Feb. 9, 1932.

R. C. MATHES

1,844,423

ATTENUATION AND VOLUME CONTROL

Filed Oct. 8, 1930

2 Sheets-Sheet 1

FIG. 1A

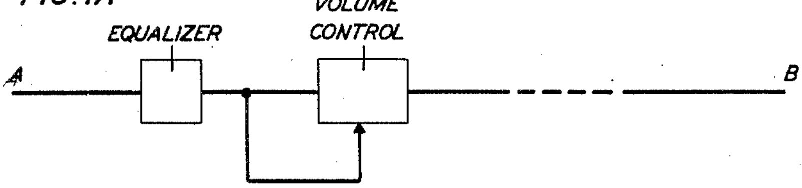


FIG. 1B

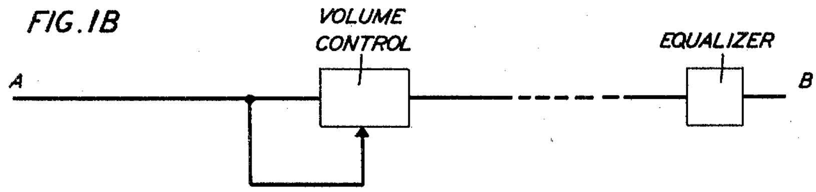


FIG. 1C

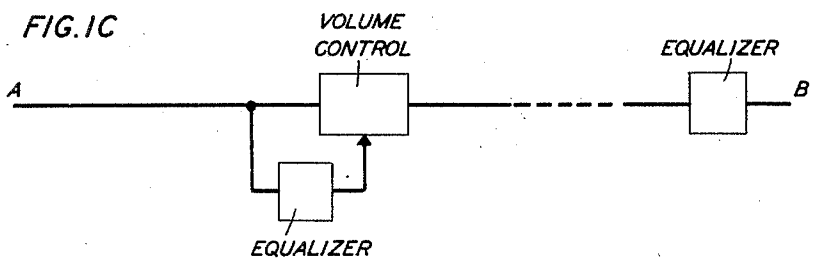


FIG. 2A

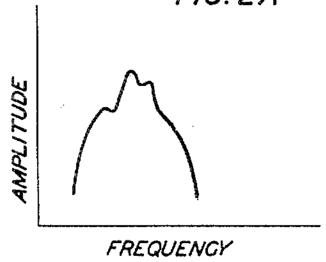
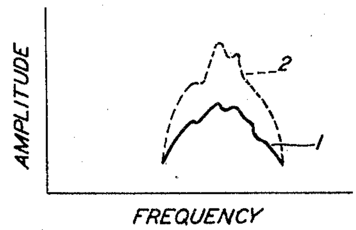


FIG. 2B



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ATTENUATION AND VOLUME CONTROL

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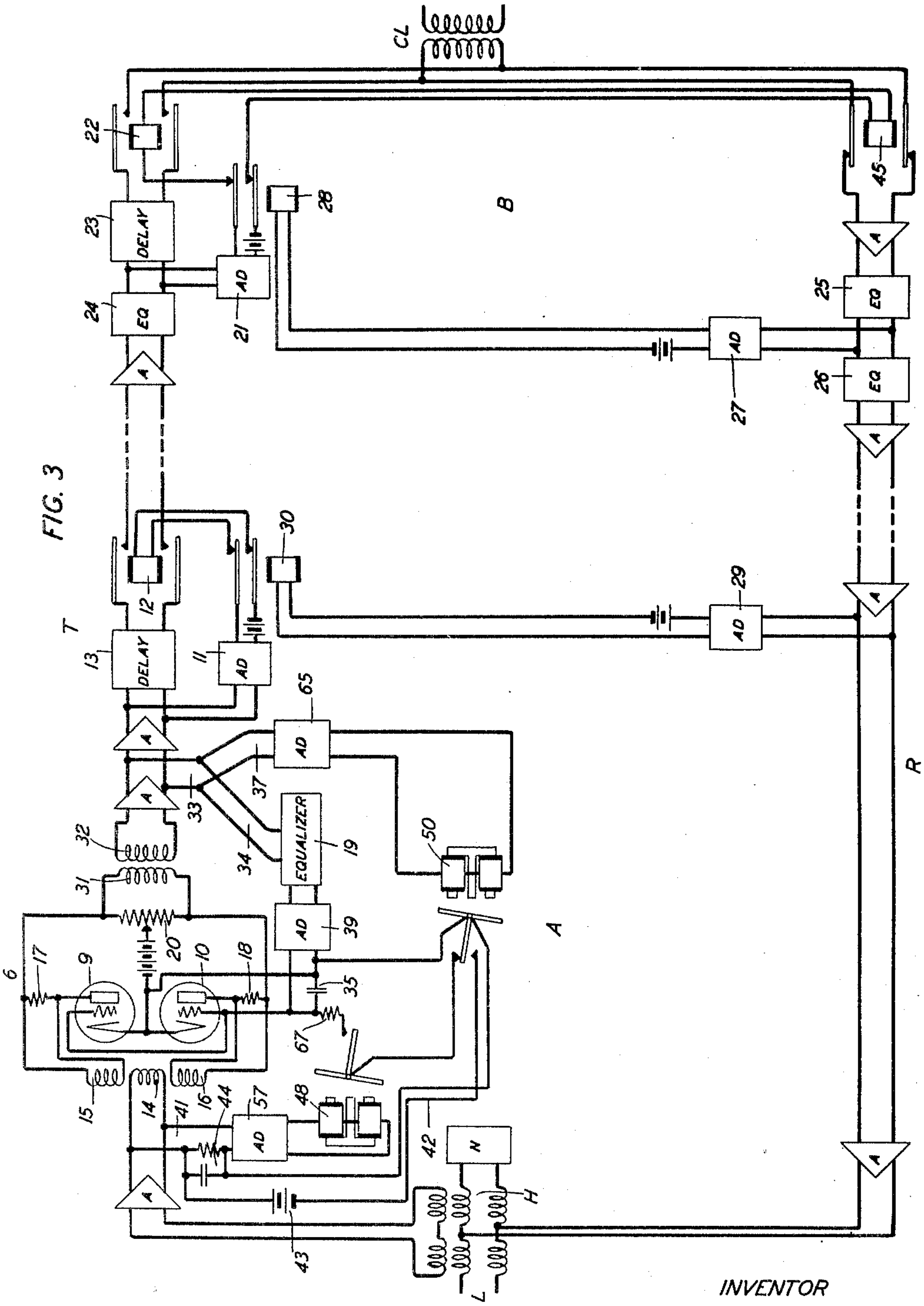

FIG. 3

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UNITED STATES PATENT OFFICE

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ATTENUATION AND VOLUME CONTROL

Application filed October 8, 1930. Serial No. 487,209.

The present invention relates to speech or similar transmission over systems of variable attenuation and varying input volume level.

The invention has for an object a novel combination of volume and attenuation regulation resulting in improved transmission.

A related object is to control volume independently of frequency amplitude variations in the transmitted waves.

In the case of a long transmission path of high attenuation such as a transatlantic cable or other long line it is important to shape the speech waves impressed on the line and also to maintain nearly constant volume level in the input waves. The shaping of the waves is to assist in over-riding noise and it may also assist in compensating for the unequal attenuation at the different frequencies in the speech band. The volume control enables maximum permissible power to be applied to the line notwithstanding fluctuations in volume level of the speech that is to be sent. An example of a system in which a sending end equalizer and volume control are used in the input circuit to such a cable or line is disclosed in an application of Mathes and Horton Serial No. 412,612 filed December 9, 1929 for cable telephony.

These two elements of a system, the sending end equalizer and volume control may be located at the same point in the system or may be widely separated. In particular if the cable station is located at a distance from the point at which the technical supervision and control of the system is exercised, it is convenient to have the volume control at the latter point where direct manipulation of it can be made if necessary. The sending end equalizer, on the other hand, need not be under the direct control of the technical operator and for reasons that will be made clear presently it is more advantageous to locate the equalizer at the transmitting station for the cable rather than at the distant control point.

A volume control acts in response to varying volume level to maintain constant output level. A sending end equalizer operates as a function of frequency and generally produces relative gain in high frequencies with respect to low. Since the energy spectrum of speech is not flat but is high over the low and middle frequency regions and falls off rapidly toward the high frequency end, a volume control if made responsive to natural speech will ordinarily introduce some frequency amplitude compensation in the same direction as that provided by the sending end equalizer. That is, it will produce relative gain in some of the high frequency components. Suppose for example that the volume control is timed so as to effect a variation in output level for every variation in the level of the applied speech which takes place within the duration of one or a very few syllables. Sounds made up of the stronger vowels and semi-vowels comprise relatively low frequencies and their volume level is high with respect to weak vowel and consonant sounds of high frequency. The latter cause the volume control to raise the output level, hence the high frequency syllables are sent out at increased energy level relative to the low frequency syllables. This frequency compensation is only partial and depends in part upon the timing of the volume control. For instance, if the volume control corrects only for difference in speakers' voices it may be made very sluggish in action, responding only to a long time average of volumes. Even where the volume control is timed to respond to practically instantaneous sound increments, if high frequencies exist coincidentally with low frequencies, there may be no equalizing effect produced by the volume control since it responds to volume level and ordinarily the low frequency components are stronger and will control. The sending end equalizer, however, responds to frequency and emphasizes the high frequency components whether accompanied by other components or not.

The long toll line which connects the technical operator's position with the sending station on the cable or other high attenuation path forms part of the toll network of the telephone system, so that cross-talk and other transmission requirements of the system must be met. Cross-talk between neighboring lines is greater at high frequencies than at low, whether due to capacity or inductive coupling between the lines. On this account it is better from the cross-talk standpoint not to transmit the high frequency speech components at high volume over the line leading to the cable station. For this reason it is more advantageous to place the equalizer at the cable station than back at the supervising or control station at the distant end of the toll line.

A difficulty arises in locating the volume control at the supervising station because of the equalizing which it does, as above described, tending toward increased cross-talk.

This difficulty has been overcome by the invention by using an equalizer in the control circuit of the volume control so that instead of the latter producing its variation of output level in response to natural speech, it is controlled by speech that has been compensated for variation of amplitude with frequency. Low pitched or high pitched sounds occurring separately, so long as their level difference amounts only to that represented by the energy spectrum of natural speech will exert no difference in control on the volume control device. Thus the output volume is maintained constant to the requisite degree and equalization that would result in emphasis of the high frequency components more than the low is avoided.

Other advantages together with the various features and objects of the invention will be made apparent from the following detailed description of the embodiments of the invention illustrated in the accompanying drawings.

Referring to the drawings,

Figs. 1A, 1B and 1C are explanatory diagrams which, taken with the graphs shown in Figs. 2A and 2B, will be made use of in explaining the principles of the invention; and

Fig. 3 is a schematic circuit diagram of a terminal station for a transatlantic cable or other long line of high attenuation with which the invention is adapted to be used.

The principles of wave shaping and volume control that have been discussed in general terms hereinbefore may be briefly summarized by referring to the Figs. 1A, 1B, 1C, 2A and 2B. In Fig. 1A the speech which is sent out from the station A on the line will be equalized both as to frequency amplitude variations in the speech and as to volume level because the system employs an equalizer and a volume control both inserted in the line. The difference in operation of this circuit and that of Fig. 1B may be seen by reference to the graphs of Fig. 2. Fig. 2A is intended to represent a short word or syllable in which the energy is concentrated in a lower part of the speech frequency range. In Fig. 2B the impulse indicated as 1 is intended to represent a short word or syllable in which all of the energy is concentrated toward the high frequency end of the speech range. Assuming that the equalizer in Fig. 1A is designed to send out practically flat speech, that is, speech in which all of the different frequency components are adjusted to substantially the same amplitude, this equalizer will convert the impulse 1 into the impulse indicated by dotted lines at 2. In order to do this it will be assumed of course that the equalizer contains amplification as well as a variable attenuating network. In a circuit arranged as in Fig. 1A it will be seen that the impulses impressed on the circuit and represented in Figs. 2A and 2B will have the same effect on the volume control (which for convenience will be assumed to be no effect at all, the impulses representing normal volume level).

In the arrangement of 1B, however, impulse 1 of Fig. 2B is very much below normal and would have a tendency to operate the volume control to raise the volume by a certain amount. If the volume control circuits act sufficiently rapidly the impulse 1 of Fig. 2B might be raised in amplitude corresponding to impulse 2 of this figure. With a somewhat slower time operation of the volume control, the correction would not be as great as is indicated in Fig. 2B, but there might nevertheless be some increase. For the condition indicated in Figs. 2A and 2B, it will be seen therefore that the arrangement of Fig. 1B produces an equalizing effect which is somewhat similar to that shown in Fig. 1A even though a speech equalizer is omitted from the transmitting end of the system of Fig. 1B.

In both of these cases the high frequencies are sent over the line with an amplitude greater than their occurrence in normal speech and as explained hereinbefore the tendency toward crosstalk between the line A—B and neighboring lines is increased.

In Fig. 1C which represents the arrangement according to the invention, the equalizer is placed in the control circuit of the volume control and the volume level is regulated without at the same time performing an equalizing action on the transmitted waves. In Fig. 1C impulses such as are represented in Fig. 2A and Fig. 2B are equalized before they are impressed upon the control circuit and the effect of these waves upon the volume control is the same as explained above in connection with Fig. 1A. Since, however, the equalizer does not lie in the line of transmission for the speech waves, no equalizing action is produced in the speech waves and the waves that are sent out from the station A of Fig. 1C are normal speech waves except that their volume level has been regulated to fit the requirements of the system.

In order to equalize the waves at station B before they are transmitted into a transatlantic cable or other long line, an equalizer is placed in the line. For the circuit of Fig. 1C to have the same net effect on the waves that arrive at station B as the circuit of Fig. 1A, the equalizer in the control circuit of Fig. 1C should be the same as the equalizer used at the distant end of the line at station B. The circuit of Fig. 1C is superior to that of Fig. 1A from the crosstalk standpoint since the high frequency components are sent out with relatively less energy in the circuit of Fig. 1C. The separtion of the equalizer from the volume control in accordance with Fig. 1B gives an inferior system to that of Fig. 1A from two standpoints. The volume control of Fig. 1B has impressed upon it, waves of rapidly varying amplitude and there is a tendency for the volume control to be operated too much of the time. Due to this rapid operation of the volume control and to the equalizing effect produced as a result of it, there is a double equalization in the system which results in undesired distortion. This is due to the fact that the equalizer at station B does not have impressed upon its input normal speech waves but waves which have already undergone a certain amount of equalization. A still further disadvantage of the arrangement of Fig. 1B is that any noise incoming to the station A is augmented along with the high frequency components when the volume control operates which is quite frequently. This produces an undesirable noise condition on the line A—B and makes it necessary to decrease the sensitivity of voice operated switching devices which may be associated with the system. These various drawbacks are absent from the system of Fig. 1C.

Reference will now be made to the circuit diagram of Fig. 3. In this figure the land line L is connected by a four-wire circuit comprising transmitting branch T and receiving branch R with the cable circuit CL which is located at a distant point. That is, each of the circuits T and R is a long line and connects apparatus which is located at two separated stations A and B as indicated in the drawing by the dotted line portion of the two circuits. In an actual transatlantic system station A might be New York and a station B some point in Newfoundland. The land line L terminates in the usual hybrid coil H and balancing network N. The various amplifiers shown throughout the circuit are labeled A and will not be referred to specifically. The transmitting branch T at the station A includes a volume control 6 which is of the type disclosed and claimed in an application of Hogg and Doba, Serial No. 445,543 for transmission systems, filed April 19, 1930. In that application a compensating volume control is also disclosed in the receiving branch R, but for simplicity in the present disclosure, the compensating control has been omitted, although it could be used if desired. Otherwise the circuit is the same as that of the Hogg-Doba application.

The transmitting circuit T also has at the station A suitable voice operated switching circuits including amplifier detector 11 and relay 12 and delay circuit 13, the operation of which will be described hereinafter. There is also included at the station A an equalizer in the control circuit of the volume control, this equalizer being indicated at 19.

At the distant station B, the transmitting branch T includes a further voice operated switch control comprising amplifier detector 21, relay 22 and delay circuit 23. There is also included at this station an equalizer 24 which may be a duplicate of equalizer 19 at station A, these equalizers corresponding to those shown in Fig. 1C.

The receiving station B includes an equalizer 25 with possibly further equalizers as may be required, one of which is indicated at 26, and an echo suppressor circuit comprising amplifier detector 27 and relay 28.

The receiving branch R includes at station A another echo suppressor circuit comprising amplifier detector 29 and relay 30.

For a complete understanding of the volume control, reference is made to the Hogg-Doba patent application above identified. Sufficient explanation will be given here however, to afford an understanding of the operation of the present invention.

This volume control comprises two vacuum tubes 9 and 10, the anode-cathode paths of which are included effectively in series in the transmitting circuit T. The series path interposed in the transmission line may be traced from the cathode of tube 9 to the anode, through the secondary winding 15 of the input coil, through the primary output coil 31, through the secondary input coil 16 to the anode of device 10 and back to the cathode of tube 9. The two secondary input windings 15 and 16 are equally influenced by the primary winding 14. Impedances 17, 18 and 20 are associated with these tubes for proper regulation of their characteristics as described more fully in the Hogg-Doba application referred to.

The grids of the tubes 9 and 10 are connected in a grid bias control circuit across which condenser 35 is connected. By a proper control of the grid bias potential on the tubes 9 and 10 the impedance which these tubes offer in the transmission line T can be varied at will and in this way the volume of waves transmitted over the circuit can be regulated. The grid bias potential is controlled by regulating the amount of charge on the condenser 35 as will be more fully explained hereinafter.

For the purpose of controlling the charge on the condenser 35, there is branched from the outgoing circuit of the volume control 6 a circuit 33 which divides into two control circuits 34 and 37. Circuit 34 leads through equalizer 19 and amplifier detector 39 to the two sides of the condenser 35. Speech waves in the output of the volume control 6 pass in part through circuits 33 and 34, then through the equalizer 19 and are rectified and if necessary amplified, at 39 so as to control the voltage supplied to the condenser 35.

Condenser 35 may be discharged through a resistance 67 which is adapted to be connected across the condenser when relays 48 and 50 throw their armatures to the proper position. Both of these relays as shown are in their unoperated condition. Relay 48 is controlled by speech waves in the input of the volume control, these waves passing in part through the circuit 41 and into the amplifier detector 57. Relay 50 is controlled from the output side of the volume control by speech waves which pass in part into the control circuit 37 and through amplifier detector 65.

It is the purpose of the relays 48 and 50 to enable the volume control 6 to respond to sufficiently small variations in volume level and to act with sufficient rapidity to give a desired degree of regulation and at the same time to protect the volume control against unnecessary operation such as might occur when the input speech falls to zero for short intervals of time, as for instance, between words or syllables. Relays 48 and 50 accomplish this by determining whether or not the charge is to be left upon condenser 35, or whether the condenser is to be discharged. The condenser will be discharged only on condition that relay 48 is operated and relay 50 is unoperated. Only under those conditions is there a circuit closed through resistance 67 and the two armatures of relays 48 and 50 across the condenser 35. Relay 48 closes its contacts whenever there is speech impressed upon the transmitting circuit T and opens its contacts when the speech ceases. Relay 50 opens the contacts in this discharge circuit whenever the speech level on the output side of the volume control is above the lower limiting value that has been predetermined for the outgoing speech.

The operation of the volume control will be made clearer by following through a typical sequence of operations. The tubes 9 and 10 are set for normal operation when normal speech volume is being transmitted. The amplifier 39 is marginal in its operation and does not place a charge on condenser 35 unless the output volume rises above the upper prescribed limit. When this occurs, a charge builds up on condenser 35 which is proportional to the excess volume in the outgoing circuit. This charge applies a negative voltage to the grids of the tubes 9 and 10 and increases their impedance to an extent required to reduce the outgoing volume to within the volume range limits for which the circuit is set. On account of the use of equalizer 19 as was explained above in connection with Figs. 1 and 2, the same correction is not made in the tubes 9 and 10 for wave components of all frequencies, but the low frequencies predominate in the control of the tubes 9 and 10 on the assumption that the speech that is eventually to be sent out has its high frequency components strengthened.

If a pause should occur in a conversation which is of too high a level and which therefore results in placing a negative potential on the grids of the tubes 9 and 10, due to the charge on condenser 35, both relays 48 and 50 immediately release. This prevents the discharge circuit from being connected across condenser 35 and the charge therefore remains on the condenser and maintains the volume control in the condition to which it was previously adjusted. This is desirable so that when the conversation which has been assumed to represent too high volume is resumed, the volume control will have the desired setting.

If there is a charge on condenser 35 produced from excessive volume and if instead of a cessation in the speech the input speech level drops to a low value and likewise the output level falls below the lower limit, then relay 48 remains energized but relay 50 is unoperated and condenser 35 is discharged through resistance 67, which is of such magnitude as to give a proper control of the rate of discharge. The potential on the grids of tubes 9 and 10 is therefore brought back to the proper value to cause the output level to fall within the prescribed limits.

The circuit 42 which is controlled by the make contacts of relay 50 is for the purpose of quickly releasing relay 48 when a pause occurs in the speech on the input side of the volume control. This circuit 42 includes a bias battery 43 and a combination resistance and capacity indicated at 44 as is more fully disclosed in the Hogg-Doba application referred to.

As a result of the operation of the volume control 6 as has been described above, with the aid of equalizer 19, the volume of the outgoing circuit T is maintained within the proper level, but there is substantially no frequency-amplitude compensation.

The speech arriving at the input of the delay circuit 13 is passed in part into the amplifier-detector 11 and causes actuation of relay 12 which closes the speech circuit through to the outgoing line. The delay circuit 13 delays the speech sufficiently to allow relay 12 to fully attract its armatures before the speech reaches the relay contacts. Delay circuit 13 may be of the low pass filter type usual in the art or may be an acoustical or mechanical delay or any other desired type such as is known in the prior art.

From this point the speech waves pass over the connecting line to the distant station B. Here they pass through the equalizer 24 which is preferably a duplicate of the equalizer 19 at station A. They then pass in part into the amplifier-detector 21 which causes relays 22 and 45 to operate. Relay 22 closes the transmitting circuit through to the cable circuit CL and relay 45 opens the receiving branch R. The delay circuit 23 delays the speech until relay 22 has fully operated.

The apparatus which has been illustrated in the receiving branch R is purely conventional and may take any desired form depending upon the system requirements. When there is no speech outgoing into the cable from transmitter branch T the receiving branch is normally in condition to receive from the cable because relay 45 is normally deenergized. Under these conditions, speech received from the cable passes into the receiving branch R where there are located suitable equalizers, two of which are shown at 25 and 26. These equalizers are preferably designed to compensate for the unequal attenuation of the cable circuit over the frequency band that is being transmitted. Relay 25 may for example be for that purpose. Equalizer 26 is preferably designed to effect the opposite transformation in the speech waves to that produced by equalizer 24 at the distant transmitting point. At some suitable point in the receiving branch R, there is branched off from the main circuit an amplifier-detector circuit 27 leading to relay 28. Speech waves in the receiving branch R cause the operation of relay 28 which opens the voice operated circuit on the transmitting side and prevents speech in the branch T from operating relays 22 and 45. The speech waves in branch R pass on to the station A where there is located a similar amplifier-detector 29 which causes operation of relay 30 and disables the voice operated circuit 11, thus preventing operation of relay 12. The speech in branch R passes on out into line L through hybrid coil H which prevents the speech from passing directly across into the input of transmitting branch T.

What is claimed is:

1. In a system for transmitting waves of a band of frequencies subject to varying energy level, means responding to the energy level of said waves for automatically maintaining the output level constant within predetermined limits and means comprising a frequency-amplitude distorting device in circuit with said first means for counteracting frequency-amplitude distortion of the transmitted waves by said first means due to unequal amplitudes of different frequency components of the same speech.

2. The combination with a line, of a volume control device inserted therein, a control circuit for said device, impressed with control waves from said line, and a frequency-amplitude equalizer in said control circuit.

3. In combination in a telephone system, a volume control having a speech transmission path and a control circuit, said control circuit determining the level of waves outgoing from the volume control, a long line outgoing from said volume control, a speech distorting device in said line at a distance from said volume control, and a similar distorting device in said control circuit.

4. The combination with a line having a varying attenuation over the range of transmitted frequencies of a volume control device consisting of a variable loss element and a control circuit for varying the loss in accordance with the volume level of waves traversing said line, and a device included in said control circuit for transmitting waves of the range of frequencies traversing said line and variably attenuating said waves throughout said range.

5. In an input system for a transmission path of high attenuation, a long line leading to said transmission path, a volume control device in said line, at a point remote from said path, for regulating the volume level transmitted over said line, and means comprising a frequency-amplitude distorting device in circuit with said volume control for preventing the volume level regulations from introducing frequency amplitude distortion due to unequal amplitudes of different frequency components of the same speech.

6. In a telephone system, a line having an attenuation equalizer adjacent its receiving end for compensating for unequal attenuation in a path outgoing therefrom, a volume control device in said line at an electrically distant point from said equalizer, said device including a control circuit operating in response to volume level of transmission on said line for automatically adjusting said device, and an equalizer in said control circuit but not in the line, similar in characteristic to that at the receiving end of the line.

7. In a transoceanic telephone system including an ocean cable of high attenuation and of varying attenuation within the transmitted frequency band, a long land line leading up to the cable, an attenuation equalizer associated with said line and cable adjacent the cable terminal for compensating for the unequal attenuation of the cable over the transmitted band, said line including at a remote point an automatic volume control operating in response to line voltage for maintaining the transmission level within prescribed limits, said volume control having a circuit branched off from the line and leading to the control elements of said volume control, and an attenuation equalizer inserted in said control circuit between the line and said control elements, similar in characteristic to that adjacent the cable terminal.

In witness whereof, I hereunto subscribe my name this 6th day of October, 1930.

ROBERT C. MATHES.