Oct. 5, 1937. H. H. BEVERAGE 2,095,050

SIGNALING

Filed April 26, 1933 2 Sheets-Sheet 1

Fig. 1

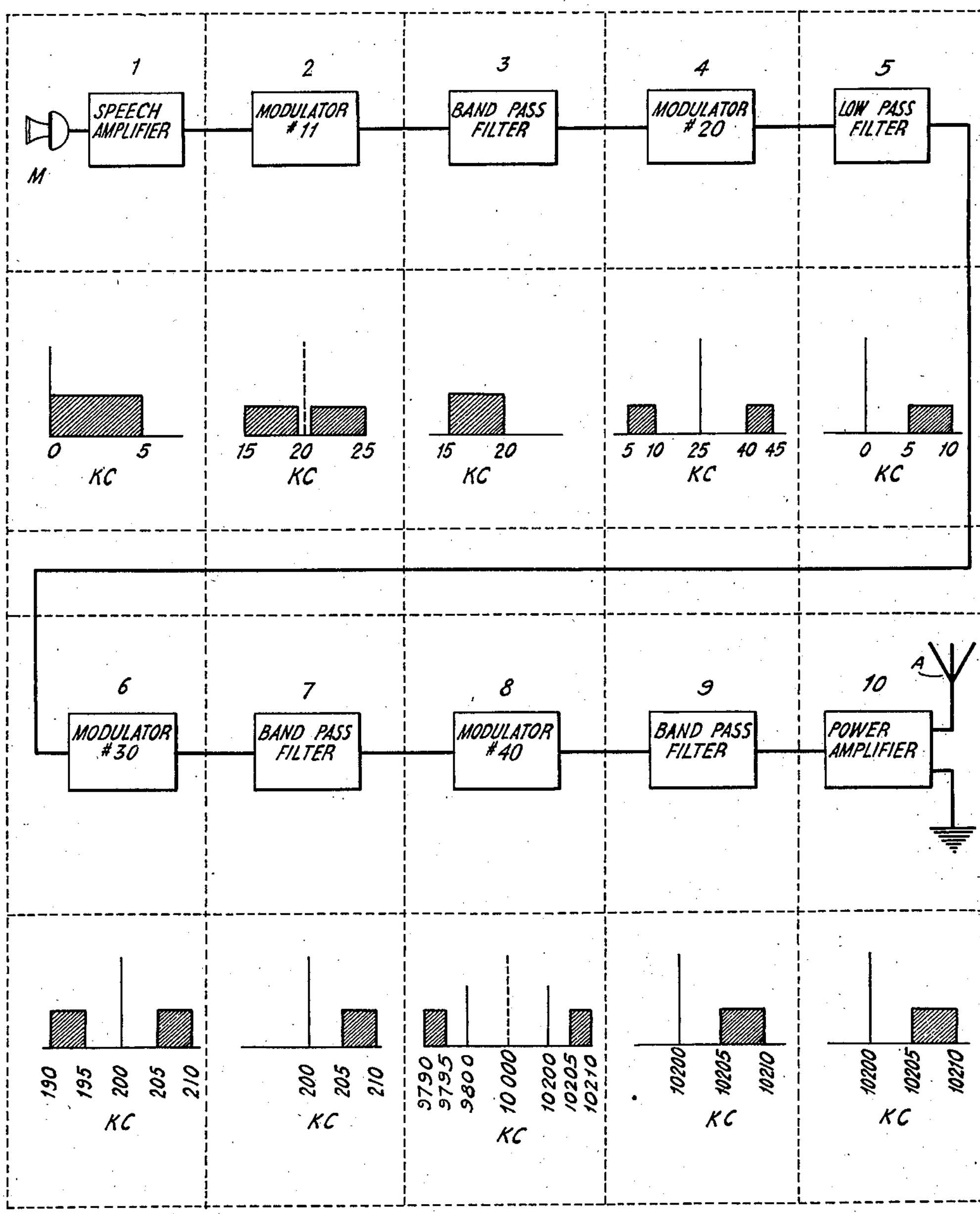

Fig. 4

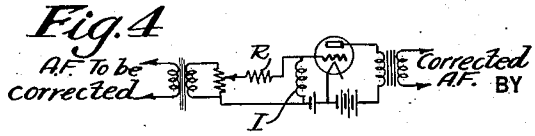

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Fig. 2

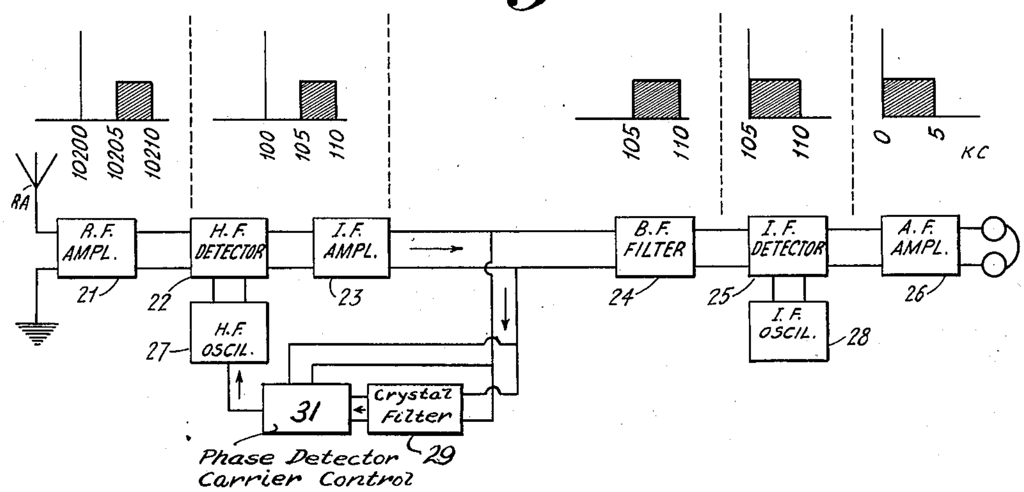
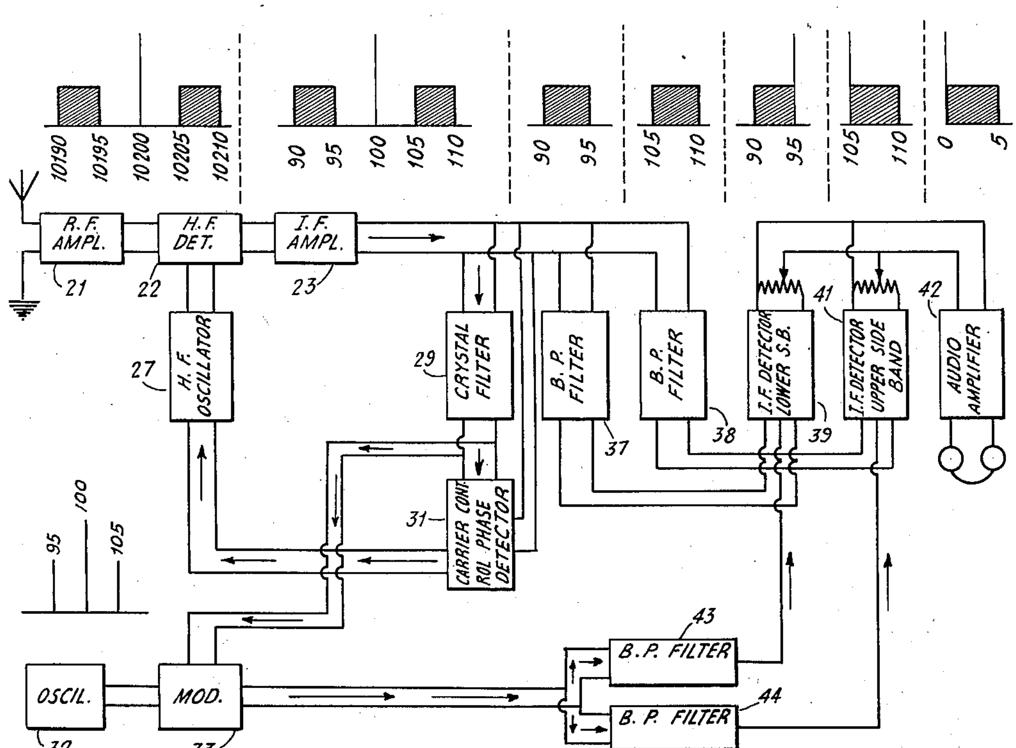


Fig. 3



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SIGNALING

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Application April 26, 1933, Serial No. 668,098

8 Claims. (Cl. 250—6)

This invention discloses a method for transmitting and receiving over a single sideband and carrier, double sideband and carrier or single sideband only. It may also be applied to either amplitude, phase or frequency modulation.

Briefly, the idea is to modulate a relatively low frequency carrier, select a single sideband by means of a band-pass filter and combine this single sideband with a second carrier in such a manner that there is a space between the second carrier and the group of sidebands which carry the intelligence. Due to this spacing between the carrier and the sidebands, it is relatively easy to select the carrier and a single sideband or a single sideband only, in the further stages containing conventional modulators. Furthermore, if the energy is radiated with an idle space between the carrier frequency and the intelligence bearing sidebands, it is relatively easy to design a receiver which can select the sidebands independently of the carrier.

In the prior art, it has been customary to modulate a carrier in such a way that sidebands extend outward from the carrier with no idle space between the carrier and the sidebands representing the lower modulation frequencies. This method of signaling has several disadvantages. In the first place, during transmission through the ether, particularly at short wavelengths, the fading is not uniform over the band of frequencies transmitted. This phenomena, which is known by the term "selective fading", results in impaired quality. For example, if the carrier frequency should fade out leaving the sidebands, the two sidebands beat together producing a great many harmonic frequencies which did not exist at the transmitting station. If the carrier does not fade completely out, the effect is not as serious, but, nevertheless, distortion is produced since the beating between the sidebands and the reduced carrier is equivalent to overmodulation. Furthermore, the phase relations between essential frequencies in the upper and lower sidebands, are continually changing, also producing distortion. In order to eliminate these distortions, it is highly desirable to eliminate one of the sidebands, or at least to receive each sideband separately, and combine them afterwards in their proper phase relations.

In the ordinary method of modulating a transmitter, the sidebands are so close to the carrier that it is difficult to separate the sidebands from the carrier and from each other. In the system which I am proposing, the sidebands and the carrier are separated in frequency a sufficient amount to make it possible to select them separately at the receiver.

The novel features of my invention have been set forth with particularity in the claims appended hereto as required by law.

The art of signaling in accordance with my novel method and the means necessary to carry out such signaling will be best understood by reading the detailed description which follows and therefrom when read in connection with the attached drawings, in which:

Figure 1 illustrates diagrammatically one means for transmitting signals developed in accordance with my invention;

Figure 2 shows a receiver of signals developed in accordance with my method;

Figure 3 shows a modification of Figure 2; while

Figure 4 illustrates a correction circuit which may be used at the transmitter or the receiver to alter the character of the same whereby phase modulation and demodulation may be accomplished.

In Figure 1 I have shown the setup for one form of transmitter embodying my invention. I have divided the various operations into ten separate stages and below the block diagram representing the various stages I have shown the frequencies which pass through each portion of the equipment. This is merely a typical case to aid in the description of the operation of my invention.

In stage 1 a microphone M, adapted to be energized by speech waves, is connected with a speech amplifier as shown. The frequency range of the microphone and amplifier is assumed to be zero to 5 kilocycles, as shown by the block diagram directly below stage 1, although, of course, in actual practice, it might be from 30 cycles to 5,000 cycles. Stage **2** includes a modulator **11** in which a carrier frequency of 20 kilocycles, supplied from a carrier source as shown, is modulated by the speech frequencies, producing two sidebands extending from 15 to 25 kilocycles, as indicated, by the energy diagram directly below stage **2**. A band pass filter in stage **3** selects the lower sideband of 15 to 20 kilocycles, as shown diagrammatically below stage **3**. This lower sideband is then combined in the modulator of stage 4 with the 25 kilocycle carrier from any source in a second modulator **20**. The lower sideband extends from 5 to 10 kilocycles and the upper sideband extends from 40 to 45 kilocycles as shown diagrammatically in the energy diagram below stage 4. Between the carrier of 25 kilocycles and each sideband there is a blank space of 15 kilocycles. The lower sideband may be selected by a low pass filter included in stage 5, which filter allows all frequencies below 10 kilocycles to pass. We now have an idle zone containing no frequencies between zero and 5 kilocycles and the speech intelligence bearing frequencies are concentrated between 5 and 10 kilocycles, as shown below stage 5. This band of frequencies is applied to stage 6 which includes a third modulator 30, where it modulates a carrier of 200 kilocycles supplied from a source as shown. From this modulation an upper sideband between 205 and 210 kilocycles and a lower sideband between 190 and 195 kilocycles are obtained, as shown by the graphs below stage 6. The upper sideband and carrier are selected by a band-pass filter included in stage 7, which passes 200 to 210 kilocycles. The output of the filter in stage 8 modulates a 10,000 kilocycle carrier which includes a fourth modulator 40. A band-pass filter passing 10,200 kilocycles to 10,210 kilocycles included in stage 9 selects the upper sideband only, which, it will be noted by inspection of the graph below stage 9, consists of a carrier, a 5 kilocycle space and a single 5 kilocycle sideband. Modulator 40 may be arranged to suppress the 10,000 kilocycle carrier and it will be noted that the various sidebands are well spread out, making it possible to select the desired frequencies with a relatively inexpensive filter. The output of the final filter is amplified by a power amplifier included in stage 10 and radiated into space from an aerial A.

The generators, filters and modulators used in this system per se form no part of the present invention and for that reason have not been described in detail here. However, the generators should provide oscillations of substantially constant frequency and amplitude. The modulators may be of any known type and may modulate the oscillations in any of its characteristics including phase, frequency and amplitude. Likewise, the filters may be of any known type which have the desired cut off characteristics, etc. For purposes of illustration I have assumed that the oscillations are to be modulated in amplitude.

Figure 2 shows a receiver which may be used to receive the radiations from the transmitter of Figure 1. The signals including the carrier and sideband, as shown above the receiver, are picked up on the antenna RA and amplified by radio frequency amplifier 21. High frequency detector 22 combines the incoming energy with oscillations from the high frequency oscillator 27. Intermediate frequency amplifier 23 is assumed to be tuned to 100 kilocycles and further amplifies the signals of reduced frequency and passes them on to band-pass filter 24, which separates the sideband from the carrier, as shown above the filter. It will be noted that the carrier is removed 5 kilocycles from the lowest frequency in the sideband, corresponding to a separation of 5 percent., which makes it possible to separate the sideband from the carrier with a relatively inexpensive band-pass filter 24.

In the intermediate frequency detector 25 the sideband frequencies are combined with the carrier of 105 kilocycles supplied from the intermediate frequency oscillator 28. The output of the intermediate frequency detector then represents the original voice frequency spectrum which existed in microphone M of Figure 1. It is obvious that a variation in the frequency of the incoming signal will cause frequency variations to exist in the intermediate frequency detector between the 105 kilocycle intermediate frequency oscillations and the sideband frequencies from the band-pass filter 24. In order to eliminate this difficulty, the frequency of the oscillations produced by 27 is regulated by a carrier controlled circuit connected between the intermediate frequency amplifier 23 and band-pass filter 24. This circuit consists of a 100 kilocycle crystal filter 29 followed by a phase detector 31, which in turn operates on frequency determining means in the high frequency oscillator 27 to produce a constant carrier frequency and consequently an intermediate frequency exactly equal to 100 kilocycles.

The crystal filter circuit may be of any type but is preferably of the type disclosed in United States application Serial No. 564,770, filed September 24, 1931, Patent No. 2,001,387 and United States application Serial No. 203,901, filed July 7, 1927, Patent No. 2,005,083, or in United States application No. 616,803, filed June 13, 1932, Patent No. 2,065,565 or any other type of filter which has the desired characteristics. The phase detector and oscillator control means may be of any type. Preferably, this control means may be of the type disclosed in United States application Serial No. 616,803, filed June 13, 1932, Patent No. 2,065,565. In this manner the sideband frequencies are held in proper relation to the oscillator 28 independently of small variations in the received signal frequency.

In my description of this invention I have so far described a transmitter which is amplitude modulated and radiates a carrier and one sideband. I have also described a receiver designed to receive the modulations of the transmitter shown in Figure 1.

Referring to Figure 1, it will be noted that the output of modulator 30 consists of a carrier and two sidebands. If the band-pass filter of stage 7 had been adjusted to cover a frequency band of 190 to 210 kilocycles, both sidebands would have been passed on to the modulator 40. The lower sideband then would have consisted of a band of frequencies between 10,190 and 10,195 kilocycles, a carrier of 10,200 kilocycles and an upper sideband of 10,205 to 10,210 kilocycles. Then if the band-pass filter in stage 9 had been adjusted to select all frequencies between 10,190 and 10,210 kilocycles, and this energy had been amplified by the power amplifier in stage 10, the resulting radiation would have consisted of two sidebands symmetrically spaced about a carrier of 10,200 kilocycles, as shown at the left of Figure 3, just above the radio frequency amplifier 21.

The receiver of Figure 3 operates in the same manner as the receiver of Figure 2 with the exception that the output of the intermediate frequency amplifier 23 is associated with two band-pass filters 37 and 38, the first of which receives the lower sideband of 90 to 95 kilocycles and the second of which receives the upper sideband of 105 to 110 kilocycles. Part of the 100 kilocycle carrier output from the crystal filter 29 is combined with oscillations from a 5 kilocycle oscillator 32 in modulator 33, producing two sidebands of 95 and 105 kilocycles. The lower sideband of 95 kilocycles is selected by band-pass filter 43, while the upper sideband of 105 kilocycles is selected by band-pass filter 44. In the intermediate frequency detector 39 the 95 kilocycle carrier is combined with the lower sideband output from filter 37. In intermediate frequency detector 41 the 105 kilocycle carrier from filter 44 is combined with the upper sideband from filter 38. The output of detector 39, as well as the output of detector **41** now each includes the original voice frequency which impinged on microphone M of Figure 1. Under some conditions, it may be advantageous to combine the output of the upper sideband with the output from the lower sideband, as just shown in connection with Figure 3, thereby obtaining some improvement due to frequency diversity between the upper and lower sidebands. During other conditions, in which the phases between the upper and lower sidebands are rapidly changing, it would probably be desirable to receive the output produced by one sideband only, as shown in connection with Figure 2.

So far I have described the use of my invention for amplitude modulation only. I now propose to briefly describe how the same arrangement may be applied to either phase or frequency modulation.

In Figure 1, if we take the output of the filter in stage **5**, we can phase modulate or frequency modulate modulator **30** in the conventional manner. In the case of frequency modulation, it will be noted that the modulation frequencies lie between 5 kilocycles and 10 kilocycles, a ratio of 2 to 1. On the other hand, when we frequency modulate a transmitter, in a manner known in the art, with voice frequencies ranging between, say, 50 cycles and 5,000 cycles, we have a ratio of 100 to 1 between the lowest and highest modulation frequencies.

In frequency modulation, the frequency swing is the same for all frequencies which produces an effect equivalent to over-modulation on the low frequencies. In a frequency modulated sideband, the relative amplitudes of the sideband frequencies are inversely proportional to the modulation frequencies, for moderate amounts of modulation, especially at the higher modulation frequencies. That is, the sideband amplitude for a given frequency will be double that for twice that frequency. Thus, if the frequency band extends from 5,000 to 10,000 cycles, the sideband amplitude at 5,000 cycles will be double that at 10,000 cycles for equal input to the modulator at the transmitter. By limiting the frequency range to 2 to 1, as I have done in my invention, it will be noted that the effective percentage of modulation is nearly the same over the entire range of modulation frequencies. The overall result, therefore, is intermediate between normal frequency modulation and phase modulation produced by conventional methods. Furthermore, if we wished to correct frequency modulation to phase modulation we may do so by making the modulation voltage proportional to the modulating frequency, as disclosed in United States application Serial No. 608,383, filed April 30, 1932. Briefly, this may be accomplished by passing the modulating potentials through a circuit as shown in Fig. 4, including a high resistance R and inductance I in series, and utilizing the modulating potentials from the inductance so that the higher signal frequencies are stressed and the output potentials varied proportionally as the frequency of the input potentials vary. Any other correcting circuit having the characteristics outlined above may be used. The correcting circuit may be used at any point in the audio frequency path at the transmitter, for example, said circuit may be interposed between the speech amplifier **1** and the modulator **2**. The correcting circuit may also be used in any of the audio frequency circuits at the receiver. Of course, the problem of producing phase modulation in this manner is extremely simplified by the present invention because the range of modulating frequencies is limited to only two to one.

The correcting network in the audio frequency output at the receiver may also consist simply of a resistance R and inductance I in series as shown in Fig. 4, with the audio amplifier connected across the inductance. If the series resistance is high enough, the audio frequency current through the inductance will be substantially independent of the frequency. Consequently, since for the same current, the reactance drop will be twice as high at 10,000 cycles as at 5,000 cycles, the output at the higher frequencies will be increased in just the right proportion to compensate for the amplitudes as received from the detector.

As a further modification, it is also obvious that the output from the filter in stage **5** of Figure 1 could be used to modulate a high frequency transmitter directly by conventional methods without passing through the additional modulator **40**. For example, suppose we should modulate by conventional methods a carrier of 10,200 kilocycles with the output from the filter in stage **5**. We would obtain a carrier of 10,200 kilocycles, an upper sideband ranging between 10,205 and 10,210 kilocycles and a lower sideband ranging between 10,190 and 10,195 kilocycles. The modulation could be either amplitude, phase or frequency. The receiver of Figure 3 could be used for receiving such transmissions in exactly the manner described previously in this disclosure.

Since the sidebands are selected and detected separately, no change in adjustment at the receiver would be required when changing from amplitude modulation to phase modulation, providing only one sideband is being received. If both sidebands are being received and combined in the manner shown in Figure 3, it would be necessary to reverse the output of one of the sideband detectors when changing from amplitude to phase modulation or vice versa, as shown in United States application Serial No. 618,154, filed June 20, 1932.

Having thus disclosed my invention and the operation thereof, what I claim is:

1. A receiver for receiving signal energy comprising a carrier and two sidebands which during transmission have been separated from said carrier by substantial frequency bands comprising, signal absorbing means, heterodyne demodulating means connected therewith, said demodulating means including a high frequency oscillator, a pair of band-pass filters connected with said demodulating means, each band-pass filter being adapted to pass one sideband only of the demodulated energy, a local oscillator, a modulator coupled thereto to be energized thereby, a filter coupling said modulator to said demodulator to impress filtered energy from said demodulator on said modulator, signal detecting means connected with each of said band-pass filters, separate filters tuned to different frequencies connecting said detecting means to said modulator to impress selected energy from said modulator on said detecting means, a single indicating means connected with said detecting means, and a frequency control device interposed between said high frequency oscillator and the output of said demodulating means to control the frequency of the high frequency oscillator in accordance with energy from said demodulating means.

2. The method of receiving signal energy comprising a carrier and sidebands which during

transmission are spaced by a substantial frequency band which includes the steps of, combining said carrier and sidebands with high frequency oscillations to produce a beat note including two signal carrying sidebands, separating said sidebands, modulating said beat note with a lower frequency to obtain two new carrier frequencies, beating each of said sidebands with the proper one of said new carrier frequencies, demodulating each sideband and its carrier separately to produce resultant energies, and combining the resultant energies in proper phase to produce indications characteristic of the signal.

3. A signaling system comprising, a source of signal potentials of a pre-determined frequency range, a circuit for impressing said signal potentials on carrier frequency oscillations of a value such that a side band resulting from said modulation extends substantially from the carrier to the lowest side band frequency and to the highest side band frequency, a filter connected with the output of said modulator for selecting one of said side bands, a circuit including a second modulator for impressing said selected side band on to carrier frequency oscillations of such a value that the side bands in the output of said circuit are separated from the carrier by a frequency band relatively large as compared to the frequency range of the side bands whereby one of said side bands may be readily separated from the other sideband and carrier, a transmitting device, a filter connecting the output of said modulator to said transmitting device, said filter being tuned to pass the carrier and one sideband, receiving means tuned to a frequency intermediate the carrier frequency and the side band passed by said filter, a demodulating circuit including a source of carrier frequency oscillations coupled to said receiving means, said source of oscillations being of such a frequency that side band energy in the output of said demodulator is separated from the carrier by a considerable frequency range and may be readily separated from the energy resultant from said demodulation, a filter circuit connected with said demodulator and signal translating means connected with said filter.

4. The method of receiving signal energy comprising a carrier and both side bands which during transmission are spaced from the carrier by a substantial frequency band which includes the steps of, combining said carrier and side bands with high frequency oscillations to produce resultant energy comprising two bands of signal carrying frequencies each materially spaced from a new carrier wave, separating said bands of signal carrying frequencies from each other and from said new carrier wave, reducing the frequency of said bands to derive the signal, separating said new carrier wave from said resultant energy, filtering said separated carrier wave to remove all signal components therefrom, and utilizing said filtered carrier wave to control the frequency of the oscillations combined with said received carrier to maintain the resultant energy obtained thereby within predetermined limits.

5. A receiver for receiving signal energy comprising a carrier and two side bands which during transmission have been separated from said carrier by substantial frequency bands comprising signal absorbing means, heterodyne demodulating means connected therewith, said demodulating means including a high frequency oscillator, an intermediate frequency amplifier connected to said demodulator, a pair of band-pass filters connected with said intermediate frequency amplifier, each band-pass filter being adapted to pass one side band only of the demodulated energy, signal detecting means connected with each of said band-pass filters, a single indicating means connected with said detecting means, and a frequency control device including a highly selective filter interposed between said source of high frequency oscillations and the output of said intermediate frequency amplifier.

6. The method of signaling which includes the steps of, distorting modulating potentials to relatively increase the amplitude of the higher modulation frequencies, impressing said distorted modulating potentials on wave energy of an intermediate frequency, impressing a sideband of the resultant energy on other wave energy of intermediate frequency to produce a carrier and sidebands spaced from said carrier by substantial frequency bands, the higher frequency of each of said sidebands being substantially twice as high as the lower frequency of the same sideband, selecting one of said sidebands, and modulating the frequency of wave energy of high frequency in accordance with the energy of said selected sideband to produce resultant frequency modulated energy, the effective percentage of modulation of which is substantially the same over the entire sideband frequency range.

7. The method of signaling which includes the steps of, impressing modulating potentials on wave energy of an intermediate frequency to produce a carrier and sidebands spaced from said carrier by frequency bands of a width substantially equal to the width of the sidebands, the higher sideband frequency being substantially twice as high as the lower sideband frequency, selecting one of said sideband frequencies, and modulating the frequency of wave energy of high frequency in accordance with the energy of said selected sideband to produce resultant frequency modulated energy, the effective percentage of modulation of which is substantially the same over the entire modulation frequency range.

8. The method of receiving oscillatory energy comprising a carrier and sidebands the length of which are modulated in accordance with signaling potentials, which sidebands are spaced from the carrier by a frequency band at least as wide as the frequency band of the signal modulations which includes the steps of, impressing said carrier and sidebands on high frequency oscillations to produce resultant signal carrying energy of low frequency, impressing said resultant signal energy of low frequency on oscillatory energy of intermediate frequency to render the signal, distorting the amplitude of the rendered signal proportionally to its frequency and producing indications of the resultant energy.

HAROLD H. BEVERAGE.