

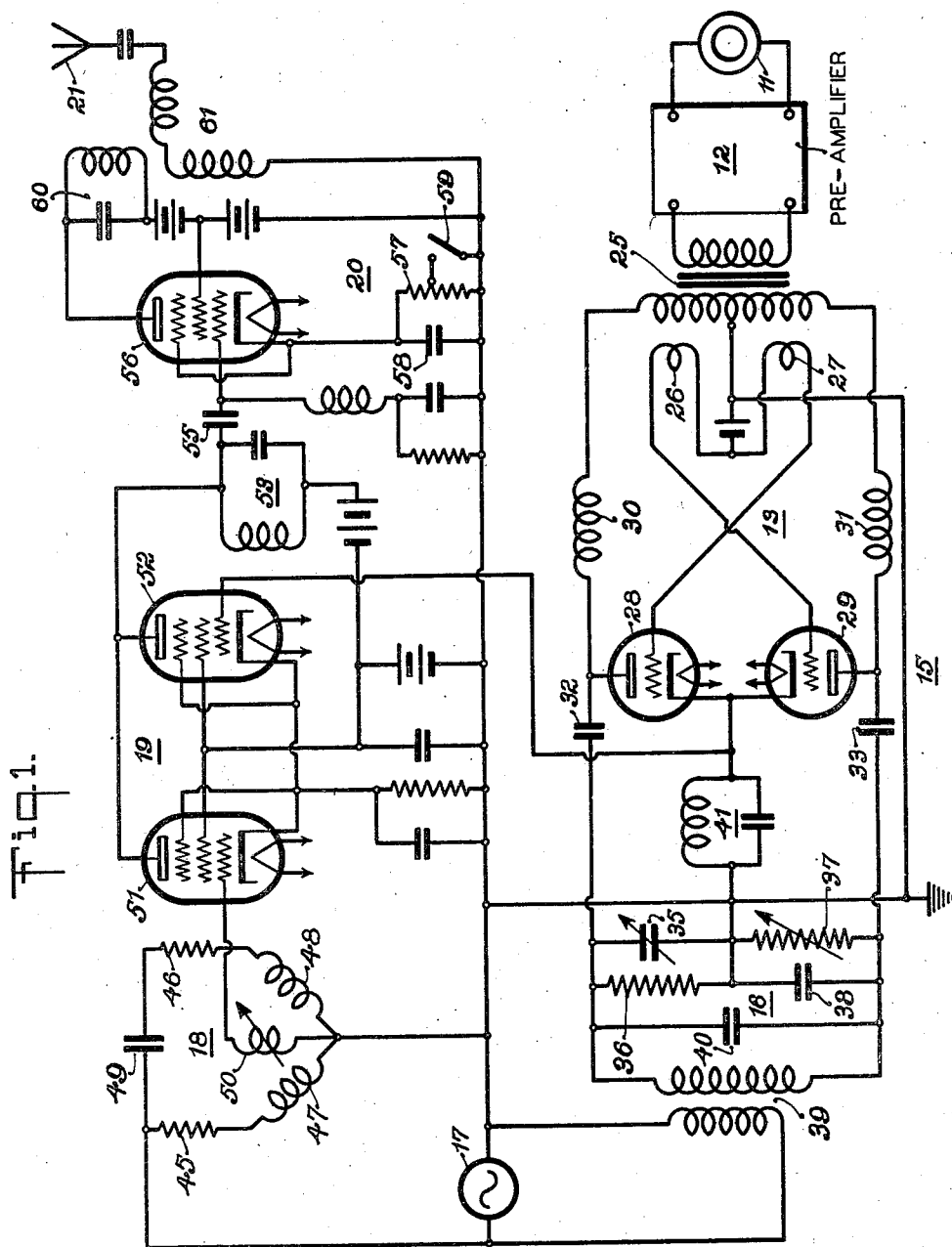
Dec. 31, 1946.

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2,413,348

SIGNALING SYSTEM

Original Filed Feb. 10, 1940 4 Sheets-Sheet 1



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2,413,348

SIGNALING SYSTEM

Original Filed Feb. 10, 1940 4 Sheets-Sheet 2

Fig. 2a.

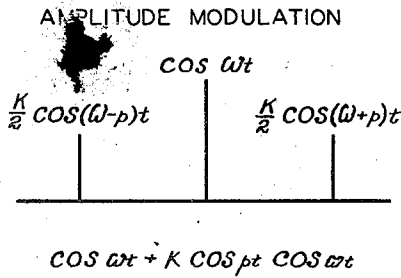


Fig. 2b.

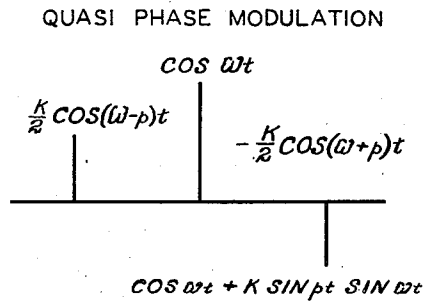


Fig. 2c.

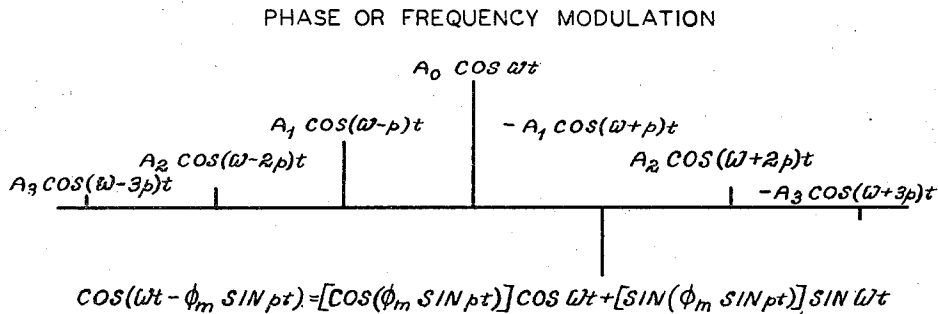
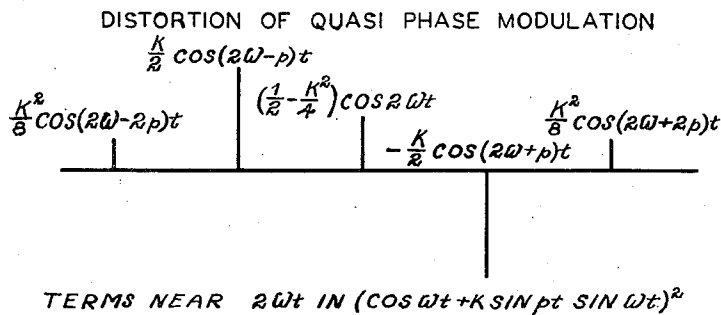


Fig. 2d.



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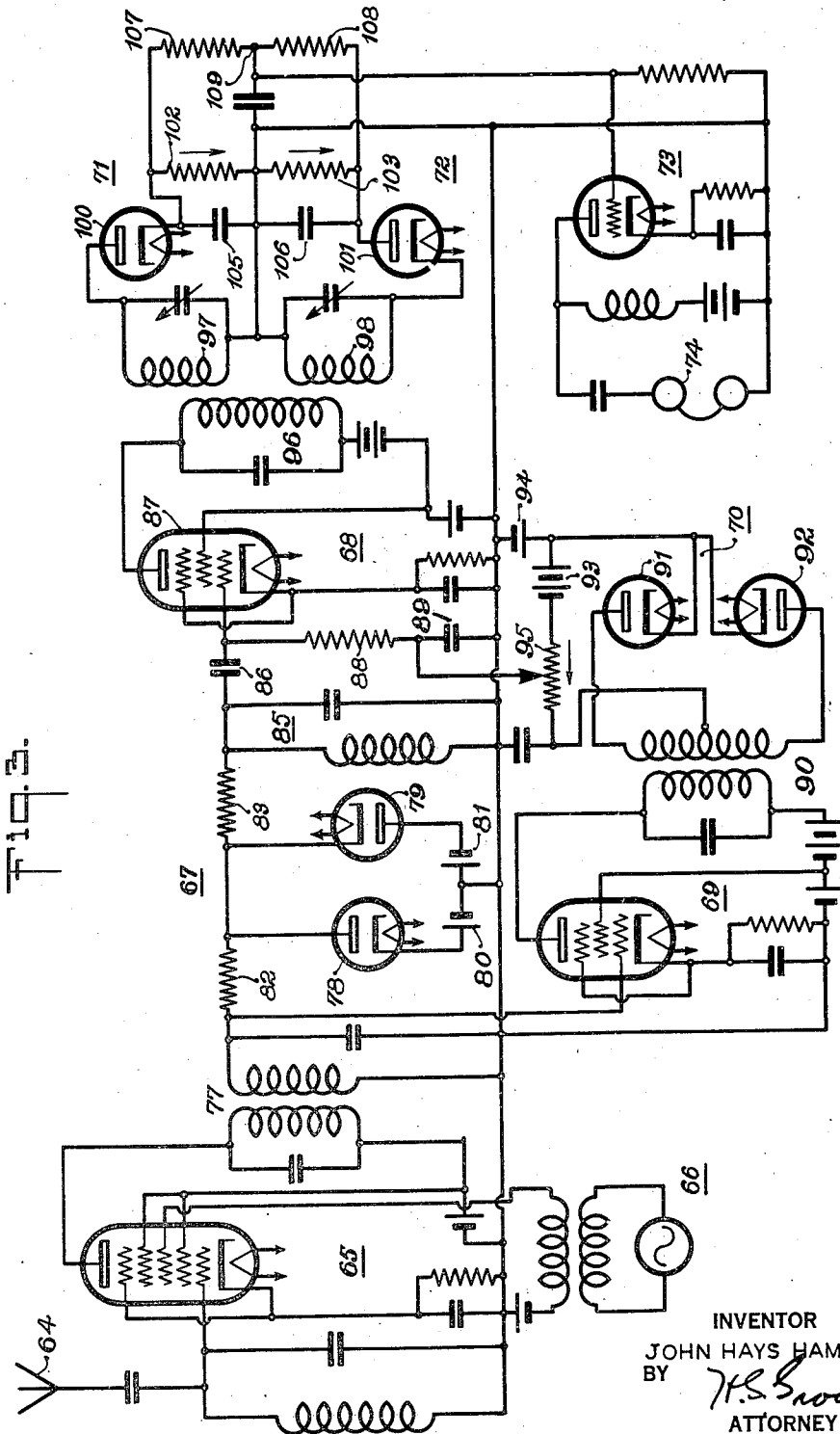
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SIGNALING SYSTEM

Original Filed Feb. 10, 1940

4 Sheets-Sheet 3



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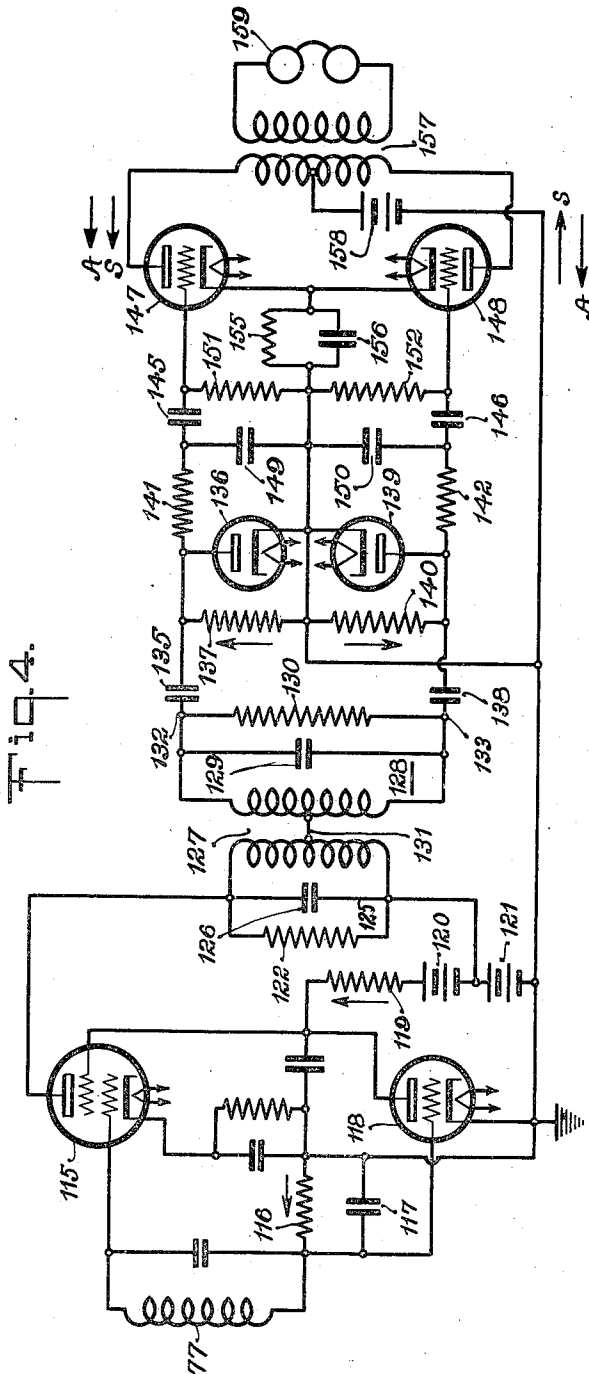
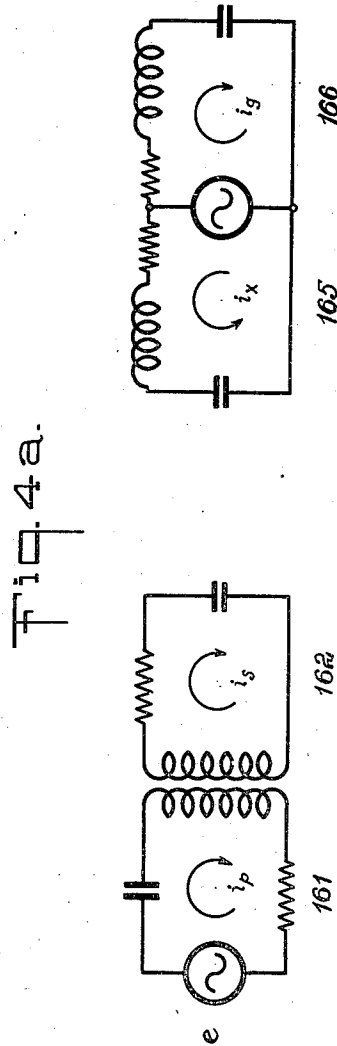
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SIGNALING SYSTEM

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4 Sheets-Sheet 4



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2,413,348

SIGNALING SYSTEM

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Original application February 10, 1940, Serial No.
318,221. Divided and this application Novem-
ber 12, 1942, Serial No. 465,307

11 Claims. (Cl. 178-44)

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This invention relates to phase modulation systems, and more particularly to systems of the above type having phase characteristics adapted to permit the separate detection of the upper and lower side bands. This application is a division of my application Serial No. 318,221, filed Feb. 10, 1940.

An object of the invention is to provide a system of the above type which is free from fading and from interference by extraneous influences, such as static or interfering amplitude modulated signals.

Another object is to provide a frequency modulation system having characteristics suited to permit separate detection and recombining of various components thereof.

Other objects and advantages will be apparent as the nature of the invention is more fully disclosed.

It is well known in the art to which the present invention appertains that there is no mathematical distinction between phase modulation and frequency modulation. Accordingly, in the following specification and appended claims the term "timing modulation" has been used generically to characterize phase modulation and frequency modulation as distinguished from "amplitude modulation."

In accordance with the present invention, a phase modulated wave is radiated which comprises upper and lower side bands, and a carrier which is displaced from the phase relationship adapted to produce the usual amplitude modulated wave. The carrier is preferably displaced in phase by 90° , and is adapted, when combined with the upper and lower side bands respectively, to produce low frequency, or detected, waves which are displaced in phase by 180° . These waves are, accordingly, adapted to be combined in opposed relationship to reproduce the original signal. Extraneous noises or amplitude modulated signals, however, are balanced out during the combining process, because such disturbances appear in the same phase in both parts of the balanced circuit, whereas the desired signals are 180° out of phase, and, accordingly, are converted into additive instead of subtractive relationship.

In the receiver, the phase modulated wave is passed through suitable amplifiers and limiting devices so as to obtain a wave of constant amplitude prior to the detection of the signals. In this way the effect of fading, and other variations in signal strength, is eliminated. The system, accordingly, produces a signal of constant intensity

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which is substantially unaffected by extraneous influences.

Although the novel features which are believed to be characteristic of this invention are pointed out more particularly in the claims appended hereto, the invention will be better understood by referring to the following description, taken in connection with the accompanying drawings forming a part thereof, in which certain specific embodiments have been set forth for purposes of illustration.

In the drawings:

Fig. 1 is a diagrammatic representation of a transmitter adapted to transmit a wave modulated in accordance with the present invention;

Figs. 2A, 2B, 2C and 2D are a series of charts indicating the energy distribution in the radiations produced in accordance with the present invention;

Figs. 3 and 4 are diagrammatic views showing receivers adapted to receive the radiations of Fig. 1, and embodying the features of the present invention; and

Fig. 4A is a diagram representing the operation of certain elements in Fig. 4.

Like reference characters denote like parts in the several figures of the drawings. In the following description and in the claims parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring to the drawings, Fig. 1 shows a transmitter which includes a microphone 11 connected to a pre-amplifier 12 which operates into the low frequency end 13 of a push-pull modulator 15, the high frequency end 16 of which is supplied with energy from a high frequency source 17. The high frequency source 17, also, supplies energy through a phase shifter 18 to an electronic mixing amplifier 19, which, also, receives energy from the output circuit of the push-pull modulator 15. The combined output of the mixing amplifier 19 is impressed upon a power amplifier 20, the output of which is fed to an antenna 21.

In the particular embodiment shown, the pre-amplifier 12 is connected through a transformer 25 to the low frequency end 13 of the push-pull modulator 15. Inductively coupled to the transformer 25 are two coils 26 and 27 which are connected to the grids of two tubes 28 and 29. The secondary of the transformer 25 is connected through chokes 30 and 31 to the plates of the tubes 28 and 29, which, in turn, are connected

through blocking condensers 32 and 33 to the high frequency end 16 of the modulator 15.

The high frequency end 16 is shown as comprising a variable condenser 35 bridged by a resistor 36, a variable resistor 37 bridged by a condenser 38, and the secondary of a transformer 39 shunted by a condenser 40. The primary of the transformer 39 is connected to the high frequency source 17. The output circuit of the modulator 15 includes a tank circuit 41. The phase shifter 18 is shown as comprising two resistors 45 and 46 in series with two coils 47 and 48 mounted at right angles to each other, a condenser 49 and an output coil 50 being mounted in the space between the coils 47 and 48.

The mixing amplifier 19 is shown as including two pentode tubes 51 and 52 and a tuned output circuit 53. The first grid of the tube 51 is connected to the output coil 50 of the phase shifter 18, and the first grid of the tube 52 is connected to one side of the tank circuit 41. The output circuit 53 is connected through a condenser 55 to the first grid of a pentode tube 56 which forms a part of the power amplifier 20. The cathode of the tube 56 is connected to ground through a resistor 57 by-passed by condenser 58. A part of the resistor 57 may be short-circuited by a switch 59. The amplifier 20 is provided with a tuned plate circuit 60 which is inductively coupled through an antenna circuit 61 to the antenna 21.

Operation

Energy from the microphone 11 is amplified by the preamplifier 12, and is fed through the transformer 25 to the low frequency end 13 of the modulator 15. At the same time energy from the high frequency source 17 is fed through the transformer 39 to the high frequency end 16 of the modulator. The modulated energy is then fed from the output circuit 41 to the grid of the tube 52.

High frequency energy from the source 17 is, also, fed to the phase shifter 18, and from the output coil 50 the energy is impressed upon the input grid of the tube 51. The combined output of the tubes 51 and 52, comprising the carrier and side bands, is fed through the tuned circuit 53, and is impressed upon the first grid of the tube 56. The energy is amplified by the power amplifier 20 and is impressed, through plate circuit 60 and antenna circuit 61, upon the antenna 21, which radiates energy corresponding to the combined carrier and side band energy in the circuit 53. The bias on the tube 56 may be increased by opening the switch 59 which increases the resistance of the cathode to ground resistor network. In this case, the circuits 60 and 61 may be tuned in the vicinity of twice the frequency of the tuned circuit 53.

Fig. 2A shows the energy in circuit 53 when the phase shifter device 18 is set so as to give an amplitude modulation effect. By a 90° shift of the rotor 50, the energy in circuit 53 at a suitable instant in the operation may be made to correspond to the chart Fig. 2B, in which one side band is reversed from the normal condition of Fig. 2A. This may be called "quasi-phase" modulation.

Fig. 2C represents a spectral distribution of a timing modulated, phase modulated or a frequency modulated wave. The central frequency and first order side frequencies are substantially identical with the central and side frequencies of Fig. 2B. The radiations of 2B, however, can do much that can be done by timing, phase or

frequency modulation radiation of Fig. 2C, and possess the advantage of requiring only the band width required by amplitude modulations as in Fig. 2A.

If it is desired to produce higher order side bands from the energy distribution of 2B and build up a radiation similar to that shown in 2C, distortion devices may be utilized. That is the energy of circuit 53 may be put through abrupt limiting devices, such for example as shown in U. S. Patent 1,560,206 of Emery L. Chaffee which chop off the peaks of energy and reduce the amount of amplitude modulation. Or it may be put through devices such as a square law detector, for which the result can be directly demonstrated as follows:

Let the output of a detector device be given, say, by:

$$i = a + be + ce^2$$

in which e is the instantaneous impressed voltage, i is the instantaneous output current, and a , b , c are fixed quantities independent of e .

If the voltage e impressed on the detector is made that corresponding to the quasi-phase modulated signal of Fig. 2B, that is

$$e = (\cos \omega t + k \sin pt \sin \omega t)$$

the complete expression for the output current of the detector specified by the above equation is

$$i = a + \frac{c}{2} + \frac{ck^2}{4}$$

(Direct current)

$$+ b(\cos \omega t + k \sin pt \sin \omega t) - c\left(\frac{k^2}{4} \cos 2pt\right)$$

(Repeated current) (Detected current)

$$+ c\left(\frac{k^2}{g} \cos (2\omega - 2p)t + \frac{k}{2} \cos (2\omega - p)t\right)$$

(Lower side bands)

$$+ c\left(\left(\frac{1}{2} - \frac{k^2}{4}\right) \cos 2\omega t\right)$$

(Carrier)

$$+ c\left(-\frac{k}{2} \cos (2\omega + p)t + \frac{k^2}{8} \cos (2\omega + 2p)t\right)$$

(Upper side bands)

That is, in addition to the direct current, repeated current, and detected current, there are currents of five frequencies grouped about twice the frequency of the central frequency of Fig. 2B, with the spacing and phase relations precisely as in the frequency modulation pattern of Fig. 2C. This pattern, for k equal 1 as in 2B is shown in 2D, for comparison with the frequency or phase modulation pattern of 2C.

This output energy of the detector may be tuned by the circuit 60 and antenna circuit 61, centered at double the frequency to which circuit 53 is tuned, with the result that a radiation closely simulating a phase or frequency modulated wave, with at least first and second order side bands will be radiated.

The spectral distributions of Figs. 2A to 2D inclusive, represent the same amount of total energy. The process of producing radiations of double frequency, with second order side bands, is similar to the process of producing additional side band energy by distorting devices of the instantaneously operative type. The creation of additional order side bands by the distortion process may be combined with the doubling process, but it should be noted that frequency doubling can be accomplished without distortion effects. That is, the process here outlined is dis-

tortion in combination with tuning to the double frequency distortion output.

It will be understood, however, that with the power amplifier operating normally and with circuits 60 and 61 tuned similar to circuit 53 and the tube 56 chosen of small energy handling ability, then second order side bands will be produced by the distortion process resulting from overloading the amplifier, without frequency doubling.

Receiver

A receiver for use in connection with the radiations produced by the transmitter of Fig. 1, either with first order side bands or with first and higher order side bands, is shown in Fig. 3. This receiver comprises an antenna 64, a frequency lowering converter 65, an oscillatory source 66, a limiting channel 67, an amplifier 68, an amplifier circuit 69, a rectifier circuit 70, two detector circuits 71 and 72, an amplifier 73 and a reproducer represented generally as a set of head phones 74.

The converter 65 and oscillator 66 may be of any well known construction, and need not be more fully described herein. The output circuit of the converter 65 is connected through a transformer 77 to the limiting channel 67. The latter is shown as including two diodes 78 and 79 in a reversed connection with the elements biased by batteries 80 and 81. Resistors 82 and 83 may be included in the channel 67, if desired. A tuned circuit 85 is provided which may be tuned similarly to the transformer 77, and is connected through a condenser 86 to the input grid of a pentode tube 87 forming part of the amplifier 68. A direct current path is provided from the first grid of this tube by a resistor 88 with a condenser 89 forming an alternating current impedance from grid to ground.

The amplifier 69, which may be of well known construction and need not be more fully described herein, is connected through a transformer 90 to the rectifier circuit 70. The latter, as shown, is of the push-pull type and includes two rectifier tubes 91 and 92. Bias batteries 93 and 94 are provided, the former being connected in series with a potentiometer 95 which functions as an output resistor.

The output circuit of the amplifier 68 includes a tuned circuit 96 which is coupled to two secondaries 97 and 98 forming part of the two detector circuits 71 and 72, which also include two rectifier tubes 100 and 101 and two respective resistors 102 and 103 each shunted by condensers 105 and 106 respectively. The cathode end of resistor 102 and the anode end of the resistor 103 are bridged by two equal high value resistors 107 and 108, the center point 109 of which is connected to the input circuit of the amplifier 73. The output circuit of the latter includes the head phones 74. The amplifier 73 may be of well known construction, and need not be more fully described herein.

Operation

The transmitted radiations are received by the antenna 64 and are impressed upon the frequency lowering converter 65, which is supplied with local energy from the oscillator 66. The output energy, which is of lower frequency but otherwise similar to the incoming energy, is selectively transmitted through the transformer 77 to the limiting channel 67.

To accomplish the elimination of the undesired

effects such as amplitude modulation transmissions, fading and stray static disturbances which pass through the transformer 77, two independent devices may be employed. Firstly, limiting devices may be used to cut down energy represented by amplitude modulations more rapidly than energy represented by phase, or frequency, modulation. That is, the limiter device may be adjusted to be inoperative unless the amplitude exceeds a predetermined limit, so that no effect is produced unless there are amplitude variations of the high frequency energy impressed on the limiting device. Such limiting devices for purging the amplitude variations without disturbing the frequency, or phase, variations are disclosed in my U. S. Patents 1,977,438 and 1,977,439.

Secondly, due to the special properties of the phase modulated signal, quasi-phase modulated signal or frequency modulated signal, it is possible separately to detect energy at the lower end of the spectrum and energy at the upper end of the spectrum, so as to produce signal currents out of phase. These detected currents can be combined in a back-to-back manner so that the effects of the signal modulations are additive, while any amplitude effects common to both portions of the spectrum will be cancelled out. Suitable circuit arrangements for performing this are disclosed in my U. S. Patents 1,935,776 and 1,976,393.

The present receiver provides two methods of limiting action prior to the conversion of the desired signals to amplitude modulated signals and detection. In the first method, energy from the secondary of the transformer 77 is impressed through the abrupt type limiting channel 67 upon the grid circuit of the amplifier tube 87. This limiter is so arranged that the devices do not pass current unless the instantaneous impressed voltage is above a certain predetermined value. It is to be understood that it is within the scope of the present invention to have the circuit 85 and other subsequent circuits tuned to double, or other higher frequencies, the frequency transmitted through the transformer 77, and to use zero, or reversed, values for the bias devices 80 and 81 so that distortion with double frequency tuning may be used.

With this type of limiter the energy of the circuit 85 is freer from amplitude modulation than the energy in the transformer 77, provided that it is suitably designed to pass the higher order side bands. The energy in the circuit 85 may be much freer from variations due to fading than the energy in the transformer 77, and in any event is a slightly rising function of the energy in the transformer 77. Further limiting devices of this type may be used, if desired, to produce improved effects. The second limiter device may be of a slower acting type, in which the incoming signal controls the gain of a succeeding tube in a manner similar to operation of automatic volume control devices. This circuit may be arranged to provide "delayed automatic volume control" so as not to be effective until a predetermined level is reached. It may, also, be arranged to be quick acting.

For this purpose, amplifier circuit 69 is actuated from the secondary of transformer 77, and the amplified energy drives the rectifier circuit 70 operative at sufficiently high level to produce negative voltage across bias condenser 89. This controls the gain of the tube 87, energized from the circuit 85 through the condenser 86, with the resistor 88 providing a direct current path with al-

ternating current impedance from grid to ground.

When the impressed voltage from the amplifier circuit 69 is sufficient, the rectifier 70 operates to produce a current in the direction of the arrow in the potentiometer 95 thereby changing the grid bias of the tube 87 in a negative direction. The rectifier circuit 70 itself is positively biased by the battery 94, and in the absence of signals the grid of the tube 87 is biased negatively with respect to the rectifier circuit 70 by the delay circuit battery 93. The voltage of the battery 93 exceeds that of the battery 94 so that in the absence of signal the tube 87 is biased negatively to its normal value. When rectification occurs, due to the voltage from the amplifier 69 exceeding a value determined by the battery 93, the bias of tube 87 rapidly becomes more negative and the gain of tube 87 diminishes. The abruptness of control is enhanced by the use of the high voltage batteries 93 and 94 differently connected. The control would be more gradual if the battery 94 were omitted, and a lower voltage battery substituted for the battery 93.

These two limiting methods may be organized, coordinated and adjusted so that they supplement each other in making the output of tube 87 of very constant level, and substantially free from amplitude modulation or other amplitude variation effects. The various condenser and resistor elements in the rectifier output circuit may be organized, coordinated and adjusted to produce sufficiently rapid response, and, in addition, delay action by circuits introduced between circuit 85 and tube 87 may be utilized to give higher precision operation.

The output of the tube 87 may be tuned by the circuit 96, coupled to the two secondaries 97 and 98, which operate into the linear detectors 100 and 101. For example, circuit 96 may be tuned to the middle of the transmitted band, circuit 97 to the upper portion of the band, and circuit 98 to the lower portion of the band. As a result detector 100 will be energized from the upper portion of the band more than from the lower, and detector 101 will be energized from the lower portion more than from the upper. These circuits may be organized for best operation depending on the nature of the incoming signals. The output of detectors 100 and 101, as regards the desired signal, are 180° out of phase, but as regards undesired signals present in both channels, are in phase. Therefore, the outputs may be differentially connected to succeeding amplifier circuits.

The output of detector 100 passes through resistor 102, shunted by condenser 105, in the direction indicated by the arrow. The output of detector 101 similarly passes through resistor 103, shunted by condenser 106, in the direction of the arrow. These circuits are symmetrical, and the input circuits are so adjusted that with the transmitter unmodulated the currents are equal. As the cathode end of resistor 102 and the anode end of resistor 103 are bridged by the two equal high-valued resistors 107 and 108, the center point 109 will be at ground potential when the transmitter is unmodulated. During modulation the upper and lower rectifiers 100 and 101 are operative alternately, so that the potential of the point 109 varies with respect to ground in accordance with the modulation, and a receiver voltage is produced matching the transmitter voltage in wave form. It is to be understood that various condensers, resistors, etc., may be organized to reinforce certain frequencies at the expense of others to produce fidelity of transmission. The

output energy is then fed to the amplifier 73 where it is amplified and impressed upon a sound reproducing device, such for example as the head phones 74.

It is to be understood that the above described receiver may be used with timing modulated energy that is phase modulated, or frequency modulated energy, or with various combinations thereof. It has been described for convenience in relation to phase-modulated energy. Other methods of accomplishing the same practical results as those described in connection with Fig. 3 lie fully within the scope of the present invention, and can readily be devised by those skilled in the art. Such an arrangement, may, for example, be that shown in Fig. 4, in which the limiting means, distributing means to the detectors, detector arrangements and combining circuits are somewhat different from those shown in Fig. 3, but accomplish the same general purposes.

In the modified form of receiver shown in Fig. 4 the circuits up to, and including, the transformer 77 are similar to those shown in Fig. 3. The secondary of the transformer 77 is connected to the first grid of a dual-grid, amplifying, limiting tube 115 in the grid return path of which is connected a resistor 116 shunted by a condenser 117. One end of the resistor 116 is connected to the grid of a triode tube 118, in the plate circuit of which is a resistor 119 and two series plate batteries 120 and 121. The second grid of the tube 115 is connected to the plate of the tube 118, and the plate of the tube 115 is connected through a resistor 122 to an intermediate point between batteries 120 and 121.

The resistor 122 is included in a circuit 125 which, also, comprises a condenser 126 and the primary winding of a transformer 127. The secondary of the latter is included in a secondary circuit 128 comprising a condenser 129 and a resistor 130. The center taps of the primary and secondary of the transformer 127 are connected together at point 131, the primary and secondary circuits 125 and 128 being substantially identical in nature with magnetic coupling therebetween.

The point 132 is connected through a blocking condenser 135 to a rectifier 136 which is shunted by a resistor 137. The point 133 is connected through a blocking condenser 138 to a rectifier 139 which is shunted by a resistor 140. The plates of the rectifiers 136 and 139 are connected through resistors 141 and 142 and blocking condensers 145 and 146 to the grids of two amplifier tubes 147 and 148. Condensers 149 and 150 are provided to by-pass high frequency currents, and are prevented from short-circuiting the rectifiers 136 and 139 by the resistors 141 and 142. Resistors 151 and 152 are provided to establish a direct current conductive connection with alternating current impedance from the grids of tubes 147 and 148 to ground.

The tubes 147 and 148 are biased by a cathode resistor 155 and shunt condenser 156. The output circuits of the amplifier tubes 147 and 148 are connected in a push-pull arrangement. The primary winding of an output transformer 157 has a center tap which is made positive with respect to ground by a battery 158. The secondary of the transformer 157 is connected to an indicator, such for example as a pair of head phones 159.

Operation

The operation of the modified form of receiver shown in Fig. 4 is similar to that of the receiver

shown in Fig. 3 up to, and including, the transformer 77. Energy from the transformer 77 is impressed upon the tube 115 which uses grid rectification to chop the peaks and control of the second grid to change the gain of the tube 115 in a gradual manner. This is accomplished by the rectified grid current, due to the chopping process, flowing through the resistor 116 in the direction of the arrow to put negative bias on the grid of tube 118. This results in a decrease of the flow of plate current through the resistor 119 which raises the potential of the second grid of the tube 115 with respect to the potential of the plate, and decreases the ability of the plate circuit to receive current and amplify the grid-impressed energy.

The combined chopping of input energy to the first grid of tube 115 and change of potential on the second grid, under the action of the chopping, serves to make the amplified output of tube 115 substantially independent of input signal strength and amplitude variations.

For distributing the energy differently to the two detectors 136 and 139 use is made of the following principle of coupled circuits. If two identical circuits 161 and 162 (Fig. 4A) are magnetically coupled, and are energized by a voltage e , then a primary and a secondary current i_p and i_s will result. The primary current i_p is the vector sum of the current i_x , that the same voltage e would produce in a suitable circuit 165 tuned higher than circuits 161 and 162, and the current i_y , that this voltage would produce in a suitable circuit 166 tuned lower than circuits 161 and 162. On the other hand, the secondary current is the vector difference of the currents producible in the single circuits.

That is, $i_p = (i_x + i_y)$; $i_s = (i_x - i_y)$.

This principle is utilized by making the circuit 125, loaded by the tube 115, the primary circuit and the circuit 128, loaded by the elements 129 and 130 the secondary of the transformer 127. The high frequency potential of point 131 with respect to ground is proportional to $\frac{1}{2}(i_x + i_y)$, and the potential of point 132 with respect to point 133 is proportional to $(i_x - i_y)$. Because of the connection between the center taps at 131, the potential of points 132 and 133 with respect to ground (assuming the proportionality factor is unity) are given by—

$$e_b = \frac{1}{2}(i_x + i_y) + \frac{1}{2}(i_x - i_y) = i_x$$

$$e_c = \frac{1}{2}(i_x + i_y) - \frac{1}{2}(i_x - i_y) = i_y$$

The voltages produced by the tube 115 and impressed on the blocking condensers 135 and 138 are, therefore, proportional to the voltages which would be created by differently tuned single circuits analogous to the arrangement shown in Fig. 3. By the rectifier action of the tubes 136 and 139 direct current components are developed through the circuits in the direction shown by the arrows, but due to the rectifier 136 being driven from one end of the energy spectrum and the rectifier 139 being driven from the other end of the energy spectrum, the detected currents are polarized differently from the direct currents. That is, when the plate of the rectifier 136 is most positive the plate of the rectifier 139 is most negative.

The arrows S and A serve to indicate the polarities of the currents due to the signal and amplitude effects, respectively, due to any in-phase energies impressed upon the two detectors. It will be seen that the signal currents produce additive effects in the head phones 159, while the

currents due to the amplitude effects are neutralized.

The circuits shown in Fig. 4 differ from those depicted in Fig. 3 first with respect to the nature of the limiter circuits; secondly, with respect to the method of distributing energy from different ends of the spectrum to the two rectifiers; thirdly, with respect to the nature of the rectifier circuits; and fourthly, with respect to the nature of the push-pull connections from the rectifiers to the indicating device. These two circuits are illustrative of differences of design which can be arranged by those skilled in the art, under the broad principles disclosed herein and within the scope of the following claims.

Although only a few of the various forms in which this invention may be embodied have been shown herein, it is to be understood that the invention is not limited to any specific construction, but may be embodied in various forms without departing from the spirit of the invention within the scope of the appended claims.

What I claim is:

1. In a timing modulated carrier energy transmission system, an electron discharge device comprising at least an electron emission element, an electron collection electrode and an electron control electrode, an energy input circuit connected between said control electrode and emission element, a resistor-condenser network in a series circuit with said input circuit between said control electrode and emission element to develop a unidirectional voltage which increases in a negative polarity sense with energy amplitude increase, an auxiliary electron control element for the electron stream from said emission element to the collection electrode, and means, directly responsive to said voltage, for increasing said auxiliary control element potential in a positive polarity sense thereby to decrease the electron flow to said collection electrode.

2. In a timing modulated carrier energy transmission system, an electron discharge device comprising at least an electron emission element, an electron collection electrode and an electron control electrode, an energy input circuit connected between said control electrode and emission element, a resistor-condenser network in a series circuit with said input circuit between said control electrode and emission element to develop a unidirectional voltage which increases in a negative polarity sense with energy amplitude increase, an auxiliary electron control element for the electron stream from said emission element to the collection electrode, and electron discharge tube means, directly responsive to said voltage, for increasing said auxiliary control element potential in a positive polarity sense thereby to decrease the electron flow to said collection electrode.

3. In a modulated carrier energy transmission system, an electron discharge device comprising at least an electron emission element, an electron collection electrode and an electron control electrode, an energy input circuit connected between said control electrode and emission element, a resistor-condenser network in series between said emission element and said input circuit to develop a unidirectional voltage which increases in a negative polarity sense with energy amplitude increase, an auxiliary electron control element for the electron stream from said emission element to the collection electrode, and means, directly responsive to said voltage, for increasing said auxiliary control element poten-

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tial in a positive polarity sense thereby to decrease the electron flow to said collection electrode and an energy output circuit connected to said collection electrode.

4. In combination, in a phase or frequency modulation receiver, an amplitude limiter network comprising a tube having at least a cathode, a plate and a pair of control grids in the electron stream to said plate, a signal input circuit, a grid rectification network in circuit with said input circuit between one control grid and the cathode, said rectification network developing direct current voltage from amplitude variations in the signal energy of said input circuit, a signal output circuit coupled to the plate, means for applying a positive potential to each of the plate and the second control grid, and means, directly responsive to said voltage, for increasing the positive potential of the second grid relative to the plate.

5. In combination, in a phase or frequency modulation receiver, an amplitude limiter network comprising a tube having at least a cathode, a plate and a pair of control grids in the electron stream to said plate, a signal input circuit, a grid rectification network in circuit with said input circuit between one control grid and the cathode, said rectification network developing direct current voltage from amplitude variations in the signal energy of said input circuit, a signal output circuit coupled to the plate, means for applying a positive potential to each of the plate and the second control grid, and means, directly responsive to said voltage, for increasing the positive potential of the second grid relative to the plate, and said last means comprising a tube having an input electrode and an output electrode, means applying said voltage to said input electrode and means connecting the output electrode to said second control grid.

6. In combination, in a phase or frequency modulation receiver, an amplitude limiter network comprising a tube having at least a cathode, a plate and a pair of control grids in the electron stream to said plate, a signal input circuit, a grid rectification network in circuit with said input circuit between one control grid and the cathode, said rectification network developing direct current voltage from amplitude variations in the signal energy of said input circuit, a signal output circuit coupled to the plate, means for applying a positive potential to each of the plate and the second control grid, and means, directly responsive to said voltage, for increasing the positive potential of the second grid relative to the plate, said applying means comprising a current source having its positive potential terminal connected to said second control grid through a resistor, and said responsive means comprising a tube having its cathode to plate path in shunt with the current source and resistor, and a control element, connected to said rectification network, for regulating the conductivity of said cathode to plate path.

7. An amplitude limiter circuit of the type comprising a cathode, signal grid, positive screen grid and positive output electrode, a signal input circuit, a resistor arranged in series with said

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input circuit between the signal grid and cathode, a condenser in shunt with the resistor to provide a grid rectification network, an electronic impedance device in circuit with said screen grid, and means, directly responsive to rectified grid current flowing through said resistor, for varying the magnitude of said impedance thereby to vary the screen grid potential.

8. A method of limiting the amplitude of modulated signal energy which comprises passing electrons through successive control grids to an electron collection electrode, applying signal energy to be limited to the first control grid, developing direct current voltage from electron current flowing to said first grid, and increasing the potential of the second control grid in a positive potential sense thereby to divert electrons from said collection electrode in direct response to said voltage.

9. In combination in an amplitude limiter network, a tube having at least a cathode, a plate and at least two control grids in the electron stream to said plate, a signal input circuit, a grid rectification network in a series circuit with said input circuit between one of said control grids and the cathode, said rectification network developing direct current voltage from signal energy at said input circuit, a signal output circuit coupled to the plate, means for applying a positive potential to each of the plate and the second control grid, and means, directly responsive to said direct current voltage, for increasing the positive potential of the second grid relative to the plate.

10. In an amplitude limiter network comprising a tube having a cathode, a plate and at least two control grids in the electron stream to said plate, a signal input circuit, a grid rectification network in a series circuit with said input circuit between one control grid and the cathode, said rectification network developing direct current voltage from signal energy at said input circuit, a signal output circuit coupled to the plate, means for applying a positive potential to each of the plate and the second control grid, and means, directly responsive to said voltage, for increasing the positive potential of the second grid relative to the plate, said applying means comprising a current source having its positive potential terminal connected to said second control grid through an impedance and said responsive means comprising a tube having its cathode to plate path in shunt with the current source and impedance, and a control element, connected to said rectification network, for regulating the conductivity of said cathode to plate path.

11. A method of limiting which comprises passing electrons through at least two successive control grids to an electron collection electrode, applying signal energy to the first control grid, developing direct current voltage from electron current flowing to said first grid, and varying the potential of the second control grid in an increasingly positive potential sense in response to said direct current voltage thereby to divert electrons from said collection electrode.

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