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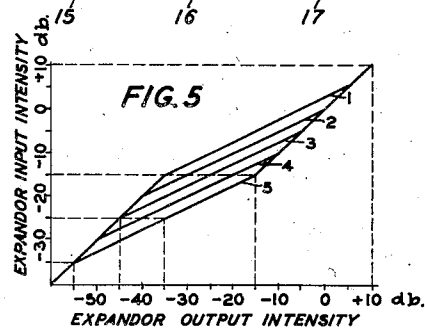
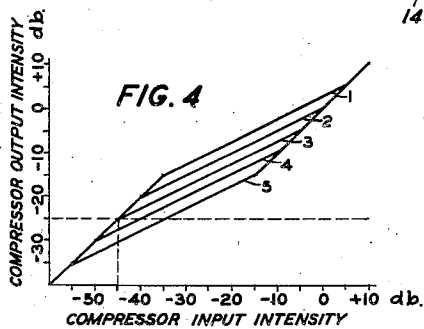
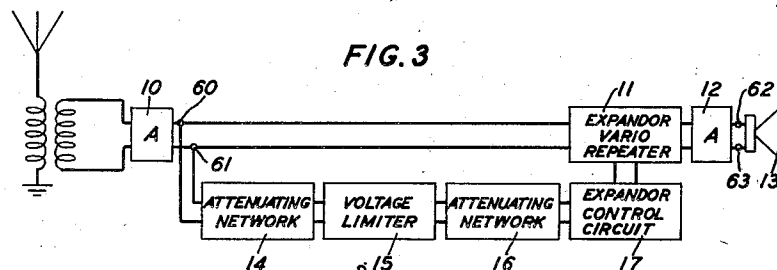
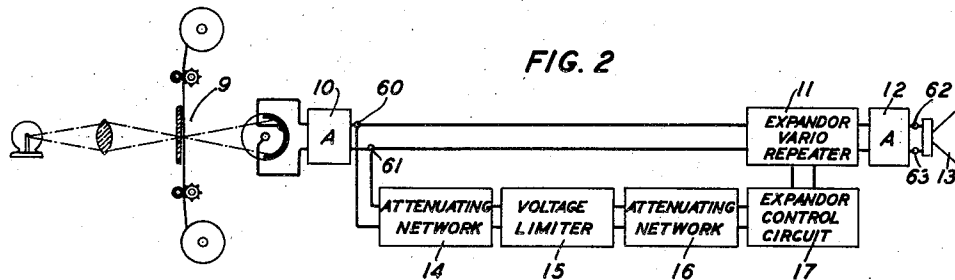
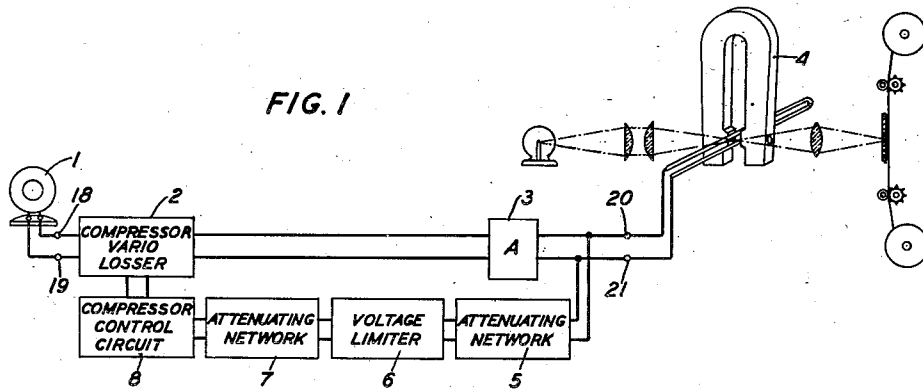
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2,063,334

TRANSMISSION SYSTEM

Filed Jan. 15, 1935

2 Sheets-Sheet 1



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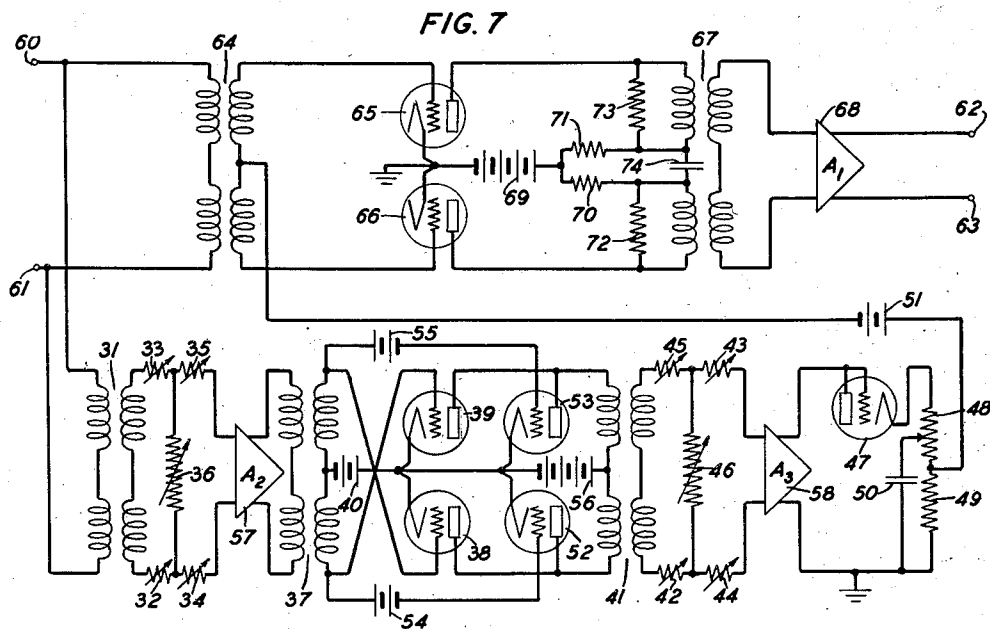
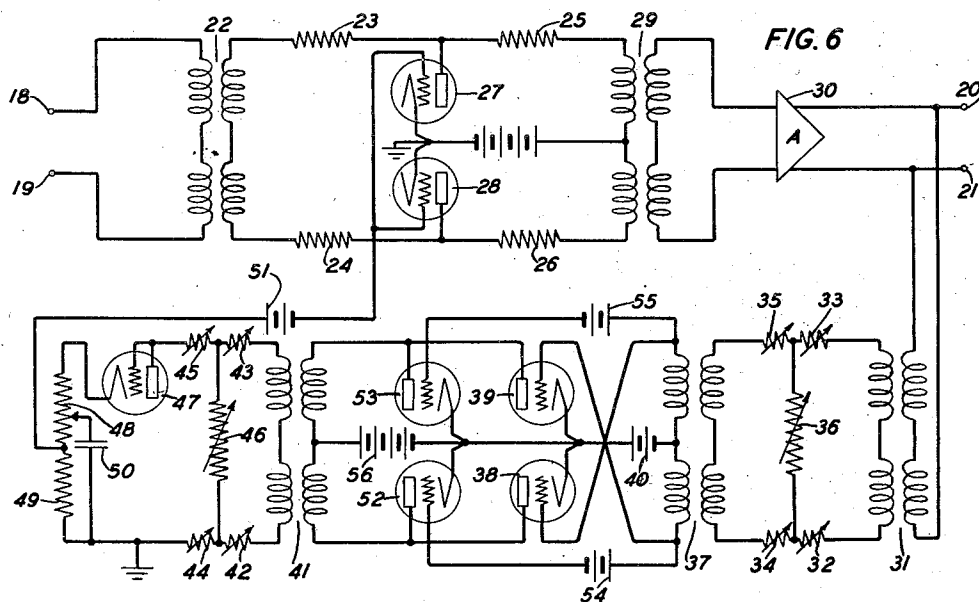
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TRANSMISSION SYSTEM

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2 Sheets-Sheet 2



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TRANSMISSION SYSTEM

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Application January 15, 1935, Serial No. 1,899

6 Claims. (Cl. 178—44)

This invention relates to signal transmission systems and particularly to the control of the range of volumes of the signals transmitted by such systems.

5 The object of the invention is to provide a system in which the signals within a predetermined intensity range are compressed or expanded to a definite degree while signals lying outside this range are neither compressed nor expanded.

10 A feature of the invention is a voltage limiting device connected in the control circuit of a compressor or expander.

Transmission systems in which the whole intensity range of the signals is compressed or expanded are well-known. A complete description of the theory of operation and construction of such a system is given in an article "The compander—An aid against radio static" by R. C. Mathes and S. B. Wright published in Electrical Engineering by the American Institute of Electrical Engineers, vol. 53, No. 6, June 1934, pages 860 to 866. Such systems have proven satisfactory in the transmission of signals in which the intensity range to be compressed is about 40 or 50 decibels.

In the system described in the above-mentioned article, the rate of compression of the signals is comparatively slow. By using a slow rate of compression, the frequency range of the compressed signals is not materially wider than the frequency range of the original signals. In such systems, however, if a transient of large amplitude follows a signal of small amplitude, the control system may not operate rapidly enough to compress the whole transient, thus some peaks of the transient may escape compression and be impressed on the transmitting medium at full amplitude and thus overload the medium.

40 When the initial intensity range of the signals is say 60 or 70 decibels, this effect may be serious. In accordance with the present invention, only a portion of the range in decibels is compressed and expanded. In the recording of music, for example, the intensity range in decibels of the music may be 60 decibels. The intensity range of the recording medium may be only 40 decibels. In such a case, in accordance with the invention, only the lower 40 decibels of the range would be compressed say to 20 decibels and the upper 20 decibels of the range transmitted without compression. The intensity range recorded will then be 40 decibels. As the peaks of the music are not compressed at any time, they cannot overload the recording device. Also, as the range to be compressed is only 40 decibels, the compander may be designed to compress the signal to be recorded and expand the reproduced signal without appreciable distortion.

60 An expander constructed in accordance with

the present invention may also be used alone to reduce the effect of undesired small currents, such as noise currents, cross-talk, etc., in a transmission system. The expander is connected to the transmission system at the receiving end, 5 and the range of expansion is limited so that only currents which are of less amplitude than the least important amplitude of the signal currents are expanded. Now, if an undesired current which is smaller than the least important 10 signal is transmitted through the expander during a silent period, it will suffer a relative loss in the expander as a result of the expanded range so that the undesired current delivered to the receiving device will be smaller than the 15 least signal. The effect of undesired small currents on the receiving device is thus reduced.

In the drawings,

Fig. 1 shows in diagrammatic form the limited range compressor embodied in a system for re- 20 cording signals on a photographic film;

Fig. 2 shows in diagrammatic form the limited range expander embodied in a system for reproducing compressed signals from a photographic film; 25

Fig. 3 shows in diagrammatic form the limited range expander embodied in a radio receiving system;

Fig. 4 is a graph showing the effect of the limited range compressor on the signal intensities; 30

Fig. 5 is a graph showing the effect of the limited range expander on the signal intensities;

Fig. 6 schematically shows a preferred type of limited range compressor; and 35

Fig. 7 schematically shows a preferred type of limited range expander.

In Fig. 1, a source, such as the microphone 1, produces an electric current modulated in accordance with any desired signal, such as a sound wave. The modulated currents pass through a compressor vario-losser 2, which may be a variable loss device. The modulated currents, suitably amplified in an amplifier 3, are supplied to the recording device 4, which is shown as a conventional two string light valve. The invention is in no way limited to the light valve disclosed, any other type of light valve or other signal responsive device may be used.

A portion of the output of the amplifier 3 flows through the attenuating network 5 to the voltage limiter 6. The voltage limiter 6 will pass equally all amplitudes of modulated currents below a predetermined level. When the amplitude of the signal currents exceeds the predetermined level, the transmission of the voltage limiter 6 decreases proportionately to the increase in amplitude of the signal currents so that the output is substantially constant. 55

The output of the voltage limiter 6 is applied 60

through an attenuating network 7 to the control circuit 8. The control circuit 8 normally applies a biasing potential to the vario-losser 2, that makes the loss in the vario-losser 2 small. When modulated currents are applied to the control circuit 8, the modulated currents produce a rectified component which increases the loss in the vario-losser 2 in accordance with an increase in the amplitude of the modulated currents applied to the control circuit 8. When the modulated currents flowing through the network 5 exceed a certain amplitude, the voltage limiter 6 produces a constant output, which is supplied to the control circuit 8 and produces a constant bias on the vario-losser 2. For such amplitudes exceeding the predetermined level, the loss in the vario-losser 2 is constant, and the vario-losser operates as a pure repeater.

For the range of signal amplitudes which are less than the predetermined level, the rectified voltage from the control circuit 8 varies with the amplitude of the signal currents. Thus, the loss in the vario-losser 2 varies as a function of the amplitude of the signal currents, and increases as the amplitude of the signal currents increases. In this range of signal amplitudes the output of the vario-losser 2 is compressed.

The cut-off level of the limiter 6 may be predetermined and set as a certain absolute voltage applied to the terminals of the limiter 6. The relationship between this absolute voltage and the corresponding amplitude of signal voltages in the output of the amplifier 3 will be determined by the setting of the attenuating network 5. Thus, by adjustment of the attenuating network 5, which determines the relationship between the amplitude of signal voltage and the cut-off level of the limiter 6, the upper limit of the range within which compression takes place may be determined.

In Fig. 4, the abscissas represent in decibels a range of signal input intensities from -60 decibels to +10 decibels relative to 10 milliwatts such as may frequently be encountered in recording sound. In curve 1, the network 5 is set so that the cut-off of the limiter 6 is at +5 decibels, and for input signal intensities from +5 decibels to -35 decibels, compression takes place. This range is shown on the ordinate representing output intensities as having been compressed to a range from +5 decibels to -15 decibels. Intensities above and below the range are not compressed.

The curves 2, 3, 4 and 5 similarly depict the compression produced when the network 5 is set so that the cut-off of the limiter 6 is respectively 0 decibels, -5 decibels, -10 decibels and -15 decibels. The curves shown in Fig. 4 are ideally correct, and probably only may be approximately realized in practice. However, apparatus has been built which will very nearly produce the ideal conditions shown.

In Fig. 2, the compressed record produced by the recording system shown in Fig. 1, is scanned by the conventional reproducing equipment 9 to produce modulated signal currents in the output of the amplifier 10. The compressed and uncompressed signal currents are supplied to an expander vario-repeater 11, which may also have the form of a variable loss device. In the expander 11 the compressed portion only of the range is expanded to its normal condition, and the expanded and the uncompressed signal currents supplied to the amplifier 12 and reproducer 13.

A portion of the signal currents pass through the attenuating network 14, voltage limiter 15, and attenuating network 16 to the expander control circuit 17. The rectified signal currents in the control circuit 17 vary the loss in the vario-repeater 11 to expand the compressed portion of the range. The attenuating network 14 may be set so that the limiter 15 operates over a range equivalent to the range of compression in Fig. 1.

In Fig. 5, the ordinates represent the partially compressed input to the expander 17. Curve 1 in Fig. 5 corresponds to curve 1 in Fig. 4. The compressed input range from +5 decibels to -15 decibels is expanded by the vario-repeater 11 to a range from +5 decibels to -35 decibels. Intensities above and below this range are neither compressed nor expanded, for example, the input range from -35 decibels to -55 decibels of the compressor input in Fig. 4, becomes an uncompressed output range from -15 decibels to -35 decibels. This output range in Fig. 4 becomes the input range from -15 decibels to -35 decibels in Fig. 5 and becomes an output range of -35 decibels to -55 decibels. In each case this unaffected portion of the range extends over 20 decibels and is uncompressed and unexpanded.

The curves 2, 3, 4 and 5 in Fig. 5 correspond to curves 2, 3, 4 and 5 of Fig. 4 and represent respectively the conditions when the cut-off of the limiter 15 in Fig. 2 is set at 0 decibels, -5 decibels, -10 decibels and -15 decibels.

In known systems of recording, the material of the record produces undesired noises during the reproduction of the record. The smallest reproduced sound should be appreciably larger than the reproduced noise, thus, the smallest signal as recorded should be larger than the noise. Consider the case of a recording material in which the maximum reproduced noise is say -35 decibels. If the signal is at -45 decibels when recorded, upon reproduction, the signal will be masked by the noise. By contrast, consider such a signal at -45 decibels to be applied to the input of the limited range compressor as set to operate on curve 3 of Fig. 4. The signal at the output of the compressor will be at -25 decibels and this signal is impressed on the recording material. In this case, the signal is at -25 decibels and the noise, as before, is at -35 decibels. The reproduced signal and noise are applied to the limited range expander set to operate on curve 3 of Fig. 5. After expansion, the signal will be restored to its proper value of -45 decibels as reproduced, while the noise as reproduced will be at -55 decibels. The smallest signal as reproduced is now appreciably larger than the reproduced noise. By the use of the present invention the relative magnitude of the noise compared to a small signal has been reduced 20 decibels, that is, an improvement of 20 decibels in the signal to noise ratio has been attained.

In Fig. 3, a similar effect is employed to reduce the undesired noise present in a signal receiving channel such as a radio receiving set. The signals are received and detected in a known manner and applied to a limited range expander similar to the expander in Fig. 2. Similarly numbered elements in Figs. 2 and 4 have similar functions and the expander in Fig. 3 will operate in general similarly to the expander in Fig. 2, as described hereinbefore. The voltage limiter 15 and network 14 in Fig. 3 are adjusted so that only the range of intensities smaller than the

smallest desired signal is expanded. The useful signal range is thus not expanded and the signals are not distorted. Assume that the desired signals have a range from +10 decibels to -15 decibels while the noise in the communication channel has a range from -25 decibels to -35 decibels. Let the signals and noise be applied to the input of an expander set to operate on curve 5 of Fig. 5. The range of the signals in the output of the expander will be unchanged and will be from +10 decibels to -15 decibels. The range of the noise in the output of the expander has been expanded, and the magnitude decreased so that the noise is now from -35 decibels to -55 decibels. The total energy of the noise will be reduced and will not produce as much interference in the intervals between the signals.

In Fig. 6, terminals 18, 19, 20, 21 correspond respectively to terminals 18, 19, 20, 21 shown in Fig. 1. The signal currents are applied through transformer 22 to a balanced attenuating network, formed of the series resistors 23, 24, 25, 26. The anode-cathode resistances of the thermionic devices 27 and 28 form the shunt resistances of the network. A change in the anode-cathode resistances of the devices 27 and 28 will change the loss incurred by the signals in passing through the network. The reduced signals are transmitted through the transformer 29 and amplifier 30 to the terminals 20 and 21.

A part of the reduced signals, suitably amplified if desired, are transmitted through transformer 31 and the variable attenuating network formed by series resistors 32, 33, 34, 35 and shunt resistor 36 to transformer 37. The voltage applied to the transformer 37 will be reduced with respect to the voltage delivered by the transformer 31 in a ratio which depends upon the values of the resistances in the attenuating network.

The output of transformer 37 is applied to the input circuit of the amplifiers 38 and 39 connected in push-pull relationship. The control electrodes of the amplifiers 38 and 39 are biased to normal potential by a source of voltage such as battery 40. The output circuits of the amplifiers 38 and 39 are connected in push-pull relationship through the transformer 41. A battery 56 supplies power to the anode-cathode circuits.

The output of transformer 41 is applied through an attenuating network formed of the series resistors 42, 43, 44, 45 and the shunt resistor 46 to the rectifier 47 in serial relationship with the resistors 48, 49, variably shunted by the capacitor 50. The signal currents rectified by the rectifier 47 will produce a drop of potential across the resistors 48 and 49. The rapidity with which this potential develops will depend largely on the setting of the wiper on resistor 48 and the capacity of the capacitor 50, and the rapidity with which this potential decreases will depend largely upon the capacity of the capacitor 50.

A source of potential 51 produces a negative bias upon the control electrodes of the devices 27 and 28. When no signal currents are flowing, this bias potential is large enough that the anode-cathode resistances of the devices 27 and 28 is large, and the loss in the compressor is small. When rectified currents flow in resistors 48 and 49, the potential developed across the resistor 49 opposes the potential of the battery 51, reducing the negative bias on the control electrodes of the devices 27, 28. The anode-cathode resistances of devices 27, 28 will thus decrease, increasing the loss in the compressor as the intensity of the

signal currents increases. The intensity range of the signals is thus reduced, that is, the output of the compressor is compressed into a smaller intensity range.

The potential of the battery 51 may be larger than the bias voltage required to reduce the anode-cathode current of the devices 27, 28 substantially the zero. In such case, a small potential developed across the resistor 49 will not cause any perceptible change in the anode-cathode resistance of the devices 27, 28. Not until the potential developed across resistor 49 is large enough to reduce the resultant bias potential applied to the control electrodes of the devices 27, 28 to less than the cut-off potential will the resistance of the devices 27, 28 change enough to materially affect the signals. Thus, with such an adjustment, signal currents of small intensity will not be compressed, but will simply be repeated without change in relative intensities.

The control electrodes of the thermionic devices 52, 53 are connected in reverse phase to the transformer 37, while the anode-cathode circuits are connected in parallel relation to the anode-cathode circuits of the devices 38, 39. The control electrodes of the devices 52, 53 are biased respectively by the batteries 54, 55 above the cut-off potential, so that normally substantially no current flows in the anode-cathode circuit of the devices 52, 53.

When signal voltages of large intensity are applied through the transformer 37 to the control electrodes of the devices 52, 53, the peak values of the voltages will exceed the biasing potential applied by the batteries 54, 55. Current will then flow in the anode-cathode circuit of the devices 52, 53. However, due to the reversed phase connection of the control electrodes of the devices 52, 53, the output currents of the devices 52, 53 flowing in the transformer 41 are in the reverse direction to the output currents from the devices 38, 39 and tend to diminish the output from the transformer 41. Thus, for small signal voltages only the devices 38, 39 are operative and the output of transformer 41 increases with an increase in the intensity of the signal voltages. For signal voltages large enough to overcome the added potential due to the batteries 54, 55 all the devices 38, 39 and 52, 53 are operative, the output of the devices 52, 53 opposing the output of the devices 38, 39 thus the output of the transformer 41 is constant and will not increase with further increase in the intensity of the signal voltages. The combination of the devices 38, 39, 52, 53 thus acts to limit the maximum voltage which may be applied to the rectifier 47.

As explained above, the voltage applied to the transformer 37 is a fraction of the voltage delivered by the transformer 31, and this fraction is determined by the setting of the network 32, 33, 34, 35, 36. The voltage limiter 38, 39, 52, 53 determines the maximum voltage from transformer 37 transmitted to the rectifier 47, thus determining the upper limit of the range of intensities in which compression of the range occurs. Thus the setting of the network 32, 33, 34, 35, 36 determines the portion of the total range of signal intensities within which compression takes place.

Due to the losses incurred in the control networks and the type of rectifier 47 employed, it may be necessary to insert suitable amplifiers in the control channel to the rectifier 47. Such amplifiers are shown for example as 57, 58 in Fig. 7.

In Fig. 7, the control circuit is very similar to the control circuit in Fig. 6. Elements having similar functions in Figs. 6 and 7 have been similarly numbered and no detailed explanation of the control circuit in Fig. 7 appears to be required.

Terminals 60, 61, 62, 63 in Fig. 7 correspond respectively to the similarly numbered terminals in Figs. 2 and 3.

In Fig. 7, the signal voltages are applied through transformer 64 to the input circuits of a pair of thermionic amplifiers 65, 66 connected in push-pull relationship. The outputs of the amplifiers 65, 66 are connected in push-pull relationship through transformer 67 and amplifier 68 to the terminals 62, 63. A battery 69 supplies power to the anode-cathode circuits of the amplifiers 65, 66. The resistors 70, 71, 72, 73 and capacitor 73 aid in reducing any distortion which might be produced by the variation in the relation between the impedance of the transformer 67 and the varying impedance of the amplifiers 65, 66.

The battery 51 applies a negative bias to the control electrodes of the amplifiers 65, 66. If this bias voltage be made comparatively large, the gain of the amplifiers 65, 66 will be small and the intensities of the signals in the output will not be materially larger than the intensities of the signals before amplification. The signal voltages applied to the transformer 31 produce a rectified voltage across the resistor 49 that tends to reduce the effective biasing potential on the control electrodes of the amplifiers 65, 66. So long as the effective biasing potential is larger than the potential required to cut off the amplifiers 65, 66, the gain is small and virtually constant and the amplifiers 65, 66 act as repeaters. When the effective biasing potential is less than the cut-off potential, the gain of the amplifiers 65, 66 increases as a function of the increase in the intensities of the signals. This function of the increase in intensity is made the reciprocal of the function of the increase in intensity in the compressor. Thus, if the biasing voltages of the compressor and expander are made equal, signals below the cut-off are merely repeated, and signals above the cut-off are expanded by an amount equal to the previous compression. Expansion will occur until the signal intensities from transformer 31 override the bias on the devices 52, 53. The devices 52, 53 then limit the voltage developed in resistor 49, and the amplifiers 65, 66 act as repeaters having a fixed gain. If the bias on the devices 52, 53 in Figs. 6 and 7 is the same, and the signal intensities supplied by transformer 37 in Figs. 6 and 7 are the same, the upper limit of the region of expansion will agree with the upper limit of the region of compression, and the signal intensities in the output of the expander will agree with the signal intensities in the input of the compressor, that is, no over-all distortion of the signals will be produced.

When the expander is used as shown in Fig. 3, alone, to reduce noise in a communication channel, the voltage developed by transformers 31, 37 and amplifier 57, Fig. 7, is made large relative to the biasing potential of the batteries 54, 55. Thus, only the range of intensities which are less than the smallest useful signal is expanded. The intensities of the signals are thus not distorted but the noise during periods between signals is reduced.

What is claimed is:

1. The method of transmitting by a medium a

range of intensities exceeding the range of the medium which consists in producing electric currents varying with a signal, continuously and proportionally compressing a part only of the range of intensities of said currents until the range of the compressed intensities and the range of the uncompressed intensities is within the range of the medium, transmitting said compressed and uncompressed currents by said medium, continuously and proportionally expanding the compressed intensity range of said currents to the original range and supplying said expanded and said uncompressed currents to a receiver.

2. The method of receiving signal currents and undesired currents of small magnitude which comprises expanding the range of intensities of all currents of less intensity than the intensity of the least signal, transmitting said signal currents without expansion and supplying the expanded undesired currents and the unchanged signal currents to a receiver.

3. The method of transmitting signal currents by a medium having a limited range of intensity which comprises compressing a part only of the range of intensities of said signal currents until the range of the compressed currents and the range of the uncompressed currents is within the range of the medium, recording said compressed and said uncompressed currents on the medium, reproducing said currents from the medium, expanding the range of the compressed currents to their normal range, and supplying said expanded and said uncompressed currents to a receiver.

4. In a signaling system, a medium capable of handling a narrow range of intensities, means for generating signaling energy having a range of intensities greater than the range of the medium, means for continuously and proportionally decreasing the intensity range of the generated energy within a part only of the range of intensities until the total range of the energy is less than the range of the medium, means for transmitting the total range of said energy and means for continuously and proportionally producing a compensating increase in the intensity range of the received energy.

5. In a signaling system, a medium capable of handling a narrow range of intensities, means for generating signaling energy having a range of intensities greater than the range of the medium, a transmitting channel including a loss device for variably decreasing the intensities of signal energy transmitted through said channel, control means comprising a rectifier energized by signaling energy to vary the loss in said loss device, and means comprising a non-linear conductor for modifying the signaling energy supplied to said control means.

6. In a signaling system, a source of signaling energy, a channel for transmitting said energy together with undesired energy of small amplitude, means comprising a loss device connected in said channel variably energized by said transmitted energy, control means comprising a rectifier energized by said transmitted energy to vary the loss in said loss device whereby the intensity range of the energy of less amplitude than the signaling energy is expanded and means comprising a nonlinear conductor for modifying the energy supplied to said control means.

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