Dec. 15, 1925. 1,565,491

H. NYQUIST

VOLUME CONTROL OF TRANSMISSION

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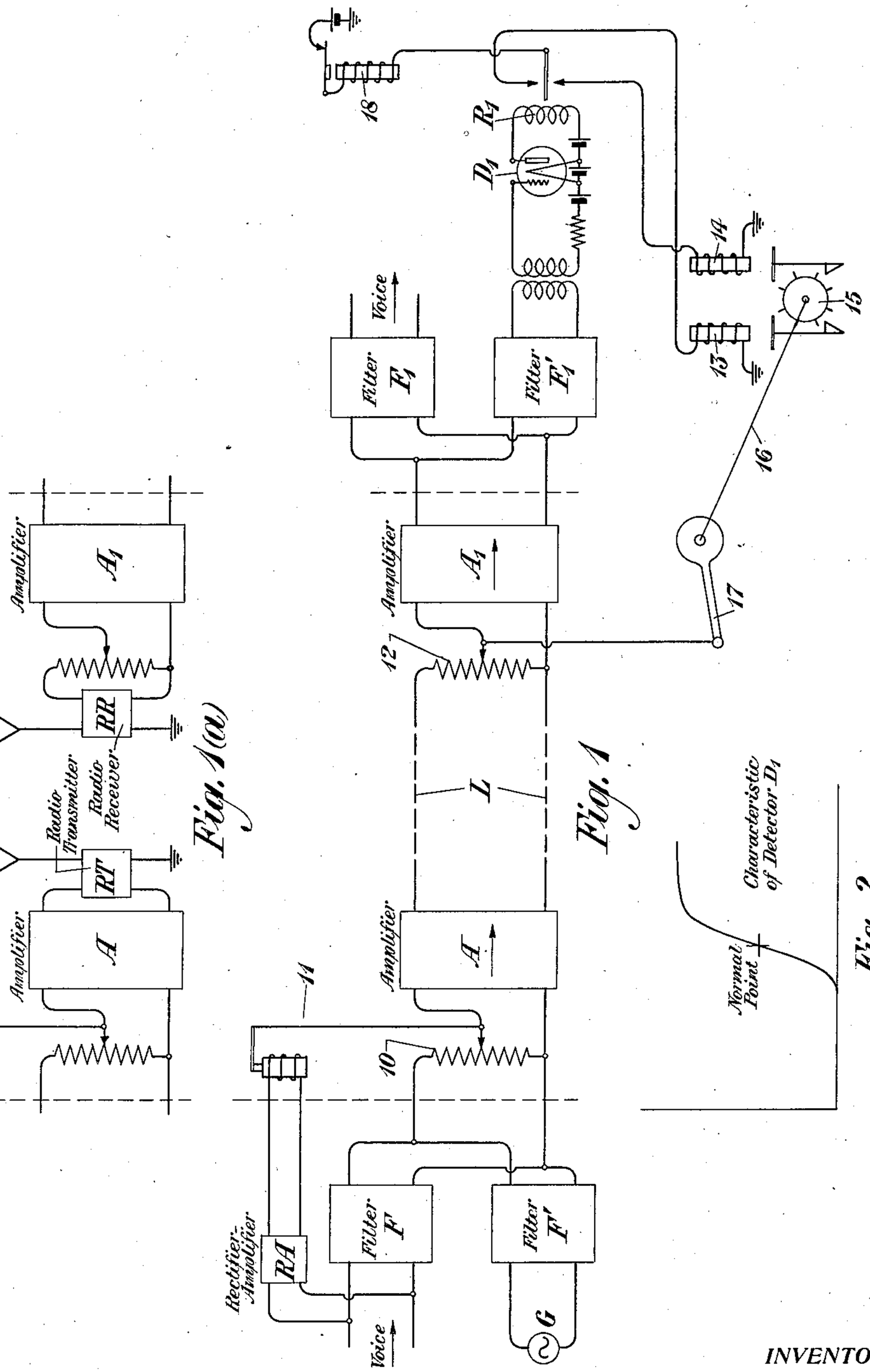

Fig. 1(a)

Fig. 1

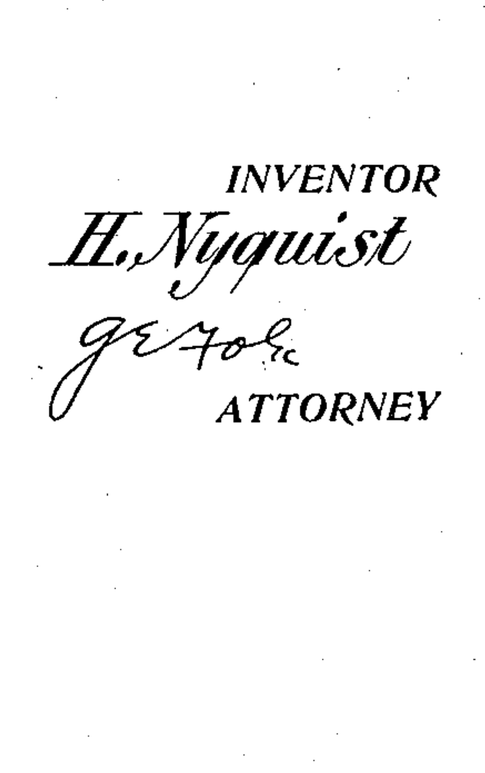

Fig. 2

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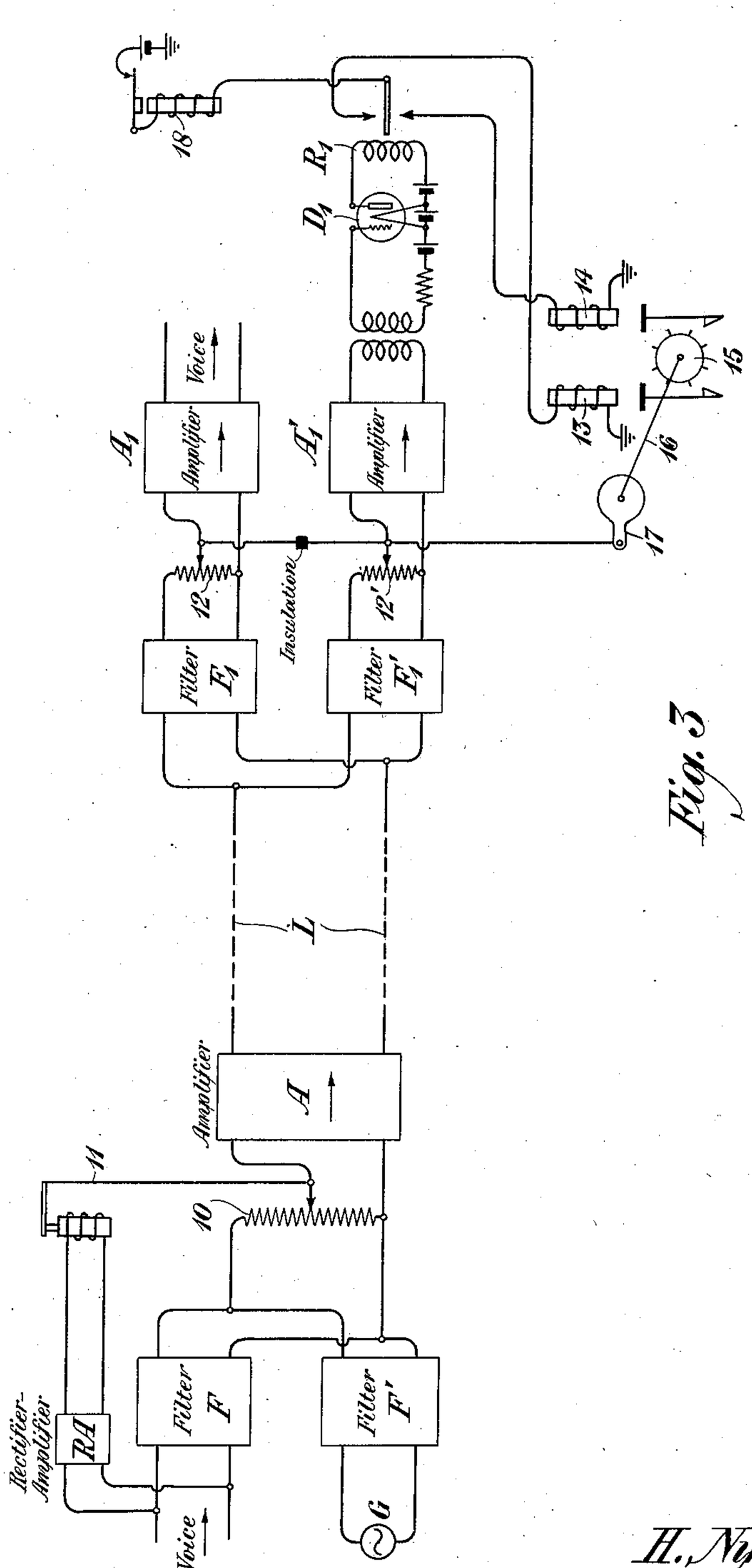

Fig. 3

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UNITED STATES PATENT OFFICE.

HARRY NYQUIST, OF JACKSON HEIGHTS, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

VOLUME CONTROL OF TRANSMISSION.

Application filed September 13, 1924. Serial No. 737,585.

To all whom it may concern:

Be it known that I, HARRY NYQUIST, residing at Jackson Heights, in the county of Queens and State of New York, have invented certain Improvements in Volume Control of Transmission, of which the following is a specification.

This invention relates to the transmission of signals, and more particularly to a means for and a method of changing the range of volume of the signals during transmission.

In telephone transmission, and in other kinds of signaling as well, it is often desirable to transmit sounds, such as speech and music, which have an extremely wide range of volume. The transmitting medium, however, may be ill adapted for the transmission of wide ranges of volume by reason of the fact that its volume range is limited, on one hand by interference from disturbing noises, and, on the other hand by the necessity of avoiding distortion due to overloading repeaters. This is particularly true of such types of transmission systems as radio transmission circuits and public address system.

In accordance with the present invention, it is proposed to adjust the volume range of the signals to be transmitted to bring it within the allowable range of the transmission medium. This may be accomplished by changing the gain at the transmitting end of the system, at the same time producing a compensating change in the gain at the other end. In other words, the transmission level will be raised at the transmitting end and correspondingly lowered at the receiving end, or vice versa, whenever the volume of the signal becomes lower or greater than the average volume.

In order that the transmission level may be adjusted at the receiving end for compensating the change in transmission level at the transmitting end, some method of control must be exercised from the transmitting end over the gain control device at the distant end. This may be accomplished in accordance with the present invention by transmitting over the medium and along with the signal a control frequency which is outside the range necessary for signal transmission. Whenever the gain control device is adjusted at the transmitting end, a corresponding change is made in the amplitude of the control frequency as it arrives at the receiving end, and this change in amplitude may be used to operate the gain control device at the receiving end to make the compensating adjustment.

The use of an auxiliary control frequency in this manner has the advantage that the gain control apparatus at the distant end will be automatically adjusted whenever there is a change in the equivalent of the transmission medium, because such change in equivalent produces a corresponding change in the amplitude of the control frequency, thus causing it to set the adjusting apparatus into operation to bring the overall equivalent of the medium back to normal.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing, Fig. 1 of which illustrates an embodiment of the invention as applied to a telephone transmission line; Fig. 1[a] of which illustrates how the apparatus of Fig. 1 may be applied to a radio system, Fig. 2 of which is a curve illustrating the operation of the detector in Fig. 1, and Fig. 3 of which illustrates a modification of the arrangement of Fig. 1.

Referring to Fig. 1, L designates an ordinary telephone transmission line having amplifiers A and A′ near the terminals thereof. The line L, if of sufficient length, may, of course, have amplifiers at points intermediate its length, as is well understood in the art. At the transmitting station, the voice or other signaling currents are applied to the line L through a band filter F and through the amplifier A. The amplifier A is provided with a potentiometer 10 of the usual type for adjusting the gain thereof. A rectifier-amplifier combination RA for controlling the voice operated relay 11 is connected to the voice input of the filter F. The voice operated relay 11, for purposes of illustration, is shown as comprising a solenoid so constructed that its armature will be attracted in proportion to the amplitude of the voice currents, thereby raising and lowering the armature. The armature is connected to the adjusting element of the potentiometer 10 in such a manner that as the amplitude of the voice current increases the solenoid adjusts the potentiometer to de-

crease the gain of the amplifier A, and if the amplitude of the voice current becomes lower than normal, the solenoid adjusts the potentiometer to increase the gain. Consequently, as the volume of the signal increases, the gain is decreased, and vice versa, so that there is a tendency to keep the volume transmitted over the line at a fairly constant level.

An auxiliary or controlling channel is provided at the transmitting station, said channel comprising a source G of alternating current having a frequency preferably outside of the voice range and a filter F′ for separating the controlling channel from the voice channel. The connections from the source G through the filter F′ are applied to the terminals of the potentiometer 10 in parallel with the voice connections. Consequently, the adjustment of the potentiometer 10, as the volume of the voice current transmitted rises and falls, has the effect of decreasing or increasing the magnitude of the controlling current as it appears on the output side of the amplifier A. Accordingly, the amplitude of the control frequency arriving at the receiving station will be decreased or increased in proportion to any change in the adjustment of the amplifier A of the transmitting station.

At the receiving station a similar amplifier A_1 is provided, said amplifier having an adjustable potentiometer 12 for controlling the gain of the amplifier. The voice currents are selected by a filter F_1 and transmitted to the voice channel while the controlling frequency is selected by the filter F_1' and transmitted to a detector D_1. The detector D_1 includes a relay R_1 in its output circuit, and this relay is so adjusted that when the normal amount of controlling current is received from the line, its armature does not rest on either contact. When the current received from the line is decreased, the armature closes one contact of the relay, and when the current is increased, it closes the other contact. This operation of the relay will be clear from the detector characteristic as shown by the curve of Fig. 2. The curve of Fig. 2 is obtained by plotting the alternate signaling currents (or potentials) applied to the detector as abscissæ, and the plate currents of the detector as ordinates. In order to make the curve of Fig. 2 as steep as possible the grid of the detector is normally biased sufficiently negative so that the applied alternating current must attain considerable magnitude before any plate current flows. By making the curve steep as shown the detector becomes very sensitive to slight changes in relative magnitude of the applied current. The contacts of the relay R_1 control the circuits of stepping magnets 13 and 14 which control a step by step mechanism 15 to rotate a shaft 16 carrying an arm 17 which is connected to the adjustable element of the potentiometer 12 to vary the setting thereof.

The operation is as follows:

If the current in the voice channel at the transmitting end becomes weaker than normal, the rectifier-amplifier combination RA produces a corresponding variation in the steady current flowing through the solenoid 11 which ultimately adjusts the potentiometer 10 to increase the gain of the amplifier A. This results in increasing the volume of the voice current applied to the transmission line L, and a corresponding increase in the amplitude of the controlling frequency from the source G is produced. The controlling current, therefore, arrives at the receiving end with increased volume, and upon being transmitted through the filter F′ to the detector D_1 causes an increase in the steady current flowing through the winding of the receiver R_1. The armature of the relay R_1 is accordingly moved to engage one of its contacts, say the upper contact, thereby completing a circuit through the winding of the stepping magnet 13 and through the interrupting relay 18. Impulses are now transmitted through the winding 13, thereby stepping the escapement wheel 15 to rotate the shaft 16 in such a direction that the potentiometer 12 is automatically adjusted to decrease the gain of the amplifier A_1. This adjustment continues until the amplitude of the controlling current impressed upon the detector D_1 is again restored to normal when the armature of the relay R_1 will move back to its neutral point. The potentiometer 12 will now be so set that the amplitude of the received voice current will have the same value as it would have had if the transmission had been direct without any increase in gain at the transmitting station and corresponding increase in gain at the receiving station.

If the current in the voice channel at the transmitting end increases in volume, the solenoid 11 automatically operates to adjust the potentiometer 11 to reduce the gain of the amplifier A. The decrease in the gain of the amplifier A produces a corresponding decrease in the amplitude of the controlling frequency from the source G, which accordingly arrives at the receiving station reduced in volume. The received controlling frequency at the receiving station is transmitted through the filter F_1' to the detector D_1, and owing to its decrease in volume produces a decrease in the steady direct current flowing through the winding of the relay R_1. The armature of the relay is therefore shifted to its lower contact, completing an interrupting circuit through the stepping magnet 14, which now steps the shaft 16 in the opposite direction and adjusts the potentiometer 12 to increase

the gain of the amplifier A_1. As the gain of the amplifier increases, the amplitude of the controlling current increases until it reaches its normal value when the armature of the relay R_1 will again assume its neutral position, and the adjustment of the shaft 16 will cease. The gain of the amplifier A_1 will now be so set that the amplitude of the voice current transmitted through the filter F_1 will be increased in proportion to the decrease in gain produced by the adjustment of the potentiometer 10 at the transmitting station. The over-all equivalent of the circuit is again the same as it was before the potentiometer at the transmitting end functioned.

It will be clear from the above operation that although the volume range of the voice current transmitted through the filter F may be quite wide, the volume range transmitted over the line L will be much narrower owing to the adjustment of the gain of the amplifier A. It will also be clear that the narrower range transmitted over the line will be translated into a volume range for transmission through the filter F_1 equal to the volume range transmitted through the filter F at the transmitting station. If the transmission equivalent of the line L should vary, due to changes in temperature or the like, the volume of the control frequency from the source G as it arrives at the receiving station will be correspondingly changed, thereby causing the relay R_1 to close one or the other of its contacts and automatically adjust the potentiometer 12 until the received controlling current impressed upon the detector D_1 is restored to its normal value. In other words, whenever the line equivalent varies from normal the equipment at the receiving end functions to restore the over-all equivalent to its normal value. Consequently the system above disclosed has the property of not only narrowing the range of volume transmitted from the transmission medium but of maintaining the transmission equivalent of the medium at a constant value.

While the invention as above described is shown applied to a line transmission medium, the invention is equally applicable to radio transmission, as illustrated in Fig. 1ª, in which the radio transmitter RT and its associated antenna, together with the radio receiver RR and its associated antenna, take the place of the transmission line of Fig. 1. The operation of the apparatus of Fig. 1ª will be apparent without further description.

In the case of line transmission, the volume range transmitted is limited, on the one hand, by the fact that the amplitude of the signaling current must be kept greater than the line or other interfering noise, while the maximum volume must not exceed the limit above which overloading of the tubes takes place. In the case of radio transmission, the upper volume limit will be determined by the overloading of the transmitting and receiving tubes, while the lower limit will be determined by static and other interfering noises.

It should be noted that the filter F, in addition to performing its selecting function, acts as a delay network to enable the automatic apparatus to adjust the potentiometer 10 in response to a change in volume, before the voice wave, in response to which the adjustment is made, has passed beyond the potentiometer. It will be noted, of course, that in order to accomplish this result the filter F may have a larger number of sections than the filter F′ in order to delay the wave passing through the filter F more than the wave passing through the filter F′.

A similar result may be accomplished at the receiving station by the modified arrangement illustrated in Fig. 3. Here, the amplifier A_1 and potentiometer 12 are arranged in the voice channel beyond the filter F_1 and a corresponding amplifier A_1', with its potentiometer 12′, is arranged in the control channel beyond the filter F_1'. The potentiometers 12 and 12′ are mechanically connected together to be operated by the arm 17, controlled by the escapement device 15.

The control frequency is selected by the filter F_1', passed through the amplifier A_1', and finally impressed upon the detector D_1. Consequently, if the amplitude of the control frequency departs from its normal value, the relay R_1 closes a circuit of the relay 13 or 14, as the case may be, to set the escapement mechanism 15 into operation, thereby adjusting the arm 17 and consequently the potentiometers 12 and 12′. When the potentiometer 12′ has been so adjusted that the amplitude of the control frequency impressed upon the detector is at its normal value, the armature of the relay R_1 will be in neutral position and the adjustment will cease. The potentiometer 12 will now be so adjusted that the change in volume introduced by the amplifier will just compensate for the change of volume introduced by the amplifier A and potentiometer 10 at the transmitting station.

By arranging the receiving apparatus in the manner above described, the filter F_1 may be so constructed as to delay the transmission of the voice currents to the potentiometer 12 and amplifier A_1 until the escapement device 15 has been operated to adjust the potentiometers 12 and 12′ in response to a change in volume. A wave corresponding to a change in volume will therefore just arrive at the potentiometer 12 at the time the potentiometer has been adjusted to compensate for the change in volume.

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 of the invention as defined in the following claims.

What is claimed is:

1. In a signaling system, a transmission medium, an adjustable transmission element at the transmitting end of said medium, means to apply signaling currents to said transmission element, means to adjust said transmission element in accordance with the variations in volume of the signaling current, means to apply a control frequency to said transmission element, a compensating transmission element at the receiving station, and means responsive to a change in amplitude of the received control current to adjust said compensating transmission element to compensate for the change in amplitude of the received control current.

2. In a signaling system, a transmission medium, an amplifier at the transmitting end of said medium, means to impress signaling currents upon said medium through said amplifier, means responsive to the change in amplitude of said signaling currents to adjust the gain of said amplifier, means to impress a controlling current upon said medium through said amplifier so that said controlling current will arrive at the receiving station with an amplitude determined by the change in the gain of the amplifier at the transmitting station, a compensating amplifier associated with said medium at the receiving station, and means at said receiving station responsive to any change in the amplitude of the received controlling current to produce a complementary adjustment of the gain of the amplifier of said receiving station.

3. In a signaling system, a transmission medium, an amplifier associated with said medium at the transmitting station, means to impress signaling currents on said medium through said amplifier, means responsive to a change in the volume of the signaling currents to produce a change in the gain of said amplifier, means to impress a controlling current upon said medium through said amplifier, said controlling current being transmitted over the medium and arriving at the receiving station with an amplitude determined by the change in the gain of said amplifier and any change in the transmission equivalent of said medium, a compensating amplifier associated with said medium at the receiving station, and means responsive to any change in the amplitude of the received control current to produce a compensating adjustment of the gain of the amplifier at said receiving station whereby the transmission equivalent of the system will be maintained substantially constant.

4. In a signaling system, a transmission medium, an adjustable transmission element associated therewith at the transmitting station, means to impress signaling currents upon said medium through such element, means to adjust said element in accordance with changes in the volume of the signaling current, means to impress a controlling current upon said medium through said element whereby said controlling current will arrive at a receiving station with an amplitude determined by the adjustment of said element and by any change in the transmission equivalent of said medium, a compensating adjustable transmission element associated with said medium at the receiving station, and means responsive to any change in the amplitude of said received control current to produce a compensating adjustment of the transmission element at the receiving station whereby the over-all transmission equivalent of the system will be maintained substantially constant.

5. In a signaling system, a transmission medium, an amplifier associated with said medium at a transmitting station, means to impress signaling currents upon said medium through said amplifier, means responsive to a change in the volume of said signaling currents to adjust the gain of said amplifier, means to impress a controlling current upon said medium through said amplifier, a compensating amplifier associated with said transmitting medium at the receiving station, a signal channel and a control channel associated with the output side of the amplifiers at the receiving station, means to select the signaling currents into the signaling channel, means to select the controlling currents into the controlling channel, and means responsive to a change in the amplitude of the selected controlling current to produce a compensating adjustment of the gain of the receiving amplifier.

6. In a signaling system, a transmission medium, an adjustable transmission element associated with said medium at the transmitting station, means to impress signaling currents upon said element, means responsive to changes in the volume of the signaling currents to produce a corresponding adjustment of said transmission element, means to impress a controlling current upon said transmission medium through said element, a compensating transmission element associated with said medium at the receiving station, a signal channel and a control channel at the receiving station, means to select signaling currents transmitted through the transmission element at the receiving station into the signal channel, means to select control currents transmitted through said transmission element at the receiving station into said control channel, and means responsive to changes in the amplitude of the selected control current to produce a compensating adjustment of

the transmission element at the receiving station.

7. In a signaling system, a transmission medium, and adjustable transmission element at the transmitting end of said medium, means to apply signaling currents to said transmission element, means to adjust said transmission element to keep the variations in volume of the signaling current transmitted to the medium within prescribed limits, means to apply a control frequency to said transmission element, said controlling frequency being transmitted over the medium and arriving at the receiving station with an amplitude determined by the adjustment of said transmission element, a compensating transmission element at the receiving station, and means to adjust said element in accordance with the amplitude of the received controlling frequency so that the transmission level will be raised when the received controlling frequency falls below normal and will be lowered when the received controlling frequency is above normal.

8. In a signaling system, a transmission medium, an amplifier at the transmitting end of said medium, means to impress signaling currents upon said medium through said amplifier, means to adjust the gain of said amplifier to keep the volume of the signals transmitted to said medium within prescribed limits, means to impress a controlling current upon said medium through said amplifier so that said controlling current will arrive at the receiving station with an amplitude determined by the change in the gain of the amplifier at the transmitting station, a compensating amplifier associated with said medium at the receiving station, and means to adjust the gain of said last mentioned amplifier so that the gain will be increased when the amplitude of the received controlling current is below normal and the gain will be decreased when the amplitude of the received controlling current is above normal.

9. In a signaling system, a transmission medium, an amplifier associated with said medium at the transmitting station, means to impress signaling currents upon said medium through said amplifier, means to adjust the gain of said amplifier to keep the volume of the transmitted signaling currents within prescribed limits, means to impress a controlling current upon said medium through said amplifier, said controlling current being transmitted over the medium and arriving at the receiving station with an amplitude determined by the change in the gain of said amplifier and any change in the transmission equivalent of said medium, a compensating amplifier associated with said medium at the receiving station, and means to adjust the gain of said last mentioned amplifier in accordance with the amplitude of the received controlling current so that the gain will be increased when the received controlling current falls below normal and will be decreased when the received controlling current is above normal, thereby maintaining the transmission equivalent of the system substantially constant.

10. In a signaling system, a transmission medium, an adjustable transmission element associated therewith at the transmitting station, means to impress signaling currents upon said medium through said element, means to adjust said elements to keep the volume of the transmitted signaling current within prescribed limits, means to impress a controlling current upon said medium through said element whereby said controlling current will arrive at the receiving station with an amplitude determined by the adjustment of said element and by any change in the transmission equivalent of said medium, a compensating adjustable transmission element associated with said medium at the receiving station, and means to adjust said transmission element to raise the transmission level when the received controlling current is below normal and to lower the transmission level when the received controlling current is above normal, thereby maintaining the over-all transmission equivalent of the system substantially constant.

In testimony whereof, I have signed my name to this specification this 9th day of September, 1924.

HARRY NYQUIST.