Aug. 28, 1945. M. G. CROSBY 2,383,848

REACTANCE CONTROL CIRCUIT

Filed Feb. 25, 1943

Fig. 1.

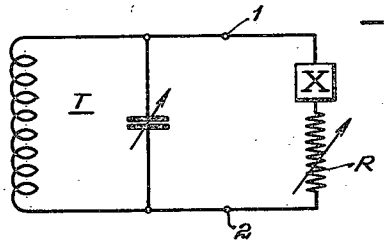


Fig. 2.

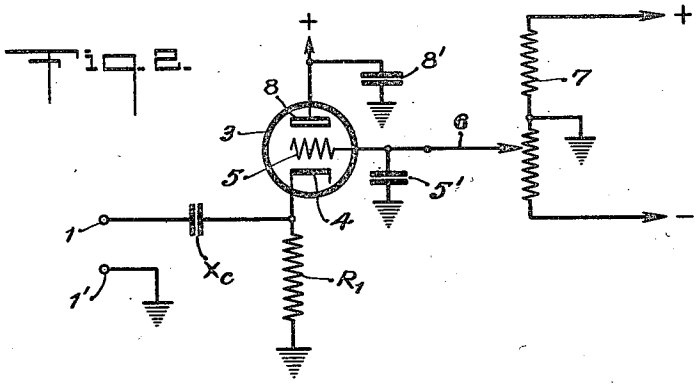
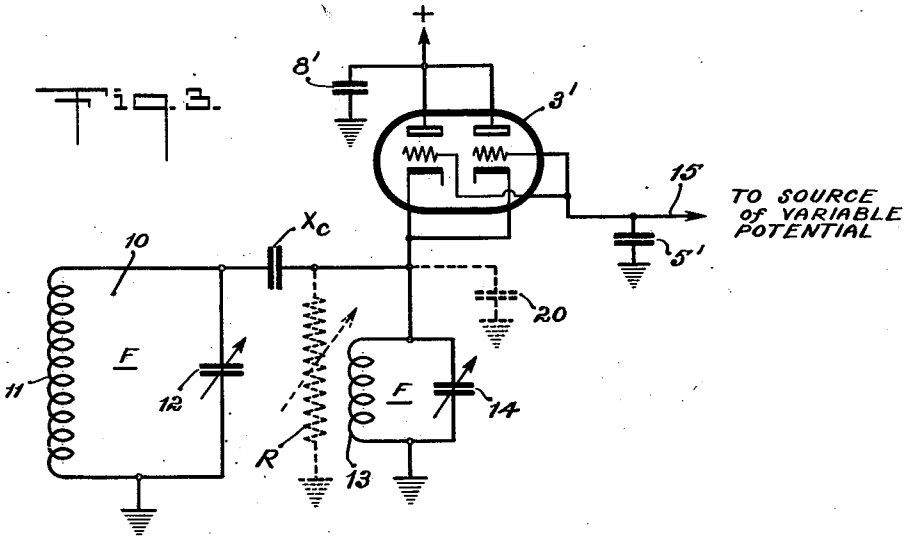


Fig. 3.



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REACTANCE CONTROL CIRCUIT

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7 Claims. (Cl. 250—40)

My present invention relates to reactance control circuits, and more especially to novel and improved circuits for adjusting the magnitude of a reactive impedance.

An important object of my present invention is to provide a novel method of adjusting the effective value of a reactance, which consists in arranging in series with the reactance a resistive impedance, and the effective minimum value of the latter being reduced to a relatively small fraction of the maximum value by an electronic device.

Another object of this invention is to provide a frequency control circuit for an oscillatory circuit; the control circuit comprising a series arrangement of a reactance and resistive impedance, the resistive impedance being adjustable over a wide range of magnitude by virtue of its location in the space current path of a tube whose plate and grid are at relatively fixed radio frequency potentials, and whose transconductance is varied to effect said adjustment.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description, taken in connection with the drawing, in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a generalized embodiment of the invention,

Fig. 2 shows one form of the invention,

Fig. 3 shows a preferred embodiment of the invention.

Referring now to the accompanying drawing, wherein like reference numerals in the various figures designate similar circuit elements, there is shown at Fig. 1 a generalized form of the circuit to which the invention is applicable. There is provided in series a reactance X and an adjustable resistor R. The resistive value of resistor R determines the effective reactance between terminals 1 and 2. These terminals may be those, for example, of a resonant high frequency circuit T. In that case adjustment of the resistive magnitude of R will determine the effective reactance shunted across circuit T. Hence, the adjustable resistor R is a frequency determining element.

In the past it has been proposed to use the plate resistance of an electron discharge tube to simulate the resistor R, with variations of the gain of the tube determining the magnitude of the plate resistance. The reactance X has been either a capacitance or an inductance. One of the main disadvantages of such prior circuits has been the fact that the minimum series impedance that could be secured in that way was the rated plate resistance of the tube. Hence, there was a definite lower limitation imposed on the range of controlled reactance that could be thrown across a circuit whose frequency characteristic was to be varied. My invention contemplates generally the substantial reduction of the lower limitation on the range of reactance adjustment. I have discovered a simple and effective method of considerably widening the range of effective resistance that can be inserted in series with the reactance X.

Assuming that X is capacitative, or X_c, there is shown in Fig. 2 a general arrangement for securing the increase in range of control over X_c. In series with the condenser X_c there is connected a resistive impedance R_1. The impedance R_1 is located in the space current path of the electron discharge tube 3, between the cathode 4 and ground. R_1 is unbypassed so as to develop thereacross alternating voltage which is applied in degenerative phase to the signal grid 5 of the tube 3. The grid 5 may have its bias varied in any desired manner. For example, the grid is shown connected to the slider 6 of a potentiometer resistor 7. The upper end of the potentiometer resistor is shown connected to the positive terminal of a direct current source, while the lower end is connected to the negative terminal. The plate 8 is connected to the positive terminal of a direct current source, and has no output work circuit connected directly thereto. Bypass condensers 8' and 5' from the plate and grid leads respectively establish the two electrodes at ground potential for radio frequencies.

Variation of slider 6 changes the gain of tube 3. This, in turn, causes the effective cathode to ground impedance of the tube to change. The degenerative feedback to grid 5 causes the effective minimum impedance in series with condenser X_c to be greatly lowered. The minimum impedance in series with X_c will be $1/g_m$; i. e., the reciprocal of the tube transconductance. The maximum value of impedance in series with X_c will be the magnitude of R_1 in the absence of space current through tube 3. Hence, when slider 6 is adjusted to apply negative cut-off bias to grid 5, the impedance in series with X_c is a maximum and is the value of R_1. When the slider 6

is adjusted to the most positive point on potentiometer resistor 7 consistent with safe operation of the tube, the series impedance is a minimum and equals substantially the reciprocal of the transconductance of tube 3.

To explain the operation of the circuit from a somewhat different viewpoint, the current through R_1 from input terminal 1 may be considered as e/R_1. The term e is the voltage applied between terminal 1 and ground terminal 1'. The current through the tube, flowing from X_c to the cathode, may be expressed as eg_m. The total current per volt of e is, therefore,

$$\frac{1}{R_1}+g_m$$

Assuming $R_1=¼$ megohm, and $g_m=10{,}000$ micromhos (max.). Then, the minimum effective resistance in series with X_c would be less than 100 ohms, while the maximum would be 250,000 ohms. Were the reactance X_c placed in series with the plate resistance of tube 3, as in the prior art, the minimum effective resistance in series with X_c would be many times higher. The advantage of this invention will, therefore, be clear, i. e., the substantial depression of the minimum effective resistance value for the purpose of widening the range of control over the effective value of X_c.

In Fig. 3 I have shown a preferred embodiment of the invention. The capacitative reactance X_c in this case is connected between the common cathode lead to the tube 3' and the high alternating potential side of the resonant circuit 10. The latter may be the tunable oscillation circuit of the local oscillator of a superheterodyne broadcast receiver. It may, also, be the tank circuit of the master oscillator of a frequency modulation transmitter. In either case the circuit 10 will comprise an inductance coil 11 shunted by a resonating condenser 12. The low end of circuit 10 is shown as established at ground potential. Let it be assumed that circuit 10 is tuned to a frequency F. Since those skilled in the art are fully acquainted with the manner of employing the invention for AFC (automatic frequency control) of the tunable circuit of the local oscillator of a superheterodyne receiver, it is not believed necessary to describe the circuit details of such an AFC arrangement. Furthermore, those skilled in the art are well acquainted with the manner of frequency modulating the tank circuit of an oscillator in a frequency modulation transmitter.

Regardless of the location of oscillatory circuit 10, the frequency thereof may be deviated, or swung, by shunting thereacross the series connection of condenser X_c and the resistive impedance R. The latter is shown as dotted, because it is the effective resistive impedance of a second tuned circuit. In other words, the tuned circuit comprising coil 13 and shunt condenser 14 functions to provide the series resistive impedance R. Circuit 13—14 is tuned to frequency F for a purpose to be described at a later point. The tube 3' is a twin triode of the 6F8G type, and consists of a pair of triode sections in parallel. Hence, the plates of the two triodes are connected to a common point of positive potential, while the cathodes of the sections are connected in common to the high potential side of circuit 13—14. The low potential side of the latter is established at ground potential.

The control grids of the triode sections of tube 3' are connected by lead 15 to any source of variable potential. The source of variable potential may be a source of audio frequency voltage in the case of a frequency modulation transmitter. In the case of automatic frequency control of a local oscillator tank circuit, the source of variable potential would be the conventional discriminator rectifier for producing the AFC bias. The resonant circuit 13—14 is employed in place of resistor R_1 of Fig. 2 in order to eliminate the effect of the cathode-to-ground capacity, which is designated by reference numeral 20 and shown by the dotted lines. It is believed that the functioning of this embodiment will be clear from a description of the operation given in connection with Fig. 2.

The advantage of the arrangement of the present invention will be appreciated when it is realized that tube 3' has a transconductance of about 6,000 micromhos at zero bias of the control grids thereof. Accordingly, the effective minimum resistance of the cathode circuit 13—14 will be the reciprocal of the transconductance, which will come to about 330 ohms. There may be situations where it will be more desirable to employ a different type of tube in place of a twin triode tube at 3'. For example, the 6AC7 type of tube has a transconductance of 9,000 micromhos at about minus 1.6 volts bias. The effective minimum cathode resistance in that case will be very small. In general, then, the higher the transconductance of the tube employed at 3', the lower will be the effective minimum series resistance in circuit with X_c.

It should be pointed out that in the case of frequency modulation of the oscillatory tank circuit 10 by a source of audio frequency potential connected to lead 15, the operating bias of the control grids should be so chosen, in the absence of modulation, as to make the reciprocal of transconductance equal to X_c. If this is done, the conductance component at the terminal 1 is substantially constant for small changes in grid voltage. The practical effect of this precaution is to minimize amplitude modulation effects when using the present invention for producing frequency modulated carrier wave energy. The circuit is readily employed for tone control in an audio signal transmission system by shunting terminals 1—1' of Fig. 2 across the transmission line. Variation of the gain of tube 3 will cause the higher audio frequencies to be variably bypassed.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular circuit organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In a system of the type comprising an alternating current network whose frequency characteristic is to be controlled, a reactive impedance of fixed value, a resistive impedance of a predetermined maximum value, said impedances being connected in series across the network; the improvement comprising means for varying the value of the resistive impedance over a wide range, said varying means including an electron discharge tube having at least a cathode, control grid and anode, said resistive impedance being located in the space current path of the tube between said cathode and a point of relatively fixed alternating potential, said reactive impedance being connected between solely the cathode end of said resistive impedance and the high alternating potential side of said network, means

for establishing said grid at a relatively fixed alternating potential, said resistive impedance being included in circuit with the grid and cathode, means connecting said anode to a source of positive direct current voltage, the anode circuit being free of any alternating current load, and means for adjusting said grid over a wide range of potential values thereby to vary the transductance of the tube.

2. In a system of the type comprising an alternating current network whose frequency characteristic is to be controlled, a reactive impedance of fixed value, a resistive impedance of a predetermined maximum value, said impedances being connected in series across the network; the improvement comprising means for varying the value of the resistive impedance over a wide range, said varying means including an electron discharge tube having at least a cathode, control grid and anode, said resistive impedance being located in the space current path of the tube between said cathode and ground, means connecting said grid to ground for alternating current, said reactive impedance being connected between solely the high potential side of the alternating current network and the cathode end of said resistive impedance, said resistive impedance being included in the grid-to-cathode circuit, means connecting said anode to a source of positive direct current voltage, means for adjusting said grid over a wide range of potential values thereby to vary the transconductance of the tube, and the minimum effective magnitude of said series resistance impedance being the reciprocal of said transconductance at maximum positive voltage of said potential range.

3. In a system of the type comprising an alternating current network whose frequency characteristic is to be controlled, a reactive impedance of fixed value, a resistive impedance of a predetermined maximum value, said impedances being connected in series across the network; the improvement comprising means for varying the value of the resistive impedance over a wide range, said varying means including an electron discharge tube having at least a cathode, control grid and anode, said resistive impedance being located in the space current path of the tube between said cathode and a point of relatively fixed alternating potential, means maintaining said anode at a positive direct current voltage, means for adjusting said grid over a wide range of potential values thereby to vary the transconductance of the tube, and said resistive impedance consisting of a resonant circuit tuned to the frequency of said alternating current network whereby the effect of capacity between the cathode and said fixed point is eliminated.

4. In a system of the type comprising an alternating current network whose frequency characteristic is to be controlled, a reactive impedance of fixed value, a resistive impedance of a predetermined maximum value, said impedances being connected in series across the network; the improvement comprising means for varying the value of the resistive impedance over a wide range, said varying means including an electron discharge tube having at least a cathode, control grid and anode, said resistive impedance being located in the space current path of the tube between said cathode and a point of relatively fixed alternating potential, means maintaining said anode at a positive direct current voltage, means for adjusting said grid over a wide range of potential values thereby to vary the transconductance of the tube, said resistive impedance consisting of a resonant circuit tuned to the frequency of said alternating current network whereby the effect of capacity between the cathode and said fixed point is eliminated, and the effective magnitude of said reactive impedance across the alternating network being inversely related to the value of said resistive impedance.

5. In combination with a high frequency oscillatory circuit whose frequency is to be varied, a frequency variation circuit connected across the oscillatory circuit, said variation circuit comprising in series a reactance and a resonant circuit, the resonant circuit being tuned to the mean frequency of said oscillatory circuit, said resonant circuit being located in the space current path of a tube whose plate is at a positive direct current voltage, said resonant circuit being connected between the tube cathode and ground, and modulating means connected to said control grid for varying the tube transconductance thereby to vary the effective resistive impedance of said resonant circuit over a wide range of values.

6. In combination with an oscillatory circuit whose frequency is to be varied, a frequency variation circuit connected across the oscillatory circuit, said variation circuit comprising a reactance in series with a resonant circuit tuned to the mean frequency of said oscillatory circuit, said resonant circuit being arranged in the space current path of a tube whose plate is at a positive direct current voltage, said resonant circuit being connected between the tube cathode and ground, and means connected to said control grid for varying the tube transconductance thereby to vary the effective resistive impedance of said resonant circuit over a wide range of values whose maximum exists when said space current is substantially zero and whose minimum is equal to the reciprocal of the tube transconductance at the most positive grid potential.

7. In combination with an oscillatory circuit whose frequency is to be deviated, a frequency deviation circuit connected across the oscillatory circuit, said deviation circuit comprising in series a capacity reactance and a resonant circuit tuned to the mean frequency of said oscillatory circuit said resonant circuit being arranged in the space current path of a tube whose plate is at a positive direct current voltage but at ground potential for the oscillatory frequency, said resonant circuit being connected between the tube cathode and ground, the control grid of the tube being at ground potential for the oscillatory frequency, and modulating means connected to said control grid for varying the tube transconductance thereby to vary the effective resistive impedance of said resonant circuit over a wide range of values.

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