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DEVICE FOR THE TRANSMISSION OF SIGNALS BY MEANS OF FREQUENCY-MODULATED CARRIER WAVES

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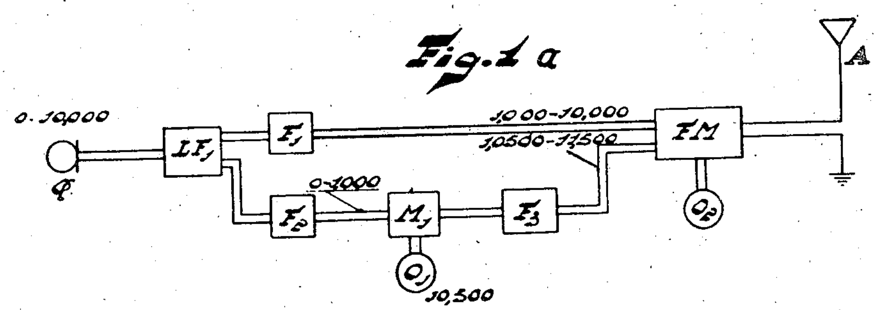

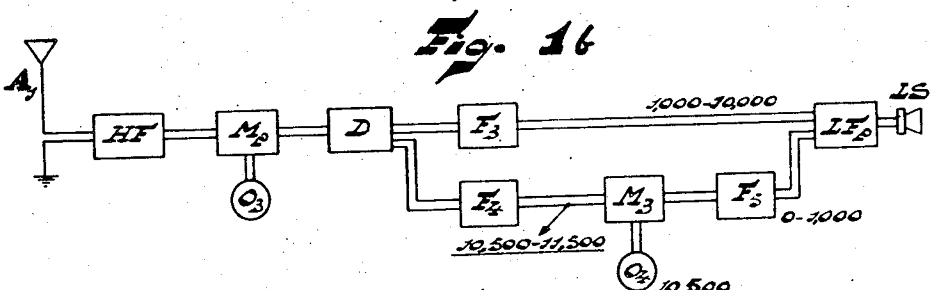

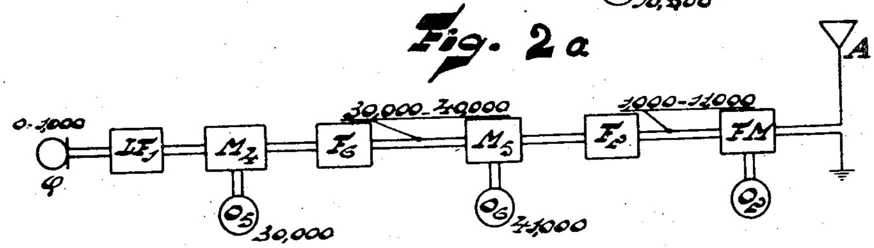

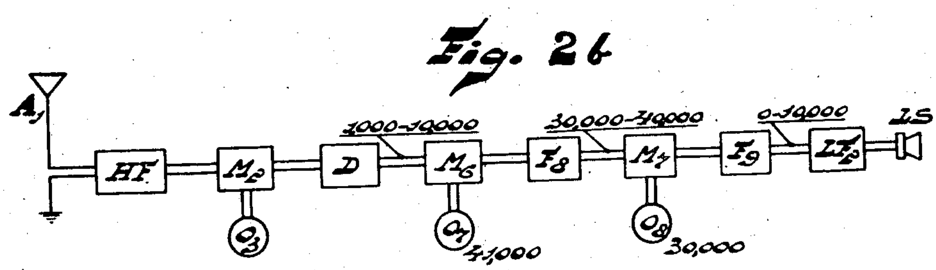

Frequencies in cycles per second

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DEVICE FOR THE TRANSMISSION OF SIGNALS BY MEANS OF FREQUENCY-MODULATED CARRIER WAVES

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2 Claims. (Cl. 250—6)

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This invention relates to a device for the transmission of signals by means of a frequency-modulated carrier wave. It is known that in various respects the use of frequency-modulated oscillations may have great advantages over amplitude-modulated oscillations.

The invention has for its object to add to these advantages another advantage viz. a considerable decrease of the distortions which may arise when the emitted signal reaches the receiver along different paths.

The invention is based on the recognition that upon reception of frequency-modulated oscillations reaching the receiver along two paths with a difference in transit time T the distortion occurring after detection depends on the frequency and is approximately inversely proportional to the frequency of the modulating oscillations. Consequently, the distortion is troublesome more particularly at the lower frequencies and for this reason a device for the transmission of frequency-modulated oscillations is, according to the invention, arranged so that at least a part of the frequency spectrum of the signals to be transmitted is heterodyned before the modulator in such manner that the frequency spectrum of the oscillations modulating the carrier wave to be transmitted solely comprises frequencies above a definite frequency which exceeds the lowest frequency of the signal frequencies to be transmitted.

The frequency spectrum of the signals to be transmitted is preferably shifted towards the higher frequencies by an amount corresponding at least substantially to the minimum frequency which may still appear in the oscillations modulating the carrier wave and which preferably amounts to about 1000 cycles/sec.

The choice of the minimum frequency is determined on the one hand by the admissible distortion which occurs after detection due to transmission along two different paths, but on the other hand the minimum frequency should not be chosen too high, since otherwise there occur too high modulation frequencies and, as is well-known, the ratio between signal and the disturbances caused in a receiving set by other transmitters, by noise or by atmospherics becomes worse as the ratio between the frequency deviation and the highest modulation frequency decreases.

The invention will be more fully explained by reference to the accompanying drawing, given by way of example, in which Fig. 1*a* represents one form of construction of a transmitting device according to the invention, in which that part of the frequency spectrum of the signals to be transmitted, which lies below the lowest admissible frequency of the oscillations modulating the carrier-wave to be transmitted is heterodyned in such manner that the transformed spectrum does not comprise frequencies below the said frequency.

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Fig. 1*b* schematically represents a receiving arrangement for the reception of frequency-modulated oscillations transmitted by means of a device as shown in Fig. 1*a*.

Fig. 2*a* represents a device for the transmission of signals, in which the whole frequency spectrum of the signals to be transmitted is shifted by an amount corresponding to the lowest frequency which may still appear in the oscillations modulating the carrier wave.

Fig. 2*b* schematically represents a receiving arrangement for the reception of oscillations emitted by means of a device as shown in Fig. 2*a*.

In describing the executional examples illustrated in the drawing it is postulated that the frequency spectrum of the signals to be transmitted comprises a frequency range of 0 to 10,000 cycles/sec. and that the oscillations modulating the carrier wave may solely comprise frequencies above 1000 cycles/sec.

In the form of construction represented in Fig. 1*a* the signals to be transmitted, which are generated in a microphone Q, are supplied through a low-frequency amplifier LF_1 to two filters F_1 and F_2, of which the filter F_1 transmits the signal frequencies exceeding the lowest frequency which may still appear in the oscillations modulating the carrier wave, the filter F_2 transmitting the signal frequencies which are lower than the said frequency. The frequencies of 1000 to 10,000 cycles/sec. transmitted by the filter F_1 are directly supplied to a frequency modulator FM, and the frequencies of 0 to 1000 cycles/sec. transmitted by the filter F_2 are heterodyned, before being supplied to the frequency modulator FM, in such manner that the frequency spectrum of the transformed oscillations no longer comprises frequencies below 1000 cycles/sec. To this end the frequencies transmitted by the filter F_2 are supplied to a modulator M_1 having also supplied to it an oscillation generated by an oscillator O_1 whose frequency is higher than the highest original signal frequency to be transmitted and amounts to say 10,500 cycles/sec., which oscillation is amplitude-modulated by the frequencies of 0 to 1000 cycles/sec. transmitted by the filter F_2. In this way there are produced two side bands comprising a frequency range of 10,500 to 11,500 cycles/sec. and 10,500 to 9500 cycles/sec. respectively. In the modulator M_1 the carrier wave of 10,500 cycles/sec. is preferably suppressed, whereas the two side bands are supplied to a filter F_3, which transmits only one of the side bands and, for the chosen value of the frequency of the oscillator O_1 passes the upper side band of 10,500 to 11,500 cycles/sec. This side band, whose frequency spectrum includes the heterodyned frequencies of 0 to 1000 cycles/sec. of the signals to be transmitted, is supplied to the frequency-modulator FM, in which modulator the carrier wave generated by an oscillator O_2 is frequency-modulated by the frequencies supplied to the modulator. The frequency spectrum of the oscillations modulating the carrier wave includes the frequency band of 1000 to 10,000 cycles/sec. transmitted by the filter F_1 and the frequency band of 10,500 to 11,500 cycles/sec. transmitted by the filter F_3, which frequency bands do not comprise frequencies below 1000 cycles/sec.

The oscillations frequency-modulated in the modulator are emitted by an antenna A.

The choice of the frequency of the oscillator O_1 determines the width of the frequency spectrum of the oscillations modulating the carrier wave. This frequency is preferably so chosen that the frequency spectrum of the modulating oscillations is but slightly broader than the frequency spectrum of the signals to be transmitted. In fact, it is advantageous in the receiver that the frequency spectrum should not be broader than is strictly necessary, since the energy of the disturbances produced in the receiver increases with an increasing width of the frequency spectrum of the oscillations frequency-modulating the carrier wave. In fact, the energy of the disturbances occurring is proportional to

$$\left(\frac{fm}{s}\right)^2$$

wherein s represents the amplitude of the variation of the momentary frequency and fm represents the maximum frequency of the modulating oscillations.

With an extension of the frequency spectrum, consequently at a higher value of fm, the energy of the disturbance appearing in the receiver is larger than will be the case upon reception of a frequency-modulated carrier wave, in which case the frequency spectrum of the modulating oscillations is as broad as the frequency spectrum of the signals to be transmitted.

The receiver represented in Fig. 1*b* which is adapted for the reception of the frequency-modulated oscillations emitted by means of a device as shown in Fig. 1*a* comprises a high-frequency amplifier HF to which are supplied the oscillations picked up by an antenna A_1. The amplified oscillations set up in the output circuit of the amplifier HF are preferably supplied through a frequency transformer or modulator M_2, to which are supplied oscillations locally generated by an oscillator O_3, to a detector D, in which the frequency variations of the carrier wave are transformed into amplitude variations which are subsequently rectified. The oscillations supplied by the detector comprise a frequency spectrum which corresponds to the frequency spectrum of the oscillations modulating the incoming carrier wave and extends from 1000 to 10,000 cycles/sec. and from 10,500 to 11,500 cycles/sec. In order to transform this frequency spectrum into the frequency spectrum of the signals to be received, the oscillations in the output circuit of the detector D are supplied to two filters F_3 and F_4, of which the filter F_3 transmits the frequency band of 1000 to 10,000 cycles/sec. and the filter F_4 transmits the frequency band of 10,500 to 11,500 cycles/sec. The frequencies transmitted by the filter F_3 are directly supplied to a low-frequency amplifier LF_2, and the frequencies transmitted by the filter F_4 are so heterodyned, before being supplied to the low frequency amplifier LF_2, that the frequency spectrum of the heterodyned oscillations corresponds to the frequency spectrum of that part of the signals to be transmitted which is transmitted by the filter F_2 in the transmitter. For this purpose the frequencies of 10,500 to 11,500 cycles/sec. transmitted by the filter F_4 are supplied to a modulator M_3, which has also supplied to it an oscillation which is generated by the oscillator O_4 and has a frequency of 10,500 cycles/sec. In the modulator M_3 there arise two frequency bands of 21,000 to 22,000 cycles/sec. and of 0 to 1000 cycles/sec. respectively, of which the lower side band including the frequencies of 0 to 1000 cycles/sec. is transmitted by a filter F_5 and supplied to the low frequency amplifier LF_2. In the low-frequency amplifier are amplified the frequency band of 1000 to 10,000 cycles/sec. transmitted by the filter F_3 and the frequency band of 0 to 1000 cycles/sec. transmitted by the filter F_5, which bands jointly comprise the frequency spectrum of the signals to be transmitted, the oscillations set up in the output circuit being supplied to a loud-speaker LS, in which the amplified oscillations are transformed into the sound vibrations to be received.

Fig. 2*a* represents one form of construction of a device according to the invention, in which the frequency spectrum of the signals to be transmitted is shifted as a whole towards the higher frequencies by an amount corresponding to the lowest frequency that may still appear in the oscillations modulating the carrier wave and preferably amounts to 1000 cycles/sec. In this form of construction the width of the frequency spectrum of the oscillations modulating the carrier wave consequently corresponds to the width of the frequency spectrum of the signals to be transmitted. In Fig. 2*a* the parts corresponding to the arrangement shown in Fig. 1*a* bear the same reference numerals; furthermore, it is assumed again that the frequency spectrum of the signals to be transmitted includes the frequency range of 0 to 10,000 cycles/sec.

In the form of construction represented in Fig. 2*a* the oscillations generated in the microphone Q, which comprise the frequency spectrum of 0 to 10,000 cycles/sec. are supplied through the amplifier LF_1 to a modulator M_4, which has also supplied to it an auxiliary oscillation supplied by an oscillator O_5 whose frequency at least corresponds to the highest signal frequency to be transmitted plus the lowest frequency which may still appear in the oscillations modulating the carrier wave to be transmitted and amounts to say 30,000 cycles/sec., which oscillation is amplitude-modulated by the amplified signals to be transmitted. In this way there arise two side bands comprising a frequency range of 30,000 to 40,000 cycles/sec. and 30,000 to 20,000 cycles/sec. respectively. Preferably the oscillation of 30,000 cycles/sec. is suppressed in the modulator M_4, the two side bands being supplied to a filter F_6, which solely transmits the upper side band, and supplies it to a modulator M_5, which has also supplied to it a second auxiliary oscillation supplied by an oscillator O_6, whose frequency is 1000 cycle/sec. higher than the highest frequency of the upper side band and consequently has a frequency of 41,000 cycles/sec. In the modulator M_5, also, there ensue two side bands, which comprise a frequency range of 71,000 to 81,000 cycles/sec. and of 11,000 to 1000 cycles/sec. respectively. This last-mentioned side-band, whose frequency spectrum is shifted by 1000 cycles/sec. towards the higher frequencies with respect to the frequency spectrum of the signals to be transmitted and consequently does not comprise frequencies below 1000 cycles/sec., is supplied, through a filter F_7 solely transmitting this lower side band, to a modulator FM, wherein the carrier wave produced by the generator O_2 is frequency-modulated by these side-band frequencies.

In the described form of construction the frequency spectrum of the signals to be transmitted is not only shifted as a whole by 1000 cycles/sec., but also the frequency spectrum is reversed, as a result of which the low and high frequencies respectively of the signals to be transmitted are high and low frequencies respectively in the frequency spectrum of the oscillations modulating the carrier wave.

This reversal of the frequency spectrum does not take place if the auxiliary oscillation supplied by the oscillator O_6 has a frequency which is 1000 cycles/sec. lower than the lowest frequency of the frequency band of 30,000 to 41,000 cycles/sec. transmitted by the filter F_6 and consequently supplies an oscillation having a frequency of 29,000 cycles/sec. In this case there ensue in the modulator M_5 two side bands comprising a frequency range of 59,000 to 70,000 cycles/sec. and of 1000 to 11,000 cycles/sec. respectively, the frequency spectrum of the lower side band being shifted by an amount of 1000 cycles/sec. with respect to the frequency spectrum of the signals to be transmitted.

However, it is preferable that the oscillator O_6 should produce oscillations whose frequency lies beyond the side bands produced in the modulator M_4; in order to achieve the desired displacement of the frequency spectrum of the signals to be transmitted the oscillator O_6, provided the filter F_6 transmits the upper side band of the side bands obtained in the modulator M_4 which comprises the frequency range of 30,000 to 41,000 cycles/sec., will consequently be tuned to a frequency which exceeds by 1000 cycles/sec. the highest frequency of this frequency band, but if the filter F_6 transmits the lowest side band of 30,000 to 20,000 cycles/sec., the oscillator O_6 will be tuned to a frequency which is 1000 cycles/sec. lower than the lowest frequency of the lower side band. In both cases the desired displacement of the frequency spectrum is accompanied by reversal of the frequency spectrum.

The receiver represented in Fig. 2*b*, which is adapted for the reception of the frequency-modulated oscillations emitted by means of a device as shown in Fig. 2*a*, comprises a high-frequency amplifier HF, to which are supplied the oscillations picked up by the antenna A_1, the frequency transformer or modulator M_2 and the detector D, the latter transforming frequency variations of the carrier wave into amplitude variations which are subsequently rectified. The oscillation supplied by the detector comprise a frequency spectrum which corresponds to the frequency spectrum of the oscillations modulating the incoming carrier wave and extends from 11,000 to 1000 cycles/sec. In order to transform this frequency spectrum into the frequency spectrum of the signals to be received the oscillations in the output circuit of the detector D are supplied to a modulator M_6 having supplied to it an auxiliary oscillation supplied by an oscillator O_7 whose frequency amounts to say 41,000 cycles/sec. In the modulator M_6 the oscillations generated by the oscillator O_7 are amplitude modulated by the oscillations comprising the frequency spectrum of 1000 to 11,000 cycles/sec., the carrier wave being preferably suppressed and the lower side band of 30,000 to 40,000 cycles/sec. of the two side bands thus produced being transmitted by a filter F_8 and supplied to a modulator M_7, in which this frequency is modulated on the auxiliary oscillation supplied by the oscillator O_8, whose frequency corresponds to the lowest frequency of the transmitted side band and consequently amounts to 30,000 cycles/sec. In this case two side bands ensue again, of which the lower, which includes the frequencies of 0 to 10,000 cycles/sec., corresponds to the frequency spectrum of the signal to be received. This lower side band is supplied through a filter F_9, which stops the carrier wave and the upper side band, to the low-frequency amplifier LF_2 and subsequently to the loundspeaker LS, in which the incoming oscillations, comprising a frequency band of 0 to 10,000 cycles/sec., are transformed again into the incoming sound vibrations.

In the form of construction represented in Fig. 2*b* the frequency of the oscillations supplied by the oscillators O_8 and O_7 corresponds to the frequency of the oscillations produced in the transmitter by the oscillators O_5 and O_6 respectively. This, however, is not imperative; in the receiver transformation of the incoming frequency-modulated oscillations into oscillations comprising a frequency spectrum of 0 to 1000 cycles/sec. may also take place by making the oscillators O_7 and O_8 generate oscillations whose frequency is different from the frequency of the auxiliary oscillations in the transmitter. As an alternative the desired transformation may be obtained by tuning the oscillator O_7 to a frequency of 31,000 cycles/sec. and the oscillator O_8 to a frequency of 20,000 cycles/sec.

However, in the form of construction under view, in which the whole frequency spectrum is shifted by an amount of 1000 cycles/sec. and conversely, the frequency difference between the oscillators O_5 and O_6 in the transmitter and the oscillators O_8 and O_7 in the receiver is equal to the minimum admissible modulation frequency of 1000 cycles/sec. in the transmitter plus the highest signal frequency of 10,000 cycles/sec. to be transmitted. In the present numerical example the difference between the oscillators O_5, O_6 and O_8, O_7 respectively consequently corresponds to 11,000 cycles/sec.

We claim:

1. In a frequency modulation system, a source of wave energy of carrier wave frequency to be modulated, a source of modulating potentials coupled to said source of wave energy to modulate the frequency of the latter in accordance with the modulating potentials, and means in said coupling for increasing the frequencies of a band of lower frequency modulation potentials by selected equal amounts which exceed the lowest modulation frequency to reduce at a receiving point distortion at said lower frequency modulation potentials due to multipath transmission comprising, filter circuits for separating a band of modulating potentials in the lower frequency range of said modulating potentials from the

remaining modulation potentials, separate paths coupling said filter circuits to said frequency modulator for supplying the modulating potentials to said frequency modulator and heterodyning means in the path supplying said band of lower frequency modulating potentials.

2. In apparatus for receiving wave energy of carrier wave frequency which has been frequency modulated directly by a band of modulated potentials falling within a band of frequencies in the higher frequency end of the modulation frequency spectrum and by a subcarrier which has been modulated by the remaining modulating potentials found within a band of frequencies in the lower end of the modulating frequency spectrum to reduce at the receiving point distortion at said frequencies in the lower end of the modulating frequency spectrum due to multipath transmission, modulated wave energy amplifying means, a frequency converter including a source of oscillations coupled to said amplifier, a frequency responsive detector coupled to said converter, means for selecting from said detector the modulation components corresponding to the components used to directly modulate said carrier in the transmitter, means for selecting from said detector the modulation components corresponding to the modulated subcarrier used at said transmitter, a demodulator for deriving from said modulated subcarrier the original modulation components in said band in the lower end of the modulation frequency components, and means at said receiver for recombining said modulation components.

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