

Aug. 25, 1942.

H. RODER

2,294,209

FREQUENCY MODULATION SYSTEM

Filed Nov. 12, 1938

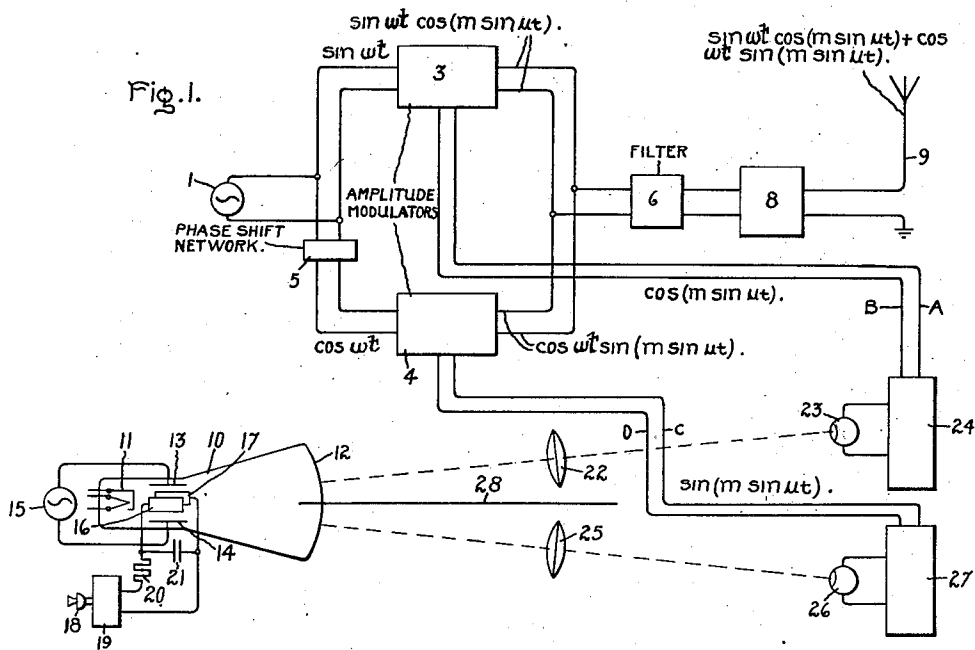


Fig. 2.

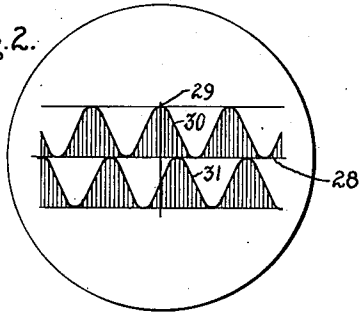


Fig. 3.

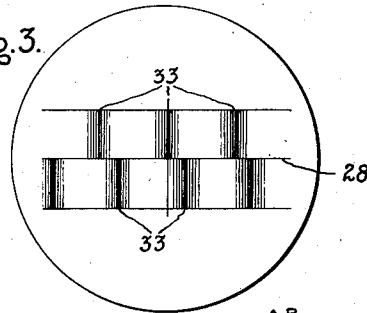
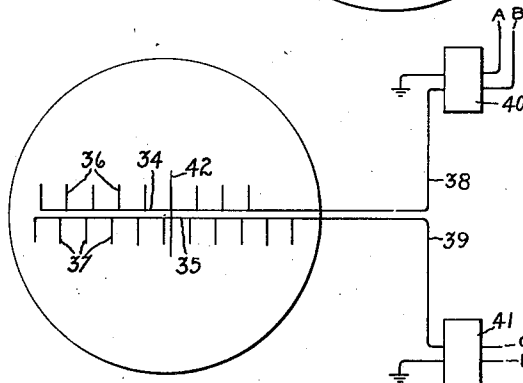


Fig. 4.



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UNITED STATES PATENT OFFICE

2,294,209

FREQUENCY MODULATION SYSTEM

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Application November 12, 1938, Serial No. 240,145

15 Claims. (Cl. 179—171.5)

My invention relates to signaling systems, and more particularly to such systems employing so-called, phase, or frequency modulation, of a carrier wave, that is, modulation of the frequency of the carrier wave in accordance with a signal. It has for one of its objects to provide a new and improved method and means for producing a carrier wave having its frequency modulated in accordance with the signal.

A further object of my invention is to produce a frequency modulated carrier wave without use of the usual frequency modulating means, i. e., without varying the frequency of any source in accordance with the signal. An object of the invention is to effect frequency modulations by the use of equipment such as is commonly used in amplitude modulation systems.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 represents an embodiment of my invention; Figs. 2 and 3 represent details thereof, and Fig. 4 represents a modification.

A phase or frequency modulated wave is mathematically represented by the following expression $\sin(\omega t + m \sin \mu t)$. This expression, by trigonometric methods, may readily be shown to be equal to the following: $\sin \omega t \cos(m \sin \mu t) + \cos \omega t \sin(m \sin \mu t)$. In these expressions $\omega = 2\pi f$ where f is the frequency of the carrier wave:

t = time

μ = the signal frequency; and m is a constant for phase modulation, and for frequency modulation

$m = \Delta\omega/\mu$ where $\Delta\omega$ is the maximum shift of the carrier frequency produced by the signal.

Referring to Fig. 1 I have indicated at 1 a source of carrier wave oscillations the output of which is supplied to two amplitude modulators 3 and 4, each of which may be of any well-known design for effecting amplitude modulation of a carrier wave. The oscillations supplied to amplitude modulator 4 are transmitted through a phase-shifting network 5 whereby these oscillations are displaced in phase by 90 degrees from the oscillations supplied to modulator 3. Accordingly the oscillation supplied to modulator 3 from source 1

may be represented by the expression $\sin \omega t$ and the oscillations supplied to modulator 4 may be represented by the expression $\cos \omega t$.

Conductors A and B, which comprise the signal input circuit of modulator 3 are supplied with currents which may be represented by the expression $\cos(m \sin \mu t)$, and similarly the conductors C and D which comprise the input to the modulator 4 is supplied with currents which may be represented by the expression $\sin(m \sin \mu t)$. These latter currents are of the signal frequency μ and modulate the currents of the carrier wave frequency supplied to the respective modulators 3 and 4 to produce, in the output of the modulator 3, a current which may be expressed $\sin \omega t \cos(m \sin \mu t)$ and at the output of modulator 4, a current which may be expressed by $\cos \omega t \sin(m \sin \mu t)$. These terms are simply the products of the terms expressing the carrier wave and signal input in the two amplitude modulators 3 and 4. These two currents are additively combined at the input of filter 6 which is tuned to the carrier frequency and the output of which is supplied through a power amplifier 8 and radiated from an antenna 9. The current in the antenna is, of course, represented by the expression $\sin \omega t \cos(m \sin \mu t) + \cos \omega t \sin(m \sin \mu t)$ which, if m be constant, represents what has been called a phase modulated wave, or if m represents $\Delta\omega/\mu$, then this expression represents what has been called a frequency modulated wave.

The remainder of the apparatus of Fig. 1 comprises means for generating the two currents which are supplied to the modulators over conductors A, B; and C, D. This means, the apparatus of Fig. 1, comprises a cathode ray tube 10 having therein the usual cathode 11 and means whereby a beam of electrons is produced and directed upon a spot on a fluorescent screen at the end 12 of the cathode ray device. The direction of the beam is controlled by four deflecting plates comprising a pair of horizontal plates 13 and 14 between which oscillations of very high frequency such as, for example, five megacycles or other suitable frequency much higher than the signal frequency are supplied from a source 15. These plates serve to deflect the beam upwardly and downwardly so as to cause it, in the absence of signal currents, to produce a luminescent line upon the fluorescent screen of the cathode ray device. The beam is also deflected horizontally by means of a pair of electrodes 16 and 17 between which the signal oscillations are supplied. The source of signal oscillations is represented as a microphone 18 the output of which is sup-

plied through an amplifier 19 and a network comprising a series resistance 20 and shunt condenser 21. In this way the luminescent vertical line produced by the source 15 of the cathode ray oscillograph is caused to deflect bodily horizontally across the screen in accordance with the signal currents. Light from the upper portion of the cathode ray screen 12 is suitably focused by means of a lens 22 upon a photoelectric cell 23 the output of which is amplified and supplied between the conductors A and B. Light from the lower portion of the cathode ray screen is focused by means of a lens 25 upon a photoelectric cell 26 the output of which is amplified by amplifier 27 and supplied between conductors C and D.

In order that light from the upper portion of the cathode ray screen may not affect the photoelectric cell 26, and similarly, in order that light from the lower portion of the screen may not affect photoelectric cell 23 a suitable screen 28 is provided which extends between the lenses 22 and 25 and to a point closely adjacent the middle of the cathode ray screen.

On the end of the cathode ray tube either exteriorly or interiorly thereof, but between the fluorescent material and the focusing lens is a suitable coating of opaque material having a design such as is indicated in Fig. 2 in which the middle portion of the screen is indicated by the line 28, which may be taken to represent the shield 28 of Fig. 1. The portion of the screen above line 28 affects photoelectric cell 23 and that below line 28 affects photoelectric cell 26. The shaded area of both portions, or sections, as shown in Fig. 2, is covered with opaque material so that light from the fluorescent screen within the tube is not visible exteriorly thereof and only light from that portion of the fluorescent screen not covered by the opaque material affects the photoelectric cells.

The vertical line 29 represents the luminescent line which is produced by the cathode ray beam when no signal currents are applied to the horizontal deflecting plates. When signal currents are applied, this line 29 moves bodily to the right and to the left, parallel with itself, in accordance with the variations of the signal currents. Since the upper portion of each of the shaded areas are bounded by sinusoidal lines 30 and 31 respectively which are displaced with respect to each other, and with respect to the mid-position of line 29, by 90 degrees, it will be seen that the light which affects the photoelectric cell 23 varies as a cosine function of the signal currents and similarly light from the lower section of the screen which affects photoelectric cell 26 varies as a sine function of the signal current. Accordingly, currents representing this cosine function of the signal currents appear upon conductors A and B at the output of amplifier 24 and similarly currents representing the sine function of the signal currents appear on conductors C and D at the output of amplifier 28.

For frequency modulation, as previously stated, m must represent $\Delta\omega/\mu$, that is, the ratio of the shift in the carrier frequency to the signal frequency. To effect this it is merely necessary to include the network 20—21 in the output of the signal amplifier 19, this network being so proportioned that the voltage between plates 16 and 17 varies inversely with the frequency. Thus the current radiated from the antenna is a frequency modulated current, the modulation

being in accordance with the current in microphone 18.

By the terms "phase modulation" and "frequency modulation" as used herein, I do not intend to infer that modulation of the frequency of the carrier wave is not involved in both of these forms of modulation. In fact, were the signal current of simple sine wave form, there would be no difference between these forms of modulation. Were the signal current of complex form the frequency of the carrier wave is still modulated in both forms of modulation. Phase modulation is merely that form of frequency modulation in which the amplitude of the frequency shift of the carrier is directly proportional to the modulation frequency as indicated by the above mathematical relationship $m = \Delta\omega/\mu$.

Of course, instead of covering a portion of the screen with opaque material and leaving the rest completely visible the entire screen may be covered with material having a varying degree of translucence, the variations being in accordance with the sine and cosine function. Such a coating for the end of the cathode ray tube is indicated in Fig. 2 in which the shaded areas 33 represent portions of minimum visibility of the screen and the unshaded portions represent the portions of greater visibility of the screen, the translucence of the material varying between these areas in accordance with a sine wave gradation. Of course, the light falling upon the photoelectric cell varies in exactly the same way as has been described in connection with Fig. 2.

In place of the fluorescent screen and the coatings illustrated in Figs. 2 and 3, conducting grids as represented at 34 and 35 in Fig. 4 may be positioned across the end of the cathode ray device. These grids may comprise parallel conductors 36 and 37 respectively spaced at regular intervals across the end of the cathode ray tube, the conductors 36 of one grid 34 being displaced from the conductors 37 of the other grid 35 by a quarter of the distance between the conductors. The conductors 36 are connected together and to conductor 38 leading to the signal amplifier 40. Similarly conductors 37 are connected together and to conductor 39 leading to signal amplifier 41.

The vertical line transcribed by the cathode ray beam, in the absence of signal currents, thus cuts across the two grids at a predetermined point indicated by the vertical line 42, and when deflected longitudinally of the two grids by signal currents causes varying charges to be impressed upon the conductors 38 and 39. That is, the charge on either conductor is a maximum when the beam falls directly upon one of the conductors 36 or 37. This charge then gradually diminishes to a minimum when the beam falls midway between such conductors. It then increases as the beam approaches the next conductor. Thus the charge on conductors 38 and 39 varies sinusoidally. Due to the relative displacement of the conductors 37 relative to conductors 36 along the lengths of the grids, the charge on conductor 38 varies as the cosine of the signal current and that on conductor 39 varies as the sine of the signal current. These charges are amplified in amplifiers 40 and 41 and supplied to the respective circuits A, B and C, D, whereby they are caused to modulate the carrier wave in the respective modulators 3 and 4.

While I have shown but two ways of producing the two currents $\cos (m \sin \mu t)$ and $\sin (m \sin \mu t)$, it will be understood that any means capable of producing such currents with the sinusoidal variations therein displaced in phase by 90 degrees may be employed. Many such devices may be devised.

Thus, while I have shown only particular embodiments of my invention it will, of course, be understood that I do not wish to be limited thereby since many modifications may be made and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

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

1. In combination, two sources of carrier wave oscillations of the same frequency one of said sources being displaced in phase from the other by substantially ninety degrees, a source of signal current, means for modulating the oscillations of each of said carrier wave sources in accordance with a sinusoidal function of said signal current, the modulation of one of said carrier wave sources being displaced in phase by ninety degrees from that of the other, and additively combining the outputs from said modulating means.

2. In combination, two sources of carrier wave oscillations of the same frequency displaced in phase by ninety degrees, a source of signal oscillations, means for producing a current varying as a cosine function of said signal oscillations and another current varying as a sine function of said signal oscillations, means for modulating that one of said carrier wave oscillations having the leading phase with that one of the signal oscillations having the lagging phase, and means for modulating the other source of carrier wave oscillations with the remaining source of signal oscillations, and means for combining the outputs from said modulating means.

3. The method of producing a carrier wave having its frequency modulated in accordance with a signal current which comprises amplitude modulating two carrier waves of the same frequency and displaced in phase by ninety degrees by currents varying as sinusoidal functions of said signal current, the phase of the current with which the carrier wave of leading phase is modulated lagging the phase of the current with which the carrier wave of lagging phase is modulated, and combining said two amplitude modulated carrier waves to produce the frequency modulated carrier wave.

4. In combination, a pair of amplitude modulators, a carrier wave source connected to the inputs of said modulators, means to displace the phase of oscillations supplied from said source to one of said modulators by ninety degrees with respect to the phase of the oscillations supplied to the other modulator, a source of signal current, means to supply current to each of said modulators varying in accordance with a sinusoidal function of said signal currents, the sinusoidal variations in said currents supplied to one modulator being displaced in phase by ninety degrees from the sinusoidal variations in said current supplied to the other modulator.

5. In combination, a source of signal current, a pair of carrier wave modulators, a translating device connected between said source and said modulators, said translating device including means to produce two currents, one varying as a

cosine function of said signal currents and the other varying as a sine function of said signal currents, a carrier wave source, and means for combining said two currents with currents from said carrier wave source to produce a carrier wave having a frequency which when linearly translated into amplitude variations reproduces the variations of said signal current.

6. In combination two sources of carrier wave of the same frequency but displaced in phase by substantially ninety degrees, a source of signal current, means to translate variations of said signal current into two light variations, each varying as sinusoidal functions of said signal current, said variations being displaced in phase by substantially ninety degrees, means for modulating the leading one of said carrier waves in accordance with the lagging one of said light variations and for modulating the remaining carrier wave in accordance with the other of said light variations, and means to combine said carrier wave after modulation.

7. In combination, a cathode ray tube having a fluorescent screen, means for producing a luminescent line across said screen, means to deflect said line along said screen in accordance with signal current, said screen having two sections, means to render the luminescence of said screen visible exteriorly of said cathode ray tube in amounts varying sinusoidally from predetermined points simultaneously traversed by said line on both sections of said screen, said variations being displaced with respect to each other by ninety degrees, a pair of photoelectric means to detect the light variations of the respective sections of said screen exteriorly of said tube, two sources of carrier wave of the same frequency, and means to modulate the amplitude of each of said sources by current controlled by a respective one of said photoelectric means and to combine the modulated currents to produce a carrier wave the frequency of which corresponds to variations of said signal current.

8. In combination, a cathode ray tube, means to deflect the electron beam of said tube in a straight line, a pair of grids, each grid having a plurality of conductors connected together and extending parallel with said line, said conductors being spaced apart at regular intervals in a direction transverse of said beam, means to deflect said beam along said grids in accordance with signal currents, the various conductors of each grid being displaced from the conductors of the other grid by one-quarter of the distance between conductors, a pair of sources of carrier wave of the same frequency displaced in phase by ninety degrees, means to modulate one of said carrier wave sources in accordance with the electromotive force induced in one of said grids and to modulate the other of said sources in accordance with the electromotive force induced in the other grid, and means to combine the output from said carrier wave sources.

9. The method of modulating the frequency of a carrier wave in accordance with a current represented by the expression $m \sin \mu t$, which comprises producing two currents represented by the expressions $\sin \omega t$ and $\cos \omega t$, producing two additional currents represented by the expressions $\cos (m \sin \mu t)$ and $\sin (m \sin \mu t)$, amplitude modulating the current $\sin \omega t$ with the current $\cos (m \sin \mu t)$, amplitude modulating the current $\cos \omega t$ with the current $\sin (m \sin \mu t)$

and combining the modulated currents so produced, where

t =time

μ =the signal frequency

$\omega=2\pi f$ where f is the frequency of the carrier wave

m =a constant

10. The method of modulating the frequency of a carrier wave in accordance with a current having a frequency μ which comprises producing two currents represented by the expressions $\sin \omega t$ and $\cos \omega t$, producing two additional currents represented by the expressions $\cos (m \sin \mu t)$ and $\sin (m \sin \mu t)$, amplitude modulating the current $\sin \omega t$ with the current $\cos (m \sin \mu t)$, amplitude modulating the current $\cos \omega t$ with the current $\sin (m \sin \mu t)$ and combining the modulated currents so produced, where

t =time

$\omega=2\pi f$ where f is the frequency of the carrier wave

$m=\Delta\omega/\mu$ where $\Delta\omega$ is the maximum shift of the carrier frequency produced by the signal.

11. The method of producing a carrier wave electromotive force having its frequency modulated in accordance with a signal current, which includes producing two unmodulated carrier waves of the same frequency having a predetermined phase displacement, modulating the amplitude of each of said waves in accordance with sinusoidal functions of signal current, and displacing the phase of said sinusoidal functions, the phase relation between said carrier waves and that between said sinusoidal functions being such that the modulated waves when combined produce the desired frequency modulated wave.

12. The method of producing a carrier current having its frequency modulated in accord with a signal current which comprises producing two carrier currents of the same frequency displaced in phase, modulating the amplitude of each car-

rier current in accord with a periodic function of the signal current, the modulations of the two carrier currents having the same phase displacement one from the other as the two carrier currents, and combining the resulting carrier currents.

13. The method of producing a high frequency carrier current having its frequency modulated in accord with the variations of a lower frequency signal current which comprises producing two high frequency carrier currents of the same high frequency displaced in phase ninety degrees, modulating the amplitude of each of these high frequency carrier currents in accord with periodic functions of said lower frequency signal current, said modulations of the two carrier currents having a ninety degree phase displacement one from the other, and combining the resulting two carrier currents into a single carrier current whereby a carrier wave is produced having its frequency modulated in accord with said signal current.

14. The method of modulation which includes the steps of generating a constant frequency carrier wave, producing signalling voltage of arbitrary wave form, utilizing said signalling voltage to generate an auxiliary wave which is a simple sinusoidal function of the instantaneous value of said signalling voltage, and modulating said carrier wave in accordance with said auxiliary wave.

15. Means for producing polyphase alternating currents having an instantaneous frequency determined by the rate of change of a signal voltage comprising, an energy carrying beam, means for deflecting said beam by an amount determined solely by the instantaneous potential of said signal, a succession of targets in the path of said beam, a second succession of targets in the path of said beam displaced with respect to said first set of targets, and means for producing current from the impinging of said beam on said targets.

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