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PHASE MODULATION

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FIG. 1

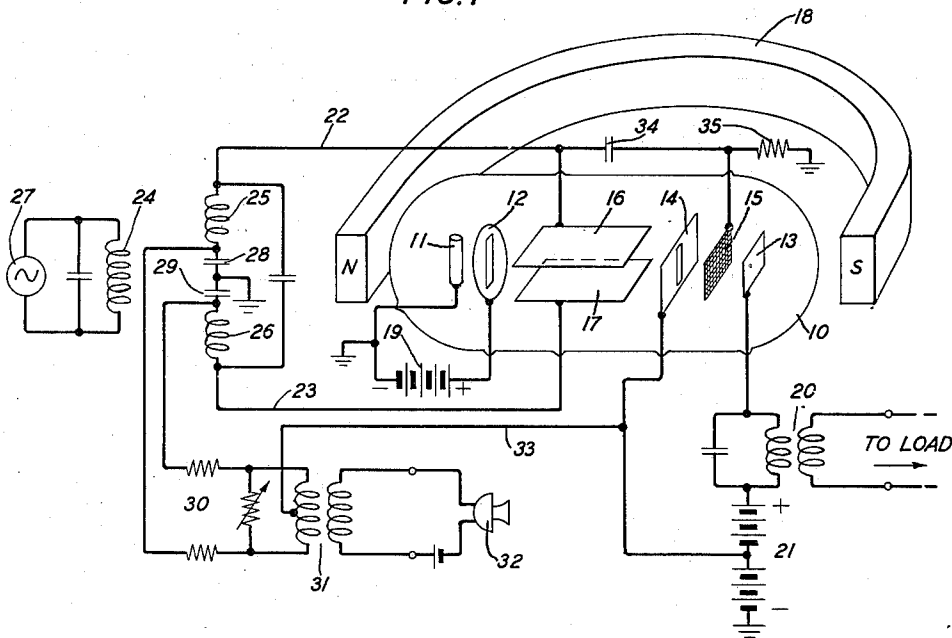
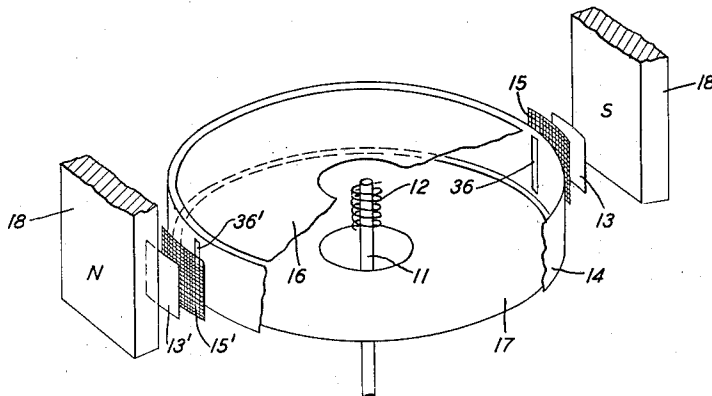


FIG. 2



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PHASE MODULATION

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5 Claims. (Cl. 179—171.5)

This invention relates to signalling means and more particularly to means for modulating the phase or the frequency of a high frequency carrier wave in accordance with a signal.

One known method of phase modulation consists in superimposing a current representing a signal upon a high frequency carrier current of substantially greater amplitude and deriving from the resulting complex current a train of short impulses timed to coincide with the instants at which the complex current passes through its zero values. By selecting alternate impulses and suppressing the others there is obtained an impulse train rich in harmonics, all of which are phase modulated in accordance with the signal in degrees proportional to their respective frequencies and any of which may be selected for utilization by means of suitable filters.

The present invention provides improved means for producing a phase modulated impulse train by the general method described above. Its principal objects are to permit an increase in the frequency at which the modulation step may be performed and to simplify the selection of the desired set of alternate impulses.

The modulating device of the invention consists of a focussed cathode ray or electron beam tube in which there is interposed in the path of the beam a shield plate having a narrow slot like aperture so placed that the beam can pass to the target anode only when it is in its undeflected position. The tube is provided also with beam deflecting means upon which the input oscillations, carrier and signal, may be impressed. When the deflecting means is subject to the influence of a high frequency sinusoidal oscillation the beam is caused to swing laterally in synchronism with the oscillation so that it traverses the aperture in the shield plate at the instants of zero intensity of the oscillation. Electrons would thus, in the absence of any retarding action, pass to the target in spurts of short duration at equal time intervals corresponding to the half period of the oscillation cycle and would produce a synchronous train of sharp current impulses in a circuit connected to the target. If, now, a signal oscillation of relatively small amplitude be superimposed upon the high frequency oscillation, the timing of the electron spurts and the resulting current impulses will be modified, one set of alternate impulses being advanced in time or phase by amounts proportional to the instantaneous value of the signal oscillation and the other set being correspondingly retarded. Each set of impulses is phase modulated in accordance with the signal,

but the two sets are modulated in opposite senses and to obtain a single phase modulated wave it is necessary to select one set to the exclusion of the other. This is accomplished in accordance with the invention by means of a grid interposed between the target and the apertured shield upon which there is impressed a carrier frequency voltage substantially in phase with one set of the electron spurts to the target. During the negative half of the grid voltage cycle the flow of electrons to the target is suppressed with the result that only the alternate impulses appear in the output circuit.

The invention will be more fully understood from the detailed description which follows and by reference to the accompanying drawing of which:

Fig. 1 is a circuit schematic of a modulating system embodying the invention, and

Fig. 2 is a perspective view of the electrode structures in one form of the modulating device of the invention.

Referring to Fig. 1, 10 is a cathode ray or electron beam tube the electrodes of which comprise an indirectly heated cathode 11, the heater circuit of which is not shown, an apertured anode 12, a target anode 13, a shield 14 having a single narrow aperture running parallel to the axis of the cathode, a grid 15 located between shield 14 and target 13, and electrostatic deflecting plates 16 and 17. Focussing of the electron stream is effected by means of a magnet 18 so disposed in relation to the tube that the field between its poles is parallel to the central axis of the electrodes.

Cathode 11 is grounded and is connected to anode 12 through battery 19, or other convenient source of direct current, which establishes an electron stream directed generally towards target 13. An output circuit connected to target 13 comprises a tuned transformer 20 and a direct current source 21, the negative pole of which is also grounded.

Deflecting plates 16 and 17 constitute the input electrodes of the vacuum tube and are connected to the input circuit by leads 22 and 23. The input circuit, which is balanced with respect to ground potential, includes a tuned high frequency transformer comprising a primary winding 24, to which is connected a high frequency carrier wave source 27, and a divided secondary winding 25, 26, the two parts of which are connected in series through high frequency by-pass condensers 28 and 29. The source 27 should preferably be one having a high degree of frequency stability, for

example, a quartz crystal controlled vacuum tube oscillator. Bridged across the outer terminals of condensers 28 and 29 is a signal current circuit including an adjustable attenuator 30, transformer 31, and a signal current source 32, for example, a microphone and its energizing battery. The shield 14 and the deflecting plates are all polarized at the same positive potential, which may be somewhat less than the potential of target 13. This polarizing potential may be derived from source 21 in the manner indicated in the drawing, the connection to the deflecting plates being made through lead 33 which is tapped into the mid-point of the secondary winding of transformer 31.

Grid 15 is coupled to one side of the input circuit through a phase shifting network comprising condenser 34 and resistance 35, one terminal of which is grounded. The purpose of this phase shifter is to ensure that the carrier frequency potential between grid 15 and ground is substantially in quadrature with the carrier frequency potential between the deflecting plates or between either plate and ground. Accordingly, condenser 34 should have a substantially higher impedance than resistance 35 at the carrier frequency and should be of sufficiently low capacity so that the balance of the input circuit is not seriously disturbed. If need be the circuit balance may be maintained by the connection of a similar condenser and resistance combination between plate 17 and ground.

The electron beam tube is of the same general type as is disclosed in my copending application, Serial No. 342,601, filed June 27, 1940. There it is shown that the use of an axial magnetic field for focussing purposes brings about the result that an electrostatic field between the deflecting plates produces a deflection of the electron beam in a plane parallel to the plates instead of towards the one or the other. I have also found that the deflection sensitivity of the beam is great so that a large deflection can be produced with a quite small potential difference between the plates.

In the operation of the system the field magnet should first be oriented so that in the absence of any alternating voltage on the deflecting plates the focussed beam is centered squarely on the aperture in shield plate 14. This adjustment may be checked by measuring the direct current in the output circuit connected to anode 13. Signal and carrier frequency voltages are superimposed upon each other in the secondary windings 25 and 26 of the carrier input transformer, the signal voltage being adjusted by means of attenuator 30 so that its maximum amplitude does not exceed a value of about half the amplitude of the carrier wave. The resulting complex voltage impressed on the deflecting plates causes a synchronous deflection of the electron beam so that it is intercepted completely by shield 14 except at the instance it passes over the aperture therein.

Because of the phase shift produced by network 34, 35 through which grid 15 is coupled to deflector 16, the carrier frequency potential on grid 15 is in quadrature with the potential between the deflecting plates. It will therefore have its maximum values at the instants the carrier component of the voltage between the deflectors has zero value and, since the signal voltage is small compared with the carrier voltage, the voltage maxima on the grid will coincide with electron spurts flowing to plate 13. Alternate spurts en-

counter a negative potential on grid 15 and so are prevented from reaching plate 13 while the intermediate spurts are aided in their flow to the plate by a positive potential on the grid. One set of alternate impulses is thus selected to the exclusion of the other, the selected group, as already pointed out, forming a true phase modulated train.

The individual impulses of the train so produced are sharp and of short duration relatively to the carrier wave half period. The train is therefore rich in harmonics all of which are modulated in accordance with the signal in degrees directly proportional to their respective frequencies. Any desired harmonic may be selected by appropriate tuning of the output transformer 20 and then delivered to a utilization circuit connected to the terminals of the transformer secondary winding.

It will be understood that the showing of Fig. 1 is of a schematic character and admits of various modifications without departing from the method of operation described. The excitation of the suppressor grid 15 may, for example, be obtained directly from carrier source 27 through a circuit containing an adjustable phase shifter of any well known type. The vacuum tube, while still employing the same methods of focussing, deflecting, and suppression of the unwanted impulses, may take different forms, one form which has been found to be advantageous having the electrode structure shown in Fig. 2.

In Fig. 2 some of the tube structure, such as as the glass envelope and the electrode supporting means, has been omitted for the sake of clarity in the showing of the essential electrode form and arrangement. Part of the electrode structure is broken away to show more clearly the internal arrangement of the parts.

Two electron beams are provided by a symmetrical concentric arrangement of the electrode. The cathode 11 is the central electrode and the anode 12 takes the form of helical grid surrounding the cathode spaced relatively close thereto. The cathode, which is of the indirectly heated type, is provided with an active coating only on a short section lying centrally within the grid. The shield electrode 14 is in the form of short cylinder concentric with the cathode and provided with two narrow axial slots 36, 36', located at diametrically opposite points as shown. The deflecting electrodes, 16 and 17, consist of two circular plates with centrally located circular apertures and are so placed as to substantially close the ends of the cylinder formed by shield 14 without making electrical contact with it. Two target anodes 13, 13', and two suppressor grids 15, 15' are provided, one of each being located outside the slots in shield ring 14 as shown. The electrodes may advantageously be enclosed within a cylindrical glass envelope coaxial with the cathode and the focussing magnet 18 may be adjustably mounted outside the envelope. With the arrangement shown in Fig. 2, I have been able to construct efficient modulating tubes the outside diameter of which does not exceed about 2.25 inches.

The modulator circuit using a tube of the type shown in Fig. 2 is the same as is shown in Fig. 1, the two targets 13 and 13' being connected directly together and the two suppressor grids being likewise directly connected together so that each pair constitutes a single electrode so far as the circuits external to the tube are concerned.

The electrode system per se has little directive

effect on the flow of electrons, consequently electrons leaving the cathode would ordinarily tend to flow in all radial directions towards the positively polarized shield ring. However, in the presence of a magnetic field directed diametrically through the space enclosed by the shield ring, the electrons divide into two oppositely directed streams parallel to the magnetic field. A field strength of about 160 gauss, which is readily obtainable with a permanent magnet, produces adequately sharp focussing of the beams and, by proper orientation of the magnet, the focussed beams may be centered simultaneously on the slot 36 and 36'. Under the influence of a potential difference between the deflecting plates both beams are deflected synchronously, but in opposite directions, that is, one is deflected clockwise and the other anticlockwise. This has no effect on the timing of the impulses in the output circuit.

An actual tube constructed in accordance with Fig. 2 employed deflecting plates of 1.67 cm. radius spaced one centimeter apart. The cathode was $\frac{1}{4}$ inch in diameter and was coated with active material over a length of $\frac{1}{4}$ inch near its end. A focussing field strength of 160 gauss gave a beam $\frac{1}{4}$ inch long and $\frac{1}{8}$ inch wide at the radius of the shield plate, about 1.8 cm. The vertical slots in the shield plate were about $\frac{3}{8}$ inch wide and $\frac{1}{4}$ inch long. With positive voltages of 22.5, 30, and 130 on grid 12, shield 14, and target anode 13 respectively, a total target current of 1.4 milliamperes was obtained. These voltages provided a high deflection sensitivity. Increasing the shield and target voltages to 90 and 180 volts respectively increased the target current to 5.4 milliamperes, but diminished the deflection sensitivity somewhat. These values serve to show that the device is capable of giving impulses of substantial intensity with relatively low polarizing voltages.

Using a tube of the type described above in a circuit like that shown in Fig. 1, phase modulation of a carrier current having a frequency of 1.25 megacycles was readily accomplished and the impulses of the modulated train were found to be sufficiently sharp to permit a strong sixteenth harmonic of 20 megacycles to be selected by the tuned output transformer. Considerations of the electron transit time of the electrons as they pass between the deflecting plates show that fundamental carrier frequencies as great as 300 megacycles may be used and that phase modulated harmonics of several thousand megacycles may be obtained.

What is claimed is:

1. The method of phase modulation which comprises producing a complex oscillation by the superposition of signal oscillations upon high frequency sinusoidal oscillations of substantially greater amplitude, controlling the deflection of a focussed beam of electrons in accordance with the complex oscillation, deriving a train of cur-

rent impulses synchronous with the instants of zero intensity of the complex oscillation by intercepting the swinging electron beam at its undeflected position, and periodically retarding the electrons of the beam to suppress alternate current impulses.

2. Phase modulating apparatus comprising in combination, means for producing a complex oscillation by the superposition of signal oscillations on high frequency sinusoidal oscillations of substantially greater amplitude, means producing a focussed electron beam, an anode disposed in the path of the beam so as to receive electrons only when the beam is in its undeflected position, an output circuit connected to said anode, means for deflecting the beam in accordance with the complex oscillation whereby current impulses synchronous with the instants of zero value of the complex oscillation are produced in said output circuit, and means for periodically retarding the electrons of the beam to suppress alternate current impulses.

3. Apparatus in accordance with claim 2 in which the beam deflecting means comprises a pair of plates arranged to produce an electric field perpendicular to the beam proportional to the intensity of the complex oscillation and in which the electron retarding means comprises a grid located in front of the anode and energized by a potential in phase quadrature with the high frequency potential between the said deflecting plates.

4. Phase modulating means comprising an electron tube, means for producing a focussed electron beam in said tube, means for deflecting the beam so produced in accordance with impressed oscillations, an anode disposed in said tube to receive the electron beam in its undeflected position only, a grid interposed in the path of the beam to said anode, an input circuit connected to said deflecting means, a source of carrier oscillations and a source of signal oscillations included in said input circuit, and a circuit coupling said grid and said carrier source, said coupling circuit having a phase characteristic such as to provide a voltage on the grid in substantial phase quadrature with the deflection of the beam.

5. Phase modulating apparatus comprising means producing a focussed electron beam, means for deflecting the beam from a central path in accordance with the instantaneous value of superposed carrier and signal oscillations, an anode located in the central path of the beam, an output circuit connected to said anode, a shield plate in front of said anode, said shield plate having an aperture therein so located that the beam can pass to the anode only in its undeflected position, a grid interposed between said shield and said anode, and means for energizing said grid with a potential substantially in phase quadrature with the deflection of the beam.

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