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2,460,965

PHASE MODULATION SYSTEM

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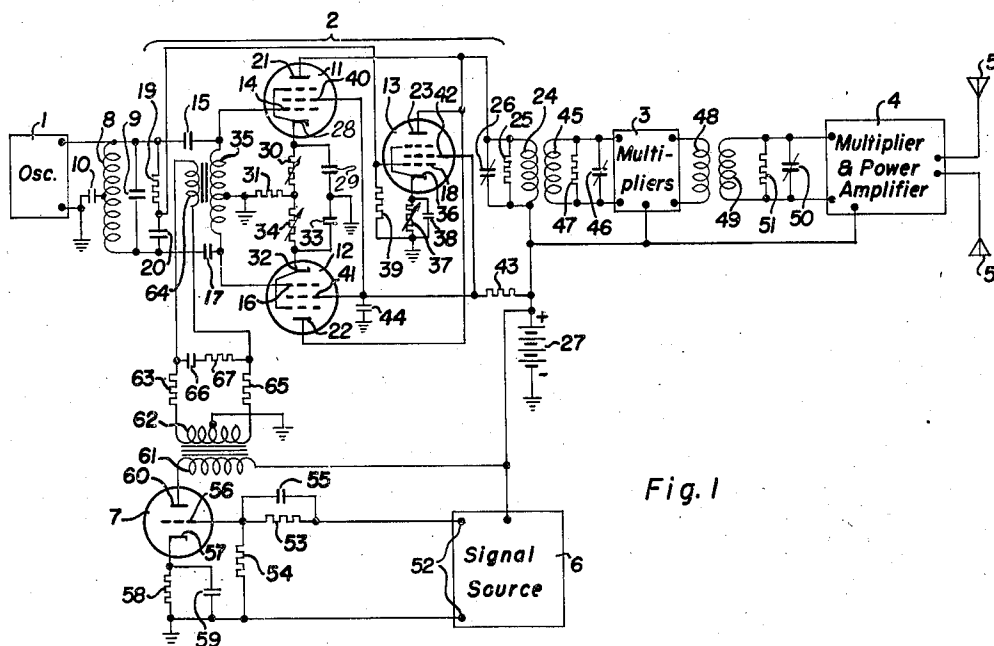


Fig. 1

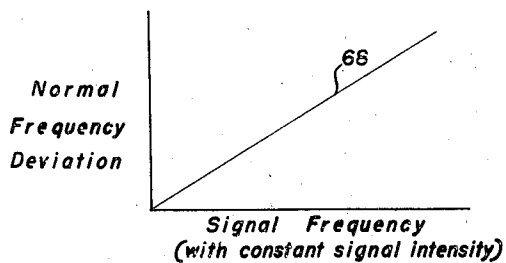


Fig. 2

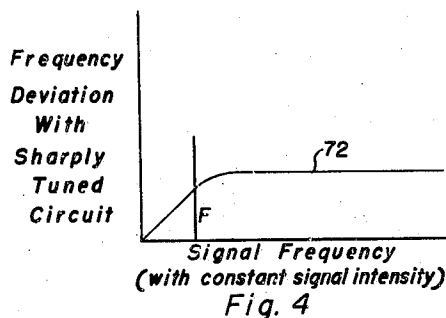


Fig. 4

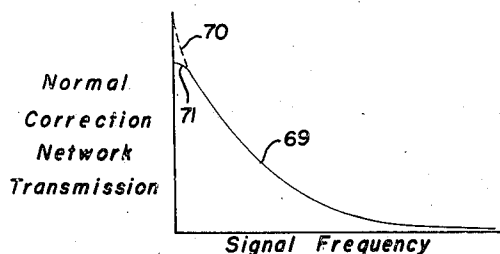


Fig. 3

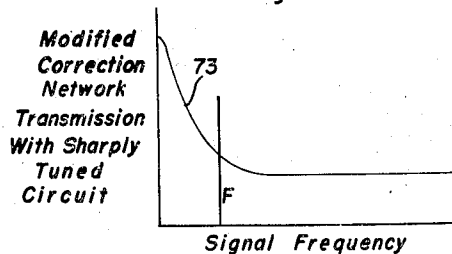


Fig. 5

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PHASE MODULATION SYSTEM

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4 Claims. (Cl. 179—171.5)

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This invention relates to phase modulation carrier wave communication systems of the type in which the phase of a carrier wave is modulated in accordance with intelligence to be transmitted in such a way as to produce frequency modulation of the carrier wave. Normally, the carrier wave amplitude in such a system is made constant, but it is within the scope of this invention to produce such frequency modulation of the carrier wave accompanied by amplitude modulation caused by the same or different intelligence. As the term is used herein—"phase modulation carrier wave communication system" is intended to mean such a system.

Phase modulation carrier wave systems have been arranged in the past with means for modifying a signal or intelligence to be transmitted in such a way that, when the carrier wave is modulated in phase in accordance with the modified signal, the resulting carrier wave is substantially constant in amplitude and is modulated in frequency in accordance with the unmodified signal. The required modification of the signal is a reduction in signal intensity as signal frequency increases, so that, for an unmodified sine wave signal of increasing frequency and of constant intensity, the modified signal has a constant product of signal frequency and signal intensity. In consequence, at high signal frequencies the signal intensity is extremely small, and is in fact so small that extraneous noise voltages are comparable in magnitude and cause phase modulation of the carrier wave in amounts comparable to the carrier wave modulation caused by the signal itself. It has therefore been extremely difficult to make the quality of such systems sufficiently high, that is, to decrease the noise inherent in such systems to a level sufficiently low that the signal is not adversely affected by such noise.

Such noise is not only introduced by thermal agitation in the circuits and vacuum tubes of the system, but also by electrostatic and electromagnetic coupling with external sources of extraneous voltage. It has been extremely difficult to shield such systems to such an extent that such extraneously induced voltages become negligibly small in comparison with the extremely small signal voltages which have heretofore had to be utilized.

It is accordingly an object of this invention to provide an improved phase modulation carrier wave system in which the difficulties heretofore experienced with undesired noise voltages are greatly minimized or substantially eliminated.

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It is a corollary object of the invention to make possible the practical use of phase modulation systems in which the carrier wave center frequency may be directly controlled (as by a piezoelectric oscillator) in applications where extremely low noise level is essential and in some cases is required by governmental regulation.

It is another object of this invention to provide such an improved system in which the elements are few and simple and are readily adjustable for high quality performance.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The present invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with accompanying drawings in which:

Figure 1 illustrates a radio transmitter constructed in accordance with the invention; and

Figures 2 through 5 illustrate certain characteristics of phase modulation carrier wave systems.

For the purpose of explaining with sufficient clarity the principles of the invention, it is necessary first to describe in some detail a particular phase modulation system of which many parts are known but cooperate with novel elements and organizations thereof to utilize the present invention.

In Figure 1 a phase modulation radio carrier wave transmitter includes a highly stable oscillator 1, a carrier wave phase modulator 2 energized by the oscillator 1, frequency multipliers represented by the rectangle 3 for multiplying the frequency of the phase modulated carrier wave from the modulator 2, an additional frequency multiplier and a final power amplifier represented by the rectangle 4 for further multiplying by a factor N the frequency of a carrier wave from the multiplier 3 and for amplifying it to high power for transmission, and an antenna 5 from which the high power carrier wave is radiated. A signal source represented by a rectangle 6 produces signal voltage which is amplified through an electron discharge amplifier 7 and is impressed on the phase modulator 2 to modulate the phase of the carrier wave therein.

The phase modulator 2 includes a tuned input circuit having a center tapped inductance 8 connected in parallel with a condenser 9, the center tap of the inductance 8 being connected to ground through a by-passing condenser 10. The

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highly stable oscillator 1 is connected between ground and one terminal of the tuned circuit 8, 9, which is resonant to the frequency of the output of the highly stable oscillator 1. The phase modulator 2 also includes three electron discharge amplifier devices 11, 12 and 13 which respectively amplify the carrier wave in phase quadrature with each other. These carrier waves are derived from the tuned circuit 8, 9 by connection of the first control electrode 14 of the device 11 through coupling condenser 15 to one terminal of the tuned circuit 8, 9, by connection of the first control electrode 16 of the device 12 through coupling condenser 17 to the other terminal of tuned circuit 8, 9, and by connection of the first control electrode 18 of device 13 to a point between a resistance 19 and a condenser 20, the resistance 19 and condenser 20 being connected serially between the terminals of the tuned circuit 8, 9, the impedances of the resistance 19 and condenser 20 being equal at the frequency of the carrier wave from oscillator 1. By such connections, the carrier wave voltage is impressed on control electrode 14 in phase with the voltage from oscillator 1. A carrier wave is impressed on control electrode 16 in opposite phase to that from oscillator 1, and a carrier wave is impressed on control electrode 18 which lags the carrier wave voltage from oscillator 1 by 90°, all of the carrier wave voltages on the three control electrodes 14, 16 and 18 being substantially equal in intensity.

The discharge devices 11, 12 and 13 are suitably connected to act as amplifiers for the carrier waves impressed on their control electrodes, the respective anodes 21, 22 and 23 being all connected together and through a parallel resonant circuit including an inductance 24, a resistance 25 and a condenser 26 to the positive terminal of a suitable source 27 of operating current, the negative terminal of the source 27 being grounded. Cathode 28 of the discharge device 11 is connected through a by-passing condenser 29 to ground, and is connected through biasing resistances 30 and 31 connected in series to ground. Cathode 32 of the device 12 is connected for high frequency current through by-passing condenser 33 to ground and is connected through a biasing resistor 34 and through biasing resistor 31 to ground. The control electrodes 14 and 16 are connected to the respective terminals of the secondary 35 of a transformer, the center tap of the secondary 35 being grounded so the discharge currents flowing through the resistances 30, 31 and 34 produce bias voltages between the cathode 28 and control electrode 14, and between the cathode 32 and control electrode 16. These bias voltages may be individually adjusted by suitable adjustment of the resistances 30 and 34. The cathode 36 of discharge device 13 is connected to ground through a biasing resistance 37 by-passed with a condenser 38, and control electrode 18 of discharge device 13 is connected to ground through a large resistance 39 so the discharge current flowing through the resistance 37 produces a biasing potential between the control electrode 18 and cathode 36. This biasing potential may be adjusted by suitable adjustment of resistance 37. Resistance 39 is large with respect to resistance 19 so that it does not produce an appreciable alteration of the phase angle of carrier wave voltage between control electrode 18 and ground. The respective screen electrodes 40, 41 and 42 of the discharge devices 11, 12 and 13 are all connected together and through a resistance 43 to the posi-

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tive terminal of source 27. The screen electrodes 40, 41 and 42 are also connected to ground through a by-passing condenser 44 which has low reactance at the lowest frequency of signals from signal source 6.

The respective gains of the discharge devices 11, 12 and 13 are adjusted by suitable adjustment of resistances 30, 34 and 37 so that they are substantially equal, in order that the amplified carrier wave potentials through each of those discharge devices shall appear across the tuned circuit 24, 26 in substantially equal intensities, although in phase angle differing respectively by substantially 90°. The reactance of the secondary 35 connected between control electrodes 14 and 16 is high at the carrier wave frequency. Since the carrier wave potentials amplified by devices 11 and 12 are substantially opposite in phase, the connection between the anodes 21 and 22 causes the substantially complete cancellation of carrier wave potentials amplified through devices 11 and 12 so long as no potential appears in the secondary 35. Therefore, under such conditions, carrier wave potentials appearing across the tuned circuit 24, 26 are substantially only those amplified through device 13.

The carrier wave potential appearing across the tuned circuit 24, 26 is transferred to the frequency multipliers 3 by reason of magnetic coupling between the inductance 24 and an inductance 45 connected across the input terminals of the frequency multipliers 3. A condenser 46 is connected in shunt with the inductance 45 and is adjusted to resonate with the inductance 45 at the carrier wave frequency from the stable oscillator 1, which is also the resonant frequency of the tuned circuit 24, 26. A resistance 47 is also connected in shunt with the inductance 45, and the resistances 25 and 47 respectively damp the tuned circuits 24, 26 and 45, 46 so that those tuned circuits are rather broadly resonant to the carrier wave frequency.

An inductance 48 is connected between the output terminals of the frequency multipliers 3 so that a carrier wave potential of suitably multiplied frequency appears across it. This inductance 48 is untuned and is magnetically coupled with an inductance 49 with which a condenser 50 is connected in shunt, and with which a resistance 51 is also connected in shunt. The parallel combination of inductance 49 and condenser 50 is resonant at the multiplied carrier wave frequency from the frequency multipliers 3, and the resistance 51 produces a critical amount of damping in the resonant circuit 49, 50 for a purpose to be described later.

The carrier wave of multiplied frequency induced across the tuned circuit 49, 50 is impressed between the input terminals of the frequency multiplier and power amplifier 4, in which the frequency of such carrier wave is further multiplied by the factor N to reach the desired final carrier wave frequency at which the desired frequency deviation Δf is achieved and in which the power amplifier raises the power level of that carrier wave of multiplied frequency to a power suitable for radiation. The output terminals of the frequency multiplier and power amplifier 4 are connected to the antenna 5 so that the high power frequency multiplied carrier wave is radiated into space.

Signals from the signal source 6 are caused to produce phase shift of the carrier wave in the phase modulator 2 by transmission through the following circuit: The terminals 52 of source 6

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are connected respectively to the terminals of a resistance 53 and a resistance 54, connected serially, a condenser 55 being connected in shunt with the resistance 53. That output terminal 52 of the signal source 6 which is connected to resistance 54 is grounded, and the control electrode 56 of the electron discharge amplifier device 7 is connected to a point between resistances 53 and 54. The cathode 57 of the device 7 is connected through a biasing resistance 58 to ground, and a large by-passing condenser 59 is connected in shunt with the resistance 58. The anode 60 of the device 7 is connected through the primary 61 of a transformer to the positive terminal of the source 27. The transformer primary 61 has high reactance at all signal frequencies from the source 6 and the discharge device 7 so connected amplifies signals from the source 6 and impresses them across the transformer primary 61. The network including resistances 53 and 54 and condenser 55 is effective to produce an initial modification of signals from the source 6, commonly termed "preemphasis." To produce such an effect, this network is so adjusted as to produce for a sine wave signal from the source 6 of increasing frequency from a certain upward minimum frequency approximately a 6 decibel increase in intensity for each octave increase in frequency of the signal. Such "preemphasis" is commonly utilized in phase or frequency modulation transmission systems for the purpose of minimizing noise voltages appearing in the carrier wave modulator and in subsequent portions of the system. This network is included in this system only for the purpose of producing a standard type of modulation with "preemphasis."

The transformer primary 61 is suitably magnetically coupled for signal frequencies with a secondary 62 of which the center tap is grounded. One terminal of the secondary 62 is connected through the resistance 63 to one terminal of the primary winding 64 of the transformer whose secondary is the winding 35. The other terminal of the transformer secondary 62 is connected through a resistance 65 to the other terminal of the transformer primary 64. A condenser 66 and a resistance 67 are connected serially between the terminals of the transformer primary 64 and the network including resistances 63, 65 and 67 and condenser 66, together with the critical adjustment of damping resistance 51 in the tuned circuit 49, 50, produces the great degree of noise suppression achieved by this invention.

Let f_0 represent the frequency of an unmodulated wave. Such a wave may be modulated in phase by a sine wave of lower frequency f_m with a maximum phase excursion ϕ (measured in radians). Such a phase modulated wave may also be regarded as a wave of varying frequency. Let the maximum deviation of frequency of such modulated wave from f_0 be called D .

Then:

$$D = \phi f_m \quad (1)$$

Let ϕ , and D , represent corresponding characteristics of the wave at the input to the frequency multipliers 4.

Then similarly:

$$D_1 = \phi_1 f_m \quad (2)$$

which is a statement, illustrated by line 66 in Fig. 2, that with constant phase shift or in other words constant signal intensity at the input terminals of the phase modulator 2, there is a direct proportionality between D_1 and f_m . For 75

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certain technical and legal reasons, it is usual to design such a system for a maximum deviation D_{max} which is the same for all signal frequencies f_m . To satisfy that requirement it is necessary to modify the signal before it is impressed on phase modulator 2.

The required modification is:

$$\phi_1 = \frac{D_{max}}{f_m} \quad (3)$$

for the phase excursion ϕ , corresponding to maximum signal intensity.

This means that attenuation should be produced in the signal (before it is impressed on phase modulator 2) so that the intensity of signal impressed on modulator 2, with constant intensity signal at source 6, is inversely proportional to signal frequency f_m . This relation is illustrated by hyperbola 69 and its dotted end 70 in Fig. 3. A true hyperbolic relation of that nature is not readily attained and the correction network designed to produce such attenuation is in practice arranged to deviate from the true hyperbola at extreme low signal frequencies according to the end portion 71 of curve 69.

Let $D_{A(max)}$ represent maximum deviation at antenna 5 corresponding to D_{max} at the input to multiplier 4, and N , the factor by which frequency is multiplied in multiplier 4.

Then

$$\phi_1 = \frac{D_{A(max)}}{N f_m} \quad (4)$$

A proper choice of N is possible so that ϕ_1 is small compared to unity ($\phi_1 \ll 1$) at least at higher signal frequencies.

Now assuming that for a particular signal frequency f_m this condition that $\phi_1 \ll 1$ is fulfilled, the wave of frequency f_0 phase modulated by the signal of frequency f_m may be closely approximated by the combination of an unmodulated or center frequency wave of frequency f_0 and two side bands, each of constant frequency, phase and amplitude, of respective frequencies $f_0 + f_m$ and $f_0 - f_m$ and of amplitudes $\frac{1}{2}\phi$ with the amplitude of the unmodulated wave being regarded as unity.

When such a modulated wave is transmitted through a resonant system, the amplitudes of the center frequency wave f_0 and the sidebands $f_0 + f_m$ and $f_0 - f_m$ are changed in relation to each other as dictated by the frequency characteristic of the resonant system. It has been common practice to make the resonant systems following the phase modulator 2 of sufficient bandwidth that substantially no attenuation is produced in either of the sidebands $f_0 + f_m$ and $f_0 - f_m$ at any time.

According to the present invention, a more sharply resonant system is introduced between frequency multiplier 3 and frequency multiplier 4 which transmits uniformly a frequency band of width $2F$ centered around f_0 , but symmetrically attenuates frequencies outside this band. F corresponds to a signal frequency f_m which is substantially lower than the upper limit of signal frequencies to be transmitted through the system, but high enough that ϕ_1 is still much less than unity.

Let a signal frequency f_m higher than F be attenuated by a factor a . After passing through such an attenuating system the sideband amplitudes are reduced from

$$\frac{1}{2}\phi \text{ to } \frac{1}{2}\frac{\phi}{a}$$

The result is that the sidebands after such attenuation are as though they had been caused by a signal of correspondingly smaller intensity. At the output of multiplier 4 the deviation is reduced by the factor a . This effect takes place only when signal frequency f_m exceeds the limit corresponding to F , so that the sidebands fall within the regions of attenuation. For lower signal frequencies the deviation is not affected.

The previous discussion is actually a simplification of fact in assuming that amplitude is no less at $f_0 \pm F$ than at f_0 . In practice where a single turned circuit is used to produce the desired attenuation, as the circuit 49, 50, 51 in Fig. 1, the damping resistor 51 is adjusted so that the amplitude at $f_0 \pm F$ is 70% of the amplitude at f_0 . For frequencies differing from f_0 by amounts greater than F , expressed as $f_0 \pm KF$ (where $K > 1$), the attenuation a is substantially equal to K .

With such adjustment of the circuit 49, 50, 51 the curve 72 (Figure 4) illustrates the relation between signal frequency f_m (with constant phase excursion or signal intensity at the input to modulator 2) plotted as abscissa, and the resulting frequency deviation D , measured at the input to multipliers 4, plotted as ordinate. This relation may be expressed in terms of Equation 2 when it is understood that for a signal frequency $f_m = KF$ (where $K > 1$) side band attenuation causes approximately a reduction of the deviation by factor K .

That is:

$$D_1 \approx \frac{1}{K_1} f_m = \frac{1}{K} KF = \phi F \quad (5)$$

For the signal frequencies f_m less than F Equation 2 remains approximately true.

According to the invention, the correcting network 63, 65, 66 is so modified by addition of resistance 67 that the voltage introduced into the phase modulator 2 is inversely proportional to f_m so long as f_m is smaller than F but remains substantially constant when f_m is larger than F . In the practical network 63, 65, 66, 67 in Fig. 1, the transmission at $f_m = F$ is not actually equal to the constant amount of transmission at much higher frequencies, but is 141% as much, so as to compensate for the described shape of attenuation characteristic of the turned circuit 49, 50, 51. This relation is illustrated by curve 73 in Fig. 5, in which signal frequency f_m is plotted as abscissa against network transmission plotted as ordinate.

In such a system, the resulting phase excursion for full deviation never is reduced at any signal frequency below

$$\frac{D_{A(\max)}}{NF}$$

Expressed in another way, the effect of extraneous voltages and noise on the system is reduced by the factor K , which in a practical case may be made quite large with a corresponding large reduction in the effect of high frequency noise. In fact, such a system is readily constructed, without any special critical adjustments, using conventional phase modulating means and frequency multipliers to transmit a high fidelity signal of excellent broadcast quality where such a system without the present invention is incapable of such performance.

Choice of the frequency limit F is based on the fact that the representation of a phase modulated wave by a carrier wave and only two sidebands is valid only where phase excursion is much

less than one radian ($\phi < 1$). Sidebands of substantial amplitude spaced farther from the center frequency f_0 appear when ϕ becomes nearly equal to or greater than unity.

Now for:

$$\phi = \frac{D_{A(\max)}}{NF} = \frac{D_1}{F}$$

To make this phase excursion ϕ_1 small enough, F must be chosen several times larger than D_1 .

D_1 itself may be made relatively small by making N large, which means carrying out a large fraction of the total frequency multiplication in multiplier 4 following the resonant system 49, 50, 51. However, if N be made too large (by having too little or no frequency multiplication in multiplier 3 ahead of the resonant system 49, 50, 51) noticeable noise effects appear in the first stages of frequency multiplication following the resonant system. A practical upper limit for N is thus defined for any particular final deviation ratio.

Then for a low frequency signal f_m , where ϕ is large, many sidebands appear, covering substantially the entire band from $f_0 - D_1$ to $f_0 + D_1$, and this band of frequencies then is much wider than that between the first two sidebands $f_0 - f_m$ and $f_0 + f_m$, but since F is chosen several times larger than D_1 , even that wide band from $f_0 - D_1$ to $f_0 + D_1$ is transmitted without substantial attenuation so that the transmission of low frequency signals remains substantially unaffected.

Purely by way of example, let it be assumed that a transmitter of this type be desired for operation at 96 megacycles with a maximum deviation $D_{A(\max)}$ of 75 kilocycles. The various portions of such a system may be adjusted as follows for satisfactory operation.

Then:

$$\begin{aligned} N &= 384 \\ f_0 &= 250 \text{ kilocycles} \\ D_1 &= 195 \text{ cycles} \\ F &= 1500 \text{ cycles} \end{aligned}$$

and it follows that the tuned circuit 49, 50, 51 is resonant at 250 kc. and is adjusted to have a figure of merit of 83, and that the reactance of condenser 66 is equal to resistance 67 at 1500 cycles.

For noise at 3000 cycles, an improvement in signal to noise ratio of about six decibels is attained, and for noise at the upper limit frequency of 15,000 cycles the improvement is about 20 decibels.

While a simple arrangement using a simple resonant circuit and simple compensating circuit has been illustrated because it is susceptible of reasonably simple explanation which approaches the truth, it should be understood that it is within the scope of the invention to utilize more complicated networks to replace tuned circuit 49, 50, 51 and correspondingly more complex compensating circuits to replace circuit 63, 65, 66, 67. For example, it may be desired to provide a relation between side band attenuation and signal frequency other than that described with a corresponding compensating network to obtain any desired transmission of the signal. Further, the network 53, 54, 55, may be omitted and the network 63, 65, 66, 67 modified to carry out, in addition to its described function, the function of providing preemphasis.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects, and,

therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. In combination, a carrier wave source, a frequency multiplier for multiplying the frequency of the carrier wave from said source, a modulating signal source, the signals from said signal source lying in a band of frequencies including a first and a second range contiguous with each other, said second range including higher frequencies than said first range, a modulator connected between said carrier wave and signal sources and constructed to vary the phase of the carrier wave from said carrier wave source as a function of the instantaneous amplitude of the signal from said signal source, said modulator including a filter circuit constructed to cause the maximum phase excursion of said carrier wave to be substantially inversely proportional to the frequency of modulating signals lying within said first range of frequencies and to be less than one radian for modulating signals lying in said second range, said carrier wave having an unmodulated frequency, and a tuned circuit connected between said modulator and said frequency multiplier and constructed to attenuate side band components produced by signals lying in said second range directly as a function of the magnitude of such signal frequency, and to pass without substantial modification carrier waves modulated by signals in said first range.

2. In combination, a carrier wave source, a frequency multiplier for multiplying the frequency of the carrier wave from said source, a modulating signal source, the signals from said signal source lying in a band of frequencies including a first and second range contiguous with each other, said second range including higher frequencies than said first range, a modulator connected between said carrier wave and signal sources and constructed to vary the phase of the carrier wave from said carrier wave source as a function of the instantaneous amplitude of a signal from said signal source, said modulator including a filter circuit constructed to cause the maximum phase excursion of said carrier wave to be substantially inversely proportional to the frequency of modulating signals lying within said first range of frequencies and to be less than one radian for modulating signals lying in said second range, said carrier wave having an unmodulated frequency equal to its center modulated frequency, and a tuned circuit connected between said modulator and said frequency multiplier, resonant at said center frequency and constructed to attenuate side band components produced by signals lying in said second range directly as a function of the magnitude of such signal frequency, and to pass without substantial modification carrier waves modulated by signals in said first range.

3. In combination, a carrier wave source, a frequency multiplier for multiplying the frequency of the carrier wave from said source, a modulating signal source, the signals from said signal source lying in a band of frequencies including a

first and a second range contiguous with each other, said second range including higher frequencies than said first range, a modulator connected between said carrier wave and signal sources and constructed to vary the phase of the carrier wave from said carrier wave source as a function of the instantaneous amplitude of a signal from said signal source, said modulator including a filter circuit constructed to cause the maximum phase excursion of said carrier wave to be substantially inversely proportional to the frequency of modulating signals lying within said first range of frequencies and to be less than one radian for modulating signals lying in said second range, said carrier wave having an unmodulated frequency equal to its center modulated frequency, and a single tuned circuit connected between said modulator and said frequency multiplier and damped to attenuate side band components produced by signals lying in said second range directly as a function of the magnitude of such signal frequency, and to pass without substantial modification carrier waves modulated by signals in said first range.

4. In combination, a carrier wave source, a frequency multiplier for multiplying the frequency of the carrier wave from said source, a modulating signal source, the signals from said signal source lying in a band of frequencies including a first and a second range contiguous with each other, said second range including higher frequencies than said first range, a modulator connected between said carrier wave and signal sources and constructed to vary the phase of the carrier wave from said carrier wave source as a function of the instantaneous amplitude of a signal from said signal source, said modulator including a filter circuit constructed to cause the maximum phase excursion of said carrier wave to be substantially inversely proportional to the frequency of modulating signals lying within said first range of frequencies and to be less than one radian for modulating signals lying in said second range, said carrier wave having an unmodulated frequency equal to its center modulated frequency, and a single tuned circuit resonant at said center frequency connected between said modulator and said frequency multiplier and damped to attenuate side band components produced by signals lying in said second range directly as a function of the magnitude of such signal frequency, and to pass without substantial modification carrier waves modulated by signals in said first range.

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The following references are of record in the file of this patent:

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Number	Name	Date
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Certificate of Correction

Patent No. 2,460,965.

February 8, 1949.

ROBERT ADLER

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 3, line 59, for the numeral "64" read $3\frac{1}{2}$; column 6, line 44, for " $f_o - f_m$ " read $f_o + f_m$; line 57, same column, for the word "and" read *or*; column 10, line 43, claim 4, for "moduating" read *modulating*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 28th day of June, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.