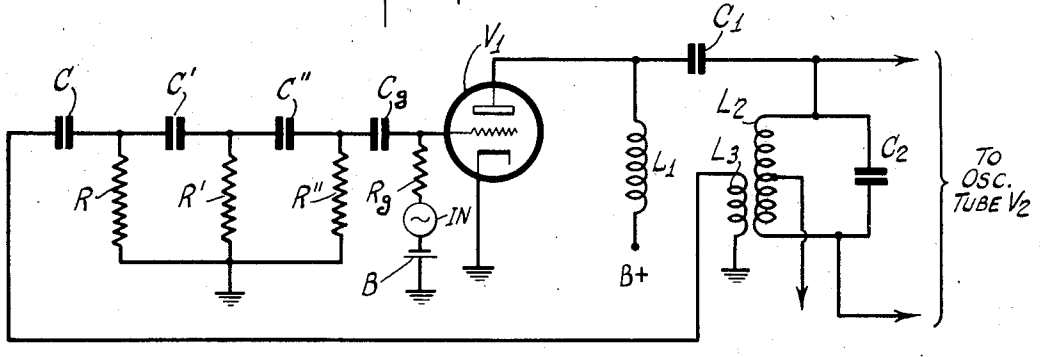
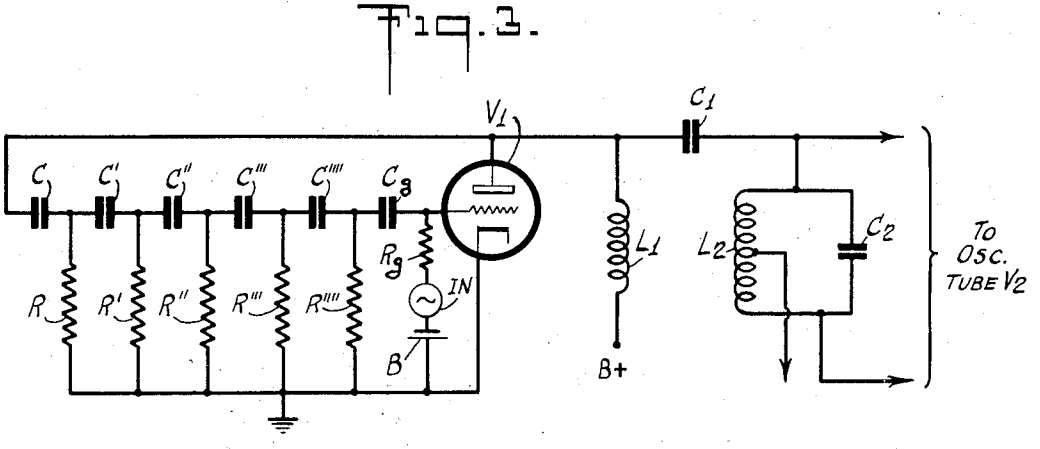


Fig. 3.



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Fig. 4.

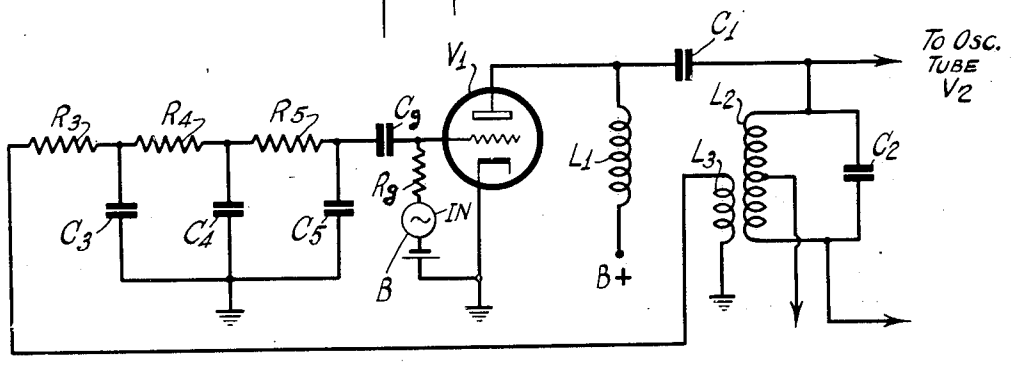


Fig. 5.

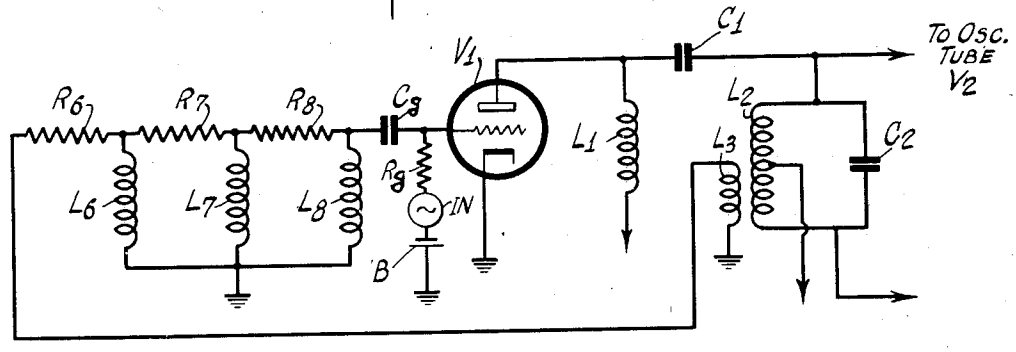
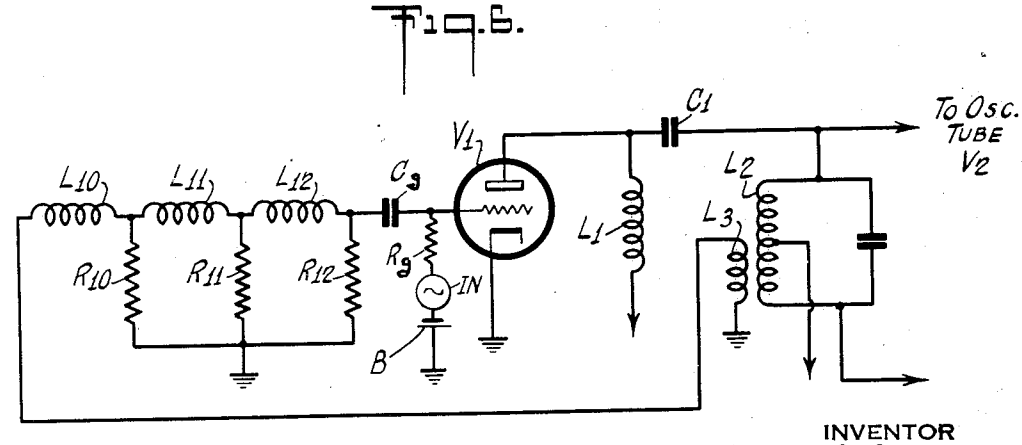


Fig. 6.



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OSCILLATOR STABILIZING CIRCUIT

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Application May 16, 1942, Serial No. 443,193

12 Claims. (Cl. 179—171.5)

This invention relates to improvements in a frequency modulation system, and more particularly to a method of and means for stabilizing the mean frequency of the oscillator in a frequency modulated transmitter or any transmitter employing a self-excited oscillator controlled by a reactance tube.

Briefly stated, the invention comprises a reactance tube modulator circuit which is so constructed and arranged that the susceptance of the reactance tube varies with oscillator frequency in such direction and magnitude as to restore the oscillator frequency to its assigned mean value, while permitting a controllable change in the frequency of the oscillator by a change in the transconductance of the reactance tube.

In the conventional reactance tube circuit known in the art for frequency modulating a self-excited oscillator, where the series condenser and shunt arranged resistor of the phase shifting network are both small, the reactance tube acts as a constant capacity whose reactance varies inversely as the oscillator frequency. A common circuit of this type is shown in Fig. 1 which illustrates diagrammatically a conventional reactance tube circuit for frequency modulating a self-excited oscillator. In Fig. 1, the radio frequency oscillator is represented by vacuum tube V_2 with its parallel tuned circuit L_2, C_2 connected in a Hartley arrangement. Of course, any other self-excited oscillator circuit can be used. The reactance tube is represented by V_1, which has its anode coupled to the oscillator through the coupling condenser C_1. The elements of the reactance tube comprise a phase shifting network having a resistance R and a capacity C, both of which have small values, and a radio frequency choke coil or so-called decoupling inductance L_1. This phase shifting network (in order to give 90° phase shift to the radio frequency voltage at the grid of tube V_1) must of necessity have a small value of R and a small value of C. With this condition then, the RC network of the reactance tube has an amplitude characteristic which causes the amplitude of the radio frequency grid voltage to vary directly as the frequency of the applied radio frequency anode voltage. As a result of this, the radio frequency anode current which is the reactive current in the reactance tube circuit, will vary directly as the frequency of the radio frequency voltage applied to the anode. The reactance tube circuit then acts as a constant capacity whose reactance varies inversely as the frequency. Because of the small values of C and R, the reactance of C is large compared with the resistance of R. The source of modulating potentials, usually speech waves, is diagrammatically represented by the label IN. A battery B serves to supply suitable bias to the grid of the reactance tube.

According to one embodiment of the present invention, the reactance tube circuit is so constructed and arranged that its capacity is made to vary as the square of the frequency or the reactance vary as the one-third power of the frequency. For this condition, the radio frequency grid voltage applied to the reactance tube varies as the cube of the frequency instead of directly with it as heretofore. Thus, by making the capacity of the reactance tube vary with the applied radio frequency instead of being constant, I am able to make this variation in such direction and magnitude as to substantially prevent the self-excited oscillator from departing from a given frequency. To achieve this result, I cause a change in frequency of the oscillator to result in a change of capacity of the reactance tube, thus restoring the oscillator to its original operating frequency. This stabilization of the oscillator frequency prevents such factors as changes in atmosphere, humidity, or voltage variations from causing the oscillator to depart from its assigned mean frequency. It should be understood, however, that by means of the invention I am able to controllably vary the frequency of the oscillator by producing a change in the transconductance (i. e., Gm) of the reactance tube, and this is done by applying modulating voltages to the grid or any other suitable control element of the reactance tube.

A more detailed description of the invention follows in conjunction with a drawing, wherein Fig. 1 illustrates a conventional circuit of a reactance tube and self-excited oscillator whereby the frequency of the oscillator can be modulated, and Figs. 2, 3, 4, 5 and 6 show different embodiments of the present invention. In the drawings, the same parts are represented by the same reference numerals. Figs. 2 to 6, inclusive, merely illustrate those parts which are necessary for an understanding of the principles of the present invention, it being understood that the circuits of these figures can be coupled to the radio frequency oscillator in the same manner shown in Fig. 1.

Referring to Fig. 2, there is shown a reactance tube V_1 having three C, R circuits for enabling the capacity of the reactance tube to vary as the square of the frequency, or the reactance vary

as the one-third power of the frequency. This is equivalent to making the grid radio frequency voltage vary as the cube (third power of the oscillator frequency). The three C, R circuits are represented by C, R; C', R'; C'', R''. The three capacities C, C', C'' are small and of the same value, and similarly the three resistors R, R', R'' are also small and of the same value. Since each of the two additional RC circuits (over and above the single one shown in Fig. 1) produces a 90° phase shift, it will be obvious that there is an additional 180° phase shift applied to the reactance tube over and above the phase shift obtained from a single R, C circuit. In other words, the network produces a phase shift of 270°. In order to correct for this additional 180° phase shift, so as to produce the desired quadrature or 90° phase relation between the plate voltage and the grid voltage, the coupling coil L_3 (which abstracts high frequency energy from the radio frequency oscillator tank) is suitably poled. In effect, the three capacity and resistance networks of the reactance tube of Fig. 2 constitute a high pass filter circuit, but the system is so designed that the reactance tube operates on the linear slope portion of the high pass filter characteristic of frequency versus grid voltage. The circuit of Fig. 2 includes the usual grid leak condenser combination herein represented as C_g, R_g, but these have such values as not to alter the desired phase shifting characteristic of the network. The modulating source of speech waves is diagrammatically represented by IN, while a battery B is a bias battery.

In the operation of Fig. 2, a decrease in the oscillator frequency will produce a great loss in the radio frequency voltage on the grid of the reactance tube, and the reactance tube will act like a smaller capacity, thereby tending to increase the oscillator frequency. Conversely, a rise in the oscillator frequency will produce a great increase in the radio frequency voltage on the grid of the reactance tube and this reactance tube will act as a larger capacity thereby tending to lower the oscillating frequency.

Fig. 3 illustrates another modification of the invention and is an alternative arrangement to the system of Fig. 2. Instead of the inductive coupling between the oscillator and the grid of the reactance tube, as shown in Fig. 2, there is here provided a direct coupling (except for the phase shifting networks) between the anode and grid of the reactance tube. The circuit of Fig. 3 includes, it should be noted, two additional R, C circuits represented by R''', C''' and R'''', C'''' which secure the additional 180° phase shift for compensating for the 180° phase shift provided by the first two additional R, C networks. The network in this figure produces a phase shift of five times 90° or 450°. In this way I am able to get the proper 90° phase or quadrature relation between the plate voltage and the grid voltage. The circuit of Fig. 3, of course, makes the capacity of the reactance tube vary as a still greater power of the frequency than the cube, thus giving additional stabilization.

In Fig. 4, the objects of the invention are achieved by working on the effective inductance of the reactance tube instead of on the effective capacity thereof. This is done by using capacities of the network in shunt and the resistors in series, as shown. The three networks of Fig. 4 are R_3, C_3; R_4, C_4; and R_5, C_5. The resistors R_3, R_4, R_5 are large and of the same value, and the condensers C_3, C_4, C_5 are also large and of the same value. It should be understood, of course, that the values of the grid leak and condenser combination are such as not to upset the phase shifting characteristic of the network. The voltage applied to the grid is derived from the oscillator tank circuit by virtue of the small coupling coil L_3, in substantially the same manner as heretofore described in connection with Fig. 2. In Fig. 4, in effect, the resistance and capacity constitute a low pass filter circuit, but here again we operate on the linear slope portion of the phase shifting network characteristic.

In Fig. 5, which shows another embodiment of the invention, we obtain an effective capacity for the reactance tube by using inductors L_6, L_7 and L_8 in shunt, and resistors R_6, R_7 and R_8 in series for the phase shifting network. The resistances R_6, R_7 and R_8 are of the same value and relatively large and the inductances L_6, L_7 and L_8 are equal but of small value. Here again, it is desired that the reactance tube work on the linear portion of the phase shifting network characteristic.

Fig. 6 is still another embodiment of the invention employing inductances L_{10}, L_{11}, and L_{12} in series, and resistors R_{10}, R_{11} and R_{12} in shunt. The coils L_{10}, L_{11} and L_{12} are relatively large and equal in value while the resistors R_{10}, R_{11} and R_{12} are relatively small in value and equal. The network of Fig. 6, in effect, is a low pass filter upon whose linear slope the circuit works.

It is understood that the resistances in the phase shifting network do not have to be equal for proper operation of the circuit but for convenience of discussion and construction are said to be equal. The same applies to the capacities or inductances.

The same theory of operation hereinabove described in connection with Figs. 2 and 3 applies generally to the system of Figs. 4, 5 and 6, except that in Figs. 2, 3 and 5 the reactance tube functions as an effective capacity, while in Figs. 4 and 6 the reactance tube functions as an effective inductance.

What is claimed is:

1. A stabilized oscillation generator comprising a vacuum tube oscillator having a frequency determining circuit, a reactance tube having a control electrode and a cathode and coupled to said oscillator, a phase shifting network coupled between said control electrode and the cathode of said reactance tube, and a connection coupling said network to said frequency determining circuit, said network having a plurality of lumped reactance elements of the same kind and a plurality of resistor elements, the number of said elements and their values being so related as to produce a phase shift substantially equal to an odd multiple of 90° but not substantially less than 270°, said elements being so arranged that the susceptance of said reactance tube varies with the frequency of the oscillations produced by said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value.

2. A stabilized oscillation generator comprising a vacuum tube oscillator having a frequency determining circuit, a reactance tube coupled to said oscillator, and a phase shifting network coupled between a control element and the cathode of said reactance tube, and a connection coupling said network to said frequency determining circuit, said network having lumped reactance and resistor elements, the number of said elements and their values being so related as to produce

a phase shift substantially equal to an odd multiple of 90° but not substantially less than 270°, said elements being so constructed and arranged that the effective capacity of said reactance tube varies with the frequency of the oscillation produced by said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value.

3. A stabilized oscillation generator comprising a vacuum tube oscillator having a frequency determining circuit, a reactance tube coupled to said oscillator, and a phase shifting network coupled between a control element and the cathode of said reactance tube, and a connection coupling said network to said frequency determining circuit, said network having lumped reactance and resistor elements of such number and of such related values that there is produced a phase shift substantially equal to an odd multiple of 90° but not substantially less than 270°, said elements being so constructed and arranged that the effective inductance of said reactance tube varies with the frequency of the oscillations produced by said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value.

4. A stabilized oscillation generator comprising a vacuum tube oscillator having a frequency determining circuit, a reactance tube coupled to said oscillator, and a phase shifting network of series capacitance elements and shunt resistance elements coupled to a control element of said reactance tube and also to said frequency determining circuit, the constants of said network being so chosen that it operates on the substantially linear slope portion of its filter characteristic, the number of said elements of said network and their values being so related as to produce a phase shift substantially equal to an odd multiple of 90° but not substantially less than 270°, whereby the effective capacity of said reactance tube varies with the frequency of the oscillations produced by said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value.

5. A stabilized oscillation generator comprising a vacuum tube oscillator having a frequency determining circuit, a reactance tube coupled to said oscillator, and a phase shifting network of series resistance elements and shunt capacitance elements coupled to a control electrode of said reactance tube and also to said frequency determining circuit, the constants of said network being so chosen that it operates on the substantially linear slope portion of its filter characteristic, the number of said series and shunt elements and their values being so related as to produce a phase shift equal to an odd multiple of 90° but not substantially less than 270°, said capacitor elements and resistor elements being so constructed and arranged that the effective inductance of said reactance tube varies with the frequency of the oscillations produced by said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value.

6. A stabilized oscillation generator comprising a vacuum tube oscillator having a frequency determining circuit, said frequency determining circuit including a coil, a reactance tube coupled to said oscillator, and a phase shifting network having a filter characteristic coupled between a control element and the cathode of said reactance tube, and a coil coupling said network to the coil of said frequency determining circuit, said network having a plurality of series impedance elements of the same value and shunt impedance elements of the same value, the constants of said elements being such that the network operates on the linear slope portion of the filter characteristic, the number of said elements and their values being so related as to produce a phase shift substantially equal to an odd multiple of 90° and not substantially less than 270°, the elements being so constructed and arranged that the susceptance of said reactance tube varies with the frequency of the oscillations produced by said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value.

7. In a frequency modulation system, a radio frequency oscillator, a reactance tube having a phase shifting network coupled to said oscillator, a low frequency modulating source coupled to a control element of said reactance tube for producing controllable changes in the frequency of said oscillator in accordance with changes in the transconductance of said reactance tube, said network having a plurality of series elements and a plurality of shunt elements of such constants that the network operates on the substantially linear slope portion of its filter characteristic, the elements of one of said plurality being reactances of the same kind, while the elements of the other plurality are resistors, the number of said series and shunt elements and their values being so related as to produce a phase shift substantially equal to an odd multiple of 90° but not substantially less than 270°, said series and shunt elements being so constructed and arranged that the susceptance of said reactance tube varies with the frequency of said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value, while permitting controllable changes in the oscillator frequency by changes in the transconductance of the reactance tube.

8. A stabilized generator comprising a vacuum tube oscillator having a frequency determining circuit, a reactance tube coupled to said oscillator, and a phase shifting network having a high pass filter characteristic coupled to a control element of said reactance tube and also coupled to said frequency determining circuit, said network having a plurality of capacitor elements of small value in series and a plurality of resistor elements of small value in shunt, the constants of said network elements being such that the network operates on the linear slope portion of the filter characteristic, the number of said series and shunt elements and their values being so related as to produce a phase shift equal to an odd multiple of 90° but not substantially less than 270°, said capacitor elements and resistor elements being so constructed and arranged that the susceptance of said reactance tube varies with the frequency of the oscillations produced by said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value.

9. A stabilized generator comprising a vacuum tube oscillator having a frequency determining circuit, a reactance tube coupled to said oscillator, and a phase shifting network having a low pass filter characteristic coupled to a control element of said reactance tube and also coupled to said frequency determining circuit, said network having a plurality of resistor elements of large value in series and a plurality of capacitor elements of large value in shunt, the constants of said network elements being such that the network operates on the linear slope portion of the filter characteristic, the number of said series and

shunt elements and their values being so related as to produce a phase shift equal to an odd multiple of 90° but not substantially less than 270°, said capacitor elements and resistor elements being so constructed and arranged that the susceptance of said reactance tube varies with the frequency of the oscillations produced by said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value.

10. In a frequency modulation system, a radio frequency oscillator having a frequency determining circuit, a reactance tube, a phase shifting network coupled between a control electrode and the cathode of said reactance tube, a circuit inductively coupling said network and said frequency determining circuit, a source of modulating currents coupled to a control element of said reactance tube for producing controllable changes in the frequency of said oscillator in accordance with changes in the transconductance of said reactance tube, said network having a plurality of series elements and a plurality of shunt elements of such constants that the network operates on the substantially linear slope portion of its filter characteristic, the elements of one of said plurality being reactances of the same kind, while the elements of the other plurality are resistors, the number of said elements and their values being so related as to produce a phase shift substantially equal to an odd multiple of 90° but not substantially less than 270°, said elements being so constructed and arranged that the susceptance of said reactance tube varies with the frequency of said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value, while permitting controllable changes in the oscillator frequency by changes in the transconductance of the reactance tube.

11. In a frequency modulation system, a radio frequency oscillator having a frequency determining circuit, a reactance tube, a phase shifting network coupled between a control electrode and the cathode of said reactance tube, a capacitive connection between said network and said frequency determining circuit, a source of modulating currents coupled to a control element of said reactance tube for producing controllable changes in the frequency of said oscillator in accordance with changes in the transconductance of said reactance tube, said network having a plurality of series elements and a plurality of shunt elements of such constants that the network operates on the substantially linear slope portion of its filter characteristic, the elements of one of said plurality being reactances of the same kind, while the elements of the other plurality are resistors, the number of said series and shunt elements and their values being so related as to produce a phase shift substantially equal to an odd multiple of 90° but not substantially less than 270°, said series and shunt elements being so constructed and arranged that the susceptance of said reactance tube varies with the frequency of said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value, while permitting controllable changes in the oscillator frequency by changes in the transconductance of the reactance tube.

12. In a frequency modulation system, a radio frequency oscillator, a reactance tube having a phase shifting network coupled to said oscillator, a low frequency modulating source coupled to a control element of said reactance tube for producing controllable changes in the frequency of said oscillator in accordance with changes in the transconductance of said reactance tube, said network having a plurality of series elements and a plurality of shunt elements of such constants that the network operates on the substantially linear slope portion of its filter characteristic, the number of said series and shunt elements and their values being so related as to produce a phase shift substantially equal to an odd multiple of 90° but not substantially less than 270°, said series and shunt elements being so constructed and arranged that the susceptance of said reactance tube varies with the frequency of said oscillator in such direction and magnitude as to oppose changes in the oscillator frequency from its assigned value, while permitting controllable changes in the oscillator frequency by changes in the transconductance of the reactance tube.

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