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ELECTRICAL APPARATUS

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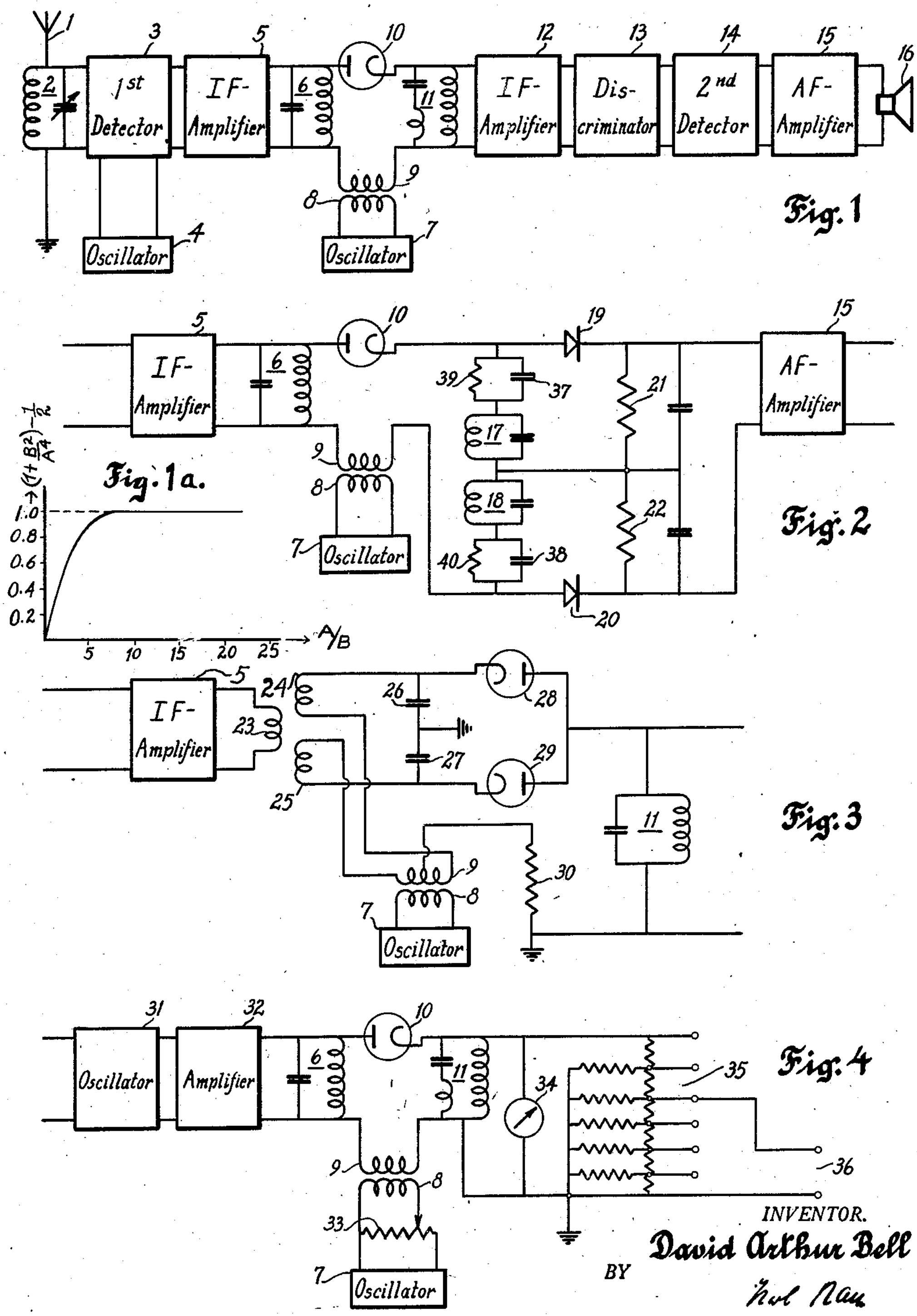

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ELECTRICAL APPARATUS

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This invention relates to limiters for removing amplitude variations from angular velocity-modulated carrier waves, this term being generic for frequency or phase modulated waves.

The invention substantially comprises a method of limiting the amplitude of a frequency or phase modulated signal wave which consists in heterodyning said wave in a linear rectifier with an auxiliary oscillation having a constant frequency different from the frequency of said signal wave and having a constant amplitude less than the smallest amplitude of said signal wave and to which it is to be limited, and in extracting one of the beat frequency waves from the heterodyning product of said signal wave and auxiliary oscillation.

The invention may be applied in various types of apparatus handling frequency or phase modulated waves, for example, radio transmitters, radio receivers and signal generators.

When the invention is applied to radio receivers, the major part of the amplification is normally carried out before the limiting heterodyne stage, so that the amplitude of the heterodyning oscillation, as applied to the linear rectifier, need not be unduly small. The amplification may be effected at radio frequency. If, however, the radio receiver is intended for reception of signals at various radio carrier frequencies, it is preferred that the frequency be changed and the amplification effected with a fixed intermediate carrier frequency, so that the frequency of the limiting heterodyne oscillator need not be varied.

In the accompanying drawing, Figure 1 is a circuit diagram of a radio receiver embodying the invention. Figure 1*a* is a graph illustrative of the function of the invention. Figures 2 and 3 are fragmentary diagrams showing alternative arrangements for certain stages of a radio receiver of the kind shown in Figure 1. Figure 4 is a circuit diagram of a signal generator for generating frequency modulated signals.

In the circuit shown in Figure 1, the frequency modulated radio signals picked up by aerial **1** are developed across aerial tuning circuit **2** and are then applied to first detector **3**, in which they are heterodyned with oscillations of suitable frequency generated in the first local oscillator **4**. The frequency of this local oscillator is varied with the tuning of aerial tuning circuit **2** in the conventional manner to maintain a fixed difference beat frequency. The signals at this difference beat frequency are selected and amplified in the first intermediate frequency amplifier **5**.

The signal output from intermediate frequency amplifier **5** is impressed across tuned circuit **6**, which must be sufficiently broadly tuned to respond to all frequencies within the range which is covered by the frequency modulation of the first intermediate frequency.

A second local oscillator **7** generates oscillations of constant frequency and amplitude which, by means of coupling coils **8** and **9**, are mixed with the signals developed across tuned circuit **6** and applied to diode rectifier **10**.

The amplitude of the oscillation from local oscillator **7**, as applied to diode **10**, must be smaller than the smallest amplitude of signal from intermediate frequency amplifier **5**, as applied to diode **10**, which it is desired to handle in the receiver. It will then follow that the resultant voltage at difference frequency developed across tuned circuit **11** will be substantially constant.

This function of the invention will be further understood from the following:

Let it be assumed that the input of a linear rectifier consists of the sum of the following two oscillations or signal waves

$$A \sin w_1 t \text{ and } B \sin w_2 t$$

of which the first may represent the incoming signal and the second a locally generated oscillation in accordance with the invention.

The sum of these two oscillations applied to a linear rectifier may be written as a single oscillation of complex form as follows:

$$\{A^2+B^2+2AB \cos (w_1-w_2)t\}^{1/2} \sin (w_0 t+\phi)$$

wherein w_0 and ϕ can be expressed in terms of A, B, w_1 and w_2 (see e. g. Terman "Radio Engineering," McGraw-Hill Book Company, 1937 edition, pages 448 and 449.

The amplitude of this complex wave is

$$\{A^2+B^2+2AB \cos (w_1-w_2)t\}^{1/2} = (A^2+B^2)^{1/2}\left\{1+\frac{2AB}{A^2+B^2}\cdot \cos (w_1-w_2)t\right\}^{1/2}$$

which may be expanded into

$$(A^2+B^2)^{1/2}\left\{1+\frac{1}{2}\cdot\frac{2AB}{A^2+B^2}\cdot \cos (w_1-w_2)t \ . \ . \ . \right\}$$

Since the rectifier is followed by a tuned circuit or other means to extract the component having a frequency corresponding to the difference between the frequencies w_1 and w_2, only the terms containing w_1-w_2 need be considered in the output.

Furthermore assuming that A, i. e. the amplitude of the incoming signal is considerably greater than B or the amplitude of the auxiliary oscillation, then only the first term of the expression shown above need be considered. Accordingly therefore, the amplitude of the resultant wave extracted by the tuned circuit following the rectifier will be determined as follows:

$$(A^2+B^2)^{1/2}\cdot\frac{AB}{A^2+B^2}=B\left(1+\frac{B^2}{A^2}\right)^{-1/2}$$

This function rapidly approaches the limit B as A becomes large compared with B as indicated by the graph shown in Figure 1*a* which represents the term

$$\left(1+\frac{B^2}{A^2}\right)^{-1/2}$$

as a function of

$$\frac{A}{B}$$

From the foregoing it follows that in the arrangement according to the invention, when the amplitude of the input signal is large compared with the amplitude of the local oscillation, the output is determined by the amplitude of the local oscillation and is independent of the amplitude of the input signal. Thus, by properly choosing the amplitude of the local oscillation and maintaining it substantially constant, the input signal may be limited to any desired amplitude such as for the elimination of undesired or spurious amplitude modulation of a frequency modulated signal wave. The frequency or phase of the output is equal to w_1-w_2 and it therefore faithfully represents the variations in frequency or phase of the input signal.

The difference beat frequency signals are selected and amplified in tuned circuit 11 and the second intermediate frequency amplifier 12. Tuned circuit 11 must be sufficiently broadly tuned to respond to all frequencies within the range which is covered by the frequency modulation of the second intermediate frequency. Also, tuned circuit 11 is so designed as to by-pass signals of first intermediate frequency by a series resonance.

The signal output from intermediate frequency amplifier 12 is applied to discriminator 13 and the resulting amplitude modulated signals are demodulated in demodulator 14 and amplified in audio-frequency amplifier 15 and finally applied to reproducer 16.

It is desirable to arrange that the second intermediate carrier frequency, to which circuits 11 and 12 are tuned, shall be substantially different from the first intermediate carrier frequency, to which circuits 5 and 6 are tuned, so that the passage of signals of first intermediate frequency to the demodulator is minimized. The second intermediate frequency may, however, be selected either higher or lower than the first intermediate frequency.

The parameters of the circuit of rectifier 10 can easily be so selected that the constancy of the voltage at second intermediate frequency impressed upon the input terminals of amplifier 12 is not disturbed, even by very sudden variations of the amplitude of the signals received at aerial 1.

In the modified arrangement shown in Figure 2, the tuned circuit 11 and the second intermediate frequency amplifier 12 of Figure 1 are omitted, and the signals of second intermediate frequency resulting from heterodyning in rectifier 10 are directly impressed across the frequency selective circuits of the discriminator. The discriminator diagrammatically shown is of a conventional type comprising circuits 17, 18 resonant at frequencies above and below the limits of the frequency modulation range; the amplitude-modulated signals developed across circuits 17, 18 being separately demodulated by rectifiers 19, 20 developed across rectifier loads 21 and 22, and added in opposition before application to audio-frequency amplifier 15.

Condensers 37, 38 are series-resonant with the equivalent inductances represented by tuned circuits 17, 18 at the first intermediate frequency, to by-pass components of that frequency which would otherwise produce some response in the discriminator. These condensers are of low reactance at the second intermediate frequency, which is here assumed to be higher than the first. They are by-passed for direct current by resistances 39, 40 of high value relative to the condenser reactances at first intermediate frequency.

In the modified arrangement shown in Figure 3, in order to minimize the passage of signals of first intermediate frequency to the demodulator, a balanced heterodyning stage is provided between the output of the first intermediate frequency amplifier 5 and the beat frequency resonant circuit 11.

In this arrangement, the output from the first intermediate frequency amplifier 5 is impressed across coil 23, which is coupled to coils 24 and 25. Coil 9, which is coupled to coil 8 introducing the oscillations from local oscillator 7, is connected between coils 24 and 25, and its centre point is earthed through resistance 30. Thus both the locally generated oscillations and the first intermediate frequency signals are introduced into the circuit of diode rectifiers 28, 29 in the form oscillations balanced about earth.

Condensers 26, 27 are provided to tune inductances 24, 9, 25 to resonance at the first intermediate frequency, the tuning being sufficiently broad for response at all frequencies within the range of frequency modulation thereof.

Linear rectification of the mixed intermediate frequency signals and local oscillations is provided by diode rectifiers 28, 29, and the difference beat frequency output is developed across tuned circuit 11 for input to the second intermediate frequency amplifier. Alternatively, it could be applied directly to a discriminator as described with reference to Figure 2.

Resistance 30 carries the direct component of the rectified current, and provides the necessary rectifier bias. Inductances 24, 9, 25, however, offer high impedance to frequencies higher than the first intermediate frequency. An earth connection is, therefore, provided at the midpoint of condenser arm 26, 27 for these components.

In the signal generator circuit shown in Figure 4, signals of modulated frequency, but not necessarily constant amplitude, generated in oscillator 31, are amplified in amplifier 32 and impressed across tuned circuit 6, which must be sufficiently broadly tuned to respond to all frequencies within the range of modulation. Local oscillator 7 generates oscillations of constant frequency and amplitude, which by means of coupling coils 8 and 9 are mixed with the signals developed across tuned circuit 6 and applied to diode rectifier 10. The amplitude of the oscillation from local oscillator 7, as applied to diode 10, will always be smaller than the amplitude of the oscillation from oscillator 31, as applied to diode 10.

The amplitude of the resultant voltage at sum or difference frequency developed across tuned circuit 11 is substantially determined by the amplitude of the oscillation from local oscillator 7, as applied to diode 10. Continuously variable adjustment of the output voltage may, therefore, be effected by variation of the position of the tapping on potentiometer 33 through which the oscillations from oscillator 7 are passed, and the tapping may be arranged for operation by a control knob to provide adjustment of the amplitude as required.

Radio frequency voltmeter 34 will indicate the amplitude of the difference beat frequency signals developed across tuned circuit 11.

The output voltage may be varied in large steps by adjustment of the moveable contact on attenuator 35. The output is taken between this moveable contact and earth at terminals 36.

I claim:

1. The method of limiting the amplitude of an angular velocity-modulated wave which consists in heterodyning the wave in a linear rectifier with an auxiliary oscillation of constant frequency different from the frequency of said wave and of constant amplitude which is smaller than the smallest amplitude to which said wave is to be limited, and in extracting one of the beat frequency waves from the heterodyning product of said wave and auxiliary oscillation.

2. The method of limiting the amplitude of an angular velocity-modulated electric signal wave which comprises the steps of combining said wave in a linear rectifier with an auxiliary wave of different frequency and having a constant amplitude which is less than the smallest amplitude to which said signal wave is to be limited, and extracting difference frequency energy from the heterodyning product of said waves.

3. The method of limiting the amplitude of an angular velocity-modulated electric signal wave which comprises the steps of combining said wave in a linear rectifier with an auxiliary wave having a frequency different from said signal wave, adjusting the amplitude of said auxiliary wave to a value less than the smallest amplitude to which said signal wave is to be limited, and extracting difference frequency energy from the heterodyning product of said waves.

4. An amplitude limiter for angular velocity-modulated electric signal wave energy comprising a linear rectifier, means for applying to said rectifier the wave energy to be limited, further means for applying to said rectifier auxiliary wave energy of a frequency different from said signal wave energy and having a constant amplitude less than the smallest amplitude to which said signal energy is to be limited, and means for extracting difference frequency energy from the output of said rectifier.

5. An amplitude limiter for angular velocity-modulated electric signal wave energy comprising a linear rectifier, means for applying to said rectifier the wave energy to be limited, further means for applying to said rectifier auxiliary wave energy of a frequency different from said signal wave energy and having a constant amplitude less than the smallest amplitude to which said signal wave energy is to be limited, and means for extracting difference frequency energy from the output energy of said rectifier.

6. An amplitude limiter for angular velocity-modulated electric signal wave energy comprising a balanced modulator circuit having a pair of input and an output circuits and including a pair of linear rectifiers, means for impressing the energy to be limited upon one of said input circuits, further means for producing and impressing auxiliary wave energy upon the other input circuit, said auxiliary energy having a frequency different from said signal wave energy and having a constant amplitude which is less than the smallest amplitude to which said signal wave energy is to be limited, and means for extracting energy from said output circuit having a frequency equal to the difference between the frequency of said first and second energies.

7. An amplitude limiter for angular velocity-modulated electric signal wave energy comprising a balanced modulator having a pair of input and output circuits and including a pair of linear rectifiers, means for impressing the energy to be limited upon one of said input circuits, further means for producing and impressing auxiliary wave energy upon the other input circuit of said modulator, said auxiliary energy having a constant frequency different from said signal energy, further means for adjusting the amplitude of said auxiliary energy to a valve less than the smallest amplitude to which said signal energy is to be limited, and means for extracting energy from said signal output having a frequency equal to the difference between the frequencies of said signal and auxiliary energies.

8. An amplitude limiter for angular velocity-modulated electric signal wave energy comprising means for producing auxiliary wave energy of constant frequency different from the frequency of said signal energy and having an amplitude which is less than the smallest amplitude to which said signal energy is to be limited, means including linear rectifying means for intermodulating said signal energy with said auxiliary energy, and further means for extracting from the intermodulation product energy having a frequency equal to the difference between the frequencies of said signal and auxiliary energies.

9. An amplitude limiter for angular velocity-modulated electric signal wave energy comprising means for producing auxiliary wave energy of constant frequency different from the frequency of said signal energy, means for adjusting the amplitude of said auxiliary wave energy to a value less than the smallest amplitude to which said signal energy is to be limited, means including linear rectifying means for intermodulating said signal energy with said auxiliary energy, and means for extracting from the intermodulation product energy having a frequency equal to the difference between the frequencies of said signal and auxiliary energies.

10. In a system for receiving angular velocity-modulated electric waves of varying carrier frequency, means for changing the frequency of a received signal wave and amplifying it at a first fixed intermediate carrier frequency, amplitude limiting means comprising a linear rectifier, means for applying to said rectifier the amplified intermediate frequency wave and an unmodulated heterodyning oscillation having a constant frequency different from said intermediate frequency and having an amplitude which is less than the smallest amplitude to which said intermediate frequency wave is to be limited, means to extract from the output of said rectifier energy at the difference beat frequency resulting from said oscillation and the amplified intermediate frequency wave, and means for demodulating and translating the resultant amplitude limited angular velocity-modulated wave energy.

11. In a system for receiving angular velocity-modulated electric waves of varying carrier frequency, first heterodyning means for changing the frequency of a received signal wave and amplifying it at a first fixed intermediate carrier frequency, amplitude limiting means comprising sec-

ond heterodyning means for changing said first intermediate frequency to a second intermediate frequency and including linear rectifying means, means for applying to said rectifying means the amplified intermediate frequency wave and an unmodulated heterodyning oscillation having a constant frequency different from said intermediate frequency and having an amplitude which is less than the smallest amplitude to which said intermediate frequency wave is to be limited, means to extract from the output of said rectifying means second intermediate frequency energy at the difference beat frequency resulting from said oscillation and the amplified first intermediate frequency wave, means for demodulating and translating the resultant intermediate frequency amplitude limited angular velocity-modulated wave energy, and means for preventing energy of the first intermediate frequency from interfering with the second intermediate frequency energy.

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