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A. B. CLARK

ARRANGEMENT FOR CONTROLLING VOLUME RANGE

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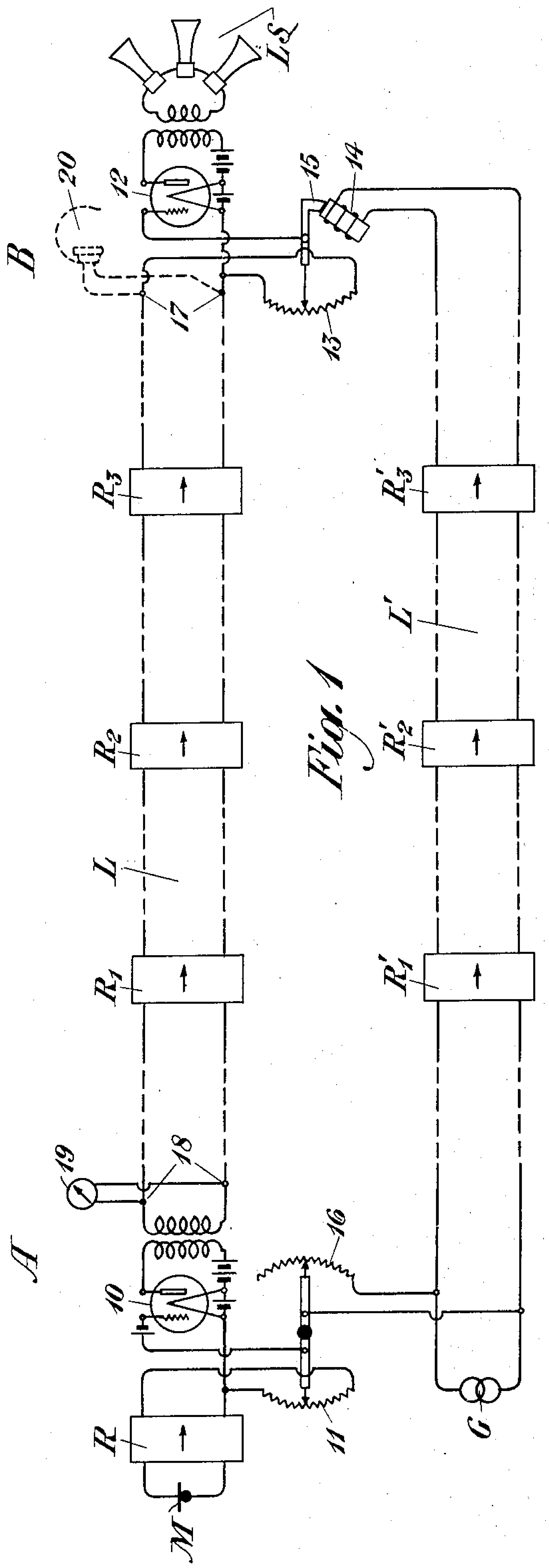

Fig. 1

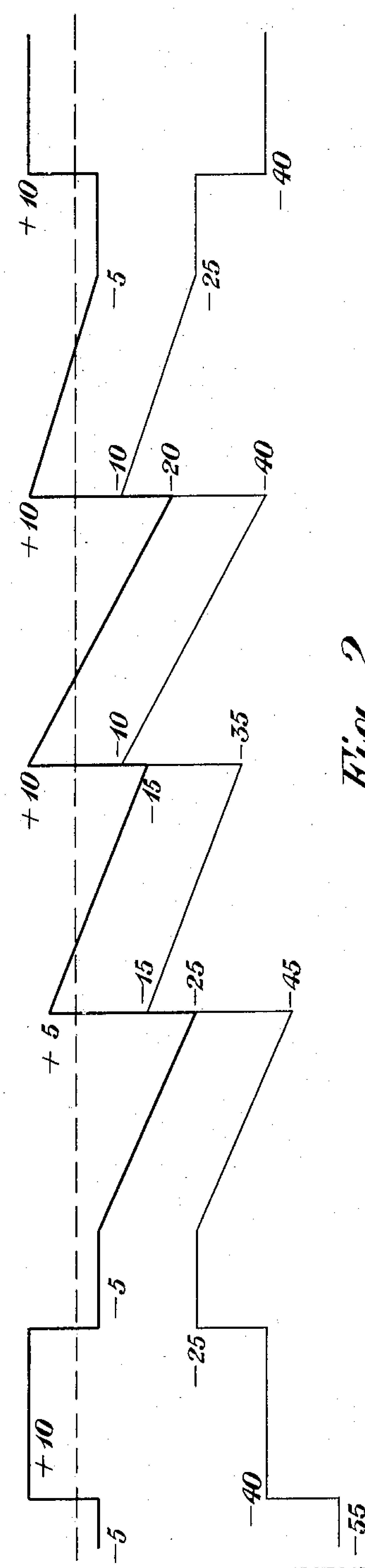

Fig. 2

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UNITED STATES PATENT OFFICE.

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ARRANGEMENT FOR CONTROLLING VOLUME RANGE.

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To all whom it may concern:

Be it known that I, ALVA B. CLARK, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Arrangements for Controlling Volume Range, of which the following is a specification.

This invention relates to transmission circuits, and more particularly to arrangements for enabling a transmission medium inherently capable of transmitting only a narrow range of volume to produce at the receiving station a wider range of variation in volume than the medium is able to transmit.

In the case of a transmission medium, such as an ordinary telephone line, the range of volume variation of the transmitted signal is limited by factors which are not under control. In transmitting high grade performances, particularly musical selections, the range of variation in volume is frequently quite large. In order to transmit such material over a medium of limited volume range, it will be necessary to modify the very loud or very soft passages or both to bring them within the limits imposed by the medium, with a consequent loss in the contrast between the piano and forte parts.

In accordance with the present invention it is proposed to overcome this difficulty by regulating the volume impressed upon the transmission medium at the transmitting station so as to keep it within the limits of the medium, and at the same time producing a change in some transmission element at the receiving station to compensate for the change made at the transmitting station. For example, if the volume is reduced before being impressed upon the transmitting medium, a transmission element at the receiving station will be adjusted so as to correspondingly increase the volume, and vice versa.

This method is useful particularly in connection with public address and radio broadcasting systems where a program delivered at one point must be transmitted to an audience located at a distant point over a transmission medium whose volume range is limited.

The invention may now be more fully understood from the following detailed description thereof, when read in connection with the accompanying drawing, Figure 1 of which shows a circuit arrangement embodying the principles of the invention, and Fig. 2 of which is a transmission level diagram illustrating the operation of the circuit of Fig. 1.

Referring to Fig. 1, L indicates a telephone transmission line extending from station A to station B. The line L is provided with amplifiers or repeaters of a well known type as indicated at R_1, R_2 and R_3. At station A a so-called pickup microphone M is provided for picking up the musical selection or other program to be transmitted to station B. An amplifier or repeater R is associated with the pickup microphone for amplifying the telephone currents resulting from the pickup action of the microphone before impressing them upon the line L. At the receiving station a group of loud speakers LS is provided for delivering the program transmitted over the line to an audience.

In order to keep the volume impressed upon the line L from the repeater R within the volume limits of the transmission circuit, a volume regulating arrangement is provided which comprises an amplifying vacuum tube 10 having an adjustable potentiometer 11 in its input circuit. By suitable adjustment of the potentiometer 11, the potential applied to the grid may be adjusted so that the output from the tube 10 may be made either greater or less than the input. If the volume delivered by the repeater R is greater than the maximum limit of which the line L is capable, the potentiometer 11 will be adjusted so that the vacuum tube 10 will reduce the amplitude before it is impressed on the line. If, on the other hand, the volume delivered by the repeater R is smaller than the minimum volume which the transmission line L will carry without producing undesirable effects at the receiving station, the potentiometer 11 will be adjusted so as to cause the tube 10 to amplify the currents and impress them upon the line L with a volume sufficiently great for proper transmission.

The limiting factors which determine the maximum and minimum volumes which the line will properly transmit are usually the overloading of the vacuum tubes of the repeaters on the one hand, and the amount of noise present in the transmission circuit on the other hand. That is to say, the maximum volume of the circuit is limited by the power carrying capacity of the repeaters and by the fact that the power must not be allowed to become so strong that it will produce serious cross-talk in the other circuits. The minimum value is limited by the amount of noise present in the transmission circuit due to various causes, such as paralleling power lines and paralleling telephone and telegraph circuits. In the case of radio transmission circuits, the range of volume is similarly limited by the power transmitting capacity of the wireless station on the one hand, and the noise due to static and other causes on the other hand.

The regulation of volume above described of course results in the transmission of successive passages of a musical selection, for example, with their volume relation so changed with respect to each other that the beauty of the selection might be largely lost if no arrangements were made for compensating for the change in volume produced. Accordingly, a compensating arrangement is provided at the receiving station B consisting of a vacuum tube 12 having associated therewith a potentiometer 13. By suitably adjusting the potentiometer 13, the vacuum tube 12 may be caused to deliver more or less power than is applied to its input circuit. It will be seen, therefore, that if, when the volume supplied by the repeater R exceeds the maximum to be transmitted over the line L so that the potentiometer 11 is adjusted to reduce the volume, the transmission arriving at the receiving station may be brought back to its proper comparative volume by adjusting the potentiometer 13 to cause the tube 12 to amplify the currents. Likewise, if the potentiometer 11 is adjusted to increase the volume, the potentiometer 13 may be adjusted to decrease the volume.

In order that the adjustment of the volume controlling arrangement at the station B may be controlled by the volume adjustment made at station A, an auxiliary circuit L′ is provided, said auxiliary circuit having repeaters R'_1, R'_2 and R'_3, as in the case of the circuit L. At the transmitting end a generator of some suitable frequency G is provided, and at the receiving end a magnetic arrangement 14 is connected to the circuit L′. The magnetic arrangement is responsive to alternating current and depending upon the amplitude of the alternating current received, will attract its core 15 more or less, thereby causing a corresponding adjustment of the potentiometer 13. At the station A an adjustable shunt resistance 16 is bridged across the circuit to control the volume of the alternating current impressed upon the line L by the generator G, which generator is assumed to have a comparatively high impedance. By arranging the potentiometer 11 and the shunt resistance 16 so that they are controlled together by the same adjusting operation, a change in the potentiometer 11 will produce a corresponding change in the volume of the current impressed upon the line L from the source G. This will result in a corresponding change in the attraction of the core 15 by the solenoid 14, thereby producing a setting of the potentiometer 13 which will just compensate for the change in the setting of the potentiometer 11. Thus, whenever the transmission from the main transmission circuit L is made weaker, the alternating current over the control circuit is made weaker, and vice versa. The alternating current over the control circuit, by controlling the magnetic arrangement 14—15 at the distant end, will automatically adjust the potentiometer 13 accordingly, with the result that whenever the volume at the sending station is increased or reduced a certain amount by changing the setting of the potentiometer 11, the volume impressed by the line L upon the loud speakers LS will be varied by the same amount but in the opposite direction.

The operation of the circuit may be more clearly understood from a consideration of the transmission level diagrams of Fig. 2. It will be noted from the curves of Fig. 2 that the volume supplied by the microphone M is assumed to vary from the maximum value of −5 transmission units to a minimum value of −55 transmission units, the range being 50 transmission units corresponding to a ratio of strong to weak power of approximately 100,000. Such a range of volume is frequently produced by a transmitter picking up a high grade musical performance and the range may be even greater in certain cases. It is also assumed in Fig. 2 that the maximum range of volume which can be handled by the transmission line L is 20 transmission units corresponding to a ratio of strong to weak power of only about 100.

In order to fully understand the transmission level diagram of Fig. 2, it will be necessary to define what is meant by a transmission unit. Let us suppose we have a transmission circuit upon which is impressed a given power and that we measure the power received at the other end of the transmission circuit. The ratio of the power applied to the power received is the power ratio and may be expressed as R. If there is no transmission loss in the circuit, the power received will be equal to that applied, so that the power ratio R will be unity. If the power received is only $\frac{1}{100}$ of that applied, the power ratio R is 1/100. Suppose now that the power applied to the transmission circuit is just equal to the power which would be supplied by an ordinary telephone transmitter when spoken into by an ordinary person speaking in an ordinary tone of voice. This power may be arbitrarily taken to represent the zero transmission level. Any power greater than this may be represented in terms of a certain number of positive transmission units, and vice versa, any power less than this may be represented by a certain number of negative transmission units.

It is also evident that the loss in transmission heretofore expressed in terms of the ratio of the applied power to the received power may be expressed in transmission units. It is convenient, therefore, to define the transmission unit TU in terms of the power ratio R as expressed by the following formula:

$$TU = 10 \log 10\ 1/R.$$

It is now evident that if there is no transmission loss in passing through the circuit, and the standard power heretofore referred to is impressed upon this circuit, the power ratio R will be unity and the loss in transmission units as calculated by the above formula will be zero. Similarly, if there is a loss in transmission sufficiently great so that only 1/100 of the power is supplied at the receiving end, so that the power ratio R is 1/100, this loss may be expressed in transmission units from the above formula as —20. Likewise, if, due to the use of amplifiers or for any other reason the power arriving at the receiving point is increased 100 times, so that the power ratio R is 100, this gain may be expressed in transmission units as +20. In this manner the following table may be computed:

TU.	Power ratio R.
20	100
10	10
0	1
—10	1/10
—20	1/100
—30	1/1000
—40	1/10,000
—50	1/100,000
—60	1/1,000,000

Returning now to the assumed conditions of Fig. 2 with the repeater R supplying a maximum volume of +10 transmission units and a minimum of —40 transmission units, so that the total range is 50, it will be seen that the corresponding power ratios are 1/-10,000 and 10, so that the actual ratio between the maximum and minimum volume is 100,000. Now let us consider what happens to the energy as it is transmitted from station A to station B. The maximum power generated by the transmitter of —5 transmission units is amplified by the repeater R and raised to a transmission level of 10 transmission units as indicated by the heavy line curve of Fig. 2. Upon arriving at the volume controlling element 10, the potentiometer 11 is adjusted in the case of the maximum power so as to reduce it in volume 15 transmission units, thus bringing it down to the level of —5 transmission units. The power is now attenuated in being transmitted over the line section to the next repeater R_1, so that it drops down to —25 transmission units, is then amplified to a level of +5 units, is again attenuated in being transmitted over the next section, dropping down to —15 units, and is amplified to a transmission level of +10 transmission units, etc., finally arriving at the terminals 17 of Fig. 1 at a transmission level of —5 transmission units.

Similarly, the minimum volume generated by the transmitter M of —55 units is likewise amplified by the first repeater R to bring its value up 15 transmission units, so that it arrives at a transmission level of —40 transmission units. In this case the volume control device 10 is so adjusted by means of the potentiometer 11 as to introduce a gain in transmission, thus stepping the volume up 15 units to a level of —25. The power is then impressed upon the transmission circuit and is attenuated in the line section extending to the repeater R_1, so that it falls to a level of —45 transmission units, being amplified by the repeater R_1 to bring it up to a level of —15 units, etc., the energy finally arriving at the terminals 17 with a power such that it reaches a transmission level of —25 units.

It will be seen by comparing the two curves that at all points between the input terminals 18 of the transmission line and the output terminals 17 of said transmission line, the maximum and minimum values will be separated by a range of just 20 transmission units, corresponding to the ratio of maximum to minimum volume of 100. For example, the maximum volume, upon leaving the repeater R_2 is just +10 transmission units, while the minimum volume is —10 transmission units. Referring to the table, it will be seen that these two volumes correspond to power ratios of 10 and 1/10, respectively, so that their actual ratio is 100. Similarly, the maximum and minimum values, upon arriving at the input of the repeater R_3 are a maximum of —20 and a minimum of —40 transmission units. Again referring to the table, these correspond to power ratios of 1/100 and 1/10,000 so that again the actual ratio for this power range of 20 transmission units is 100.

As has already been stated, the maximum volume which the line will transmit is determined by the power capacity of the telephone repeaters, and the minimum volume is limited by the amount of noise present in the transmission circuit, it being necessary to maintain the volume of the signal relatively greater than the noise at any given point in order that the signal will be heard without undue disturbance from the noise. In order to determine what are the maximum and minimum volumes that may be impressed upon the line L, for example, the volume indicator 19, which is bridged across the terminals 18, will be used and a telephone receiver 20 may be bridged across the receiving terminals 17. If some signal source whose volume is adjustable is then applied to the terminals 18 and the volume is increased, a point will finally be reached at which the listener who is using the receiver 20 will observe that the received signal is distorted due to overloading the tubes at some repeater point. As soon as this condition is observed, it will be at once known that the maximum limit of volume has been applied to the transmission line. If the volume indicator 19 is graduated to read in transmission units, this will be found to correspond for the case assumed to a transmission level at terminals 18 of —5 transmission units. It also happens in the case assumed that at the point 17 the corresponding volume received would be —5 transmission units if measured with a volume indicator.

If the circuit be now tested by reducing the volume applied to the terminals 18, bearing in mind that noise is being picked up along the line L at various points, the volume will finally be reduced to a point where its ratio to the noise arriving in the receiver 20 will be so small that the noise produces a disturbing effect and tends to distort or drown out the signal. When this point is reached, the minimum volume which may be impressed upon the line is at once known and if measured by the volume indicator 19 will be found to be —25 transmission units. The corresponding volume arriving at terminals 17, if measured by a volume indicator, will also in the assumed case be found to be —25 transmission units.

In the operation of the system, the range of volume to be applied to the line must, therefore, always be kept within the limits of —5 and —25 transmission units. The potentiometer 11 will, therefore, be operated preferably during pauses in the musical selection so as to cause a loss by means of the volume control device 10 when the volume is strong, and so as to produce a gain when the volume is weak, thereby reducing the range of volume to within the limits assumed, that is between the maximum limit of —5 transmission units and minimum limit of —25 transmission units. If the musical selection is of such nature, therefore, that at a given instant the volume supplied by the repeater R is +10 transmission units, it will be reduced by means of the controlling device 10 to —5 transmission units and will arrive at the terminal 17 with a volume of —5 transmission units. If an instant later the volume supplied by the repeater R should drop to —40 transmission units, the controlling device would be adjusted to produce a gain of 15 transmission units, bringing the volume up to —25 so that the volume arriving at the terminal 17 will be —25 transmission units.

It will at once be seen that while the original ratio between the volume generated at the two instants under consideration by the microphone M was 100,000, the ratio between the corresponding energies received is only 100. The controlling device 12, however, will be automatically operated over the auxiliary circuit L′ to introduce a gain of 15 transmission units in the one case and a loss of 15 transmission units in the other case, so that the volume for the maximum case is +10 transmission units and the volume for the minimum case is reduced to —40 transmission units. The total difference in range is 50 units, corresponding to a ratio of 100,000, so that the relation between the maximum and minimum volumes as applied to the loud speakers will be the same as that generated by the microphone, notwithstanding that the ratio was changed during transmission over the line L.

While for the simplicity of illustration the controlling circuit L′ has been illustrated as a separate circuit, it will be apparent that if the frequency transmitted by the generator G is outside of the frequency range for which the circuit L is employed in signaling, the circuit L may be employed for transmitting the controlling current from the generator G as in carrier transmission without in any way interfering with the transmission of the signals, suitable filters being provided, of course, to separate the controlling and the signaling currents.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit and scope of the appended claims.

What is claimed is:

1. The method of transmitting a wide range of energy volume over a transmitting medium capable of transmitting only a narrow range of energy volume, which consists in generating energy varying in volume over a range wider than the volume range of a transmitting medium, producing a change in the volume of the energy to be applied to the medium when the energy volume exceeds the limits of the transmitting medium, transmitting the energy over the medium with variations in volume extending over a narrower range than that of the energy

originally generated, receiving the energy thus transmitted over the medium, and producing a compensating change in the volume of the received energy.

2. The method of transmitting a wide range of energy volume over a transmitting medium capable of transmitting only a narrow range of energy volume, which consists in reducing the volume of the energy to be applied to the medium when the volume of energy to be so applied is greater than the medium will carry, receiving the energy thus transmitted over the medium, and producing a compensating increase in the volume of the received energy.

3. The method of transmitting a wide range of energy volume over a transmitting medium capable of transmitting only a narrow range of energy volume, which consists in generating energy varying in volume over a range wider than the volume range of a transmitting medium, increasing the volume of the energy to be applied to the transmitting medium when the volume of said energy is less than the lowest energy volume which the medium will transmit efficiently, transmitting the energy over the medium with variations in volume extending over a narrower range than that of the energy originally generated, receiving the energy thus transmitted, and producing a compensating decrease in the volume of the received energy.

4. In a signaling system, a transmission medium capable of transmitting a relatively narrow range of energy volume, means to generate signaling energy having variations of energy volume extending over a range greater than that which the medium is capable of transmitting, means for changing the volume of the energy generated when it exceeds the limits of the transmitting medium so as to bring it within the energy volume range which the medium will transmit, transmitting the energy over the medium with variations in volume extending over a narrower range than that of the energy originally generated and means at the receiving station for producing a compensating change in the volume of the received energy in the opposite direction.

5. In a signaling system, a transmission medium capable of transmitting a relatively narrow range of energy volume, means to generate signaling energy having variations of energy volume extending over a range greater than that which the medium is capable of transmitting, means for decreasing the volume of the generated energy when it exceeds the highest energy volume which the transmitting medium will carry, and means for producing a compensating increase in the received energy.

6. In a signaling system, a transmission medium capable of transmitting a relatively narrow range of energy volume, means to generate signaling energy having variations of energy volume extending over a range greater than that which the medium is capable of transmitting, means for increasing the volume of the generated energy when it falls below the lowest energy volume which the transmitting medium will carry, transmitting the energy over the medium with variations in volume extending over a narrower range than that of the energy originally generated and means for producing a compensating decrease in the received energy.

7. In a signaling system, a transmission medium capable of transmitting a relatively narrow range of energy volume, means to generate signaling energy having variations of energy volume extending over a range greater than that which the medium is capable of transmitting, means for changing the volume of the generated energy when it exceeds the energy volume limits which the transmitting medium will carry, and means for automatically producing a compensating change in the received energy in the opposite direction.

8. In a signaling system, a transmission medium capable of transmitting a relatively narrow range of energy volume, means to generate signaling energy having variations of energy volume extending over a range greater than that which the medium is capable of transmitting, means for increasing the volume of the generated energy when it falls below the lowest energy volume which the transmitting medium will carry, and means for automatically producing a compensating decrease in the received energy.

9. In a signaling system, a transmission medium capable of transmitting a relatively narrow range of energy volume, means to generate signaling energy having variations of energy volume extending over a range greater than that which the medium is capable of transmitting, means for decreasing the volume of the generated energy when it exceeds the highest energy volume which the transmitting medium will carry, and means for automatically producing a compensating increase in the received energy.

10. In a signaling system, a transmitting medium only capable of transmitting a relatively narrow range of energy volume, means for generating signaling energy varying in energy volume over a wider range than that which the transmitting medium will carry, means for generating controlling energy of constant volume, means to change the volume of said variable signaling energy before applying it to said medium when it exceeds the limits of the range which the medium will transmit, means to simultaneously produce a corresponding change in the volume of

said controlling energy from said constant source, means to transmit said controlling energy thus changed in volume to a receiving station, means at the receiving station to receive the signaling energy transmitted over said medium, and means responsive to the change in volume of the controlling energy to produce a compensating change in the volume of the received energy.

11. In a signaling system, a transmitting medium only capable of transmitting a relatively narrow range of energy volume, means for generating signaling energy varying in energy volume over a wider range than that which the transmitting medium will carry, means for generating controlling energy of constant volume, means to decrease the volume of said variable signaling energy before applying it to the medium when it exceeds the maximum value which the transmitting medium will carry, means to produce a simultaneous and corresponding change in the volume of said controlling energy, means to transmit said controlling energy to a receiving station, means at the receiving station to receive the signaling energy, and means at said station responsive to the change in the volume of said controlling energy to produce a compensating increase in the received signaling energy.

12. In a signaling system, a transmitting medium only capable of transmitting a relatively narrow range of energy volume, means for generating signaling energy varying in energy volume over a wider range than that which the transmitting medium will carry, means for generating controlling energy of constant volume, means to increase the volume of said variable signaling energy before applying it to the medium when it falls below the minimum value which the transmitting medium will carry, means to produce a simultaneous and corresponding change in the volume of said controlling energy, means to transmit said controlling energy to a receiving station, means at the receiving station to receive the signaling energy, and means at said station responsive to the change in the volume of said controlling energy to produce a compensating decrease in the received signaling energy.

13. The method of transmission control comprising reducing all levels of energy input in a system to levels below a given maximum, transmitting energy at the reduced level, and reproducing at a receiving point energies of different levels in substantial accordance with the unreduced original energy.

14. The method of transmission control of produced energies extending over a wide range of levels comprising transmitting energy only below a given level less than the maximum of said produced levels, transmitting control current variations, and reproducing energies under control of said variations extending over a range of levels of substantially the same width as the original level.

15. The method of effectively transmitting energy varying through a wide range of volume over a system of limited volume range capacity which consists in making changes at one point in the system to bring the energy variations within the volume limits of the system transmitting the energy over the medium with variations in volume extending over a narrower range than that of the energy originally generated and making opposite changes at another point in the system for compensation.

16. The method of effectively transmitting energy varying through a wide range of volumes over a system of limited volume range capacity which comprises changing the loss characteristics at the input of the system of limited capacity to bring the input energy within the limits of the system transmitting the energy over the medium with variations in volume extending over a narrower range than that of the energy originally generated and changing the loss characteristics at the output of the system to compensate for the changes made at the input of the system.

17. The method of effectively transmitting energy of a wide range of volumes of energy over a system of limited volume range capacity which comprises varying the energy level at the input of the system to bring the input energy within the volume limits of the system, transmitting to the output end of the system current variations representing the magnitude and direction of the changes in energy level at the input end and utilizing the transmitted current variations at the output end of the system to effect changes in the level of the energy received from the system corresponding in magnitude but opposite in effect.

18. The method of effectively transmitting energy of a wide range of volumes of energy over a system of limited volume range capacity which comprises varying the energy level at the input of the system of limited range to bring the input energy within the volume limits of the system, transmitting to the output of the system current variations corresponding to changes in the energy level at the input and varying the energy level at the output of the system in accordance with the transmitted current variations.

19. In a wave transmission system, a source of energy varying through a wide range of volume, a transmission circuit of limited volume range capacity supplied with said energy, means for reducing the volume

range of the energy input to said circuit and means for transmitting the output end of the system current variations corresponding to the changes in level of the input energy.

20. In a wave transmission system, a source of energy varying through a wide range of volumes, a circuit of limited volume range capacity supplied with said energy, means for changing the volume range of the energy input to said circuit, and means for producing corresponding changes in the energy output of said circuit, in the opposite direction from the energy input changes.

21. In a transmission system, sources to produce energy of various levels to be transmitted, a transmission circuit, means for reducing the level of energy from said sources to less than a given maximum and for applying energy of the reduced level to said circuit, means controlled by the energy reducing means for transmitting control current variations and means at a receiving point actuated in accordance with said control current variations for reproducing from the energy of reduced level energies of various levels corresponding to the energies from said sources.

22. In a wave transmission system, a source of energy of a wide range of volumes, a circuit of limited volume range capacity supplied with said energy, means for varying the energy input to said circuit to bring it within the volume limits of said circuit, means for transmitting indications of the magnitude and direction of the energy input changes to the output of said circuit, and means for varying the energy output of said circuit in accordance with said indications in the opposite direction from said energy input changes.

23. In a wave transmission system, a source of energy of a wide range of volumes, a circuit of limited volume range to be supplied with said energy, means for simultaneously making adjustments in the energy input to said first-mentioned circuit to bring it within the volume limits of said first-mentioned circuit and for transmitting signals corresponding in direction to said input energy adjustment for adjusting the energy output of said first-mentioned circuit in the opposite direction from said input energy adjustment.

24. In a signaling system having transmitting and receiving stations, means for changing the energy input delivered to said transmitting station, means for transmitting signals to said receiving station indicating the magnitude and direction of such changes in said energy input, and means controlled by said signals for changing the energy output of said receiving station to compensate for said changes in said energy input to said transmitting station.

In testimony whereof, I have signed my name to this specification this 18th day of June 1924.

ALVA B. CLARK.