

July 8, 1941.

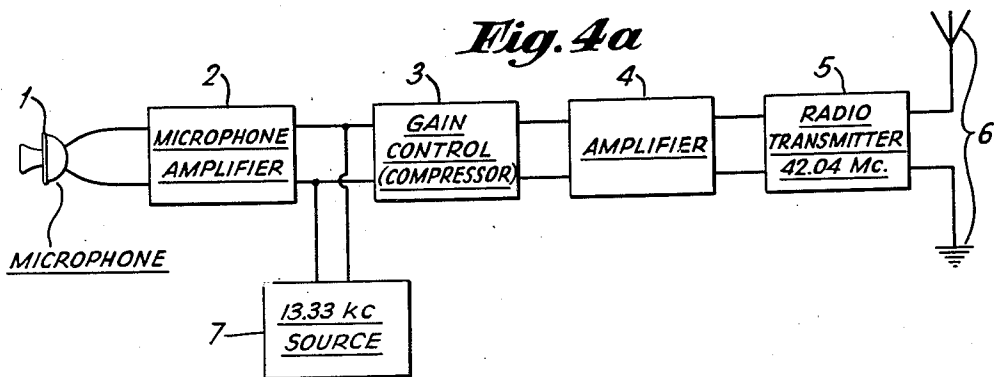
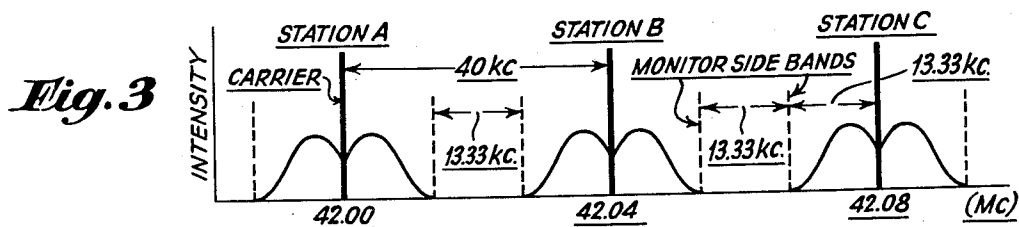
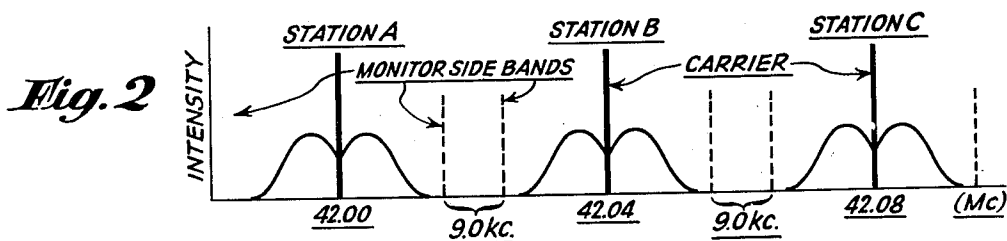
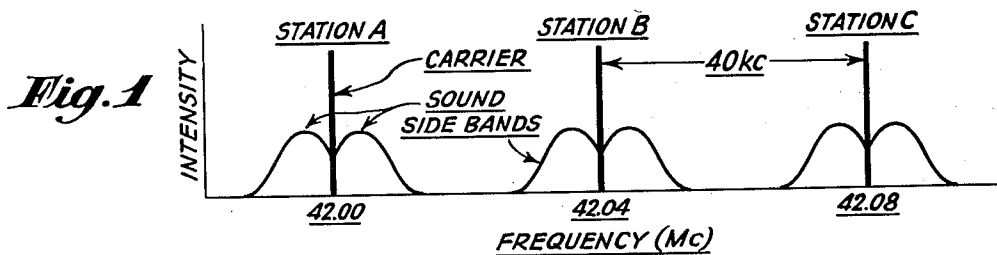
E. W. HEROLD

2,248,757

COMPRESSION-EXPANSION SYSTEM

Filed June 7, 1939

2 Sheets-Sheet 1



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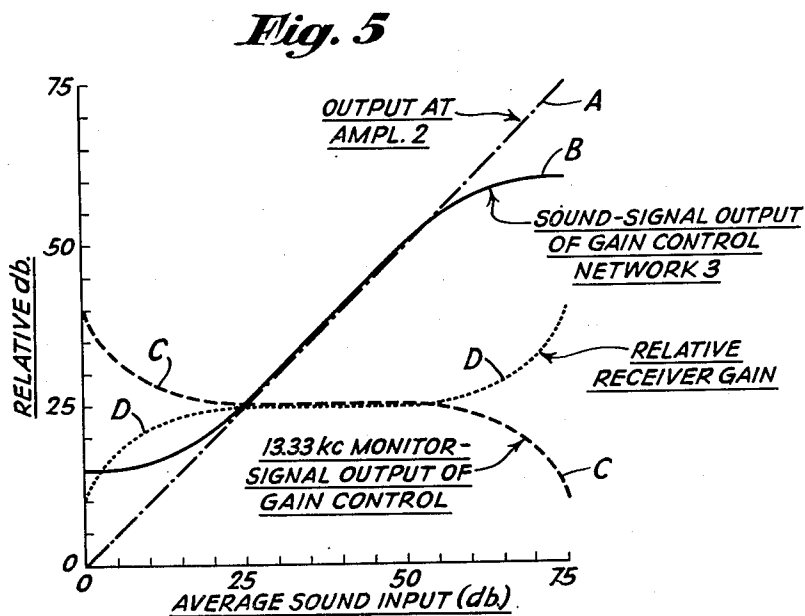
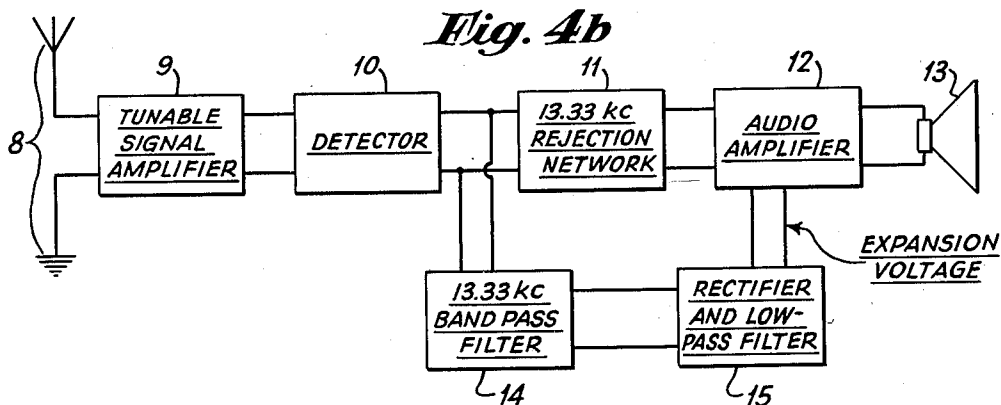
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2 Sheets-Sheet 2



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COMPRESSION-EXPANSION SYSTEM

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Application June 7, 1939, Serial No. 277,807

5 Claims. (Cl. 250-9)

My present invention relates to compression-expansion systems, and more particularly to such systems utilizing a monitor-tone frequency.

In systems for the electrical transmission of speech or music, it is well known that the volume range of the transmitted electrical energy is usually less than that of the original sound. Such a reduction in volume range must be made before transmission in order that the lowest amplitude sounds remain above the residual noise level of the system, while the highest amplitude sounds remain below the overload point. Compression of the volume range is a form of distortion in that the reproduced sound is no longer an exact replica of the original, and it is desirable to hold this form of distortion to a minimum. It is impracticable to provide a transmission medium in which the volume range is as much as is required by all types of sound and music so that it becomes necessary, if faithful reproduction is desired, to restore the volume range to its original value before reproduction. There are a number of general methods by which this can be done; they are familiar in the art. An ideal method requires the transmission of additional intelligence to that contained in the transmitted sound; this additional intelligence is preferably transmitted on a separate channel, or there is employed a separate portion of the same channel as that used to transmit the sound energy. The nature of the added intelligence, obviously, must be such as to indicate at the receiving end (i. e., reproducing end) the relative level of the original sound, or rather, the changes which had to be made in the amplification at the transmitting end in order to permit the satisfactory transmission of the electrical impulses corresponding to the sound. At the reproducing end of the system, a means responsive to the additional intelligence may then be provided which will make reciprocal changes in the amplification. That is to say, volume range expansion is used at the receiver. In this way, the overall amplification from the original sound source to the reproducer may be held a constant at all times and the reproduction is free of volume-range distortion. Such a compression-expansion system has been referred to as a "compressor" system.

The intelligence which must be added to the transmission in order to allow restoration of the full volume range is conveniently transmitted by means of a separate signal which will hereinafter be known as the "monitor" signal. If a separate transmission channel is used for the moni-

tor signal, the latter may consist of a direct current of variable magnitude, or of one or more alternating currents which may be varied in amplitude, frequency or phase in order to transmit the intelligence. It is usually both inconvenient and uneconomical to provide a separate transmission channel for a monitor signal, and a number of methods have been proposed for transmitting the monitor signal over the same channel as the sound signal. The simplest of these consists of the transmission of the monitor signal as a separate frequency which lies outside the frequency range of audible sound, and which may be separated from the sound signal at the receiving end by frequency selection.

The most useful audible sound frequencies may be said to lie between 60 and 5000 cycles although an improvement in reproduction is usually apparent when an octave is added at each end, i. e., when the reproduction is from 30 to 10,000 cycles. A monitor signal may be chosen, therefore, either between zero and 30 cycles, or above 10,000 cycles. It is possible, of course, to use a monitor frequency at some point within the sound spectrum by chopping out a "hole" in the spectrum so that no interference will result. If the sub-audible range is chosen for the monitor signal and the amplitude of the sub-audible frequency is changed to transmit the additional intelligence, it is clear that such changes in amplitude must be done at a slow rate in order to prevent the introduction of higher-frequency components which would interfere with the reproduced sound. No such limitation exists when a high frequency is chosen for the monitor. An additional advantage for a high frequency monitor signal is the comparative simplicity with which sharp frequency selective circuits may be used to separate the monitor signal from the sound signal, and the higher speed with which control circuits may be operated.

The object of this invention is the improvement of the reproduced volume range of carrier-wave radio, or wire, communication systems by means of a monitor signal whose frequency is discretely chosen with relation to the carrier frequency so as to result in a minimum of interference with, or by, signals of adjacent channels.

In the use of a number of adjacent channels for simultaneous transmission of an equal number of different sound signals, it will readily be appreciated that the choice of frequency of a monitor signal is of great importance. If it is chosen too high it will be difficult to separate this signal from the corresponding monitor sig-

nal of the adjacent channels, whereas if it is chosen too low it will interfere with the sound transmission in its own channel. In addition, cross-modulation effects may easily arise as well as difference frequencies between the monitor tones of adjacent channels. As an illustration, consider a radio broadcasting band having a number of adjacent stations with a carrier separation of 40 kc. Such a band is at present contemplated between 41 and 44 mc., and is intended for local high-fidelity broadcasting. If a monitor tone is chosen at 15 kc., the monitor tone of the adjacent channel will be 10 kc. away, so that a 10 kc. difference tone will be heard unless means are provided to assure high adjacent-channel selectivity. If a monitor tone is chosen at 10 kc., the audio spectrum must either be limited below this figure, or a sharp selective trap must be used to cut a "hole" in the audio spectrum at this point.

According to my invention the monitor tone for all signals is chosen at a frequency exactly one-third of the frequency difference between adjacent channels. With this choice the difference frequency between the monitor tone of an interfering adjacent-channel signal and the monitor tone of the desired signal is the same as the monitor tone itself. There will, therefore, be no audible interference, because this particular frequency (i. e., that of the monitor tone) will be carefully rejected from the sound spectrum in receiver design.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

In the drawings:

Fig. 1 shows the frequency spectrum of several adjacent broadcasting channels including the carrier and the sound side-bands; this figure does not embody the invention and is used for illustrative purposes only,

Fig. 2 shows the spectrum of the same stations as Fig. 1, but with 15.5 kc. monitor signals added to the station modulations; this figure is also used for illustrative purposes only and does not embody the invention,

Fig. 3 shows the spectrum of the same stations as Figs. 1 and 2, but with monitor tones added whose frequency is one-third of the channel separation in accordance with the invention,

Figs. 4a and 4b show block diagrams of an illustrative radio transmitter and receiver system respectively embodying the invention,

Fig. 5 shows graphically the operation of the invention as embodied in the system of Figs. 4a and 4b.

Referring to Fig. 1, the spectrum of three adjacent broadcasting stations is shown. Each is assumed to have an average sound modulation with accompanying side-bands as shown. The separation between adjacent channels is 40 kc., and the sound modulation extends upward to around 10 kc. or somewhat higher. When a high-frequency monitor signal modulation is added to each of these stations, a frequency spectrum such as that shown in Fig. 2 is obtained. It is to be understood, of course, that the monitor signal amplitude varies in accord-

ance with the "monitoring" of the sound signal which is done at the studio or transmitter. The monitor sidebands are placed at a 15.5 kc separation from the carrier of their respective stations. As a result, it is seen that the difference in frequency between the monitor sidebands of adjacent stations is 9 kc. This would give an audible interference tone in the sound output of a receiver unless extremely sharp selectivity were employed. It is not, however, possible to achieve extremely sharp selectivity without a great increase in cost, particularly since the 15.5 kc. monitor side-band must be accepted while the adjacent channel monitor side-band at 24.5 kc. from the carrier must be rejected.

The difficulties of the system of Fig. 2 are avoided, according to my invention, by the discrete choice of the monitor-signal frequency at one-third of the channel separation. In such a system all the audible interfering difference frequencies are equal to one-third the channel separation. An illustrative spectrum embodying this concept is shown in Fig. 3. In the illustration of Fig. 3 the audible interfering difference frequencies are 13.33 kc., which is one-third of the channel separation of 40 kc. Although other major undesirable difference frequencies may occur at 26.67 kc., they are above audibility and, therefore, are of no consequence.

In a receiver which is designed to operate in accordance with my invention, a sharply rejecting filter which rejects a frequency of one-third the station separation is incorporated in the receiver system. In the reception of the stations of Fig. 3, for example, this filter would reject 13.33 kc., and no interference with the sound program would be caused by the monitor signals. A typical system which illustrates the application of my invention to a 42.04 mc. broadcast transmitter is shown in Fig. 4a. A microphone, or other sound source, 1 is connected, through a preliminary amplifier 2, to the gain control network 3. The gain control network 3 may be manually, or automatically, operated, and is used to compress the volume range of the sound input to a range which can be accommodated by the succeeding amplifier 4 and the radio transmitter 5. A constant-amplitude alternating voltage of 13.33 kc. from source 7 is also impressed on the input to the gain control network. The radio transmitter is connected to an antenna system 6 whereby the signals are radiated to a receiving antenna system 8. In Fig. 4b is shown a conventional tunable signal amplifier 9 followed by detector 10, audio amplifier 12 and loudspeaker 13. A filter 11, which is designed to reject the 13.33 kc. output of the detector, is interposed between the detector and audio amplifier 12, and may reject either by means of a lowpass filter action, a band-rejection action, or both. The detector output circuit is also connected to a 13.33 kc. band-pass filter 14 followed by a rectifier and low-pass filter 15. The output voltage of the latter filter, in turn, is applied to the audio amplifier 12 in such a way as to vary its gain in an inverse proportion to the output amplitude of network 15. That is to say, expansion is secured.

In operation, an average sound input to the microphone which varies from relative figures of 0 to 75 db., for example, gives an electrical output from the preliminary amplifier 2 in accordance with curve A of Fig. 5. As a result

of manual, or automatic, volume compression in the control 3, an increase of gain at low input levels and a decrease of gain at high input levels may give a sound-signal output curve of the type shown at B of Fig. 5. It is evident, however, that the 13.33 kc. monitor signal will vary in amplitude at the output of the gain control 3 according to the difference between curves A and B, since this difference represents the relative attenuation of the gain control network 3. This is shown by curve C of Fig. 5. The curve C of Fig. 5 is obtained, because 7 produces a constant amplitude A. C. of 13.33 kc. at the input to gain control 3. Thus, any change in the setting of gain control 3 results in a variation of the 13.33 kc. output from 3. The setting of gain control 3, however, is varied (either automatically or manually) not because of the 13.33 kc. signal, but because of, and in correspondence with, the variations in sound input signal from amplifier 2. Thus, looking at the curves of Fig. 5, when the average sound input is around 0 db., the gain control was increased 15 db. Since the 13.33 kc. input was constant the output from the gain control of 13.33 kc. was also increased 15 db., i. e., it went from a normal output of 25 db. (flat part) up to 40 db. as shown by curve C. At high sound inputs (75 db.), on the other hand, the gain control was decreased 15 db., so that the 13.33 kc. output from the gain control went down 15 db. (from its center or normal value of 25 db. down to 10 db.) as shown by the righthand end of curve C.

At the receiver, as shown in Fig. 4b, the sound signal and monitor-tone signal are separated by filters 11 and 14, the former to be amplified and reproduced in a loudspeaker, whereas the latter is applied to a rectifier 15. The band filter 14 passes a very narrow band of 13.1 to 13.5 kc. The direct current output of the rectifier 15 is filtered of alternating components by a conventional lowpass filter and applied to a tube, or some other portion, of the audio amplifier 12 in such a way as to vary its gain in an inverse manner to the monitor-signal amplitude. For example, using the curves of Fig. 5, the audio amplifier gain would vary so that the sum of curve B and the receiver gain curve would give curve A, the original sound. The receiver gain control curve would then be shaped as curve D of Fig. 5, and the reproduced sound would be heard with the original volume range. The point is that when the original sound volume is very loud, the gain control 3 of Fig. 4 is turned down. The 13.33 kc. monitor, however, is still the same at the input to the gain control, and is, therefore, less in amplitude at the output of gain control 3 and less in amplitude at the output of 15 at the receiver. Thus any time the output of 15 decreases, it shows that the gain at the transmitter was reduced. Since we want to compensate for this at the receiver, the receiver gain must be increased to re-expand the sound. This increase in receiver gain is done by utilizing the output of 15 in such a way that a decrease in voltage out of 15 results in an increase in gain amplifier 12. In this way, the action is the reverse of the type of expander in which the sound volume is used to provide expansion and this is because the monitor signal provides the information in a reverse sense to the information in the sound.

The relative receiver gain is shown as 25 db. for the middle range of sound volumes (flat part of curve D in Fig. 5). Above 60 db. sound input,

the transmitter gain was reduced so that the monitor signal (curve C) was reduced. The amount of this reduction was 15 db. at the righthand end of the curves, as shown by the fact that curve B is 15 db. below curve A at this point. Similarly the monitor-tone (curve C) also decreased 15 db. from its means value of 25 db. (flat part of curve) down to 10 db. The receiver gain (curve D) is then increased 15 db. from its mean value of 25 db. (flat part of curve D) up to 40 db. The received sound follows curve B, but if the righthand end of B is raised by 15 db. it comes back to the desired curve A. The increase in receiver gain from 25 to 40 db. does this so that the reproduced sound follows curve A.

It is, of course, to be understood that the embodiment of my invention heretofore described represents only one specific illustrative arrangement. For example, the gain control of the receiver of Fig. 4b may be effected in the radio-frequency stages instead of the audio amplifier as shown. Again, filter 11 may be inserted between the audio amplifier and the loudspeaker, instead of between the detector and the audio amplifier. It is to be clearly understood that the gain control networks employed at 3 and 15 are well known to those skilled in the art. Any well known compression and expansion circuits can be utilized at networks 3 and 15 respectively.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In a multi-channel carrier communication system for the transmission of sound, means for radiating modulated carrier energy including monitor signals of a frequency one-third of the frequency separation of adjacent carrier channels, said monitor signals having amplitude variations in substantial correspondence with the variations of amplification between the sound source and the transmission medium, and means for utilizing the aforesaid monitor signals at a receiver to effect reciprocal changes of amplification so as to result in an overall amplification which is substantially constant.

2. In a communication system, a number of adjacent carrier wave transmitters each modulated with sound frequencies, a number of receivers capable of selecting, receiving and reproducing the transmitted intelligence of any one of said transmitters, means for the simultaneous modulation of said transmitters by monitor signals, said monitor signals giving rise to sideband frequencies adjacent their corresponding carrier waves, means for controlling the amplification between the sound sources and their respective carrier-wave transmitters, said last means maintaining the amplitude variation of said monitor signals in substantial accord with changes of amplification between the sound sources and their respective carrier-wave transmitters, and the frequency of aforesaid monitor signals being such that the frequency difference between the sideband of a given monitor signal and its corresponding carrier is substantially equal to the frequency difference between the sideband of said given monitor signal and the

sideband of the monitor signal corresponding to an adjacent carrier wave.

3. In a communication system, a number of adjacent carrier wave transmitters each modulated with sound frequencies, a number of receivers capable of selecting, receiving and reproducing the transmitted intelligence of any one of said transmitters, means for the simultaneous modulation of said transmitters by monitor signals, said monitor signals giving rise to sideband frequencies adjacent their corresponding carrier waves, means for controlling the amplification between the sound sources and their respective carrier-wave transmitters, said last means maintaining the amplitude variation of said monitor signals in substantial accord with changes of amplification between the sound sources and their respective carrier-wave transmitters, and the frequency of aforesaid monitor signals being such that the frequency difference between the side-band of a given monitor signal and its corresponding carrier is substantially equal to the frequency difference between the side-band of said given monitor signal and the sideband of the monitor signal corresponding to an adjacent carrier wave, and means responsive to amplitude variations of said given monitor signal for effecting amplification changes in the aforesaid receivers so that the overall amplification from sound source to reproducer is held substantially constant.

4. In a communication system consisting of a carrier wave transmitter including at least a

sound source, a gain control, and a sound frequency amplifier; and a carrier wave receiver including a carrier wave amplifier and selector, a detector, a filter, a second sound frequency amplifier and a sound reproducer all arranged in the direction of transmission in the order named; means for adding an auxiliary monitor signal to the system between the sound source and the gain control, the frequency of said monitor signal being equal to one-third the frequency difference between the carrier wave of said transmitter and the carrier wave of a second transmitter operating at an adjacent channel frequency, and means for utilizing variations in amplitude of said monitor signal at said carrier-wave receiver for the purpose of varying the amplification thereof.

5. In a radio communication system, means for modulating a carrier wave with signals which include a monitor-signal, compressing the volume range of said signals before modulating said carrier wave, transmitting the modulated waves, receiving the waves, detecting the modulation thereof, separating the monitor-signal modulation frequency energy, expanding the volume range of the remaining modulation frequencies with the separated monitor-signal, and spacing the frequency of said carrier wave from those of adjacent carrier waves by a frequency interval which is substantially equal to three times the value of the monitor-signal frequency.

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