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PHASE MODULATION

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Fig. 1

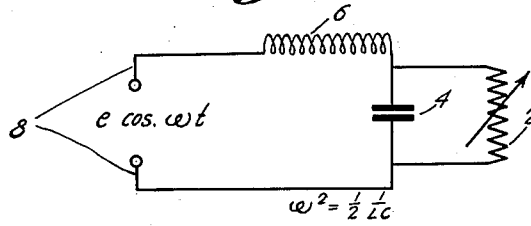


Fig. 2

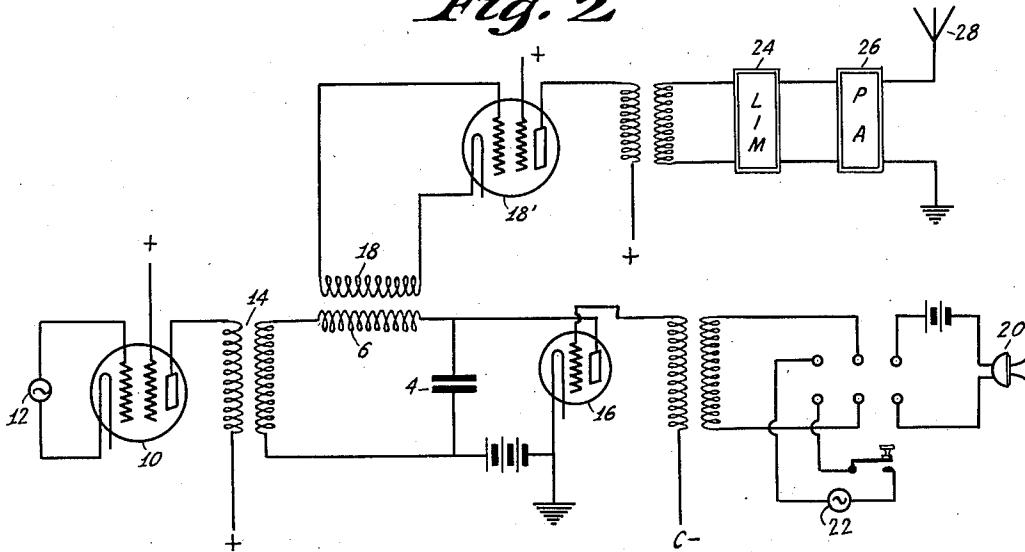
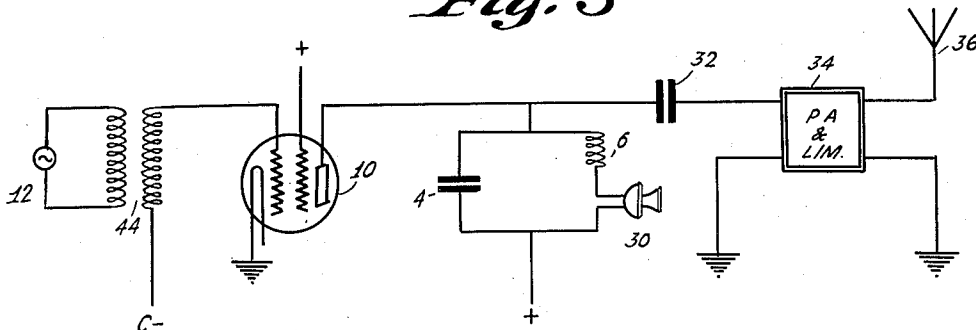


Fig. 3



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PHASE MODULATION

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7 Claims. (Cl. 179—171)

This invention has for its object the provision of new and useful methods and means for obtaining modulated energy by phase displacement of carrier energy.

5 If a network comprising the parallel combination of a pure capacity and a pure resistance in series with a pure inductance be supplied with electrical voltage of substantially constant amplitude and frequency, the voltage across the inductance will have a magnitude which is substantially constant and independent of any value given to the resistance. However, the phase of the current through the inductance will vary in accordance with variations of the resistance. It is an object of this invention to utilize this phenomenon for phase modulating carrier energy.

10 Another object of the present invention is to provide an arrangement whereby variations in the purity of the inductance; for example, where resistance free inductors are not available, will not affect operation of the system for the production of phase modulated energy. This is accomplished by arranging the network so that the inductance and resistance are in series, and the capacity parallels the series combination. In this manner, any resistance appearing in the inductance, acts as though it were included in the resistance element of the network.

15 Still a further object of this invention is to make the resistance utilized in the form of the resistance of an electron discharge device whose resistance may be varied in accordance with modulating potentials applied to the control electrode thereof.

20 Still a further object of this invention is to provide means for transmitting phase modulated energy derived in accordance with the principles of the present invention; and, to provide means for removing any amplitude modulation which may have been introduced in any fashion. This is accomplished, preferably, by limiting the modulated energy before amplification for further transmission.

25 The novel features of the invention are described with particularity in the appended claims. However, the invention may best be understood both as to its principles of operation and structural organization by referring to the accompanying drawing, wherein,

30 Figure 1 is given by way of explanation of the present invention,

35 Figure 2 illustrates a transmitting system embodying the principles of the present invention wherein the resistance of the controlling network

takes the form of an electron discharge device, and

Figure 3 is a preferred form of the invention illustrated in connection with a transmitting system.

Turning to Figure 1, if the resistance of the network illustrated, including pure resistance 2 paralleling the pure capacity 4, the parallel combination being in series with a pure inductance 6, is alone varied, then the voltage appearing across inductance 6 will remain constant in amplitude but will shift in relative phase depending upon the value given to resistance 2. The constancy of the voltage appearing across inductance 6 requires as a prerequisite, application of electrical voltage of constant frequency and amplitude to the input terminals 8 and, as an additional requirement for the constancy in amplitude of the voltage across inductance 6, it is necessary that the values of the inductance and capacity be chosen so that they satisfy the following requirement:

$$w^2 = \frac{1}{2} \frac{1}{LC}$$

where

$$\frac{w}{2\pi}$$

is the frequency.

The other symbols are thought to be sufficiently well known so as not to require further explanation.

As a shift in phase necessitates a change in frequency during phase shifting, it can be said that the voltage or energy appearing in inductance 6 is either frequency or phase modulated in accordance with variations of resistance 2.

A transmitting system embodying the foregoing features is illustrated in Figure 2. A vacuum tube amplifier 10, preferably of the screen grid type, amplifies oscillations generated at source 12 and supplies the amplified oscillations through a transformer 14 having a loosely coupled primary and secondary to a network including inductance 6, capacity 4 and a resistance in the form of the anode-cathode resistance of a vacuum tube 16. The secondary of transformer 14 may be considered as part of the inductance. By virtue of the loose coupling between the primary and secondary of transformer 14, the voltage fed to the frequency or phase controlling network including inductance 6, capacity 4 and resistance 16 will be substantially constant in frequency and amplitude.

The voltage appearing in secondary 18, how-

ever, will appear as phase modulated or frequency modulated voltage, whose modulation depends upon the modulating voltages applied to the input circuit of electron discharge device 16 which, as shown, may be either voice currents from a transmitter 20 or keyed alternating energy from a suitable source 22.

The frequency modulated energy appearing in secondary 18 is amplified by amplifier 18'; preferably of the screen grid type, fed to a suitable limiter 24, power amplifier 26, and radiated through a suitable antenna 28. Limiter 24 is of known construction and removes any extraneous amplitude modulation which may have been introduced. This limiter is not, however, essential to the practice of the invention.

As the efficacy of the network in controlling the phase or, in effect, the frequency of the supplied energy, is lessened by presence of resistance in the inductance, another arrangement, as shown in Figure 3, will eliminate this difficulty in instances wherein it is difficult to obtain an inductor free of resistance. Referring to Figure 3 a source of energy 12 of constant frequency and amplitude is coupled to an amplifier 10 through a transformer 44. In the output circuit of the amplifier 10 there is coupled a phase controlling network comprising the series combination of an inductance 6, a resistance 30 in the form of a microphone, and a capacity 4. Resistance unavoidably present in inductance 6 will not prove detrimental, but will act as though it were part of the microphone resistance 30.

At the junction point of inductance 6 and capacity 4, phase shifted or frequency modulated potentials will appear, which may be fed through a suitable blocking condenser 32 to a power amplifier and limiter 34 and thence further transmitted by land lines or preferably by a suitable radiating antenna 36.

It is not necessary that the resistance take the form of a microphone as shown in Figure 3, but it may be replaced by any device presenting resistance which can be varied by the source of modulations.

In particular, as in Figure 2, microphone 30 of Figure 3 may be replaced by the resistance offered by an electron discharge device whose control electrode is supplied with modulating potentials, although in this case a transformer of suitable construction should be connected with its high tension side in the plate circuit of said electron discharge device and its low tension side connected in place of microphone 30 in order to reduce the resistance to a suitable value. Inductance 6 may be utilized as the low tension winding of this transformer.

In Figure 3 also, inductance 6 and capacity 4 must satisfy the relation

$$w^2 = \frac{1}{2} \frac{1}{LC}$$

and the tube 10 must have a high impedance plate circuit so as to supply substantially constant current to the phase shifting network 4, 6, 30, whatever the instantaneous value of resistance 30.

By way of further explanation of my present invention reference is made in particular to the arrangement shown in Figure 3. By virtue of the characteristics of screen grid tube amplifier 10, the current output therefrom will be constant due to the fact that the impedance of tube 10 is large with respect to the load impedance.

The alternating voltage across the circuit 4, 6,

30 of Figure 3 is given by the expression $E=IZ$ where Z =the load impedance.

Now

$$Z = \frac{(r+jwL)\left(\frac{-j}{wc}\right)}{r+jwL-\frac{j}{wc}} \quad 5$$

$$= \frac{\frac{L}{c} - j\frac{r}{wc}}{r+j\left(wL-\frac{1}{wc}\right)} \quad 10$$

$$(Z)^2 = \frac{\left(\frac{L^2}{c^2} + \frac{r^2}{w^2c^2}\right)}{r^2 + \left(wL - \frac{1}{wc}\right)^2} \quad 15$$

The above expression gives the square of the absolute value of the impedance of the circuit formed by the capacity 4, inductance 6 and resistance of the microphone 30. Imposing the condition given above, namely, that

$$w^2 = \frac{1}{2Lc}$$

I find

$$(Z)^2 = \frac{\left[\left(\frac{L}{c}\right)^2 + \frac{r^2}{c^2} 2Lc\right]}{\left[r^2 + \frac{1}{2Lc}\left(L - \frac{2Lc}{c}\right)^2\right]} \quad 25$$

$$= \frac{\left(\frac{L}{c}\right)^2 + r^2 \frac{L}{c}}{\frac{1}{2} \frac{L}{c} + r^2} \quad 30$$

$$= \left(\frac{2L}{c}\right) \left[\frac{\frac{L^2}{c^2} + r^2 \frac{L}{c}}{\frac{L^2}{c^2} + r^2 \frac{L}{c}}\right] \quad 35$$

$$= 2 \frac{L}{c}$$

The final expression above indicates clearly that under the conditions assumed, variations in resistance of the network shown in Figure 3 have no effect upon the absolute impedance thereof as a result of which pure phase modulated energy may be derived therefrom.

Having thus described my invention, what I claim is:

1. In combination, a closed network comprising an inductance and a capacity in series and a resistance in the form of the internal resistance of an electron discharge device in parallel with said capacity, a generator for supplying electrical energy of substantially constant frequency and amplitude to the network, means for varying the resistance in accordance with modulating energy whereby to produce in the network a phase modulated electromotive force, means coupled to the inductance of the network for deriving therefrom phase modulated energy, limiting means connected with said output circuit for suppressing or minimizing amplitude modulation in the phase modulated energy so derived, and means for transmitting the resulting energy.

2. In combination a source of current of constant amplitude and frequency, an inductive and capacitive network containing a resistance coupled thereto, the inductance and capacity of said network being related to the frequency by the relation

$$W^2 = \frac{1}{2} \times \frac{1}{LC}$$

where

$$W = 2\pi f$$

whereby the magnitude of the complex quantity

expressing the network impedance is independent of the value of the resistance while the relative values of real and imaginary components of said complex quantity depend upon the value of said resistance, connections from said source to said network whereby constant current flows in said network, means for varying the resistance of the network in accordance with a signal to be transmitted, an electron tube amplifier, and, connections from said network to said amplifier whereby the output of said amplifier is determined by the voltage taken from said network.

3. In apparatus for transmitting phase modulated waves, a source of constant frequency constant amplitude carrier wave energy, a network comprising inductance, capacity and resistance, a circuit coupling said source of constant frequency constant amplitude wave energy to the inductance of said network, an output circuit coupled to the inductance of said network, means for varying the resistance of said network whereby the phase of energy fed from said source by way of said network to said output circuit is varied, limiting means connected with said output circuit for suppressing or minimizing amplitude modulation in the phase modulated energy appearing in said output circuit, and, means for transmitting the resulting phase modulated energy.

4. In combination, a network including, an inductance, a capacity and a resistance, said resistance including the internal resistance of an electron discharge device, means for supplying electrical energy of constant frequency and amplitude to the network, the frequency of the supplied energy being related to the values of the capacity and inductance in said network by the equation

$$W^2 = \frac{1}{2} \times \frac{1}{LC}$$

40 where

$$W = 2\pi f,$$

means for varying the resistance of the network whereby the phase of the voltage in a portion of the network is shifted in accordance with variations in the resistance, and means coupled to the network for deriving therefrom the phase modulated energy.

5. Phase modulating means including, a network comprising a capacity, inductance and a resistance, the resistance element being variable at signal frequency, means for energizing the network from a source of constant frequency constant amplitude energy, said capacity and

inductance element being related to the frequency applied to the network by the equation

$$W^2 = \frac{1}{2} \times \frac{1}{LC}$$

where

$$W = 2\pi f,$$

whereby the voltage drop across one of said reactance elements is of constant amplitude but of a phase determined by the magnitude of said resistance element, and means for utilizing the potential drop across said last named reactance.

6. Phase modulating means including, a plurality of impedance elements, at least one of which elements is inductive and another capacitive, and one of which is variable at signal frequency, means for energizing the network from a source of high frequency oscillations of constant frequency and amplitude, certain of said impedance elements being related to the frequency at which the network is energized by the equation

$$W^2 = \frac{1}{2} \times \frac{1}{LC}$$

where

$$W = 2\pi f,$$

whereby the voltage drop across one of the impedance elements is of constant amplitude but of a phase determined by the magnitude of said variable element, and means for utilizing the potential drop across said last named impedance.

7. In a system for modulating the phase of oscillations of carrier frequency at signal frequency, a network comprising a condenser, a resistance variable in accordance with signals to be transmitted and having its terminals directly connected to the condenser terminals, an inductance having its terminals connected to the condenser terminals by connections having negligible impedance at the frequency of the oscillations to be modulated, means for injecting in the branch containing said aforesaid inductance an oscillating voltage of carrier frequency and of substantially constant amplitude, an amplifier coupled to the inductive branch of said network to be excited by current flowing therein, said coupling being so arranged that the instantaneous voltage applied to said amplifier is directly proportional to the rate of change of instantaneous current in the aforesaid inductance, and a utilization circuit coupled to said amplifier.

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