

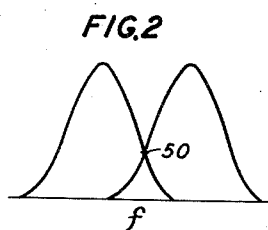
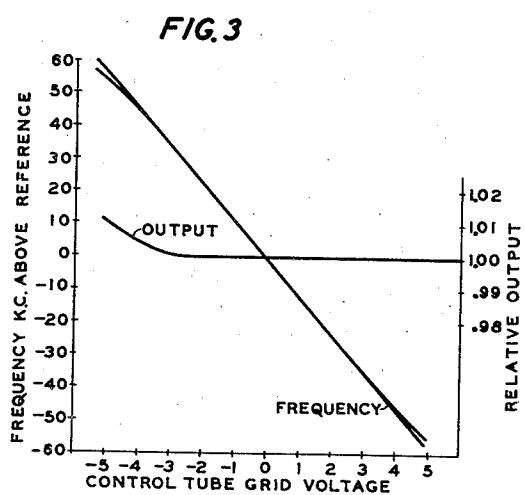
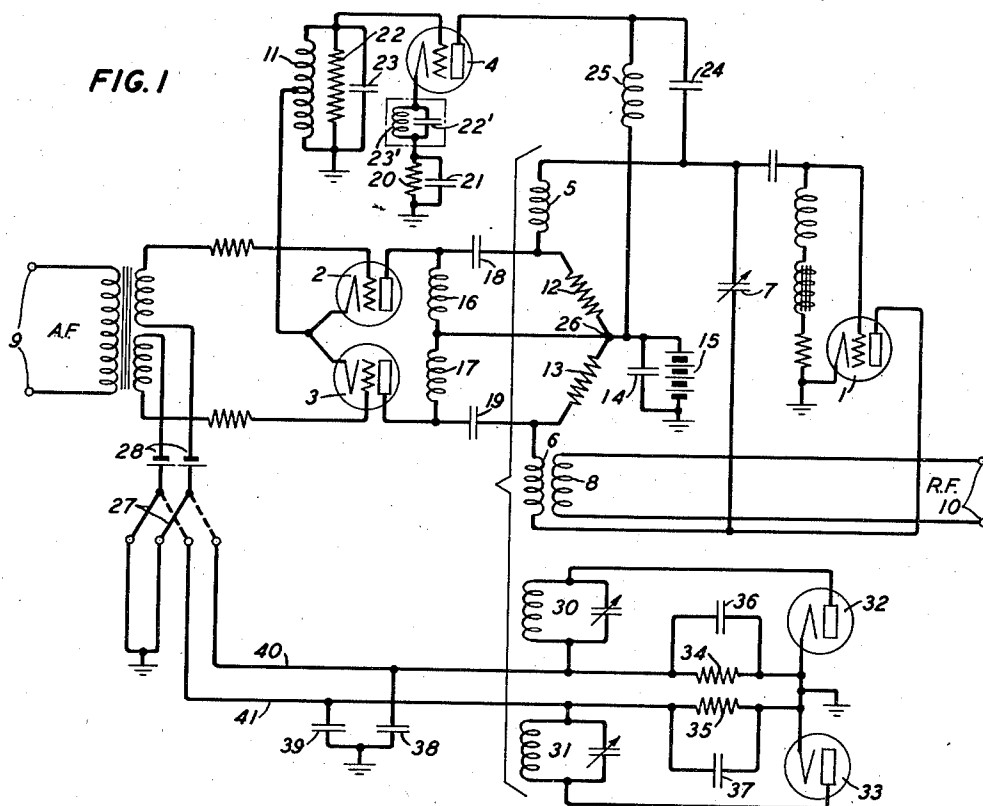
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FREQUENCY MODULATION

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FREQUENCY MODULATION

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8 Claims. (Cl. 179—171)

The present invention relates to frequency modulation of high frequency waves by signal or other modulating waves.

Among the objects of the invention, are to increase the extent or degree of modulation and to improve the quality or linearity of the modulation.

In my prior application Serial No. 152,674, filed July 9, 1937, I have disclosed a frequency modulation system capable of producing a large degree of frequency modulation without accompanying amplitude modulation. In that system, the plate impedance of one or a pair of tubes is shunted across the resonant circuit of the oscillator and the tube impedance varied by signals in proper manner to produce frequency modulation.

According to the present invention the impedance variations under control of the signal are made external to the resonant circuit so that no impedance varying at signal frequency is presented to the resonant circuit.

Other features and the various objects of the present invention will be more apparent from the following detailed description of preferred embodiments illustrated in the accompanying drawing.

In the drawing:

Fig. 1 is a schematic circuit diagram of a frequency modulating circuit embodying the invention in a preferred form, and

Figs. 2 and 3 show curves to be referred to in connection with the description of the circuit of Fig. 1.

In Fig. 1, the oscillation generator comprises tube 1 together with its resonant or tank circuit comprising inductances 5 and 6 and condenser 7. Inductances 5 and 6 preferably have tight coupling. The output circuit whose work terminals are shown at 10 may be coupled by coil 8 to inductance 6.

A pair of modulator tubes 2, 3, with speech input at 9, have their plate circuits connected respectively across resistances 12 and 13 to form with such resistances a four-arm bridge, one alternating current diagonal of which includes a suitable portion of inductance 11, ground, and by-pass condenser 14, the latter around battery 15 for supplying plate voltage to the oscillator 1 and modulator tubes 2 and 3, as well as to an amplifier tube 4 to be described. Thus, when the bridge is balanced no waves traverse this diagonal and no waves are impressed on the input of amplifier tube 4. Radio frequency choke coils 16, 17 and stopping condensers 18 and 19 sepa-

rate the direct current and alternating current plate branches of tubes 2 and 3. Coils 16 and 17 have impedance high enough not to alter seriously the bridge circuit.

Amplifier 4 is for the purpose of amplifying unbalance waves whenever the bridge becomes unbalanced, as will be described. Tube 4 is provided with grid bias resistor 20 shunted by condenser 21 as usual, these being included in series with a cathode network 22', 23' which is preferably used but is not necessary, and serves a similar purpose to the corresponding network in my prior patent application disclosure. The inductance 11 in its grid circuit is shunted by resistance 22 and capacity 23, these elements together forming a broadly tuned circuit for efficiently transmitting the side-bands of the modulated wave to be amplified by this tube.

The amplifier waves from tube 4 are impressed through condenser 24 across the grid-cathode circuit of oscillator 1, that is, across inductance 5 and resistance 12 in series. Inductor 25 is a radio-frequency choke. It will be observed that the apex 26 of the bridge is at a voltage node in the oscillator tank circuit.

The operation will now be described, assuming first that the switch 27 is in its left position, as shown, and that, therefore, the grids of the modulator tubes 2, 3 are connected to ground through bias batteries 28.

As already stated, when no speech or other modulating wave is present in input 9, the bridge composed of resistances 12, 13 and the plate impedances of tubes 2 and 3 is in balance and none of the oscillating tank circuit current appears in the diagonal traceable through inductance 11. Input speech varies the plate impedances of tubes 2 and 3, oppositely, increasing the impedance of the one and simultaneously reducing that of the other. This unbalances the bridge in proportion to the instantaneous speech amplitude. In consequence of this unbalance, a voltage is developed in the bridge diagonal including the input to amplifier 4 (the "galvanometer" diagonal) which is in phase quadrature with the voltage across the tank current terminals, for example, across condenser 7. That this is true may be seen from considering that the voltage across resistance 12 is in phase quadrature with the voltage across inductance 5 (or nearly so). Similarly the electromotive force across resistance 13 is in phase quadrature with the voltage across coil 6. The voltage across the resistance arms 12 and 13 in series is therefore in phase quadrature with that of the

wave in the resonant circuit. When the bridge is balanced, the voltage across the galvanometer diagonal is zero. In the unbalanced condition there is developed in the galvanometer diagonal a phase quadrature voltage rotated either positively or negatively with respect to the voltage across the tank circuit depending upon the direction of unbalance of the bridge. The resultant phase quadrature voltage is also proportional in magnitude to the degree of unbalance of the bridge, that is, to the amplitude of the impressed speech.

These unbalance voltages are amplified by tube 4 and applied across the grid-cathode circuit of the oscillator. They are applied to this circuit in phase quadrature to the existing oscillating voltage, the tube 4 producing a 180 degree phase reversal of the unbalance voltages. The effect of the phase quadrature voltage components is to change the frequency of the generated oscillations in proportion to the amplitude of the phase quadrature voltage fed into the tank circuit, and in a direction determined by the direction of this phase quadrature voltage, i. e., whether it leads or lags. The effect is similar to changing the tuning reactance.

It is found that this method of modulating the frequency of the generated oscillations is to a remarkable degree free of accompanying amplitude modulation. Cathode network 22', 23' counteracts the tendency for amplitude modulation to occur because of lack of exact phase quadrature relation between the voltage applied from tube 4 and that in the resonant circuit. The curves of Fig. 3 illustrate the performance of one system used by applicant. The normal frequency was 3.8 megacycles. This was modulated to the extent of ± 50 kilocycles without substantial distortion and with the production of less than 1 per cent amplitude change. In this case the resistances 12 and 13 were each of 200 ohms. Due to the push-pull connection of the modulator tubes, a high degree of linearity was obtained as seen from the curve.

In the lower portion of Fig. 1 there is shown a frequency stabilizing circuit which is brought into use by throwing switch 27 to its dotted-line or right-hand position. This stabilizing circuit includes a pair of tuned circuits 30 and 31 coupled to the tank circuit, and two diode detectors 32 and 33 connected across the respective tuned circuits in series with resistors 34 and 35, respectively. Other suitable type of detectors might be used. These resistors are by-passed for radio and audio frequencies by respective condensers 36 and 37. The condensers 38 and 39 connected across conductors 40, 41 are large enough to pass speech frequencies readily.

In operation the tuned circuits 30, 31 have crossed resonance characteristics somewhat as shown in Fig. 2 where the normal oscillator frequency is indicated at the cross-over point 50. That is, one tuned circuit, say 30, is tuned slightly off resonance from the normal carrier frequency in one direction and the other is tuned off resonance a like amount in the other direction. When the oscillator is at its normal frequency, rectifiers 32 and 33 produce equal direct current in resistors 34 and 35 the effect of which is to bias equally the grids of modulator tubes 2 and 3. This produces no unbalance effect and no effect on the oscillator frequency. Likewise, the rapid variations in frequency representing signal modulation produce no effect on the frequency stabilizer since the resultant detected

variations are by-passed to ground through condensers 37, 36, 38 and 39. A slow drift in oscillator frequency, however, increases the direct current in one resistor 34 or 35 and produces a decrease from the normal direct current in the other resistor, and these in turn cause voltages to be impressed on tubes 2 and 3 in a manner to upset the bridge balance. The corresponding unbalance voltage is amplified at 4 and fed into the oscillator tuned circuit as in the case of signal modulations, causing a shift in the average frequency to restore it to normal value. This action in no way interferes with the signal modulation already described. It will be understood that conductors 40, 41 must be connected to tubes 2 and 3 in proper polarity.

It will be understood that the invention is not to be construed as limited to the specific disclosure, which is to be regarded as typical and illustrative rather than as limiting, but that the scope is defined in the claims.

What is claimed is:

1. The method of modulating the frequency of the wave generated by an oscillation generator having a frequency determining circuit comprising deriving two high frequency voltage components from said circuit, normally balancing said components against each other, producing equal and opposite changes in said components under control of a modulating wave to produce a resultant unbalance wave proportional in amplitude to the modulating wave, and applying said unbalance wave to said resonant circuit in such phase as to vary the resonant frequency thereof.

2. In a modulating system, an oscillation generator having a frequency determining parallel resonant circuit, a resistance serially included in one branch of said circuit, a pair of discharge tubes having plate cathode impedances connected to form with the two halves of said resistance a four-arm bridge having as a diagonal branch a circuit from the cathodes of said tubes to the center of said resistance, whereby in the balanced condition of said bridge no current flows in said diagonal branch, means comprising a source of modulating waves connected to grids in said tubes for unbalancing said bridge, and means for applying the unbalance voltage across said resonant circuit.

3. In a frequency modulation system, an oscillation generator having a frequency determining parallel resonant circuit, a four-arm bridge having one diagonal serially included in one branch of said resonant circuit, such that unbalance voltage across the opposite bridge diagonal is in phase quadrature relation with the generated oscillations, means for unbalancing said bridge under control of modulating waves to produce resultant unbalance voltage in said opposite diagonal, and means to apply said resultant voltage wave to said resonant circuit to vary the resonant frequency thereof.

4. In a frequency modulation system, an oscillation generator having a tank circuit, two resistances connected to said circuit on opposite sides of a voltage nodal point, a pair of impedances connected to form with said resistances a bridge, means to vary said pair of impedances oppositely under control of a modulating wave to unbalance said bridge and produce resultant unbalance voltage proportional to the modulating wave, and means to feed the unbalance voltage into the resonant circuit in phase quadrature relation to

the generated oscillations to change the effective resonant frequency of the tank circuit.

5 5. In a frequency modulation system, an oscillator comprising a space discharge tube and a resonant circuit for determining the normal frequency, said tube having a grid and anode coupled to points of opposite phase in said resonant circuit with respect to the cathode, a pair of equal resistances connected in a branch of
10 said resonant circuit on opposite sides of the point of alternating current cathode potential whereby voltages of opposite phase are developed in the respective resistances, a pair of tubes having anode-cathode paths associated to form a bridge with said resistances and having grids connected
15 push-pull wise to a source of input signals, whereby an unbalance voltage of the oscillator frequency is produced proportional to the signal amplitude and in phase quadrature to the generated waves, and means to apply such unbalance
20 voltage across said resonant circuit.

6. A combination according to claim 4, comprising also means for detecting drifts in oscillator frequency that are slow compared to the
25 lowest frequency of the modulating wave, means responsive to said detecting means to unbalance said bridge in proportion to the extent of the frequency drift, and means to use the resulting unbalance voltage to compensate such frequency
30 drifts.

7. In a frequency modulation system, an oscillation generator having a frequency determin-

ing parallel resonant circuit, a four-arm bridge having one diagonal serially included in one branch of said resonant circuit such that unbalance voltages across the opposite diagonal of the bridge are in phase quadrature relation with the generated oscillations, means, having two
5 input or control circuits, for unbalancing said bridge to in turn control the frequency of the generated oscillations, one of said inputs leading to a signal source, and means connected to the other input for translating relatively slow
10 drifts in mean oscillator frequency into voltages for producing compensating unbalance voltages in said bridge.

8. In a frequency modulation system, an oscillation generator having a normal frequency determining system, a circuit for deriving therefrom a phase quadrature voltage and applying the same to the oscillation generator to modify the frequency of the generated oscillations in proportion to the magnitude of the applied phase
15 quadrature voltage, means under control of signals for controlling the magnitude of the derived phase quadrature voltage means including a pair of tuned detectors for detecting slower changes in oscillation generator frequency than correspond to the signal modulations, and means controlled by said detectors for causing application
20 of the phase quadrature voltage to the oscillator in magnitude and direction to oppose the aforesaid slow changes in frequency.
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