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RECEPTION OF FREQUENCY MODULATED WAVES

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Fig. 1

Fig. 2

Fig. 2A

Fig. 3

Fig. 3A

Fig. 4

Fig. 4A

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RECEPTION OF FREQUENCY MODULATED WAVES

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The object of my present invention is to provide improved circuits for the reception of angular velocity modulated waves and particularly for frequency modulated waves. Another object is to provide circuits for effectively reducing noise during the reception of frequency or phase modulated waves. Other objects, advantages and features of my invention will be apparent as the more detailed description thereof proceeds.

In the accompanying drawing.

Figure 1 is a wiring diagram of a radio system, the receiver of which has an improved signal-to-noise ratio and which does not require a so-called de-emphasizing circuit even though a so-called pre-emphasizing circuit is employed at the transmitter; and Figures 2, 3 and 4 illustrate frequency-output amplitude characteristics of a filter which is used in the receiving apparatus of Figure 1. Figures 2A, 3A and 4A are, respectively, the complementary characteristic curves of Figures 2, 3 and 4.

Referring specifically to the receiving system shown at the right-hand side of Fig. 1, it is assumed that the waves received upon the receiving antenna **22** are frequency modulated and have been pre-emphasized. That is to say, it is assumed that at the transmitter shown schematically at the left hand side of Figure 1 the audio frequency waves have been pre-emphasized in such a way that the higher frequencies thereof are amplified to a greater degree than the lower frequencies of the audio band which is employed. This pre-emphasis is described in a paper by M. G. Crosby appearing in the RCA Review for January 1940, entitled "The service range of frequency modulation," beginning at page 359.

The received waves are amplified in the radio frequency amplifier **4**, the output of which is fed into a first detector **6**. The first detector **6** is also provided with locally generated oscillations from a local oscillation generator **8** which is provided with a frequency control system **10**. This frequency control system may be of the reactance tube type such as described by M. G. Crosby in an article in the RCA Review for July 1940, entitled "Reactance tube frequency modulators."

The beat frequency output of the first detector resulting from the combination of the local oscillations from oscillator **8** and from radio frequency amplifier **4** is fed into a beat frequency or intermediate frequency amplifier **12**, the output of which is then limited by means of a limiter **14**. The limited waves are then fed from limiter **14** to a discriminator **16**, such as described by S. W. Seeley in U. S. Patent No. 2,121,103. This discriminator or converting system operates to convert angular velocity changes, such as frequency changes, into amplitude changes which are susceptible of detection. The waves so converted by the discriminator **16** are fed to a balanced detector **18**, such as described in the Seeley patent, and the output of this detector system is fed to an audio frequency amplifier **20**. The output of the amplifier **20** is fed into a suitable translation device, such as a loudspeaker **22**.

Heretofore, when pre-emphasis was used at the transmitter, of a form such as shown in Figure 2, wherein the ordinates represent output amplitude and the abscissa modulation or audio frequency, a counter correction or de-emphasizing process was employed at the receiver. This de-emphasizing was usually carried out by connecting a de-emphasizing or correcting circuit between the audio frequency amplifier **20** and the loudspeaker **22**. Since this de-emphasizing circuit had to be the complement of the pre-emphasizing circuit at the transmitter, its design had to be carefully carried out if the maximum faithfulness of reproduction was desired. When the pre-emphasizing characteristic of Figure 2 is employed in the pre-emphasis circuit P1 of the transmitter of Figure 1, the de-emphasis heretofore employed at the receiver would have followed the curve of Figure 2A.

In accordance with my invention as illustrated in Figure 1, I make use of another pre-emphasizing circuit rather than a de-emphasizing circuit at the receiver, and since the pre-emphasizing circuit may easily be made to have a characteristic which is substantially an exact replica of that of the pre-emphasizing circuit at the transmitter, greater faithfulness of reproduction is secured without loss in signal-to-noise ratio. That is, as illustrated in Figure 1, a portion of the output of the audio frequency amplifier **20** is fed through leads **24** to filter **26**, and the output of the filter is fed through reversing switch **28** in one of its closed positions to the frequency controlling system **10**.

To secure a better understanding of the arrangement, I have also illustrated in Figure 1 the transmitter. The microphone M, which picks up the sound waves, is connected to the usual audio frequency amplifier A1. Amplifier A1 is connected to the pre-emphasizing circuit P1 which, for an input of constant amplitude over the audio frequency range, produces an output with the high frequencies accentuated, as illustrated in Figure 2. The output of the pre-emphasizing circuit is fed to audio amplifier A2 and then to the

frequency modulation transmitter FMT whose output is connected to a transmitting antenna TA.

Assuming pre-emphasis circuit P1 to have a characteristic as explained above, such as shown in Figure 2, the filter 26 at the receiver is made identical to circuit P1 at the transmitter or at least is made to have a characteristic identical to that of circuit P1 of Figure 1. Switch 28 is thrown in such direction that the frequency control system 10 operates with voltages derived from filter 26 to shift the frequency of the oscillation generated by the oscillator 8 in such direction as to reduce the frequency swing in the intermediate frequency energy produced in the I. F. amplifier 12. In this way, it will be found that faithful reproduction will be secured in the output of loudspeaker 22 even though a so-called de-emphasizing or restorer network is not employed in the receiver.

If the pre-emphasis circuit P1 is given a linear characteristic, such as shown in Figure 3, so that the resulting waves transmitted by transmitting antenna TA are phase modulated, as explained in Crosby Patent 2,085,739, then filter 26 should be designed to have a similar characteristic. That is to say, for a constant amplitude voltage applied to its input terminals 30, the amplitude output versus frequency characteristic should rise at the output terminals 32 so as to be of the shape of Figure 3.

If the pre-emphasis circuit P1 is given a characteristic such as shown in Figure 4 and as described more specifically in Hansell Patent 2,179,182, whereby low frequency as well as high frequency noise is reduced, the filter 26 should also be given the same characteristic as shown in Figure 4.

It is preferred to operate the system shown in Figure 1 as I have just described wherein the filter 26 is given the same characteristic as the pre-emphasis circuit at the transmitter. Under this condition, the switch 28 should be thrown in such position as to reduce the intermediate frequency swing with increased amplitudes across terminals 32.

However, a similar result may be secured by throwing switch 28 in such a way that the intermediate frequency swing is increased with increased voltages across terminals 32. In such condition, with increase in intermediate frequency swing, characteristics for the filter 26, which are the converse of those shown in Figures 2, 3 and 4, should be employed to secure faithful signal reproduction. Thus, if the characteristic of pre-emphasis circuit P1 is that of Figure 2, then the circuit for filter 26 should have the characteristic shown in Figure 2A wherein the highs falls off; if the pre-emphasis circuit P1 has a characteristic such as shown in Figure 3 then the filter 26 should be given the characteristic shown in Figure 3A, assuming, again, switch 28 is thrown in such position as to increase the frequency swing in the intermediate frequency energy with increase in amplitude across terminals 32; and, finally with the last-mentioned position of switch 28, and assuming the pre-emphasis circuit P1 to have a characteristic such as shown in Figure 4, then the filter 26 should be arranged so as to have a characteristic such as shown in Figure 4A.

Certain changes may, of course, be made without departing from the scope of this invention. For example, other characteristics than those shown may be used and amplifiers may be inserted before and after filter 26, etc.

The frequency swing employed at the transmitter of the system shown in Figure 1 may be of any desirable value such as, for example, specified by Hansell in his U. S. Patent 2,179,182. Thus, for example, assuming the transmitter to handle a modulating frequency band of zero to 15,000 cycles, this modulating wave, at its maximum amplitude, may be used to vary the transmitted frequency plus and minus 15,000 cycles, plus and minus 20,000 cycles, plus and minus 50,000 cycles, plus and minus 100,000 cycles, plus and minus 200,000 cycles, etc. Also if desired, a frequency multiplier may be connected between the limiter 14 and discriminator 16. In this case, the admittance band of the discriminator, that is to say, the separation between the resonant peaks of the discriminator circuit, should be made wider than the maximum swing of the frequency multiplied waves. In the alternative, a frequency divider may be connected between the limiter 14 and discriminator 16, in which case the separation between the peaks of the discriminator characteristic need only be wider than the maximum swing of the divided waves. As an example, assuming that the received maximum frequency swing is plus and minus 20 kilocycles and a frequency multiplier having a multiplying factor of ten is used, then the separation of the resonant peaks of the discriminator 16 should be equal to and preferably greater than plus and minus 200,000 cycles. In the case of the divider, if we assume that the maximum received swing is plus and minus 200 kilocycles and if we assume that the divider has a dividing factor of ten, then the admittance band or the separation between the resonant peaks of the discriminator circuit should be at least equal to, and preferably greater than, plus and minus 20 kilocycles.

Having thus described my invention, what I claim is:

1. The method of receiving and translating a wave which has been modulated with a pre-distorted signal, pre-distorted in such a way that only a band of high frequencies of the signal is modified in such a way that the amplitudes of the frequencies of the band increases with an increase of signal frequency which includes receiving the modulated wave, beating the received wave with locally generated waves, deriving the signal from the resulting energy of beat frequency, emphasizing the derived signal in substantially the same manner as it was emphasized at the transmitter, and utilizing the emphasized, derived signal energy to angular velocity modulate the locally generated waves.

2. The method of receiving and translating pre-emphasized frequency modulated waves modulated by a pre-emphasized signal, said pre-emphasis following a characteristic which is flat over the lower frequencies of the signal band and which then rises for the higher frequencies of the signal band which includes receiving the waves, generating a local wave, combining the locally generated and received waves, deriving a modulation wave from the combined waves, emphasizing certain portions of the derived waves in accordance with said flat and then rising pre-emphasis characteristics, and utilizing the emphasized, derived wave to frequency modulate the locally generated wave.

3. The method defined in claim 2, characterized by the fact that the high frequency and the low frequency waves of the derived modulation waves are emphasized with respect to a wave of intermediate frequency of the signal waves prior

to utilization for frequency modulation of the locally generated wave.

4. The method as defined in claim 2, characterized by the fact that the locally generated wave is frequency modulated in such a way as to reduce the effective frequency modulation in the combined waves.

5. The method described in claim 2, characterized by the fact that the derived modulation waves are emphasized in a converse manner and that the frequency modulated local waves are produced and combined with the received waves in such a manner as to produce an increased effective frequency swing in the combined waves.

6. A receiving system for receiving frequency modulated waves comprising an antenna for picking up frequency modulated wave energy, a local generator, a detector in which the locally generated waves and received waves are combined, apparatus for converting the combined waves into waves of variable amplitude and for detecting the waves of variable amplitude, a circuit for pre-emphasizing only the high frequency portion of the detected waves, and a circuit for modulating the frequency of the locally generated waves with the pre-emphasized detected waves in such a way as to reduce the effective frequency swing of the detected waves of intermediate frequency with increase in amplitude of the locally, pre-emphasized waves.

7. The method of receiving a pre-emphasized audio modulated wave without distorting or de-emphasizing audio waves reproduced at the receiver, said pre-emphasis following a flat and then a rising amplitude versus frequency characteristic over the entire band of signal frequencies, which includes receiving the modulated waves, heterodyning the received waves with locally generated waves, deriving an audio signal from the heterodyned waves, translating one part of the audio signal, modifying in accordance with said flat and rising characteristic another portion of the audio waves produced which are not used for translation, and utilizing the modified waves to modulate the locally generated waves employed in the heterodyning process.

8. The method of receiving a pre-emphasized audio modulated wave without distorting or de-emphasizing audio waves reproduced at the receiver, said pre-emphasis following a flat and then a rising amplitude versus frequency characteristic effective over the entire band of signal frequencies, which includes receiving the modulated waves, heterodyning the received waves with locally generated waves, deriving an audio signal from the heterodyned waves, translating one part of the audio signal, modifying in accordance with said pre-emphasis characteristic another portion of the audio waves produced which are not used for translation, and utilizing the modified waves to frequency modulate the locally generated waves employed in the heterodyning process.

9. The method of receiving a pre-emphasized timing modulated wave without distorting or de-emphasizing audio waves reproduced at the receiver which includes receiving the modulated waves, heterodyning the received waves with locally generated waves, deriving an audio signal from the heterodyned waves, translating one part of the audio signal, modifying another portion of the audio waves produced which are not used for translation, in such a way that the higher frequencies of said other portion are accentuated with respect to the lower frequencies thereof, and utilizing the modified waves to frequency modulate the locally generated waves employed in the heterodyning process.

10. A receiver for receiving angular velocity modulated carrier waves comprising a circuit for receiving the waves, an oscillator for generating local heterodyning waves, a circuit for combining the local heterodyning waves with the received waves to produce waves of intermediate frequency, apparatus for deriving modulation waves from the waves of intermediate frequency, a circuit for translating a portion of the modulation waves, another circuit for modifying another portion of the modulation waves so that the higher modulation frequencies thereof are accentuated with respect to the lower frequencies thereof, and apparatus for modulating the locally generated waves with the modified waves.

11. Apparatus as claimed in claim 10, characterized by the fact that the received waves are frequency modulated waves and that the locally generated waves are frequency modulated.

12. Apparatus as claimed in claim 10 characterized by the fact that the received waves are phase modulated and that the locally generated waves are phase modulated.

13. Apparatus as claimed in claim 10, characterized by the fact that the received waves are frequency modulated waves, that the modified waves are modified in such a way that the higher frequencies thereof are accentuated with respect to the lower frequencies, and being further characterized by the fact that the locally generated waves are modulated in frequency in such a way that the effective frequency swing in the intermediate frequency waves is reduced when the amplitude of the modified waves is increased.

14. Apparatus as claimed in claim 10, characterized by the fact that the modified waves are modified in such a way that the lower and higher frequencies thereof are accentuated with respect to intermediate frequencies, and being further characterized by the fact that the modified waves are used to frequency modulate the locally generated waves in such a way as to reduce the effective frequency swing in the intermediate frequency waves when the amplitude of the modified waves increases.

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