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PHASE MODULATION

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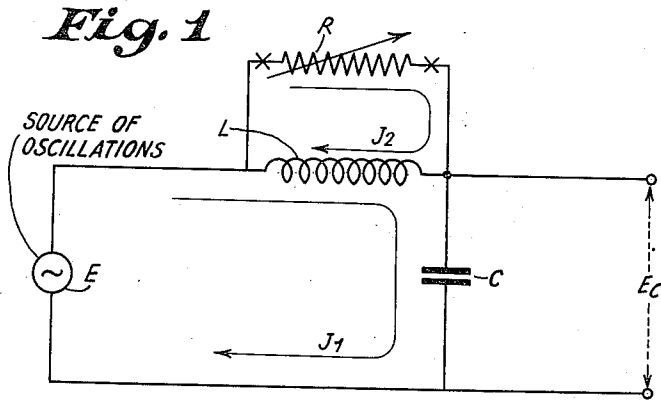


Fig. 1a

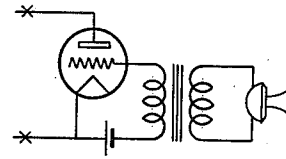
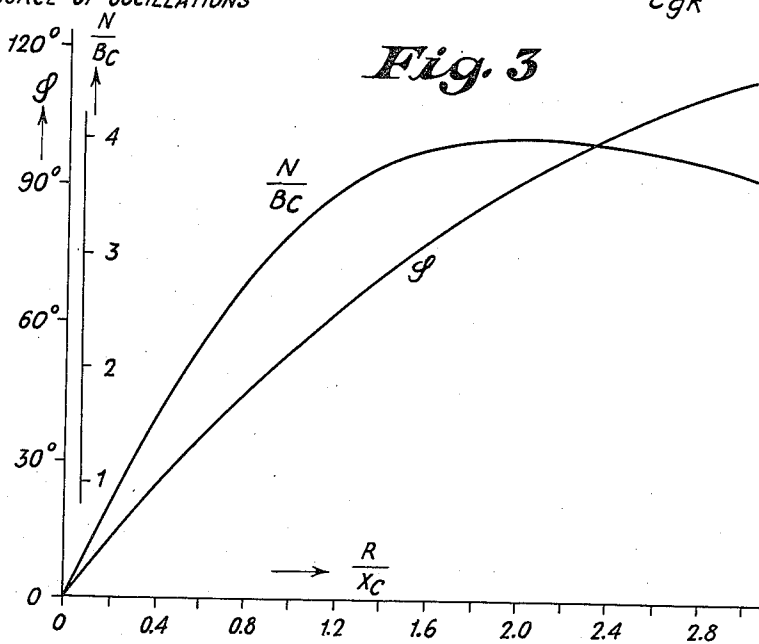
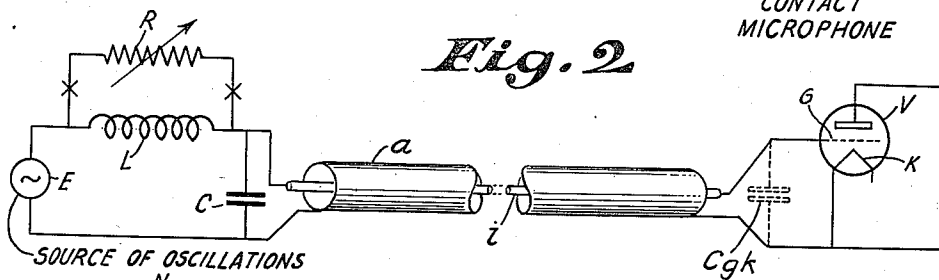
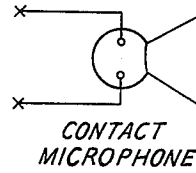


Fig. 2a



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PHASE MODULATION

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3 Claims. (Cl. 179-171)

This invention pertains to a circuit organiza-
tion adapted to phase modulation of wave energy.
An object of the present invention is to provide
an arrangement adapted to insure pure phase
modulation in oscillations without the production
of any amplitude modulation.

In German Patent #607,669, of Jan. 4th, 1935,
a circuit scheme has been disclosed which insured
the said purpose by applying alternating voltages
of constant frequency and constant amplitude to
an oscillatory circuit comprising an inductance L,
a capacity C, and a resistance R, the resistance
being variable at the rhythm of the modulation
frequency and being connected in series to the
inductance L or in parallel to the capacity C, the
inductance L and the capacity in said oscillatory
circuit being so chosen that they will at least
proximately fulfill the equation

$$\omega^2 = \frac{1}{2CL}$$

where ω is the cyclic frequency (angular velocity)
of the alternating voltage.

According to this invention, the arrangement
of the German patent is to be modified in such
a way that L and C change places; in other words,
so that the resistance R is placed either in series
with the capacity or in shunt to the inductance.
If ω is again the angular velocity of the oscilla-
tion to be modulated, then, in the case of the
present invention, the relation

$$\omega^2 = \frac{2}{LC}$$

must be preserved.

The arrangement of the invention offers ad-
vantages in several regards which means a prog-
ress of the art. A certain difficulty inherent in
the former arrangement was that the inductance
of L always presented some ohmic resistance
which could not always be reduced to sufficiently
low levels. In order to prevent undesirable and
unfavorable effects of the said ohmic resistance,
recourse must be had to comparatively compli-
cated circuit organizations. Now, this shortcom-
ing is obviated in this invention. Another point
that must be kept in mind is that, as can be fol-
lowed from a comparison of the relations be-
tween angular velocity and the constants of the
oscillatory circuit, smaller elements for the lat-
ter may be used according to this invention, for
the same wave frequency. Another advantage
will be drawn attention to in connection with
the discussion of an exemplified embodiment of
my invention.

In describing my invention, reference will be
made to the attached drawing wherein:

Fig. 1 is a simplified circuit diagram of my
phase modulator:

Fig. 2 is a somewhat more complete diagram of
my phase modulator connected with an amplifier:

Figs. 1a and 2a are modifications of the ar-
rangements of Figs. 1 and 2; while Fig. 3 is a
graph illustrating the manner in which phase
modulation is produced.

The following calculation is to show and prove
that in a circuit arrangement of the kind here
disclosed a variation of the resistance R merely
insures a phase shift of the voltage arising across
the condenser C whose absolute magnitude is
preserved. A source of alternating voltage E,
which is preferably free of resistance, works upon
a circuit system comprising a capacity C and in
series therewith a parallel arrangement of an
inductance L and an ohmic resistance R (as
shown in Fig. 1). Across the condenser C is to
be made available a voltage E_c whose phase is
made variable, while the value of the resistance
R is to be varied at the rhythm of the modulat-
ing potentials. The voltage equations for the
branch currents J_1 and J_2 flowing through arbi-
trarily chosen paths indicated by the arrows are:

$$J_1 \cdot j(X_L - X_C) - J_2 \cdot jX_L = E$$

$$-J_1 \cdot jX_L + J_2(R + jX_L) = 0$$

where X_L and X_C are the reactances of induc-
tance L and capacity C, respectively, E is the
voltage of the alternating voltage source bearing
the same reference letters, and

$$j = \sqrt{-1}$$

From these equations, the branch current J_1 is
found to be

$$J_1 = E \frac{R + jX_L}{X_L X_C + jR(X_L - X_C)}$$

Since $E_c = J_1 \cdot (-jX_C)$
there is

$$\frac{E_c}{E} = \frac{X_L X_C - jR X_C}{X_L X_C + jR(X_L - X_C)}$$

If the condition here laid down, i. e.,

$$\omega^2 = \frac{2}{LC}$$

and

$$X_L = 2 \cdot X_C$$

is satisfied, there will be

$$\frac{E_c}{E} = \frac{2X_C - jR}{2X_C + jR} = \frac{(2X_C - jR)^2}{4X_C^2 + R^2}$$

By evaluation of this equation, it is found that the phase position of vector E_c in relation to the electromotive force E of the alternating voltage source is a function of the ratio

$$\frac{R}{X_c}$$

The absolute value of the relation is given by

$$\frac{E_c}{E} = \frac{4X_c^2 + R^2}{4X_c^2 + R^2} = 1$$

In other words, it is constant, and this is what was to be demonstrated.

In the special case $R=0$ there becomes

$$\frac{E_c}{E} = 1$$

For

$$R = \infty \quad \frac{E_c}{E} = \frac{-j}{+j} = -1$$

While finally in the case where $R=2X_c$ there is

$$\frac{E_c}{E} = \frac{1-j}{1+j} = -j$$

The position of the vector E_c , as will thus be seen, upon variation of resistance R from 0 to infinite, is shifted by fully 180 degrees, from the in-phase condition as far as phase opposition. Derivations would be analogous in the case where the resistance R is in series with the condenser C .

The resistance R whose value is to be changed at the rhythm of the modulation process may consist of a contact type microphone as shown in Fig. 2a, or of the discharge path of a tube whose internal resistance is controlled by the voice voltage applied between the cathode and the control electrode, as shown in Fig. 1a, all in a way familiar to the man trained in this art.

One particular merit of the arrangement here disclosed flows from its practical application under normal working conditions. On the left-hand side in Fig. 2, is shown the scheme illustrated in Fig. 1 in which the phase-modulated alternating voltage arises across the condenser C whence it is taken off and applied to an amplifier stage V . Inasmuch as the various stages of a multi-stage transmitter are ordinarily accommodated in separate casings, and since the master oscillator is usually mounted a certain distance apart with a view to minimizing reaction of the power stage upon the master oscillator, the transfer of the phase-modulated alternating voltage from the condenser C to the grid circuit of the tube V is effected by way of an energy feed lead comprising an inner conductor i and an outer conductor a , for instance. (Secondary circuit elements associated with the amplifier stage V which are immaterial from the viewpoint of this invention, have been omitted for the sake of greater clearness of illustration). It will be noted that the said energy feeder terminates at both ends in a capacity;

i. e., at one end, there is the condenser C , while at the other end there is the grid-cathode capacitance C_{gk} , so that such disturbing resonance actions are precluded as would be produced, for instance, if the voltage output occurred at an inductance.

The fact that the modulation scheme here disclosed insures very favorable working properties will become evident from the graphs in Fig. 3. These show the dependence of power consumption and phase angle upon the size of the resistance R . Along the abscissa axis is indicated the relationship between the non-reactive (effective) resistance R and the reactance X_c . Along the ordinate axis are indicated, on the one hand, the phase angle between the condenser alternating potential E_c and the E. M. F. of the generator E , and, on the other hand, the relation between non-reactive power $N=J^2R$ and the condenser reactive power

$$B_c = \frac{E^2}{X_c}$$

It will be noted therefrom that the curvature of the ϕ -curve is so slight that no special means to correct distortion, under average requirements regarding transmission fidelity, will be necessary, while in addition the load of the generator stays practically stable inside a large modulation range.

What is claimed is:

1. In a circuit for producing phase modulation of alternating voltages, a source of alternating voltages of constant frequency and amplitude, an alternating current circuit including a capacity and an inductance in series, and a resistance in parallel with said inductance, means for varying said resistance at the rhythm and rate of modulation potentials, the inductance and capacity of the said alternating current circuit being so chosen that they will approximately obey the formula

$$\omega^2 = \frac{2}{LC}$$

where ω is the angular velocity of the supplied alternating voltage, and means for applying voltages from said source to said circuit.

2. A circuit arrangement according to claim 1, in which the variable resistance includes the internal resistance of a discharge tube.

3. In a phase modulation system, a source of oscillations, an inductance and a condenser in series with each other and with said source, a resistance variable at signal frequency connected in parallel with said inductance, an amplifier tube having a control electrode and a cathode, a tubular conductor connecting one terminal of said condenser to the cathode of said tube, and a conductor within said tubular conductor connecting the other terminal of said condenser to the control electrode of said tube.

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