

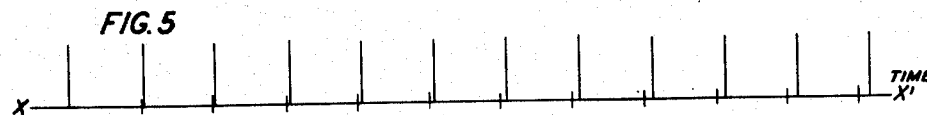
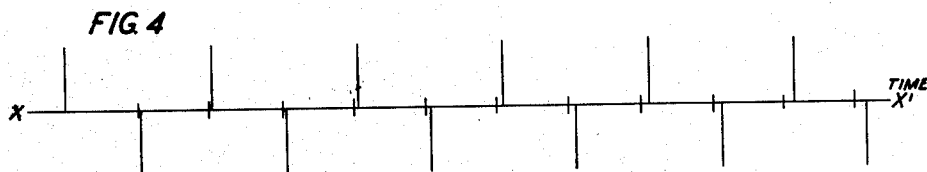
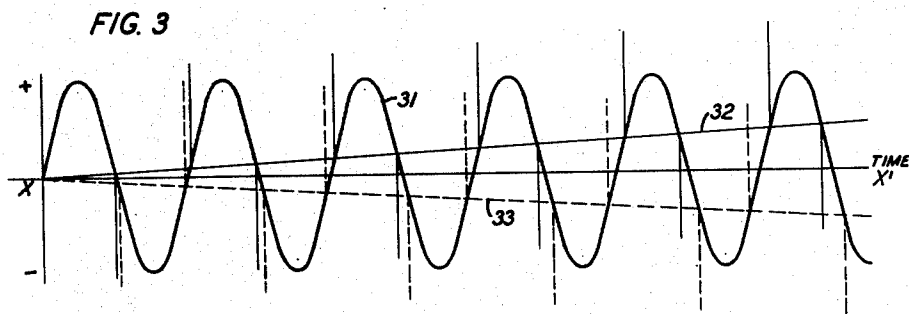
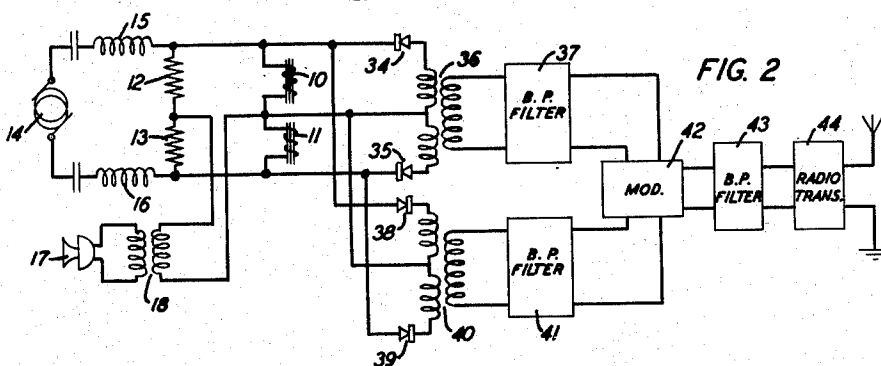
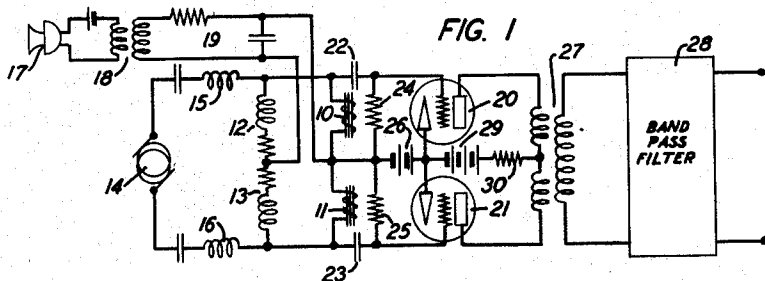
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PHASE MODULATING SYSTEM

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PHASE MODULATING SYSTEM

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5 Claims. (Cl. 179—171.5)

This invention relates to an improved method of and means for modulating the phase or the frequency of a carrier wave in accordance with a signal.

In the usual type of phase modulation system the signal is made to modulate the phase of a relatively low frequency carrier oscillation to a small extent, generally less than 30 degrees, and by successive steps of frequency multiplication the degree of modulation is increased as much as may be desired. Where very large frequency deviations are wanted, as for transmission by radio, multiplication of the initial modulation by factors of the order of one or two thousand may be necessary and, in the carrying out of the multiplication various difficulties may arise. In particular, since the steps of multiplication are essentially steps of harmonic production, difficulty may arise in the selection of a desired harmonic from the multiplicity of other harmonics produced at the same time. This tends to limit the amount of multiplication that can be effected in a single stage and, therefore, to make necessary a large number of multiplier stages. The principal objects of the invention are to simplify the process of frequency multiplication in systems of the above type and to reduce the number of multiplication stages needed for the production of wide swing modulation.

The nature of the invention and its mode of operation will be understood from the detailed description which follows and by reference to the accompanying drawing, of which:

Fig. 1 is a circuit diagram of a phase modulation system embodying the invention;

Fig. 2 shows a modified form of the invention; and

Figs. 3, 4 and 5 are diagrams illustrating the operation of the invention.

The invention makes use of the method disclosed in my copending application, Serial No. 354,357 filed August 20, 1940, according to which modulation is effected by varying the timing or phase of recurrent impulses produced by a carrier current and selecting from the modulated impulse train one of its high frequency harmonic components. As is shown in the above-mentioned application, the harmonic components of the modulated impulse train are each modulated in phase in degrees proportional to their respective frequencies. In the arrangement disclosed in my earlier application, the modulator produces a single useful impulse for each cycle of the carrier current and the harmonics of the resulting impulse train are, therefore, spaced

apart at intervals equal to the carrier frequency. By the present invention two useful impulses are produced for each carrier current cycle with a consequent doubling of the frequency intervals between the harmonic components. The increased spacing of the harmonics permits the use of simplified filters for the selection of desired harmonic components and also enables harmonics of very high order to be selected and utilized.

Referring to Fig. 1, the modulating device comprises two similar impulse coils 10 and 11, each consisting of a small finely laminated closed core of a readily saturable magnetic material wound with a few turns of wire. A nickel-iron alloy containing about 78.5 per cent nickel is suitable for the core construction, this material having the property of becoming saturated at extremely low magnetic forces and exhibiting very little hysteresis. The windings of the coils are connected in series and together with a pair of equal impedances 12 and 13 form a balanced bridge. In one diagonal of the bridge is included a high frequency carrier source 14 in series with resonant impedances 15 and 16, which are tuned to the frequency of the carrier oscillations. The other diagonal includes a signal source 17, such as a microphone, a transformer 18 and a resistance capacity network 19. By means of these circuits signal currents and carrier currents may be superimposed upon each other in the impulse coil windings, the connections being such that the high frequency currents flow in the same direction in the windings of both coils while the signal currents flow in opposite directions. The bridge arms 12 and 13 should be such as to offer a relatively low and substantially uniform impedance to currents of all signal frequencies and to present a high impedance to the carrier current and its harmonics. Series combinations of resistance and inductance, as shown in the drawing, may be used for these impedances, but more complex networks may be desirable in some instances. The impedances may be made adjustable to maintain a balance of the bridge circuit and to ensure equal division of the signal current between the two impulse coils. The resistance-capacity network 19 has the effect of attenuating the various components of the signal current in degrees proportional to their respective frequencies. Since the modulating device itself is essentially a phase modulator, this predistortion of the signal is necessary when it is desired that the final modulated wave should have the characteristics of frequency modulation. If trans-

mission by phase modulation is desired, the network 19 may be omitted.

The currents from the two sources should be so adjusted that the carrier current is substantially greater in amplitude than the maximum signal current and is sufficiently strong to cause complete saturation of the impulse coil cores throughout nearly the whole carrier cycle.

From the terminals of coils 10 and 11 the circuit extends to the input terminals of push-pull connected vacuum tubes 20 and 21, coupling between the coils and the tubes being provided by series capacities 22, 23, and shunt resistances 24, 25. A common source 26 provides a negative voltage for the grids of the vacuum tubes sufficient to bias the tubes beyond their plate current cut-off points. The output circuit of the tubes includes a three-winding transformer 27 followed by a band-pass filter 28. The transformer has two primary windings which may be wound either in aiding or in opposing inductive relation according to the character of the output desired. Plate current is supplied from a source 29 through a resistance 30 in a path connecting the cathodes and the junction point of the transformer primaries.

The action of the impulse coils in the generation of voltage impulses when their windings are traversed by an alternating current is described in an article by Peterson, Manley, and Wrathall, entitled "Magnetic generation of a group of harmonics," Bell System Technical Journal, October 1937, page 437. There it is shown that a sharp voltage impulse is induced in the coil windings at the moment the current passes through zero value. When a condenser and a resistance are connected in series across the coil, as shown in Fig. 1, the induced voltage impulse is followed immediately by a sudden discharge of the condenser which produces a sharp impulsive voltage drop in the resistance. The sharpness of the induced voltage impulse depends upon the saturation characteristic of the magnetic core and on the strength of the alternating current. With core materials of the kind mentioned above impulses lasting less than one hundredth part of the alternating current period are readily obtained. The sharpness and the duration of the condenser discharge impulse may be regulated by the choice of the capacity and resistance values.

If the carrier current were acting alone each of the impulse coils would generate a train of alternate positive and negative impulses, uniformly spaced in time and coinciding with the instants of zero value of the current. When the signal currents are also present the impulses occur at the moments of zero value of the complex current produced by the superposition of the carrier and the signal and are modulated in their timing or phase in accordance with the signal current intensity. The positive and the negative impulses generated by each coil are modulated in opposite senses, the positive impulses being advanced in their timing when the negative impulses are retarded and vice versa. Also, since the signal currents flow in reverse directions through the two windings, the modulations of the impulses generated by the two coils differ from each other in certain respects, the characteristics of the modulations and their differences being illustrated by Fig. 3.

In Fig. 3 the horizontal line XX' represents the time axis, sinusoidal curve 31 represents the carrier current, which has the same value at all

times in both impulse coils, line 32 represents the signal current in one of the impulse coils for a portion of a single signal cycle, and dotted line 33 represents the equal component of the signal current flowing in the reverse direction through the other coil. For convenience the signal currents are plotted with their phase reversed so that the moments of zero value of the complex currents in the two coils may be indicated by the positions along the time axis of the intersections of the respective signal current curves with sinusoidal curve 31. The solid vertical lines coincident with the intersections of curves 31 and 32 represent, for example, the impulses generated in coil 10 and the dotted vertical lines coincident with the intersections of curves 31 and 33 represent the impulses generated in coil 11. It will be noted that, for the particular conditions indicated, the positive impulses of the first group are retarded in time and the negative impulses of the second group are likewise retarded in time and, moreover, that the impulses in these two retarded groups occur alternately at intervals corresponding to about one-half of the carrier oscillation period. The two retarded groups when combined would constitute a single train of similarly modulated impulses occurring at the rate of two for each carrier cycle. Likewise the negative impulses from coil 10 and the positive impulses from coil 11 are both advanced in their timing, that is, are both modulated in the same sense, and when combined would provide another train of similarly modulated impulses of doubled frequency.

In the system of Fig. 1 the desired impulses are selected from the trains generated in the two coils by means of the biased amplifier tubes 20 and 21. Because of the strong negative bias tube 20 responds only to positive impulses generated in coil 10 and tube 21 responds only to impulses of opposite sign generated in coil 11. The selected impulses are repeated in the plate circuits of the tubes and are transmitted through transformer 27 to band-pass filter 28. If the two primary windings of transformer 27 are connected in aiding inductive relation, the impulse train delivered to the filter takes the form shown in Fig. 4, the alternate impulses being of opposite sign. If the polarity of one of the windings is reversed so as to place the windings in opposing inductive relation, then the corresponding impulses will be reversed in sign and the output train will take the character shown in Fig. 5. In these figures the short lines crossing the time axis represents half periods of the carrier wave and the displacement of the impulses from these marks represents the modulation produced by the signal current.

A train of the character shown in Fig. 4 may also be obtained from the fall of potential in resistance 30 common to the two plate circuits. Accordingly in a modified circuit arrangement the input terminals of filter 28 could be connected to the ends of resistance 30.

The vacuum tubes 20 and 21 function principally as a pair of oppositely poled rectifiers and, if desired, other types of rectifier may be substituted for them. Their use has the advantage, however, of providing a substantial amplification of the energy of the impulses, thereby diminishing the amount of subsequent amplification required.

Analysis of the impulse train of the types shown in Figs. 4 and 5 shows that each is composed of a multiplicity of harmonics of the carrier wave

each harmonic being phase modulated to an extent proportional to its frequency. If the impulses are very short relatively to the carrier period all of the harmonics up to a very high order will be present in substantially signal strengths. In practical systems harmonics as high as the fortieth are readily obtained. In the case of impulse trains alternately positive and negative as shown in Fig. 4, the harmonic content comprises the fundamental carrier frequency and only its odd harmonics. The train shown in Fig. 5 comprises only the even harmonics of the carrier frequency. In both cases the separation of the harmonics is twice the frequency of the carrier. Band-pass filter 28 is designed to select a desired harmonic, for example the twentieth, to the exclusion of the others and by virtue of the increased separation of the harmonics this exclusive selection is greatly simplified.

In the modification shown in Fig. 2 two doubled frequency impulse trains modulated in opposite senses are derived from the impulse coils and combined in such a manner as to produce a modulated wave of relatively low frequency but having a very large phase modulation. This wave after some subsequent frequency multiplication may be utilized for transmission by radio.

The circuit up to and including the impulse coils may be the same as the corresponding portion of the circuit shown in Fig. 1. At the terminals of the impulse coils the circuit branches into two paths. One path includes rectifiers 34 and 35 in its opposite sides, the outputs of which are supplied to the primaries of a three-winding transformer 36. In this embodiment the condenser-resistance discharge paths are omitted and the magnetically induced impulses are applied directly to the rectifiers. Rectifiers 34 and 35 are so poled as to transmit respectively the positive impulses from coil 10 and the negative impulses from coil 11, both of which groups are modulated in the same sense as shown by Fig. 3. These selected impulses are transmitted through transformer 36 and are impressed on band-pass filter 37 designed to select a desired harmonic. The other branch path contains rectifiers 38 and 39 which are so poled as to transmit the negative impulses from coil 10 and the positive impulses from coil 11, these groups being modulated in the same sense, but in the opposite sense from the groups selected by rectifiers 34 and 35 in the first path. The rectifiers deliver the selected impulses to the primaries of three-winding transformer 40 through which they are transmitted to a second band-pass filter 41 designed to select a harmonic oscillation different from that selected by filter 37. The outputs of the two filters are thus waves of different mean frequencies phase modulated in opposite senses by the same signal. These waves are impressed together on a modulator 42 in which they coact to produce a third wave of the differential frequency which is selected by band-pass filter 43. Since the two waves impressed on the modulator are phase modulated in opposite senses, the difference frequency modulation component has a phase modulation equal to the sum of the modulations of the two impressed waves. From the output of 43 the differential frequency wave is supplied to a radio transmitter 44 in which may be included such frequency multiplication means as may be necessary to raise the frequency to the value desired for radiation. This system permits very great multiplication of the phase modulation to

be obtained with a much smaller multiplication of the mean carrier frequency.

What is claimed is:

1. A phase modulating system comprising a source of carrier waves, a source of signaling currents, a pair of magnetic impulse coils, a circuit including said coils in series with each other and one of said sources, a circuit connecting the other of said sources to said coils in parallel, each of said coils under the influence of superimposed currents from said sources producing a train of alternate positive and negative voltage impulses at the carrier frequency rate, rectifying means for selecting positive impulses generated in one of said impulse coils and negative impulses generated in the other of said coils, circuit means for combining the selected impulses to provide a single impulse train, and means for selecting a desired harmonic component of the train so produced.

2. A phase modulating system comprising a source of carrier waves, a source of signal currents, a pair of magnetic impulse coils, a circuit including said coils in series with each other and one of said sources, a circuit coupling the other of said sources to said coils in parallel, each of said coils under the influence of the superimposed currents from said sources producing a train of voltage impulses of alternating polarity, one for each half cycle of the carrier wave, the timing of the impulses of opposite polarities being modulated in reverse directions by the signal currents, output circuits coupled to said coils, rectifying means in said output circuits poled to select impulses modulated in the same sense, circuit means for combining the selected impulses to constitute a single train, and means for selecting a single harmonic of the train so produced.

3. A phase modulating system comprising a source of carrier waves, a source of signal currents, a pair of magnetic impulse coils, circuit means for supplying currents from one of said sources to the windings of said coils to magnetize the cores of both coils in the same direction, a circuit for supplying current from the other of said sources to said coils to magnetize the cores of said coils in opposite directions, each of said coils under the influence of the superimposed currents producing a train of voltage impulses of alternating polarity, one for each half cycle of the carrier wave, output circuits coupled to said coils, rectifying means in said output circuits poled to select impulses of one polarity from one of said coils and impulses of the reverse polarity from the other of said coils, a load impedance, means for transmitting the selected impulses to said load impedance, and a filter included in said load impedance for selecting a single harmonic of the impressed impulses.

4. A phase modulation system comprising a source of carrier waves, a pair of magnetic impulse coils, a circuit including said carrier source and said coils in series, output circuits coupled to said coils, a rectifier in each of said output circuits, said rectifiers being poled to transmit currents of opposite polarities respectively, a load impedance coupled jointly to said output circuits, a signal source, and a circuit connecting said impulse coils in parallel with said signal source.

5. A phase modulation system comprising a source of carrier waves, a pair of magnetic impulse coils, a circuit including said source and said coils in series, said coils under the influence of currents from said source generating voltage impulses of alternating polarity at the instants

of zero value of the current, output circuits connected to said coils, a rectifier in one of said output circuits poled to transmit impulses corresponding to one set of alternate zeros of the carrier current, a rectifier in the other of said output circuits poled to transmit impulses corresponding to the other set of alternate zeros of

the carrier current, a load impedance, circuit means for supplying the selected impulses to said load impedance, a source of signal currents, and a circuit coupling said impulse coils in parallel to said signal source.

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