July 28, 1931. R. C. MATHES 1,816,599

SIGNAL TRANSMISSION SYSTEM

Filed March 29, 1929 2 Sheets-Sheet 1

FIG. 1

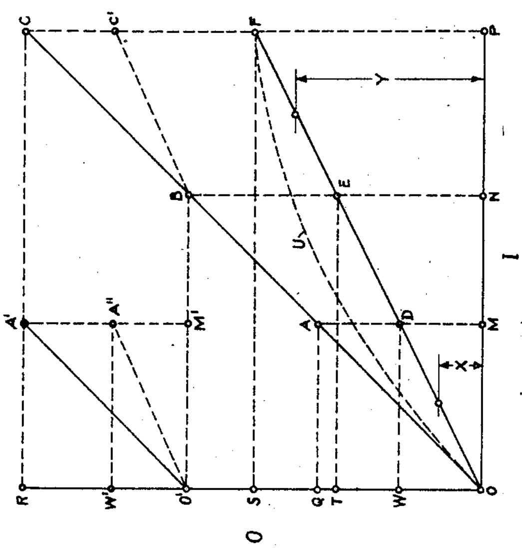


FIG. 2

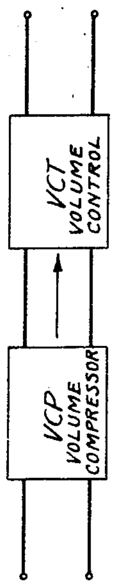


FIG. 3

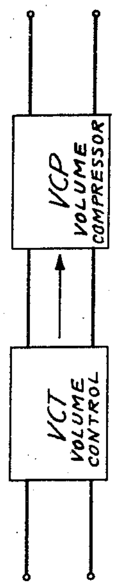


FIG. 4

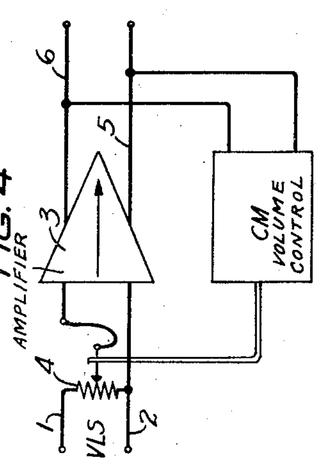
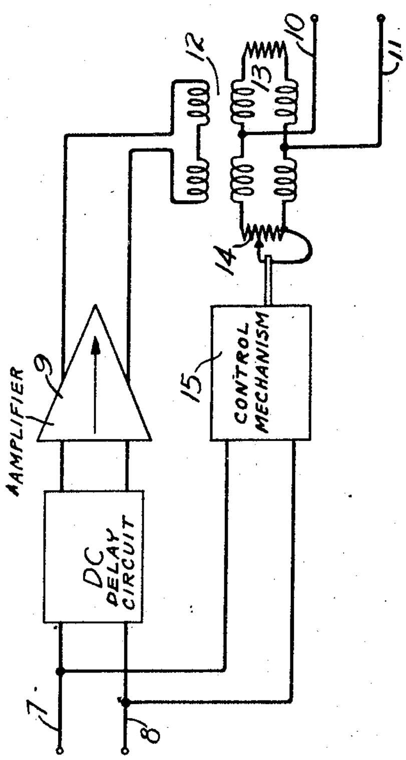


FIG. 5



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SIGNAL TRANSMISSION SYSTEM

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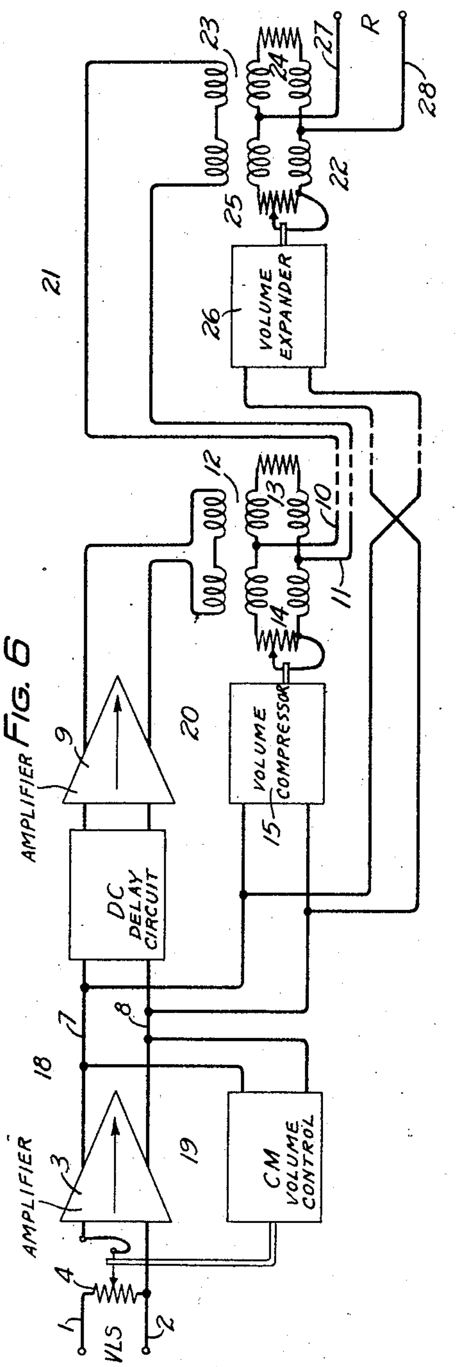

FIG. 6

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UNITED STATES PATENT OFFICE

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SIGNAL TRANSMISSION SYSTEM

Application filed March 29, 1929. Serial No. 350,971.

This invention relates to signal transmission systems and particularly to circuits for controlling the energy levels in transmission systems.

One object of the invention is to provide a signal transmission system with improved means for and method of maintaining a constant maximum peak energy level and compressing the volume range of the signals at the transmitting station.

Another object of the invention is to provide a signal transmission system, having signals of substantially the same volume range and different average levels supplied to the transmitting station, with means that shall maintain a constant maximum peak energy level and compress the volume range of the signals at the transmitting station.

A further object of the invention is to provide a signal transmission system of the above indicated character that shall maintain a constant maximum peak energy level and compress the volume range of the signals at the transmitting station and that shall expand the volume range of the signals at the receiving station.

In a signal transmission system, signals which have very different average volume levels are in many cases received at the transmitting station. The significant momentary volume range in most cases is substantially the same but may vary. The difference in the average volume level of the received signals may be caused by toll lines in telephone systems of different electrical lengths and by speakers who talk loudly and softly. The limitations in the transmission of signals caused by apparatus or line conditions may render it difficult to transmit to a distant receiving station signals which have very different average volume levels. The difference in average volume levels may be the result of any of the above mentioned causes.

When a telephone system is connected to a radio system such as in the trans-Atlantic radio system it becomes necessary to transmit over the radio system at the highest peak level possible because the noise or static level is particularly high and the received energy is particularly weak. In such systems there is a definite range of power levels between which speech may be transmitted. There is an upper limit to this range caused either by the load-carrying capacity of the transmitter or by some relay device in the circuit. The lower limit to the range is due to the presence of extraneous interference in the system.

Two general solutions have been proposed for the problems encountered in transmission systems of the above indicated character and in other transmission systems having like problems to be solved. One solution of the problem is by means of the so-called volume control circuit and another solution of the problem is by the so-called volume compression circuit. A volume control circuit may be defined as a circuit which is adapted to maintain at a particular point in a system a constant maximum peak level of power regardless of the level at which the speech power may be received at that particular point in the system. A volume compression circuit may be defined as a circuit adapted to reduce the momentary volume range or to reduce the difference between the maximum peak level and the minimum significant peak level of signals.

The difficulties produced by reason of the differences in the average volume levels of signals may be reduced either by a volume control system or a volume compression system. The limitations however in some cases may be such that neither a volume control nor a volume compression system will completely solve the problem. In accordance with the present invention it is proposed to move the average volume levels of the signals produced by a weak talker and a loud talker to the same level. When the signals have been moved to the same volume level, the volume range is compressed according to the limitations of the system. If desired the volume ranges of the different signals may first be compressed and then the signals may be moved to have a constant maximum peak level. At the receiving end of the system it may in some cases be necessary to provide a volume expander to reverse the operation of the volume compressor at the transmitting station. This is particularly true in four wire systems in which it is desirable to maintain the same round trip singing equivalent at both high and low levels. In systems in which voice switched terminal circuits are used to get substantially one way operation it may be preferably not to provide an expander at the receiving end of the line.

In the accompanying drawings, Fig. 1 is a diagrammatic view illustrating the operation of volume control and volume compression means.

Figs. 2 and 3 are diagrammatic views indicating the positions of the volume control means and the volume compression means in different systems.

Fig. 4 is a diagrammatic view of a system having volume control means included therein.

Fig. 5 is a diagrammatic view of a system having volume compression means included therein.

Fig. 6 is a diagrammatic view of a system having volume control and volume compression means at the transmitting station and volume expanding means at the receiving station.

Referring to Fig. 4 of the drawings, which discloses a system having volume control means included therein, a variable level source VLS comprising conductors 1 and 2 is connected to an amplifier 3 by means of a potentiometer 4. The output circuit of the amplifier comprising conductors 5 and 6 has the output level thereof maintained constant and at a maximum level. Volume control means CM which is connected to the output conductors 5 and 6 governs the operation of the potentiometer 4 to maintain the output from the amplifier 3 at a constant maximum level. If the level in the output circuit tends to rise, the control means CM operates the potentiometer 4 to govern the amplifier 3 and lower the level in the output circuit. If the level in the output circuit tends to fall below the fixed limit, the control means CM operates the potentiometer 4 to so control the amplifier 3 as to bring the output level up to the fixed maximum level. As an example of a system employing volume control means, attention is called to the patent to C. H. Fetter, 1,565,-555 dated December 15, 1925.

In Fig. 5 of the drawings is disclosed a system employing means for compressing the volume range of the transmitted signals. A variable level source comprising conductors 7 and 8 is connected to an amplifier 9. For the best operation of a volume compression system of this type it is probably desirable to insert a delay circuit DC before the amplifier 9. The amplifier 9 is connected to the line conductors 10 and 11 by means of a hybrid coil 12. The hybrid coil includes a Wheatstone bridge arrangement 13, one arm 14 of which is controlled to vary the range of the transmitted signals. The impedance of the arm 14 is controlled by a control mechanism 15 in accordance with the level of the signals on the supply conductors 7 and 8. A volume compression system of this type is disclosed in the patent to R. C. Mathes, 1,757,729, May 6, 1930, and a detailed description thereof is deemed unnecessary. The variable level which is received by the amplifier 9 from the supply conductors 7 and 8 is compressed so that the volume range of the signals supplied to the conductors 10 and 11 is reduced.

Referring to Fig. 6 of the drawings, a transmission system is indicated which is provided not only with volume control means and volume compression means at a transmitting station, but also with volume expanding means at a receiving station. A transmitting station 18 is provided with volume control circuits 19 of the type indicated in Fig. 4 of the drawings and volume compression circuits 20 of the type indicated in Fig. 5 of the drawings. Similar parts in Fig. 6 to those shown in Figs. 4 and 5 have been indicated by like reference characters. At the transmitting station 18 it will be noted the volume control circuits precede the volume compression circuits 20 which is preferable for reasons to be hereinafter set forth. It is to be understood, however, that if so desired, volume compression means could be provided at a transmitting station before the volume control means.

At the receiving station 21 shown in Fig. 6 of the drawings, volume expanding means 22 similar to the expanding means shown in the Mathes Patent No. 1,757,729 are provided. The line conductors 10 and 11 at the receiving station 21 are connected to a hybrid coil 23 having a Wheatstone bridge circuit 24 formed therein. One arm 25 of the bridge circuit has the impedance thereof controlled by volume expanding means 26. The volume expanding means 26 is controlled from the transmitting station 18 to reverse the function performed by the volume compression means 20 at the transmitting station. The hybrid coil 23 is connected to a receiving circuit comprising conductors 27 and 28. A volume compression system of the type shown in Fig. 6 is completely disclosed in the above mentioned patent to R. C. Mathes, No. 1,757,729. A volume compression system is also disclosed in the patent to H. S. Hamilton, 1,565,441, dated December 15, 1925.

A better understanding of the functional characteristics of the two systems shown in Figs. 4 and 5 of the drawings may be obtained by reference to the diagrammatic view shown in Fig. 1 of the drawings. In the diagram shown in Fig. 1 the abscissa represents the variable level input to the systems shown in Figs. 4 and 5; and the ordinates of the diagram represent the output from the two systems shown in Figs. 4 and 5. The ordinates and abscissæ are in terms of volume range on any suitable arbitrary scale. For example, the arbitrary scale may be in terms of transmission units corresponding to the ratio of the power supply to the power received in a system or the transmission unit equals $10 \log 10\frac{P_1}{P_2}$.

The volume range of the input OP in Fig. 1 depends on a number of factors. The useful modulation range received from different types of toll circuits will ordinarily never be less than about 20 transmission units. The lengths OM and NP shown in the diagram are considered to vary from 30 to 40 transmission units and each represents the modulation range of speech from a toll circuit. The location of each modulation range of power level may be at a high average level or a low average level, depending upon whether the talker is a person who talks loudly or softly and also upon whether he is talking over a short or long subloop. The difference in level due to whether or not the talker speaks loudly or softly may be from 25 to 30 transmission units. The difference in level due to the electrical length of the toll circuit may be about 10 to 15 transmission units.

In many circuits as before mentioned, there is a definite range of power levels between which speech may be transmitted. There is an upper limit to this range caused either by the load-carrying capacity of the transmitter or some relay device in the circuit and a lower limit due to the presence of extraneous interference in the system. In some cases, it may be desirable to pass over circuits on which are very severe restrictions, signals which have overall differences in power level in the order of from 50 to 70 transmission units. In the diagram shown in Fig. 1, the control range OM may indicate the range of a weak talker on a long loop circuit, while the distance NP may indicate the volume range of a loud talker on a short loop. If the input level range of OP were applied to a volume control system, the output level would be indicated by the straight line at 45° marked OC to produce an output OR.

In case volume control means as shown in Fig. 4 of the drawings is used for controlling an input OP as shown in Fig. 1 of the drawings, the volume range OM of the weak talker over a long loop circuit would be raised to the level of the strong talker over a short loop circuit. The line OM may be assumed to be moved towards the right to coincide with the line NP. The weak and loud talkers have the same maximum level which is indicated on the 45° line by the distance BC, which applied to the output circuit has a volume range equal to O′R. Thus when volume control means are employed, as shown in Fig. 4 of the drawings, the volume range of a weak talker and strong talker, which is transmitted to the receiving station, is equal to the transmission units indicated by the distance O′R.

In case the variable input indicated by the line OP is applied to a system including volume compression means, as shown in Fig. 5 of the drawings, the linear system considered with respect to the 45° line OC in Fig. 1 of the drawings will be replaced by some other characteristic, for example, indicated by the dotted line OUF. For practical considerations, it is desirable to make the new characteristic a straight line as, for example, the line ODEF. In considering the application of a volume compression system, the volume range of a weak talker is assumed to be indicated by the line OM as above set forth, the volume range for a loud talker being indicated by the distance NP. The volume range of a weak talker after passing through the volume compression circuits will be reduced to the range OW and the volume range of the loud talker will be reduced to the range TS as indicated on the diagrams shown in Fig. 1. The volume ranges OW and TS in the output are obtained by applying volume ranges OM and NP to the characteristic line ODEF.

Assuming that both the volume control and the volume compression circuits operate in the most ideal fashion, a choice of one system as compared with the other system will depend on whether the overall compression range is greater or less than the useful modulation speech level of a single talker. The volume range to be transmitted when volume compression circuits are employed is indicated by the distance OS in Fig. 1 of the drawings and the volume range to be transmitted when volume control circuits are employed is indicated by the distance O′R. Whether the distance OS is greater or less than the distance O′R will indicate whether or not volume compression circuits or volume control circuits should be employed.

In many cases where the restrictions of the transmission system are very severe, it may be impossible to obtain the most ideal transmission by using either volume control or volume compression means. In such cases in accordance with the invention it is proposed to use both volume control and volume compression means. In Fig. 2 of the drawings the input to the transmission line is first applied to volume compression means VCP and then to volume control means VCT. If so desired, as shown in Fig.

3 of the drawings, the input may be first applied to volume control means VCT and then to volume compression means VCP. In case the volume compression means precedes the volume control means it is apparent that the volume compression means will have to handle the full volume range of the input indicated by the line OP. In actual practice it may be very difficult at times to secure a volume compression system which will handle such an extended range.

Considering the system indicated in Fig. 2 of the drawings and referring to the diagram shown in Fig. 1, the weak talker's volume OM will be compressed to the average volume level indicated by the distance X and the loud talker's volume level will be compressed to the average volume level indicated by the distance Y. The volume control mechanism will then be used to change these average volume levels to the same point, that is, either raise X equal to Y or lower Y equal to X. The final transmission system would have to handle a volume range corresponding to the distance OW in the output. At the receiving station a volume expander might be used which would reverse the process which has been effected by the volume compression means at the transmitting station and which would be capable of expanding the volume range corresponding to OW to the volume range corresponding to OM. It would not be necessary to undo the operation of the volume control means.

In a system having a volume control means preceding the volume compression means as indicated in Fig. 3 of the drawings, the weak and loud talkers would be pulled to the same average level, as for instance by moving the weak speaker indicated by the line OM to the position of the loud speaker indicated by the range NP. Compressing the weak and the loud speakers in accordance with the characterization now only of the portion EF of the line ODEF will produce a volume range for the loud talker and the weak talker in the output equivalent to the volume range TS. At the receiving end a volume expander may be needed as in the case of the system described in connection with Fig. 2 of the drawings. The advantage of the system indicated in Fig. 3 over the system of Fig. 2 is the much simpler arrangement of the volume compression system at the transmitting end of the line to cover the more limited part EF of the total compression characteristic, ODEF.

Modifications of the system and in the arrangement and location of parts may be made within the spirit and scope of the invention and such modifications are intended to be covered by the appended claims.

What is claimed is:

1. In a transmission system, an input circuit supplied with signals having different average volume levels, and means for maintaining a constant maximum peak level for said signals and for reducing the difference between the maximum and the minimum level of said signals transmitted over the system.

2. In a transmission system, an input circuit supplied with signals having substantially the same volume range and different average volume levels, and means for maintaining a constant maximum peak level for said signals and for reducing the volume range of said signals.

3. In a transmission system, an input circuit supplied with signals having substantially the same volume range and different average volume levels, volume control means for maintaining a constant maximum peak level for said received signals, and volume compression means in series relation with said volume control means for reducing the volume range of said signals.

4. In a transmission system, an input circuit supplied with signals having different average volume levels, volume control means for maintaining a constant maximum peak level for the received signals having different average volume levels, and volume compression means in series relation with said volume control means for reducing the difference between the maximum and the minimum level of the signals transmitted over the system.

5. In a transmission system, a transmitting station input circuit supplied with signals having different average volume levels, means at the transmitting station for maintaining a constant maximum peak level for said signals, means for reducing the volume range of said signals at the transmitting station and means at a receiving station for expanding the range of the received signals.

6. In a transmission system, a transmitting input circuit supplied with signals having substantially the same volume range and different average volume levels, means at the transmitting station for maintaining a constant maximum peak level for said signals, means for reducing the volume range of said signals at the transmitting station and means for expanding the range of said signals at the receiving station.

7. In a transmission system having a transmitting station supplied with signals having different average volume levels, the method which consists in moving the levels of the received signals to maintain a maximum peak level of the received signals and in reducing the volume range of the transmitted signals.

8. In a transmission system having a transmitting station supplied with signals having different average volume levels for transmission to a receiving station, the

method which consists in moving the average volume levels of the received signals to maintain a maximum peak level in the received signals, in changing the transmitted signals to a reduced and the same volume range, and in expanding the signals at the receiving station.

9. In a transmission system of limited volume range having a transmitting station supplied with signals having different average volume levels, the method which consists in first controlling and then compressing the volume range.

In witness whereof, I hereunto subscribe my name this 27th day of March, 1929.

ROBERT C. MATHES.