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M. ARTZT

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FREQUENCY MODULATION

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Fig. 1.

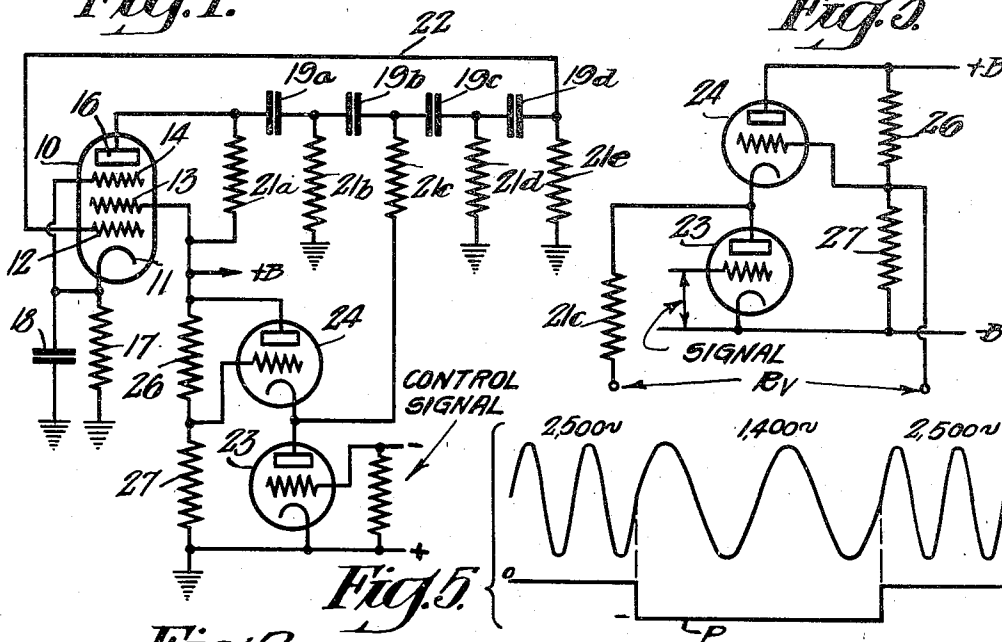


Fig. 3.

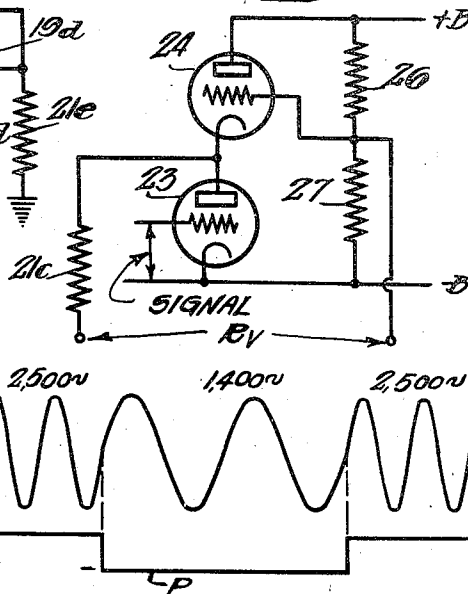


Fig. 2.

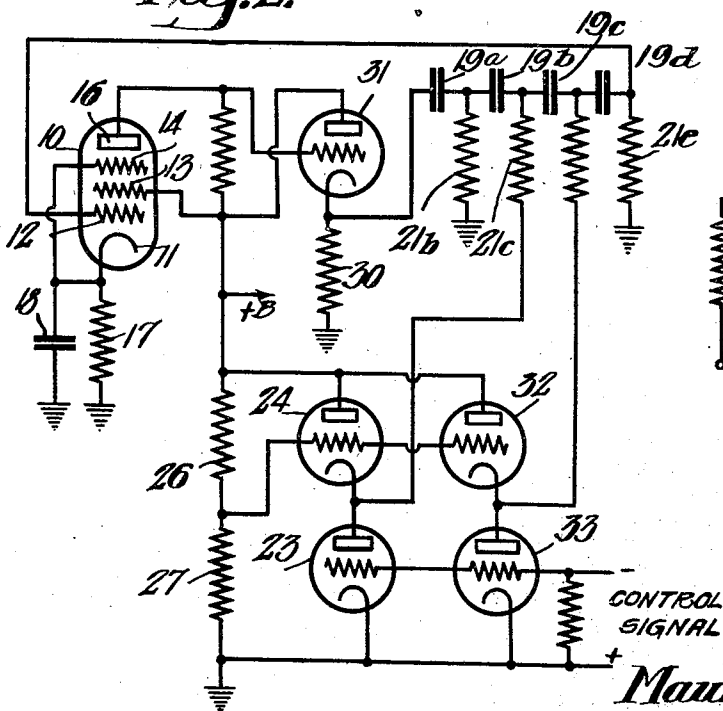
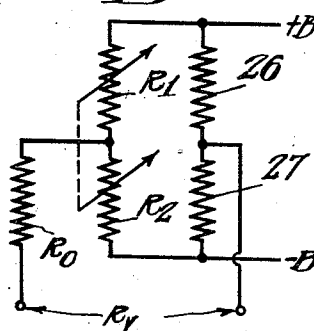


Fig. 4.



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FREQUENCY MODULATION

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6 Claims. (Cl. 179—171.5)

My invention relates to frequency modulation circuits and particularly to an improved variable resistance modulating means for modulating an oscillator of the resistor-capacitor type.

An object of the invention is to provide an improved means for supplying a frequency modulated signal.

A further object of the invention is to provide an improved means for producing a frequency shift of a carrier wave that is a high percentage of the carrier wave frequency.

A still further object of the invention is to provide an improved variable resistor network which will not introduce a variable voltage into the oscillator or other associated circuit.

In one embodiment of my invention, there is employed an oscillator in which the output of a vacuum tube is coupled to its input circuit through a resistor-capacitor delay circuit. The delay network introduces a phase shift to cause oscillation at a certain frequency, this frequency being the one at which the phase shift in the network is 180 degrees. By varying the resistance of one or more resistors in the delay network, the frequency of oscillation may be changed. Thus, a vacuum tube may be utilized as part of the resistance in the delay network and the oscillator may be frequency-modulated by applying a modulating signal to the grid of this tube.

However, if the plate-cathode impedance of a vacuum tube were simply included in the network to provide a variable resistor, the best results would not be obtained because a varying voltage would be introduced into the circuit during modulation due to the varying voltage drop across the said impedance.

In my improved circuit, the variable resistance for the delay network is provided by utilizing two vacuum tubes connected in series relation with each other and connected across a constant voltage source, the grid of one tube being connected to an intermediate point on this voltage source. The other vacuum tube functions as the desired variable resistor and, as will be explained, introduces no variable voltage.

The invention will be better understood from the following description taken in connection with the accompanying drawing in which

Figures 1 and 2 are circuit diagrams of two embodiments of the invention.

Figure 3 is a circuit diagram of the variable resistor network utilized in the circuits shown in Figures 1 and 2.

Figure 4 is a diagram showing the equivalent circuit for Figure 3, and

Figure 5 shows curves that illustrate the operation of the circuit as applied to facsimile, for example.

In the several figures like parts are indicated by the same reference characters.

In Fig. 1, the oscillator comprises a vacuum tube 10 which may be a pentode having a cathode 11, a control grid 12, a screen grid 13, a suppressor grid 14, and an anode or plate 16. The tube is self-biased by means of a cathode resistor 17 bypassed by a condenser 18.

The output of the tube 10 is fed into a resistor-capacitor delay network comprising series capacitors 19a, 19b, 19c and 19d and shunt resistors 21a, 21b, 21c, 21d and 21e. An operating voltage may be supplied from a B battery or other source (not shown) to the anode 16 through the shunt resistor 21a.

Delay voltage from the delay network is fed back through a conductor 22 to the control grid 12.

In the example illustrated, the shunt resistor 21c of the delay network is in series with a variable resistor in the form of a vacuum tube 23, its associated tube 24 and an associated voltage divider 26—27. The shunt resistance from the junction point of condensers 19b and 19c to ground consists of the resistance of resistor 21c and the plate-cathode impedance of the tube 23.

The tubes 23 and 24 may be triodes as shown, each having a cathode, a control grid and an anode or plate. The modulating or control signal is applied to the control grid of tube 23 to vary its plate-cathode impedance and thereby frequency-modulate the oscillator. The circuit connections for preventing the appearance of a varying voltage across the plate-cathode impedance of tube 23 during modulation are as follows:

The tubes 23 and 24 have their plate-cathode impedances connected in series, the plate of tube 23 being connected to the cathode of tube 24. The lower end of resistor 21c is connected to the junction point of the plate and cathode so connected.

The series combination of tubes 23 and 24 is connected across the voltage divider resistors 26 and 27, and the control grid of tube 24 is connected to an intermediate point, such as the midpoint, of the divider. Since the potential of the cathode of tube 24 will follow the potential of its associated control grid, this being "cathode follower" action, the cathode of tube 24 and the plate of tube 23 will remain at the constant potential of the above-mentioned point on the voltage divider 26—27. Thus, the plate-to-cathode

voltage of tube 23 will be constant during modulation as desired.

The operation of the variable resistor circuit may also be explained by referring to Fig. 3, where the variable resistor portion of Fig. 1 is shown with the parts slightly rearranged, and to the corresponding equivalent diagram in Fig. 4 where the plate-cathode impedances of the tubes 24 and 23 are represented by variable resistors R₁ and R₂, respectively, and where resistor 21c is indicated as R_o.

The impedances corresponding to resistors R₁ and R₂ increase or decrease together with changes in signal voltage. For example, if the grid of tube 23 is made more negative, the tube impedance R₂ increases, the resulting decrease in current through the serially connected tubes causes the cathode of tube 24 to become slightly more positive with respect to the grid of tube 24 whereby the plate-cathode impedance R₁ of tube 24 also increases so that the potential at the variable resistance terminals indicated at R_v remains practically unchanged. Preferably, the potential at R_v is made zero by balancing the bridge formed by R₁, R₂ and resistors 26 and 27. This may be accomplished, for example, by making resistors 26 and 27 equal and by employing tubes 23 and 24 that are alike.

The invention, which has many applications, has been found especially useful in facsimile transmission where the carrier wave at one frequency represents "white" and at a different frequency represents "black." Such a carrier wave and its modulating or control signal are illustrated in Fig. 5. It will be noted that the carrier wave frequency changes almost instantly and substantially without the introduction of transients when the negative control pulse P is applied. This is a very important advantage of the invention.

In Fig. 2 the circuit is similar to the one just described but it includes a cathode follower tube 31 for providing low impedance coupling into the delay network. Here the cathode resistor 30 corresponds to the low impedance resistor 21a of Fig. 1.

Also, additional vacuum tubes 32 and 33 are included in the variable resistance network for the purpose of varying a second shunt resistor in the delay network, thus producing a greater shift in the oscillator frequency upon the application of a control signal. The plates and grids of tubes 24 and 32, and the cathodes and grids of tubes 23 and 33 are connected in parallel relation. The plate-cathode impedance of tube 33 functions as the variable resistance portion of the second shunt resistor just as described for the other variable shunt resistor.

Some of the circuit constants for the circuit of Fig. 1 are given below, merely by way of example, for a design where the frequency is shifted from 2500 cycles per second to 1400 cycles per second upon the application of a negative control pulse of a certain amplitude:

Network condensers 19a, etc.	mmf.	470
Network resistors 21b, 21d, 21e	ohms	100,000
Network resistor 21c	do	30,000
Resistor 21a	do	15,000
Resistors 26 and 27	ohms each	5,000
Plate-cathode impedance of tube 23 and of tube 24	ohms to infinity each	15,000

The invention may also be utilized to advantage in the transmission of speech or music since the

modulation is linear within the modulation range of the circuit.

I claim as my invention:

1. An oscillator of the resistor-capacitor type which oscillates at a frequency dependent upon the resistance of an element in a resistor-capacitor circuit, said element comprising a variable resistance circuit which includes a pair of vacuum tubes having their plate-cathode impedances connected in series with each other, each of said tubes having a control grid, said series combination of tubes being connected across a voltage source with the control grid of one of said tubes connected to an intermediate point on said voltage source, means for connecting the plate-cathode impedance of the other of said tubes into said resistor-capacitor circuit to function as at least a portion of said resistance element, and means for varying the plate-cathode impedance of said other tube in accordance with a control signal.

2. In combination, an oscillator of the type including a resistor-capacitor delay network for reversing the phase of the feedback voltage, and a variable resistance circuit included in said network for varying the frequency of the oscillator output, said variable resistance circuit comprising a pair of vacuum tubes having their plate-cathode impedances connected in series with each other, each of said tubes having a control grid, said series combination of tubes being connected across a voltage source with the control grid of one of said tubes connected to an intermediate point on said voltage source, means for connecting the plate-cathode impedance of the other of said tubes into said delay network to function as at least a portion of one of the resistors of said delay network, and means for varying the plate-cathode impedance of said other tube in accordance with a control signal.

3. In combination, an oscillator of the type including a resistor-capacitor delay network for reversing the phase of the feedback voltage, said network consisting of series capacitors and shunt resistors, and a variable resistance circuit included in said network for varying the frequency of the oscillator output, said variable resistance circuit comprising a pair of vacuum tubes having their plate-cathode impedances connected in series with each other, each of said tubes having a control grid, said series combination of tubes being connected across a voltage source with the control grid of one of said tubes connected to an intermediate point on said source, means for connecting the plate-cathode impedance of the other of said tubes into said delay network to function as at least a portion of one of said shunt resistors in said network, and means for varying the plate-cathode impedance of said other tube in accordance with a control signal.

4. A variable resistance circuit which includes a pair of vacuum tubes having their plate-cathode impedances connected in series with each other and each having a control grid, said series combination of tubes being connected across a source of substantially constant voltage with the control grid of only one of said tubes connected to an intermediate point on said voltage source, means for connecting the plate-cathode impedance of only the other of said tubes into a utilization circuit to function as a variable resistance element, and means for applying a control voltage to the grid of said other tube only for varying its plate-cathode impedance.

5. A variable resistance circuit comprising a

pair of vacuum tubes having their plate-cathode impedances connected in series with each other and each having a control grid, said series combination of tubes being connected across a voltage divider with the control grid of only one of said tubes connected to an intermediate point on said divider, the bridge circuit formed by said tubes and said divider being balanced, means for connecting the plate-cathode impedance of the other of said tubes only into a utilization circuit, and means for applying a control potential to the grid of said other tube only for varying its plate-cathode impedance.

6. In combination, an oscillator of the type including a resistor-capacitor delay network for reversing the phase of the feedback voltage, said network consisting of a plurality of recurring sections each consisting of a series capacitor and a shunt resistor, and a variable resistance circuit included in said network for varying the frequency of the oscillator output, said variable resistance circuit comprising a pair of vacuum tubes having their plate-cathode impedances connected in series with each other, each of said

5 tubes having a control grid, said series combination of tubes being connected across a voltage source with the control grid of one of said tubes connected to an intermediate point on said source, means for connecting the plate-cathode impedance of the other of said tubes into said delay network to function as at least a portion of one of said shunt resistors in said network, means for applying a control signal to the control
10 grid of said other tube for varying its plate-cathode impedance, and a second pair of tubes each having a control grid and also having their plate-cathode impedances connected in series with each other and across a voltage source with the
15 control grid of one tube in said second pair connected to an intermediate point on said source, means for connecting the plate-cathode impedance of the other tube of said second pair into said delay network to function as at least a portion of another of said shunt resistors, and means
20 for applying said control signal also to the control grid of said last tube.

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