

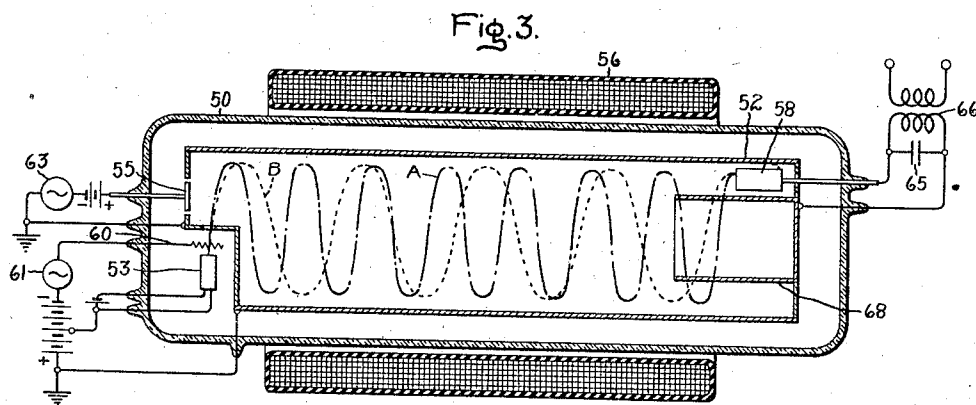
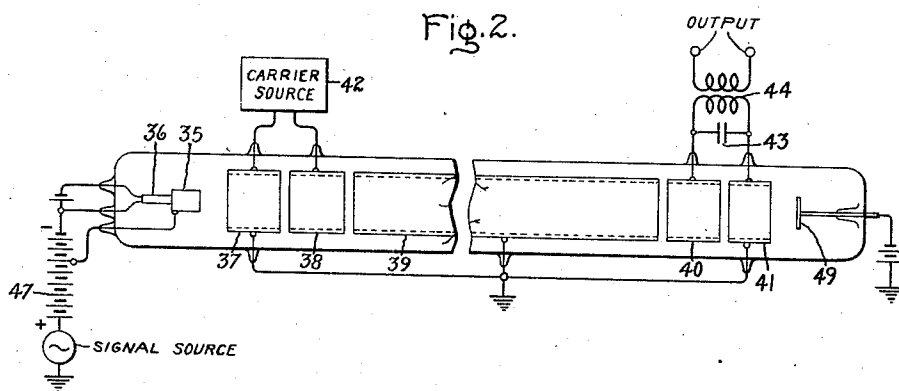
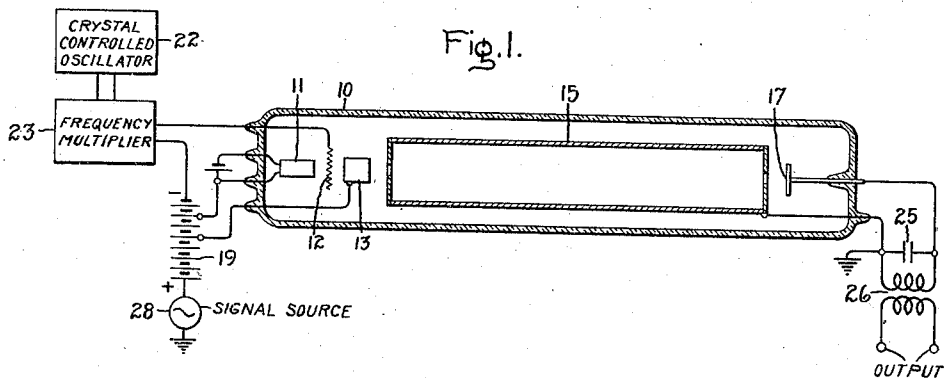
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PHASE MODULATION SYSTEM

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PHASE MODULATION SYSTEM

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316,339, January 30, 1940. This application
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2 Claims. (Cl. 179-171.5)

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The present invention relates to an improved system of phase modulation. The term "phase modulation" as used herein is intended to designate recurrent variations in phase of a fundamental quantity, such as a carrier voltage, as produced by the variations of a secondary or modulating quantity, such as an audio or video signal. It will be understood by those skilled in the art that this definition includes as a special case thereof the type of modulation currently known as "frequency modulation."

It is a primary object of the invention to provide an improved system of phase modulation in which the carrier source is sufficiently independent of the modulating means to permit separate stabilization of the carrier frequency. To this end, the invention utilizes an electron stream of such character that variations of carrier frequency may be impressed on the stream at a point which is relatively widely separated from a point at which energy is to be taken from the stream for excitation of an output circuit. By the additional provision of means for varying the electron transit time between the said two points in accordance with the variations of a signal voltage, the voltage developed in the output circuit is caused to be of phase modulated character. At the same time, no adverse or destabilizing influences are exerted on the carrier source as a result of the modulating operation.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawing, in which Fig. 1 represents diagrammatically one embodiment of the invention; and Figs. 2 and 3 respectively illustrate modifications thereof.

Referring particularly to Fig. 1, the apparatus illustrated comprises an elongated tubular envelope 10 suitably constituted of glass. Within the envelope and at one end thereof there is provided means for producing an electron stream, such means comprising, for example, a cathode part 11, a negatively biased control grid 12, and an accelerator 13 which is maintained at a fixed positive potential. After passage through the accelerator, the electron stream traverses a substantially field-free space enclosed by an elongated conductive tube 15 and is finally collected by means of an anode 17. If desired, magnetic focusing means (not shown) may be

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employed to prevent spreading of the electrons as they traverse the envelope 10.

An appropriate potential relationship may be maintained between the various elements referred to in the foregoing by the provision of a D. C. voltage source, which is conventionally illustrated in the drawing as a battery 19. In this connection the shielding tube 15 is preferably maintained at ground potential while the cathode is maintained at least several hundred volts below ground.

In the use of the apparatus described, it is proposed initially to produce high frequency variations in the electron stream by the application of a voltage of carrier frequency to the grid 12. Such voltage may be derived, for example, from a separately stabilized source such as a crystal controlled oscillator, indicated at 22. If desired, the frequency of the voltage applied to the grid 12 may be increased over that available at the terminals of the oscillator 22 by passing the output of the latter through a frequency multiplier 23.

As a result of the operation of the grid 12, the portion of the electron stream which traverses the shielded space 15 and impinges on the anode 17 will be characterized by cyclically recurrent variations in density. It may therefore be used to produce excitation of an appropriate high frequency output circuit, conventionally illustrated as comprising a condenser 25 and an inductance 26. In order to determine the character of the voltage thus developed in the output circuit, reference may be had to the following analysis.

Let it be assumed that the input voltage applied to the grid 12 is of the form $V_{in} = e_1 \sin \omega t$, where the quantity ω represents a carrier frequency. Under these circumstances the output voltage developed in the circuit 25, 26 may be expected to be of the form

$$V_{out} = e_2 (\sin \omega t - \phi) \quad (1)$$

In this latter expression, the term ϕ represents an angle of lag introduced by the transit time of electrons through the tube 15. (For present purposes, it is desired that this transit time be equal to at least several and preferably more than ten complete cycles of the carrier frequency.)

For the production of phase modulation effects by the arrangement described it is proposed to provide means for varying the average beam velocity, and consequently the electron transit time through the tube 15 at a signal (e. g., audio or video) frequency. This may be done in one

way by varying the potential difference between the grounded tube 15 and the cathode or electron source 11. To this end, in the arrangement illustrated a signal voltage source is connected between cathode and ground as indicated at 28.

Let it be assumed that as a result of the operation of the signal source, the voltage difference between the cathode and the shield may be represented as $E = E_0(1 + \delta \sin \mu t)$, where μ represents a signal frequency and δE_0 represents the magnitude of the signal voltage. Under these circumstances, since the beam velocity v is proportional to the square root of the voltage, if δ is small, we may write approximately

$$v = v_0 \left(1 + \frac{\delta}{2} \sin \mu t \right) \quad (2)$$

Also approximately

$$\frac{1}{v} = \frac{1}{v_0} \left(1 - \frac{\delta}{2} \sin \mu t \right) \quad (3)$$

Since the electron transit time angle θ is inversely proportional to beam velocity, we may further write

$$\phi = \phi_0 \left(1 - \frac{\delta}{2} \sin \mu t \right) \quad (4)$$

and substituting the above in Equation 1:

$$v_{out} = E_2 \left(\sin \omega t - \phi_0 + \phi_0 \frac{\delta}{2} \sin \mu t \right) \quad (5)$$

which is in the form of a phase modulated wave.

Due to the fact that the signal voltage acts on the electron stream at a point where the stream intensity is already fixed (i. e., by the combined action of the grid 12 and the accelerator 13), it is apparent that the voltage developed in the output circuit will be substantially free of amplitude variations of signal frequency. For this reason, the apparatus described is well adapted for use in those systems of communication in which amplitude modulation effects are intentionally suppressed at some point of the system in order to utilize the superior qualities of noise-freedom associated with phase or frequency modulated transmission.

It is a further advantage of a system such as that described that the source of carrier potential may comprise a circuit which is quite independent of the modulating system and which is of separately stabilized character. In this respect the system differs favorably from certain arrangements used heretofore in which phase or frequency modulation of a carrier is produced by changing the resonance or other characteristics of the source. This latter method of operation makes it difficult to avoid sporadic and uncontrollable variations in the normal or unmodulated carrier frequency.

In Fig. 2 there is shown a modification of the invention which differs from that previously described mainly with respect to the character of the input and output electrodes employed. In this case the electron source consists of an electron gun having parts 35 and 36. The electrode system which is traversed by the electron stream after its issuance from the electron gun comprises a series of conducting tubes, numbered 37 to 41 inclusive. Of these, the tubes which bear odd numbers are inter-connected and are conjointly maintained at ground potential. The electrodes 38 and 40, on the other hand, are free to vary in potential with respect to the adjacent conductive parts and are thus adapted to serve respectively as input and output electrodes. To this end, the electrode 38 is connected to a source 42

of carrier voltage, while the electrode 40 is connected to an output circuit including, for example, the parallel combination of a condenser 43 and an inductance 44.

For most effective operation of the system thus described it is desired that the average electron transit time through the electrode 38 shall correspond at least approximately to a half-cycle of the carrier voltage, or, under some circumstances, to an odd multiple thereof. It has been shown that when this condition is fulfilled, an electrode such as 38 will act to produce cumulative velocity modulation effects at the two gaps which bound the electrode. (A full discussion of this means of obtaining velocity modulation is given in an article by W. C. Hahn and G. F. Metcalf in the Proceedings of the I. R. E. for February 1939 at page 106). Moreover, the mode of propagation of the resultant beam disturbances along the tube is such that additive output effects may also be obtained at the two gaps which bound the electrode 40. Excitation of the output circuit 43, 44 will thus be realized.

As a result of the phase delay effect introduced by the presence of the relatively very long shielding tube 39, the relationship between the input voltage applied to the electrode 38 and the output voltage developed across the circuit 43, 44 will be substantially the same as in the device of Fig. 1. Consequently, phase modulation effects may be produced in the output of the apparatus by the inclusion of a source 47 of audio or video signal in the ground-to-cathode circuit of the apparatus, where it acts to vary the average velocity of the electron stream in accordance with the variations in the signal voltage.

After its traversal of the high frequency electrode system the electron stream may be collected by means of an anode 49.

In the various devices described above, the magnitude of the phase modulating effect is clearly a function of the total electron transit time between the input and output electrodes. It is therefore, desirable to make this time as long as possible consistent with practical considerations of tube design. In Fig. 3 there is shown an arrangement by which the aforesaid transit time may be considerably lengthened without unduly increasing the total length of the tube structure.

In the figure referred to there is provided an envelope 50 which encloses a conductive shielding cylinder 52 arranged coaxially therein. An electron stream generated by an appropriate source 53 is projected more or less parallel to the circumference of the envelope and is given a component of axial motion by the use of an appropriately biased deflecting element 55. By the influence of a magnetic field which is produced, for example, by an elongated magnet coil 56, the electrons are caused to traverse a helical path as they proceed along the axis of the tube, such path being indicated by the dot-dash line A. At the end of the tube remote from the cathode 53 the electrons are collected by means of an appropriately positioned anode 58.

Primary modulation of the electron stream at carrier frequency is produced by means of a grid 60 to which is connected a source of carrier voltage 61. Additional modulation at signal frequency is obtained by the application of a signal voltage to the deflecting plate 55, such voltage being derived, for example, from a source 63. The action of the plate 55 changes the pitch of the helical path described by the electron

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stream within the shielding cylinder 52 and thus causes the stream to follow a new course, indicated for a particular signal voltage by the dotted line B. Due to the great length of the total electron path, it is apparent that a relatively small change of this character will cause a very material shift in the time required for electrons to traverse the cylinder 52.

As a result of beam changes produced in the manner just specified, the current received by the collecting electrode 58 will contain components of phase modulation in accordance with the principles previously described. For effective utilization of this modulation the current collected by the electrode is fed into an appropriate output circuit including a condenser 65 and an inductance 66.

In order to diminish the tendency of the electrode 58 to be affected by the relatively remote components of the electron stream, it may be partially shielded by the provision of unipotential cylinder 68 extending from the end wall of the cylinder 52. This precaution assures the attainment of a higher transconductance than would otherwise be realized.

This application is a substitute for abandoned application Serial No. 316,339, filed January 30, 1940.

While I have described my invention by reference to particular embodiments thereof, it will be understood that additional modifications may be made by those skilled in the art without departing from the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A system of phase modulation including means for producing an electron stream, means for modulating the stream at a carrier frequency, means defining an elongated space to be traversed by the modulated beam, means for causing the beam to follow a helical path through said space

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so that the electron transit time through the space comprises at least several complete cycles of the carrier, means for varying the pitch of the said helical path at signal frequency thereby to vary the said electron transit time through the said space, and an output circuit adapted to be excited by the electron stream after its traversal of the said space.

2. A system of phase modulation including means for producing an electron stream, means for modulating the stream at a carrier frequency, means defining a space to be traversed by the modulated beam, means for causing the beam to follow a helical path through said space so that the electron transit time through the space comprises at least several complete cycles of the carrier, means for varying said helical path at a signal frequency thereby to vary the electron transit time through the said space and output means adapted to be excited by the electron stream after its traversal of the said space.

SIMON RAMO.

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