May 3, 1949. L. H. MONTGOMERY 2,468,832

SIGNALING SYSTEM

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Fig. 1

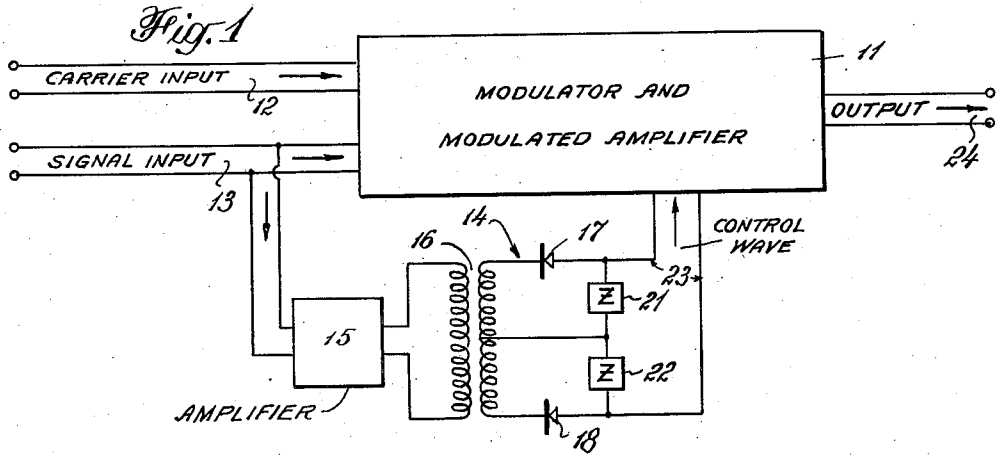


Fig. 2.

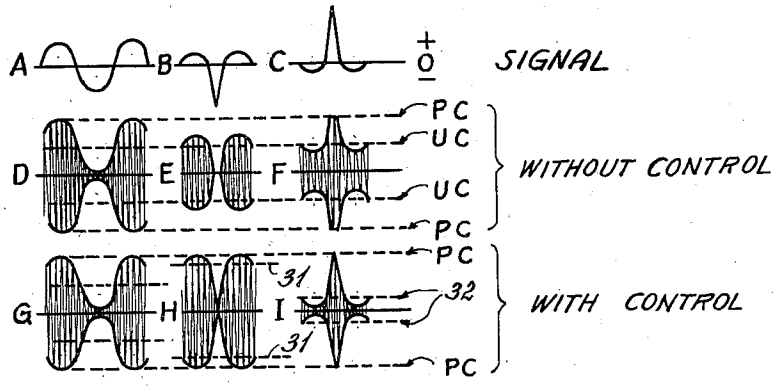
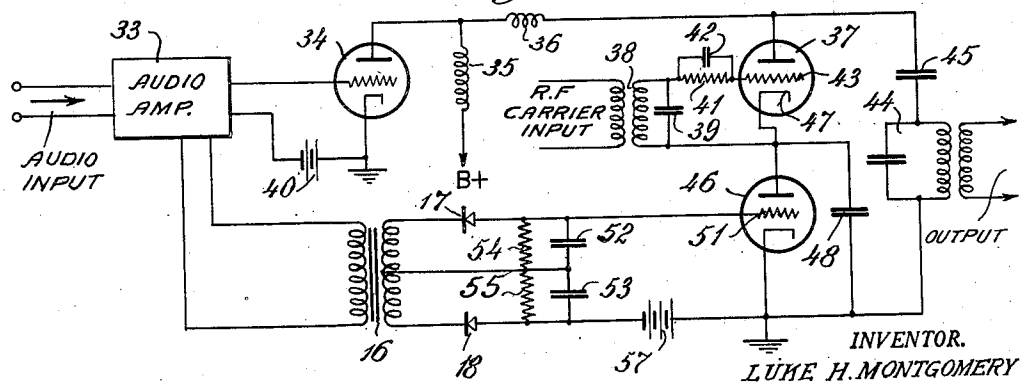


Fig. 3.



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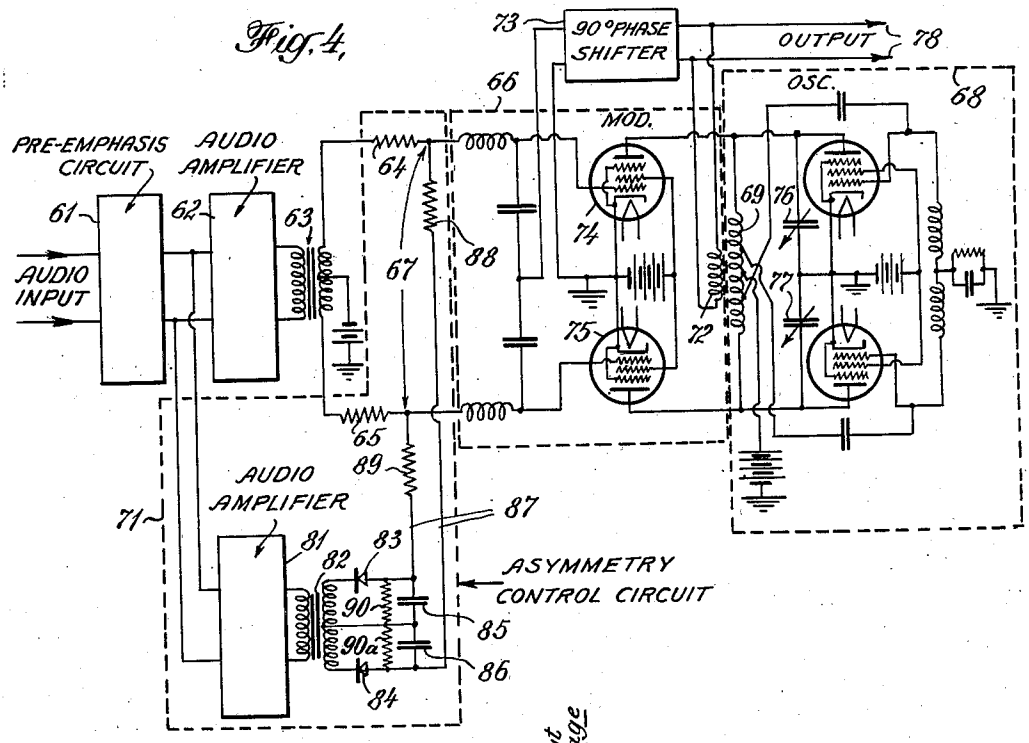
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May 3, 1949. L. H. MONTGOMERY 2,468,832

SIGNALING SYSTEM

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Fig. 4.



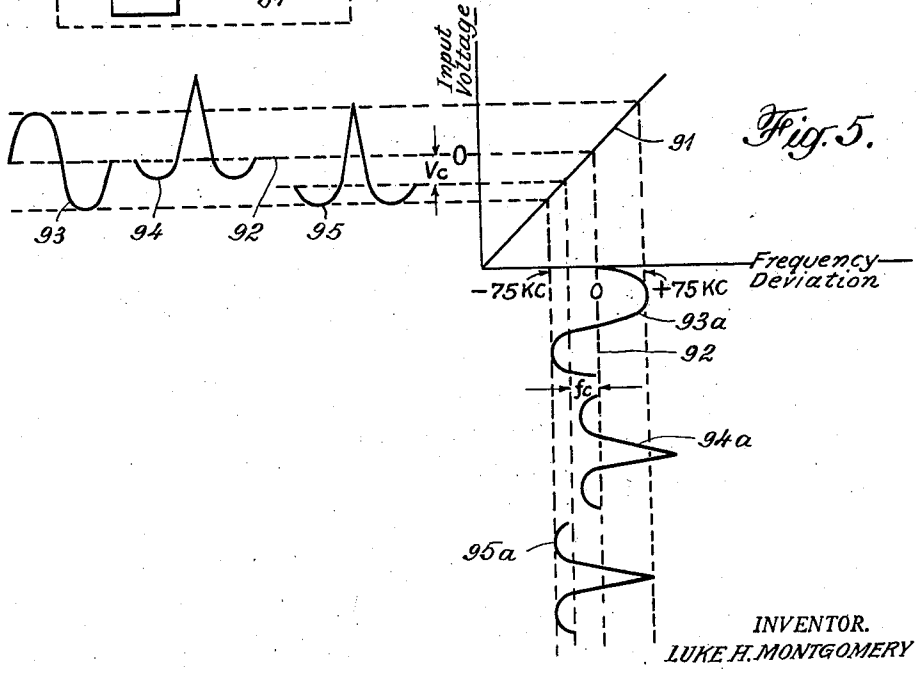


Fig. 5.

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2,468,832

SIGNALING SYSTEM

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20 Claims. (Cl. 332—38)

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This invention relates to signaling circuits and provides a method and apparatus for controlling the operation of such circuits in relation to the waveform symmetry of an alternating signal wave. While not confined thereto in its broader aspects, the invention is particularly directed to audio-frequency signal modulation circuits in which audio signals occasionally are asymmetric.

In radio transmitting stations the audio signal waves used to modulate the carrier are usually symmetrical in their positive and negative amplitude excursions. Transmitter circuits are commonly designed so that the loudest signals to be transmitted will produce close to 100% modulation, for maximum efficiency. It has been found that certain voices give asymmetrical audio waves which, in extreme cases, may give only 30% modulation in one direction for a signal level giving 100% modulation in the opposite direction. The asymmetry may be in either direction, that is, the positive amplitudes may be greater than the negative, or vice-versa, depending upon the voice. Likewise, certain musical instruments upon occasion appear to yield asymmetrical waves. Although the asymmetry is believed due to peculiarities in the voices or instruments, certain types of microphones seem more prone to give asymmetrical responses for certain voices or instruments than other types.

If a transmitter is adjusted to give 100% modulation for symmetrical audio signals of given volume, asymmetrical signals of the same volume will result in overmodulating the transmitter in one direction and under-modulating it in the other. Over-modulation results in distortion, and under-modulation results in failure to transmit the signal at the required volume level. To avoid distortion due to over-modulation, it is customary to reduce the amplitude of the audio signal wave.

The present invention prevents over-modulation by asymmetrical signals without reducing the amplitude thereof, thus permitting transmission at full volume level without distortion. This is accomplished, broadly, by developing a control wave which is a function of the asymmetry of the signal wave, and then utilizing the control wave to shift the normal unmodulated operating point of the modulation circuit.

Modulation may be defined as the process of modifying a carrier, some characteristic of which is made to vary as a function of the instantaneous value of a modulating signal wave. Amplitude-modulation and frequency-modulation are the principal types used in broadcasting at present.

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In amplitude-modulation the amplitude characteristic of the carrier is varied in accordance with the signal wave. In frequency-modulation the frequency characteristic of the carrier is varied. The present invention may be applied broadly to any type of modulation, but is particularly useful in connection with amplitude and frequency modulation.

In the specific embodiments described hereinafter, a control wave is produced by applying the signal wave to a rectifier or detector circuit which yields an output which varies with the degree of asymmetry of positive and negative portions of the signal. It is particularly advantageous to utilize peak detector circuits so as to obtain a control wave which varies with differences in the peak positive and negative amplitudes of the signal wave. The control wave is then supplied to the modulation circuit to shift the normal unmodulated carrier value when the signal wave is asymmetrical.

The invention will be more clearly understood by reference to the drawings and the following description thereof. In the drawings:

Fig. 1 is a diagram showing the manner of deriving the asymmetry control wave and applying it to a modulation circuit;

Fig. 2 is a diagram showing the effect of the asymmetry control in amplitude modulation;

Fig. 3 is a specific embodiment of an amplitude-modulation circuit utilizing a control circuit of the invention;

Fig. 4 is a diagram of a frequency-modulation circuit utilizing a control circuit of the invention; and

Fig. 5 is a diagram showing the effect of the asymmetry control in frequency modulation.

Referring to Fig. 1, a modulator and modulated amplifier 11 is supplied with a radio-frequency carrier input 12 and an audio signal input 13. The audio signal input 13 is also supplied to an asymmetry control circuit, generally designated as 14, through a buffer amplifier 15. Transformer 16 is fed from amplifier 15 and has a center tapped secondary. A pair of rectifiers 17 and 18 are connected in series with respective impedances 21 and 22 between the center tap and respective ends of the secondary of transformer 16. The rectifiers are polarized so that the waves built up in impedances 21 and 22 are in opposition. The resulting control wave across terminals 23 is therefor the difference between the waves built up in impedances 21 and 22. These impedances are reactive so as to provide a fairly smooth output control wave.

The control wave is then supplied to the modulator and modulated amplifier 11 so as to change the normal unmodulated value in accordance with the asymmetry of the signal input wave. The output of 11 is supplied through terminals 24 to the radio-frequency transmitting circuit.

In Fig. 2, a symmetrical signal wave is shown at A, an asymmetrical signal wave with greater negative excursion at B, and an asymmetrical wave with greater positive excursion at C. Below these waves are corresponding amplitude-modulated radio-frequency waves D, E and F. The dotted lines PC represent the peak carrier amplitude for 100% modulation. The dotted lines UC represent the normal unmodulated carrier level.

It will be observed that wave D shows practically 100% modulation, with the carrier amplitude varying from nearly zero to peak amplitude. Asymmetrical wave B has the same peak-to-peak amplitude as wave A, yet the positive amplitude excursion in E is not as great as in D so that the carrier is not as fully modulated. The negative excursion results in over-modulating the carrier with consequent distortion. In F, the positive peak of wave C goes beyond the peak carrier amplitude and this over-modulation results in distortion. On the other hand, the negative excursion does not reduce the carrier level as much as in D.

The lower row of waves, G, H and I, represent radio-frequency amplitude-modulated waves with the asymmetry control of the invention. The normal symmetrical modulation shown in G is the same as in D. In H, however, the normal unmodulated carrier level has been increased to 31. Thus the asymmetrical wave B modulates the carrier fully from zero to peak amplitude levels, without over-modulation or distortion. In I, the control wave reduces the normal unmodulated carrier level to 32, so that the modulating wave shown at C again fully modulates the carrier from nearly zero to peak amplitude without over-modulation or distortion.

Fig. 3 shows one specific embodiment of applicant's invention used with a conventional plate, or Heising type modulation circuit. Here the audio signal input wave is supplied through audio amplifier 33 to the control grid of modulator tube 34. A battery 40 supplies suitable grid bias. Plate voltage for tube 34 is supplied from a B+ source through coupling inductance 35. The plate of tube 34 is connected through R. F. choke 36 to the plate of the modulated-amplifier tube 37. The radio-frequency carrier is supplied to the primary of transformer 38, and the secondary is shunted by capacitor 39 tuned to resonance. The carrier is then supplied through grid leak resistor 41 and shunting capacitor 42 to the grid 43 of the modulated amplifier tube 37. The output circuit of tube 37 includes the tank circuit 44 and blocking capacitor 45.

The plate supply voltage for the modulated amplifier 37 is controlled by electronic tube 46 connected between cathode 47 and ground. Tube 46 is shunted by capacitor 48 to bypass the radio frequency component. It will be understood that as the potential applied to grid 51 of tube 46 is varied, the internal resistance of the tube varies and hence the plate supply voltage of tube 37 may be altered. Thus the carrier level may be shifted by changing the grid potential of tube 46.

The control circuit in Fig. 3 is similar to that shown in Fig. 1. The audio signal input is supplied from amplifier 33 to transformer 16, and rectifiers 17 and 18 are connected in the secondary circuit of the transformer. The impedances are here shown as capacitors 52 and 53 shunted by respective resistors 54 and 55. Each of rectifiers 17 and 18 serves as a peak detector, in that the voltage built up across capacitor 52 represents the peak amplitude of one polarity of the wave, and the voltage built up across capacitor 53 represents the peak amplitude of the other polarity. Since capacitors 52 and 53 are in series between ground and grid 51, the voltages are in opposition and the potential applied to grid 51 varies in accordance with the difference between the positive and negative peak voltages. The sign of the combined voltage across capacitors 52 and 53 is determined by the asymmetrical peak of greater amplitude. A battery 57 may be provided to establish proper operating grid bias for tube 46.

When the audio signal wave is symmetrical, no voltage is developed across capacitors 52 and 53, and the bias applied to the grid of tube 46 remains fixed at a value determined by battery 57. Thus the plate voltage of tube 37 is not varied by tube 46 and the circuit operates in the normal fashion as a plate modulation circuit. However, when the audio signal wave is asymmetrical, a voltage of proper polarity is developed across capacitors 52 and 53 and changes the grid bias on grid tube 46. This results in changing the plate voltage across tube 37 and the normal unmodulated carrier level is shifted.

It will therefore be clear that the normal operating point on the transfer characteristic between audio signal input and modulated carrier output is shifted in proportion to the magnitude and polarity of the control voltage wave, which in turn are determined by the degree and direction of asymmetry of the audio signal wave.

The polarity of the control voltage is selected so that the shift in carrier level is in the direction of the modulation produced by the smaller of the asymmetrical amplitudes. For example, referring to Fig. 2, the positive portions of wave B are of smaller amplitude than the negative portion, and the shift in the unmodulated carrier level shown at 31 in H is in the direction of the modulation produced by the positive portion of the modulating wave.

The circuit constants of the control circuit are selected in accordance with the constants of the modulation circuit and the conditions of operation. Rectifiers 17 and 18 may be of any suitable type. For example, crystal rectifiers or detectors of type 1N35 have been employed with success, but diodes may be employed if desired. It is advantageous to select values for capacitors 52 and 53 which will permit their rapid charge to peak voltage, so that the attack time is kept short. The values of shunting resistors 54 and 55 are advantageously selected so that the control wave is smoothed for the lowest audio frequency it is desired to transmit. In some cases the back resistance of crystal rectifier may provide sufficient leakage to permit dispensing with separate resistors. Time constants of the order of one-tenth of a second have been employed with success. In this manner any very low frequencies which may be injected into the modulated signal through the control circuit are kept below the frequency response of the receivers which utilize the transmitted signal.

It will be understood that as soon as the signal wave returns to its normal symmetrical condition, the total control voltage across capacitors 52 and 53 will be rapidly returned to zero. In the event that momentary over-modulation re-

sults due to the finite attack time of the control circuit, the audio signal to the modulated amplifier may be delayed slightly in order to permit the control circuit to operate before the modulation takes place.

The magnitude of the control wave for any given amount of asymmetry may be altered by changing the turns ratio of transformer **16** or by changing the magnitude of the audio signal as supplied to the transformer. It is advantageous to select values which will shift the carrier level just enough to compensate for the asymmetry, as shown in Fig. 2 at H and I. The direction of shift may readily be changed by reversing the primary or secondary connections of transformer **16**.

Referring now to Fig. 4, the application of the invention to a conventional frequency-modulation circuit is shown. The circuit is similar to that shown on page 242 of Hund's "Frequency Modulation," first edition, published by McGraw-Hill Book Company. Since the frequency-modulation circuit itself is well known, detailed description of the functioning of the elements is unnecessary and it will suffice to point out the functioning of the major components.

The audio signal input is supplied through a preemphasis circuit **61** and audio amplifier **62** to the primary of transformer **63**. The signal from the secondary of transformer **63** passes through resistors **64** and **65** to the balanced modulator circuit **66**. The input signal to the balanced modulator circuit may be considered to appear across terminals **67**. A primary FM oscillator is shown at **68**, and contains a tank circuit including inductance **69** and tunable capacitors **76** and **77**.

Neglecting for the moment the asymmetry control circuit **71**, the primary carrier frequency in tank inductance **69** is supplied through the coupled coil **72** and the 90° phase shifter circuit **73** to the cathode-grid circuits of reactance tubes **74** and **75**. The phase-shifted carrier signal is thus supplied to both grids in the same phase. At the same time, the input audio signal at terminals **67** is supplied to the grids of reactance tubes **74** and **75** in push-pull. The net effect is to vary the reactance of the tank circuit composed of inductance **69** and variable capacitors **76** and **77** so as to obtain a frequency-modulated wave. The output at **78** is then supplied to the usual frequency doublers and power amplifiers for transmission.

Referring now to the asymmetry control circuit **71**, an audio amplifier **81** supplies the audio signal to the balanced rectifier circuit composed of center-tapped transformer **82**, rectifiers **83**, **84**, capacitors **85**, **86**, and shunting resistors **90**, **90***a*. This circuit is similar to that described in connection with Fig. 3 and, as there described in detail, a control wave appears across lines **87** whose magnitude and sign varies in accordance with the degree and direction of asymmetry between positive and negative amplitudes of the audio signal wave.

Ordinarily the balanced modulator circuit has a resistance between terminals **67**. This resistance is replaced by the two resistors **88** and **89** in series with the voltage developed across capacitors **85**, **86**. Thus the control wave is effectively applied across terminals **67**, simultaneously with the audito signals supplied thereto. Resistors **64** and **65** are inserted to prevent the shortcircuiting of the control voltage supplied to terminals **67** by the secondary of transformer **63**.

The operation of the symmetry control circuit will be clear. The audio signal voltage supplied to terminals **67** varies the frequency of the modulated signal in the usual fashion. The control wave, supplied to the same terminals, shifts the normal rest frequency of the transmitted signal. Normally, in the absence of any audio signal, an unmodulated rest frequency is transmitted of value determined by the constants of the tank circuit in the oscillator **68**. A symmetrical audio signal varies the transmitted frequency symmetrically about the normal rest frequency. When an asymmetrical audio signal arrives, a control voltage is developed and applied to terminals **67**, thereby shifting the normal unmodulated rest carrier frequency. The asymmetrical audio signal then causes the carrier to vary around the shifted rest frequency.

The operation is further illustrated in Fig. 5. Here, line **91** is the transfer characteristic between the input signal voltage and the frequency deviation of the modulation circuit. Line **92** is the normal unmodulated rest condition, wherein a zero input voltage gives a zero frequency deviation. If a symmetrical audio signal wave **93** is applied, the symmetrical frequency deviation shown at **93***a* results. This is shown as a signal of maximum volume, so that the full frequency deviation of +75 kc. (present standards) results. If an asymmetrical wave such as shown at **94** is supplied to the input, and the normal rest frequency were unchanged, the frequency deviation would be as shown at **94***a*. This is overmodulated in the positive direction and modulated less than maximum in the negative direction.

In accordance with the invention, a control voltage of magnitude represented by V_c is suppied to the input circuit of the modulator so as to shift the normal rest carrier frequency by the amount f_c. This results in shifting the asymmetrical wave from the position shown at **94** to that shown at **95**, with corresponding change in frequency deviation from **94***a* to **95***a*. The latter wave shows that full frequency deviation is obtained from +75 kc. to −75 kc. without overmodulation.

The above specific embodiments illustrate the application of the invention to specific amplitude-modulation and frequency-modulation circuits. The application to other types of circuits will be clear to those in the art. Furthermore, the manner of deriving the control wave from the audio signal need not be the specific one described. since many forms of peak detector circuits are known in the art and may be adapted readily for use in the present invention.

It is also possible to use the principles of the invention in audio amplifier circuits. In many amplifier circuits, particularly in class A amplifiers, the distortion introduced by the upper and lower bends of the plate characteristic is the limiting factor. If an operating point on the transfer characteristic of the amplifier is selected to allow maximum swing for symmetrical audio signals, an asymmetrical audio signal of equal magnitude will result in distortion at either the upper or the lower bend, depending upon the direction of the asymmetry. In such case a control wave may be developed, as above described, and supplied as a bias to the audio amplifier to shift the normal operating point on the transfer characteristic when asymmetrical signals occur. This allows maximum swing for both symmetrical and asymmetrical signals without distortion.

It will be apparent to those in the art that the principles of controlling the operation of elec-

tronic circuits with respect to the waveform symmetry of the input signal as described herein are of broad application. Many specific circuits may be devised or adapted to effect the desired control, within the spirit of the invention.

What is claimed is:

1. In combination, an electronic circuit having an input circuit and an output circuit with a predetermined transfer characteristic therebetween, circuit connections for applying an audio signal wave to said input circuit to swing about a predetermined operating point on said transfer characteristic, an asymmetry detection circuit supplied with said audio signal wave and designed and adapted to yield an output control wave which varies with asymmetrical positive and negative portions of said signal wave, and circuit connections for applying said control wave to said electronic circuit to shift said operating point in the direction of swing of the smaller of said asymmetrical portions when said audio signal wave is asymmetrical.

2. In combination, an electronic circuit having an input circuit and an output circuit with a predetermined transfer characteristic therebetween, circuit connections for applying an audio signal wave to said input circuit to swing about a predetermined operating point on said transfer characteristic, a rectifier circuit supplied with said audio signal wave and connected to respond to differences between positive and negative asymmetrical amplitudes thereof to produce a control wave which varies with the asymmetry, and circuit connections for applying said control wave to said electronic circuit to shift said operating point in the direction of swing of the smaller of said asymmetrical amplitudes.

3. In combination, a circuit including an electronic tube and having an input circuit and an output circuit with a predetermined transfer characteristic therebetween, circuit connections for applying an audio signal wave to said input circuit to swing about a predetermined operating point on said transfer characteristic, a balanced rectifier circuit having a plurality of peak rectifiers connected to develop a control wave proportional to the differences in amplitude of positive and negative loops of an alternating wave impressed thereon, circuit connections for impressing said audio signal wave on said rectifier circuit to obtain a control wave varying with asymmetries in said signal wave, and circuit connections for applying said control wave to said electronic circuit to shift said operating point in the direction of swing of the smaller of said asymmetrical amplitudes.

4. In a modulated radio-frequency signalling system, in combination, a modulation circuit in which a selected characteristic of a radio-frequency carrier is varied in accordance with an audio signal wave, an asymmetry detection circuit supplied with said audio signal wave and designed and adapted to yield an output control wave which varies with asymmetrical positive and negative portions of said signal wave, and circuit connections for supplying said control wave to said modulation circuit to change the normal unmodulated value of said selected characteristic in the modulation direction of the smaller of said asymmetrical portions when said audio signal wave is asymmetrical.

5. In a modulated radio-frequency signalling system, in combination a modulation circuit in which a selected characteristic of said radio-frequency carrier is varied from a normal unmodulated value in accordance with said audio signal wave to produce a modulated signal, a rectifier circuit supplied with said audio signal wave, said rectifier circuit being connected to respond to differences between positive and negative asymmetrical amplitudes of said audio signal wave to produce a control wave which varies with the asymmetry, and circuit connections for supplying said control wave to the modulation circuit to change said normal unmodulated value when the audio signal wave is asymmetrical, whereby overmodulation of said carrier by asymmetrical signals may be diminished.

6. In a modulated radio-frequency signalling system, in combination, a modulation circuit in which a selected characteristic of said radio-frequency carrier is varied about a normal unmodulated value in accordance with an audio signal wave to produce a modulated signal, a balanced rectifier circuit having a plurality of rectifiers connected to develop a control wave proportional to the differences in amplitude of positive and negative loops of an alternating wave impressed thereon, circuit connections for impressing said audio signal wave on said rectifier circuit to obtain a control wave varying with asymmetries in said signal wave, and circuit connections for supplying said control wave to said modulation circuit to produce a proportional change in said normal unmodulated value when said audio signal wave is asymmetrical, the polarity of the control wave as supplied to said modulation circuit being selected to change said normal unmodulated value in the modulation direction of the smaller of the asymmetrical amplitudes of said audio signal wave, whereby overmodulation of said carrier by asymmetrical signals may be diminished.

7. In an amplitude-modulation signalling system, in combination, an amplitude-modulation circuit in which the amplitude of a radio-frequency carrier is varied about a normal unmodulated level in accordance with an audio signal wave, an asymmetry detection circuit supplied with said audio signal wave and connected to respond to differences between positive and negative asymmetrical amplitudes thereof to produce a control wave which varies with the asymmetry, and circuit connections for supplying said control wave to the modulation circuit to change said normal unmodulated carrier level in the modulation direction of the smaller of said asymmetrical amplitudes.

8. In an amplitude-modulation signalling system, in combination, an amplitude-modulation circuit in which the amplitude of a radio-frequency carrier is varied about a normal unmodulated level in accordance with an audio signal wave, a rectifier circuit supplied with said audio signal wave and connected to respond to differences between positive and negative asymmetrical amplitudes thereof to produce a control wave which varies with the asymmetry, and circuit connections for supplying said control wave to the modulation circuit to produce a proportional change in said normal unmodulated carrier level in the modulation direction of the smaller of said asymmetrical amplitudes.

9. In an amplitude-modulation signalling system, in combination, an amplitude-modulation circuit in which the amplitude of a radio-frequency carrier is varied about a normal unmodulated level in accordance with an audio signal wave, a balanced rectifier circuit having a plurality of peak rectifiers connected to develop

a control wave proportional to the differences in amplitude of positive and negative peaks of an alternating wave impressed thereon, circuit connections for impressing said audio signal wave on said rectifier circuit to obtain a control wave varying with asymmetries in said signal wave, the decay time constant of said peak rectifiers being longer than the period of the lowest audio frequency to be transmitted, and circuit connections for supplying said control wave to said modulation circuit to change the normal unmodulated carrier level in the modulation direction of the smaller of the asymmetrical amplitudes of said audio signal wave, whereby overmodulation of said carrier by asymmetrical signals may be diminished.

10. In an amplitude-modulation signalling system, in combination, an amplitude-modulation circuit in which the amplitude of a radio-frequency carrier is varied about a normal unmodulated level in accordance with an audio signal wave, a pair of rectifier circuits supplied with said audio signal wave, each rectifier circuit containing a storage reactive impedance and the rectifiers being polarized to derive rectified waves corresponding respectively to positive and negative amplitudes of the audio signal wave in respective impedances, connections for combining said rectified waves in opposition to obtain a control wave which varies with the difference in said positive and negative amplitudes when the audio signal wave is asymmetrical, the reactive impedances being selected to yield a decay time constant longer than the period of the lowest audio frequency to be transmitted, and circuit connections for supplying said control wave to said modulation circuit to change the normal unmodulated carrier level in the modulation direction of the smaller of the asymmetrical amplitudes of said audio signal wave, whereby overmodulation of said carrier by asymmetrical signals may be diminished.

11. In an amplitude-modulation signalling system, in combination, an amplitude-modulation circuit in which the amplitude of a radio-frequency carrier is varied about a normal unmodulated level in accordance with an audio signal wave, a transformer supplied with said audio signal wave and having a center-tapped secondary winding, a pair of rectifiers and respective capacitive impedances connected in circuit between said center tap and respective ends of the secondary winding and having decay time constants longer than the period of the lowest audio frequency to be transmitted, said rectifiers being polarized to develop a control voltage wave across said capacitive impedances proportional to the difference in peak positive and negative amplitudes of said audio signal wave when it is asymmetrical, and circuit connections for supplying said control wave to said modulation circuit to change the normal unmodulated carrier level in the modulation direction of the smaller of the asymmetrical amplitudes of said audio signal wave, whereby overmodulation of said carrier by asymmetrical signals may be diminished.

12. In an amplitude-modulation signalling system, in combination, an amplitude-modulation circuit of the plate-modulation type including a first electronic tube having grid-cathode and plate-cathode circuits, connections for supplying a radio-frequency carrier to said grid-cathode circuit, connections for supplying an audio signal wave to the plate of said electronic tube to amplitude-modulate the output thereof, a second electronic tube in the cathode circuit of the first-mentioned electronic tube to control the plate-cathode voltage thereof and thereby the unmodulated carrier level, a transformer supplied with said audio signal wave and having a center-tapped secondary winding, a pair of rectifiers connected in circuit between said center tap and respective ends of the secondary winding, a pair of shunt resistor-capacitor circuits in series between said center tap and respective rectifiers and having decay time constants longer than the period of the lowest audio frequency to be transmitted, said rectifiers being polarized to develop a control voltage wave across said resistor-capacitor circuits proportional to the difference in peak positive and negative amplitudes of said audio signal wave when it is asymmetrical, and connections supplying said control voltage wave to control the current through said second electronic tube and thereby the plate-cathode voltage of the first electronic tube, the polarity of the control wave as supplied to said second electronic tube being selected to shift the normal unmodulated carrier level in the modulation direction of the smaller of the asymmetrical amplitudes of said audio signal wave.

13. In a frequency-modulation signalling system, in combination, a frequency-modulation circuit in which the frequency of a radio-frequency carrier is varied about a normal unmodulated frequency in accordance with an audio signal wave, an asymmetry detection circuit supplied with said audio signal wave and connected to respond to differences between positive and negative asymmetrical amplitudes thereof to produce a control wave which varies with the asymmetry, and circuit connections supplying said control wave to said modulation circuit to shift the normal unmodulated carrier frequency in the modulation direction of the smaller of said asymmetrical amplitudes.

14. In a frequency-modulation signalling system, in combination, a frequency-modulation circuit in which the frequency of a radio-frequency carrier is varied about a normal unmodulated frequency in accordance with an audio signal wave, a rectifier circuit supplied with said audio signal wave and connected to respond to differences between positive and negative asymmetrical amplitudes thereof to produce a control wave which varies with the asymmetry, and circuit connections supplying said control wave to said modulation circuit to produce a proportional shift in the normal unmodulated carrier frequency in the modulation direction of the smaller of said asymmetrical amplitudes.

15. In a frequency-modulation signalling system, in combination, a frequency-modulation circuit in which the frequency of a radio-frequency carrier is varied about a normal unmodulated frequency in accordance with an audio signal wave, a balanced rectifier circuit having a plurality of peak rectifiers connected to develop a control wave proportional to the differences in amplitude of positive and negative peaks of an alternating wave impressed thereon, circuit connections for impressing said audio signal wave on said rectifier circuit to obtain a control wave varying with asymmetries in said signal wave, the decay time constant of said peak rectifiers being longer than the period of the lowest audio frequency to be transmitted, and circuit connections supplying said control wave to said modulation circuit to shift the normal unmodulated carrier frequency in the modulation direction

of the smaller of the asymmetrical amplitudes of said audio signal wave, whereby overmodulation of said carrier by asymmetrical signals may be diminished.

16. In a frequency-modulation signalling system, in combination, a frequency-modulation circuit in which the frequency of a radio-frequency carrier is varied about a normal unmodulated frequency in accordance with an audio signal wave, a pair of peak rectifier circuits supplied with said audio signal wave, each rectifier circuit containing a capacitive impedance and the rectifiers being polarized to derive rectified waves corresponding respectively to positive and negative amplitudes of the audio signal wave in respective impedances, connections for combining said rectified waves in opposition to obtain a control wave which varies with the difference in said positive and negative amplitudes when the audio signal wave is asymmetrical, the capacitive impedances being selected to yield a decay time constant longer than the period of the lowest audio frequency to be transmitted, and circuit connections supplying said control wave to said modulation circuit to shift the normal unmodulated carrier frequency in the modulation direction of the smaller of the asymmetrical amplitudes of said audio signal wave, whereby overmodulation of said carrier by asymmetrical signals may be diminished.

17. In a frequency-modulation signalling system, in combination, a frequency-modulation circuit having an input circuit supplied with an audio signal wave to swing the frequency of a radio-frequency carrier about a normal unmodulated value, a transformer supplied with said audio signal wave and having a center-tapped secondary winding, a pair of rectifiers and respective capacitive impedances connected in circuit between said center tap and respective ends of the secondary winding and having decay time constants longer than the period of the lowest audio frequency to be transmitted, said rectifiers being polarized to develop a control voltage wave across said capacitive impedances proportional to the difference in peak positive and negative amplitudes of said audio signal wave when it is asymmetrical, and connections supplying said control voltage wave to said input circuit to shift the normal unmodulated carrier frequency, the polarity of the control wave as supplied to said input circuit being selected to shift the carrier in the modulation direction of the smaller of the asymmetrical amplitudes of the audio signal wave.

18. In an electronic circuit having a predetermined transfer characteristic between input and output circuits thereof, and an audio signal wave applied to said input circuit to swing about a predetermined operating point on said transfer characteristic, the method which comprises developing a control wave which varies with asymmetrical positive and negative portions of said audio signal wave, and utilizing said control wave to shift said operating point in the direction of swing of the smaller of said asymmetrical portions when said audio signal wave is asymmetrical.

19. In an electronic circuit having a predetermined transfer characteristic between input and output circuits thereof, and an audio signal wave applied to said input circuit to swing about a predetermined operating point on said transfer characteristic, the method which comprises developing a control wave which is proportional to the difference between positive and negative asymmetrical amplitudes of said audio signal wave, and utilizing said control wave to shift said operating point in proportion thereto and in the direction of swing of the smaller of said asymmetrical amplitudes.

20. In a modulated radio-frequency signalling system in which a selected characteristic of a radio-frequency carrier is modulated in accordance with an audio signal wave, the method which comprises developing a control wave which is proportional to the difference between positive and negative asymmetrical amplitudes of said audio signal wave, and shifting the normal unmodulated value of said selected characteristic in accordance with said control wave and in the modulation direction of the smaller of said asymmetrical amplitudes, whereby overmodulation of said carrier by asymmetrical signals may be diminished.

LUKE H. MONTGOMERY.

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