Nov. 20, 1945. H. E. GOLDSTINE 2,389,356

METHOD OF REDUCTION OF SELECTIVE FADING

Filed Nov. 24, 1942 3 Sheets-Sheet 1

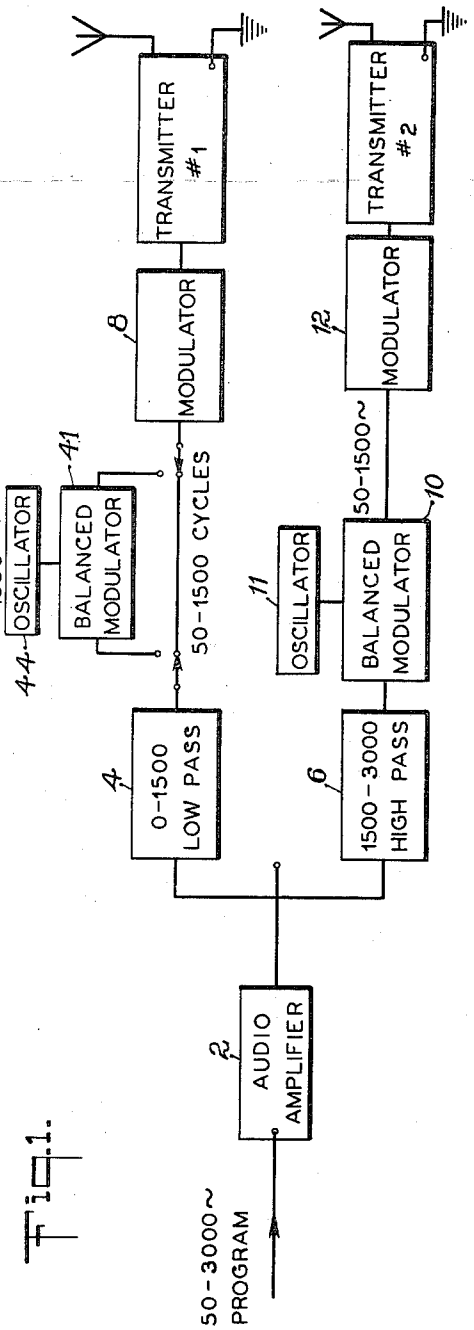


Fig. 1.

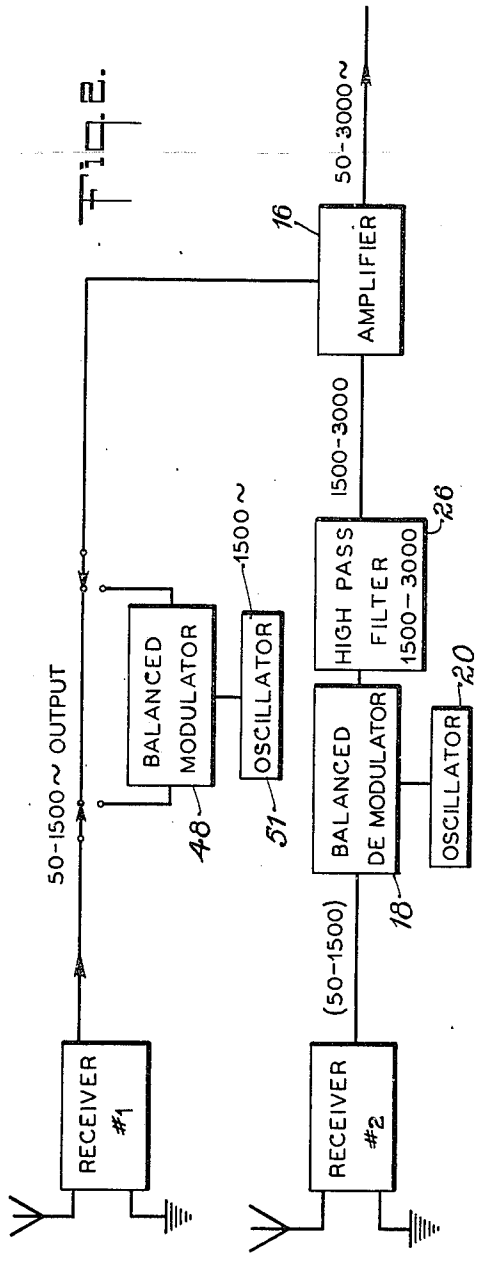


Fig. 2.

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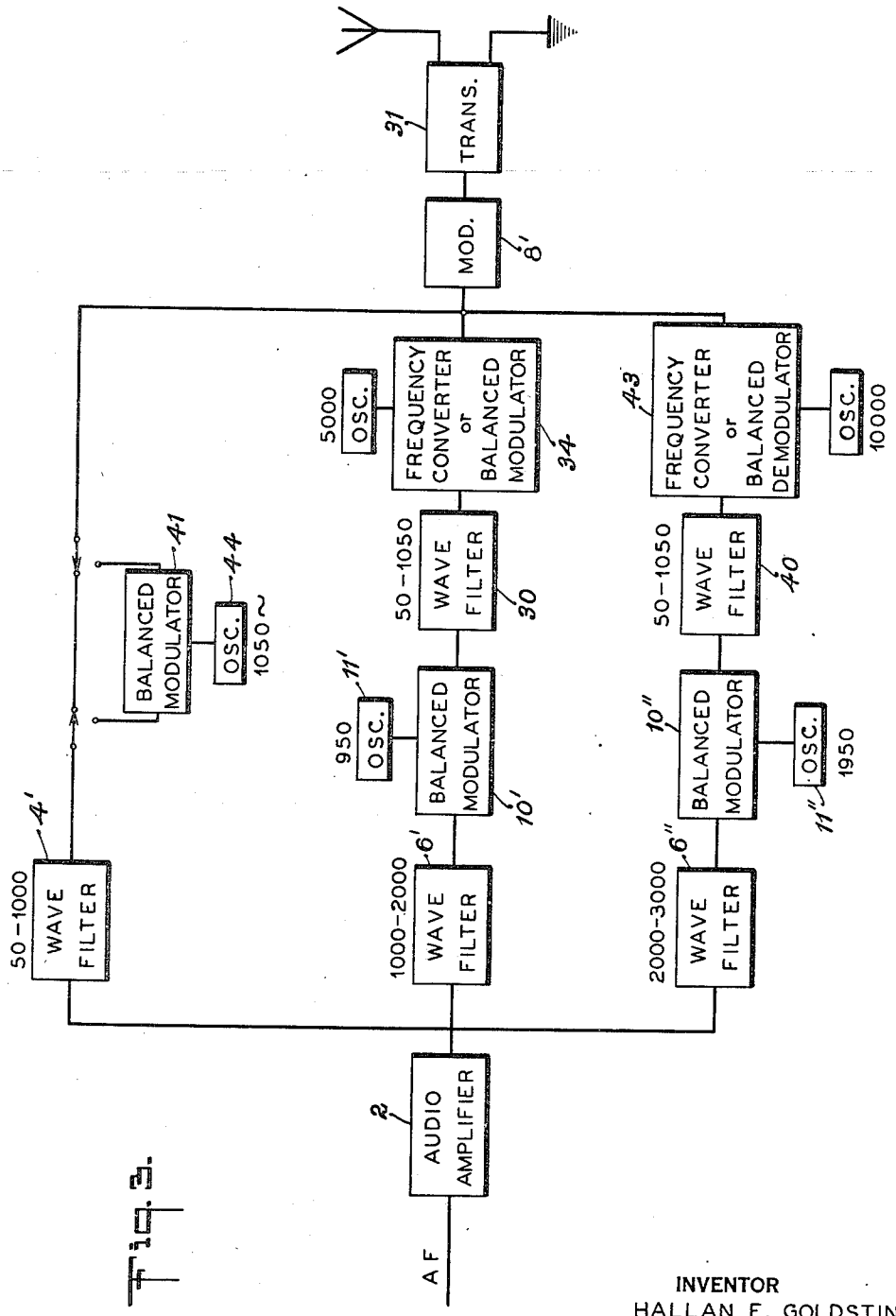


Fig. 2.

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Filed Nov. 24, 1942 3 Sheets-Sheet 3

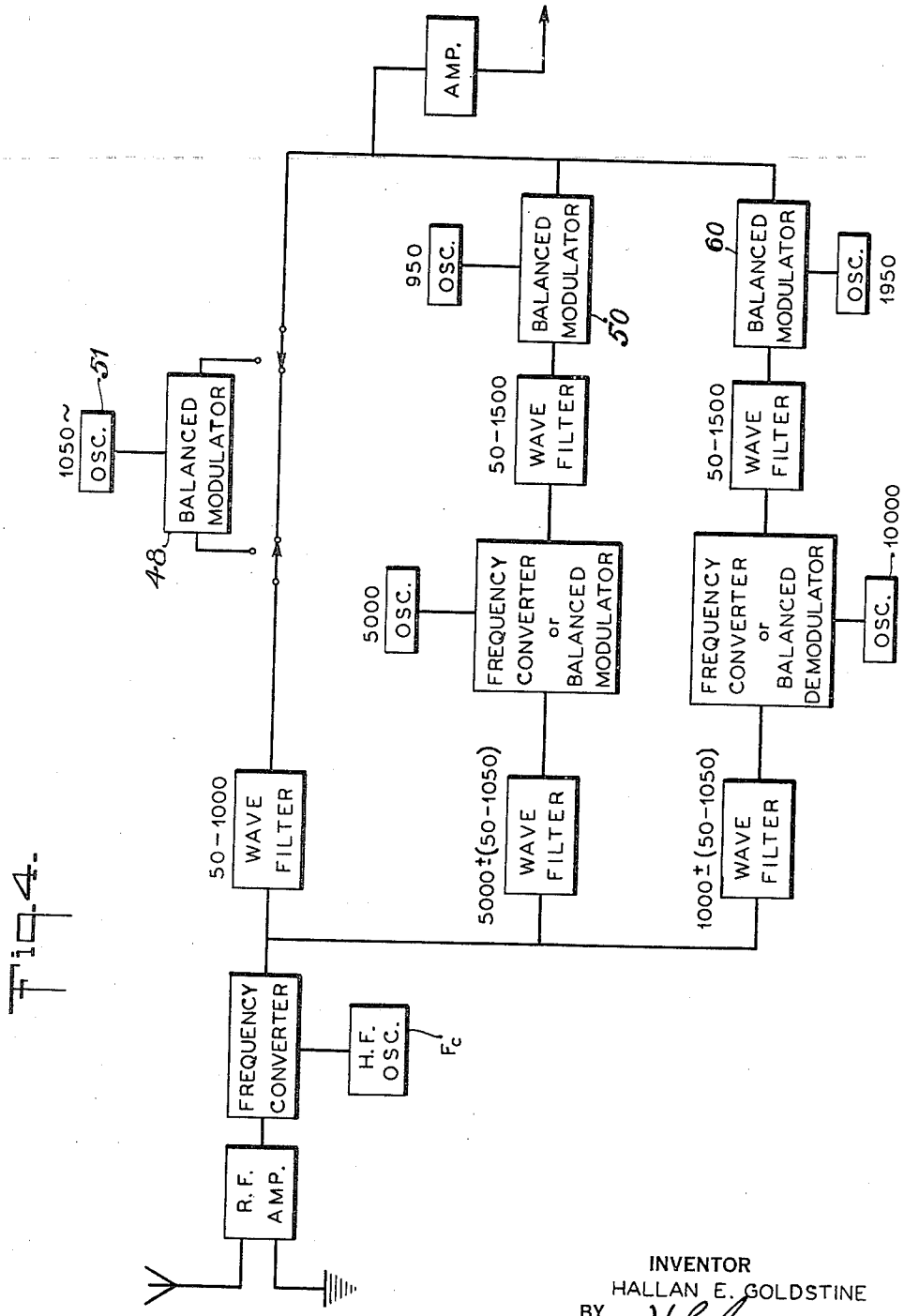


Fig. 4.

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Patented Nov. 20, 1945 2,389,356

UNITED STATES PATENT OFFICE

2,389,356

METHOD OF REDUCTION OF SELECTIVE FADING

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Application November 24, 1942, Serial No. 466,745

8 Claims. (Cl. 250—6)

This application discloses an improvement in the art of radio transmission, particularly long distance transmission by short waves. By my method and means of transmission selective fading may be appreciably reduced thereby permitting better quality transmission of telephony and high speed facsimile.

It is known to the art that the side band frequencies undergo a change in amplitude and phase relative to the carrier when selective fading is encountered. It is also known that the sidebands closest to the carrier, due to the fact that their frequencies are more nearly the same, suffer the least discrimination during selective fading.

One type of selective fading which is especially troublesome for the transmission of intelligent speech or music is when the carrier amplitude is reduced to below the sideband amplitude. This makes the effective amplitude modulation greater than 100% and results in a large amount of distortion. The automatic volume control attempts to hold the carrier at predetermined level and this results in augmenting the distortion by raising the sideband amplitude.

If, however, the sidebands are close enough to the carrier to be similarly affected in the fading process, the A. V. C. will tend to hold the level constant and the result of the fading will not be as pronounced. This is only one type of fading, and other effects are taking place simultaneously. If one uses sub-carriers and keeps the sidebands close to the sub-carriers, then the effects of excessive over-modulation are minimized.

It is an object of this invention to reduce selective fading by keeping the sidebands close to the carrier. This is done in accordance with my invention by taking the audio modulation applied to the transmitter and by means of wave filters converting it into two or more channels. The higher frequency channels are then heterodyned to a lower frequency and are used to modulate another carrier or sub-carrier. As an example, suppose I wish to transmit a frequency band of 3000 cycles. I transmit this band by dividing the modulation, by means of filters, into 50 to 1000 cycles, 1000 to 2000 cycles and 2000 to 3000 cycles. The 1000 to 2000 cycles are then heterodyned by means of a balanced modulator to a frequency of 50 to 1050 cycles and the 2000 to 3000 cycles are also heterodyned to a frequency of 50 to 1050 cycles. The higher frequency channels which have been heterodyned are then used to modulate another carrier frequency near the same frequency as the original carrier.

If it is desired, these other channels can be transmitted on sub-carriers on the original carrier so that the entire transmission can be accomplished on one carrier transmitter. It is also possible by this method to obtain secrecy of transmission by arranging the heterodyning so that the channels are inverted in frequency. The channels can also be synchronously alternated so that the different outputs of the filters will alternately modulate the different carriers. In any case, the transmitted energy comprises carriers or a carrier with sidebands closely related thereto in the frequency spectrum.

In describing my invention in detail, reference will be made to the attached drawings wherein:

Figures 1 and 3 each shows a modification of my signalling system including apparatus for transmitting a wave wherein the signal frequencies making up the sidebands are located close to the carrier so that carrier and sidebands are subject to similar selective fading effects.

Figures 2 and 4 illustrate receivers arranged and adapted to the reception of wave energy sent out from the transmitter of Figures 1 and 3 respectively.

In Figure 1, 2 is an audio amplifier, the output of which is connected to a first selective filter 4, which passes currents in a limited frequency spectrum, say from 50 to 1500 cycles, and a second selective filter 6, which passes currents in a second selective frequency spectrum, say 1500 to 2850 cycles. It has been assumed the audio range is 50 to 3000 cycles. The filters 4 and 6 may be band pass filters or low and high pass filters, as indicated. The output of the filter 4 is supplied to the modulator 8 and the modulator 8 acts on a first carrier in transmitter #1 to modulate the carrier therein.

The output of filter 6 is supplied to a balanced modulator in 10 wherein this band of frequencies is beat or heterodyned down, with oscillations from 11, to derive from the output of 10 a corresponding band of audio frequencies running from 50 to 1500 cycles. This band of frequencies is supplied to a modulator 12 and then used to modulate a second carrier of a frequency close to the frequency of the first carrier in the #2 transmitter. Note that in both of the transmitted waves the modulation frequencies comprised in the sidebands are closely spaced in the frequency spectrum with respect to the carriers so that the fading of the carriers and sidebands are more uniform.

At the receiver in Figure 2 the two modulated carriers are picked up and amplified in receivers

1 and 2. The detector in receiver 1 supplies from its output the original 50 to 1500 cycle signal, this being derived from the carrier transmitted from transmitter #1. This output is supplied to an amplifier 16. The output of receiver 2 includes also a band of audio frequencies running from 50 to 1500 cycles and this band of frequencies is supplied to a converter 18 wherein it is beat or heterodyned with oscillations from a source 20. The frequency of the oscillations from 20 will be the same as the frequency of the oscillations used at 11 in the transmitter, and the output of the converter 18 is supplied to a high pass or band pass filter 26 of the nature of the filter 6 to pass only the modulation frequencies running from 1500 to 3000 cycles; that is, the other part of the original modulation band in the output of 26 is supplied to the amplifier 16 and from the output of the amplifier 16 the original signal is derived.

As an example, we may assume the audio band is as indicated in Figures 1 and 2 from 50 to 3000 cycles. The 50 to 1500 cycle band is supplied directly through selective filter 4 and the modulator 8 to the transmitter #1. The 1500 to 3000 cycle band selected by the filter in 6 is heterodyned in a balanced modulator 11 with a 1450 cycle tone from 11 in modulator 10 and the band of frequencies from 50 to 1550 cycles supplied to modulator 12 and thence to transmitter #2. When these frequencies are used, the source at 20 will be of 1450 cycles.

In the modification shown in Figure 3, the principles used in Figure 1 are also used with the following modifications:

It is assumed that the band of audio signals from 50 to 3000 cycles are now split up into three bands: one of 50 to 1000 cycles, a second of 1000 to 2000 cycles, and a third of 2000 to 3000 cycles. The low frequency band is again supplied directly to the modulator 8' and thence to a transmitter 31. The 1000 to 2000 cycle band is selected in filter 6' and fed to a balanced modulator 10' wherein it is heterodyned against oscillations from 11' down to a band of frequencies of 50 to 1050 cycles and then fed by selective filter 30 to a frequency converter 34, wherein this band of frequencies modulates a sub-carrier, say of 5000 cycles, which is supplied through the modulator 8 to the transmitter in 31. The third band, running from 2000 to 3000 cycles, is likewise supplied to a converter 10'' and heterodyned against oscillations from 11'' down to a band of frequencies from 50 to 1050 cycles and fed by selective filter 40 to a frequency converter 43 wherein it is used to modulate a second sub-carrier of say 10,000 cycles and supplied to the modulator 8' and used to modulate the carrier in 31.

In Figure 4 I have shown a receiver adapted to demodulate the carrier sent from transmitter 31 and in this receiver a demodulation process, which is the reverse of the modulation process used in the transmitter, is carried out. The operation of the receiver and the nature thereof is clear from the drawings wherein each element shown by rectangles is fully labeled to designate its function and wherein the various bands of frequencies and heterodyning frequencies, etc., used are shown.

Where desired, the bands of audio frequencies may be inverted for secret signalling. Then the bands of audio frequencies which are lowered in the frequency spectrum, such as for example, the 1500 to 3000 cycle band in Figure 1 and the 1000 to 2000 cycle band and 2000 to 3000 cycle band in Figure 3 are inverted in the frequency spectrum during the process of lowering the same in the frequency spectrum. This is accomplished by using a beating frequency in the converters 10, 10' and 10'' laying in the upper marginal frequency, say 3050 cycles, in the converter 10, Figure 1, 2050 in the converter 10', Figure 3 and 3050 in the converter 10'', Figure 3. The 50–1500 cycle band in Figure 1 is converted and inverted by heterodyning with 1550 cycles, while in Figure 3 the 50–1000 cycle band may also be inverted by heterodyning with 1050 cycles. To do this the output of filter 4 in Figures 1 and 3 is switched to a frequency inverting modulator 41 supplied with oscillations from an oscillator 44 operating at 1550 cycles in Figure 1 and 1050 cycles in Figure 3. The inverted signals are supplied to the modulator 8 in Figure 1 and the modulator 8' in Figure 3. At the receivers in Figures 2 and 4, these signals in the lower frequency bands are reinverted by a balanced modulator frequency inverter 48 cooperating with an oscillator 51 which provides oscillations of 1550 cycles in Figure 2 and 1050 cycles in Figure 4.

Corresponding changes in the heterodyning oscillations used at 20 in the receiver of Figure 2 and at the converter 50 and 60 of the receiver in Figure 4 will reinvert these bands to their original frequency sequence.

It may be advisable in practice to change the frequency bands somewhat because the examples which are given will allow the heterodyning carrier to fall in the band pass of the selective circuits. However, in the arrangement shown the heterodyning carrier will be reduced to a very low value by means of the balanced modulators 10, 18, 10', 10'', etc.

What is claimed is:

1. In a secret signalling system, a source of signalling voltages, selective circuits for splitting said signalling voltages into at least two bands of frequencies located adjacent to each other in the signal voltage frequency spectrum, said bands together covering the entire signal voltage frequency spectrum, a frequency inverter coupled to the selective filter passing the lowest band of frequencies and inverting the same, a frequency reducer and inverter coupled to the other of said selective filters for inverting the other band and reducing the frequency thereof so that it falls in the band occupied by said lowest band of frequencies, and a modulation system for modulating carrier energy in accordance with the resulting signals.

2. A signalling system as recited in claim 1 with a receiver for said carrier energy and circuits for separating said bands of frequencies and additional circuits for reinverting the signal voltages in the said bands to their original sequence in the frequency spectrum.

3. A receiver for carrier energy from the signalling system recited in claim 1 including a detector for separating said bands of signal frequencies, a separate frequency inverter excited by each band of frequencies, and a common output coupled to all of said frequency inverters.

4. In an arrangement of the nature disclosed, a source of signalling voltages covering a given band of frequencies, selective circuits for separating said signalling voltages into a plurality of adjacent bands of voltages of less width than the original band, heterodyning systems for heterodyning the voltages in each of said bands of voltages except that band wherein the lowest signalling voltages appear to corresponding bands of voltages lying in the band of frequencies oc-

cupied by the lowest signalling voltages, a plurality of carrier wave sources, and a modulator for each band controlled by the voltages therein for modulating the carriers of said sources.

5. A receiver of wave energy of the nature described in claim 4 including means for amplifying each carrier, and means for heterodyning up signal voltages corresponding to the voltages in the bands reduced in the frequency spectrum.

6. A signalling system including means for reducing selective fading during transmission, a source of signal voltages, and a source of carrier energy, selective circuits for splitting said signal voltages into a plurality of bands of frequencies located adjacent to each other in the frequency spectrum, said bands together covering the entire signal voltage frequency spectrum, modulating means coupled to the selective circuit passing the lowest frequency band of voltages for impressing the same on said carrier energy, a frequency converter coupled to each of the other of said selective circuits, said frequency converters operating to reduce the remaining bands of signal voltages passed by said selective circuits to the band occupied by said lowest band of signal voltages, a sub-carrier source for each of the bands so reduced in frequency, a modulator connected to each of said sub-carrier sources and to a different one of said converters to modulate each of said sub-carriers by one band of signal voltages of reduced frequency, and additional modulating means for modulating said first mentioned carrier energy in accordance with said modulated sub-carriers.

7. A system as recited in claim 6 including a frequency inverter following each of said selective circuits.

8. The method of secret signalling with a band of voltages representing signals and wave energy of carrier wave frequency and reducing the effects of fading on modulated carrier energy during transmission which includes these steps, separating said band of voltages representing signals into a plurality of bands of voltages representing signals, reducing the frequency of the voltages of each of the said bands, except that band wherein the signal voltages of lowest frequency occur, so that the bands of signal voltages of reduced frequency fall in the band occupied by the band of lowest frequency, inverting the frequencies of the voltages in each band, and modulating carrier wave energy in accordance with the voltages of all of said bands.

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