Dec. 3, 1929. E. I. GREEN 1,738,000

MEANS FOR AND METHOD OF VOLUME CONTROL OF TRANSMISSION

Filed Aug. 5, 1926

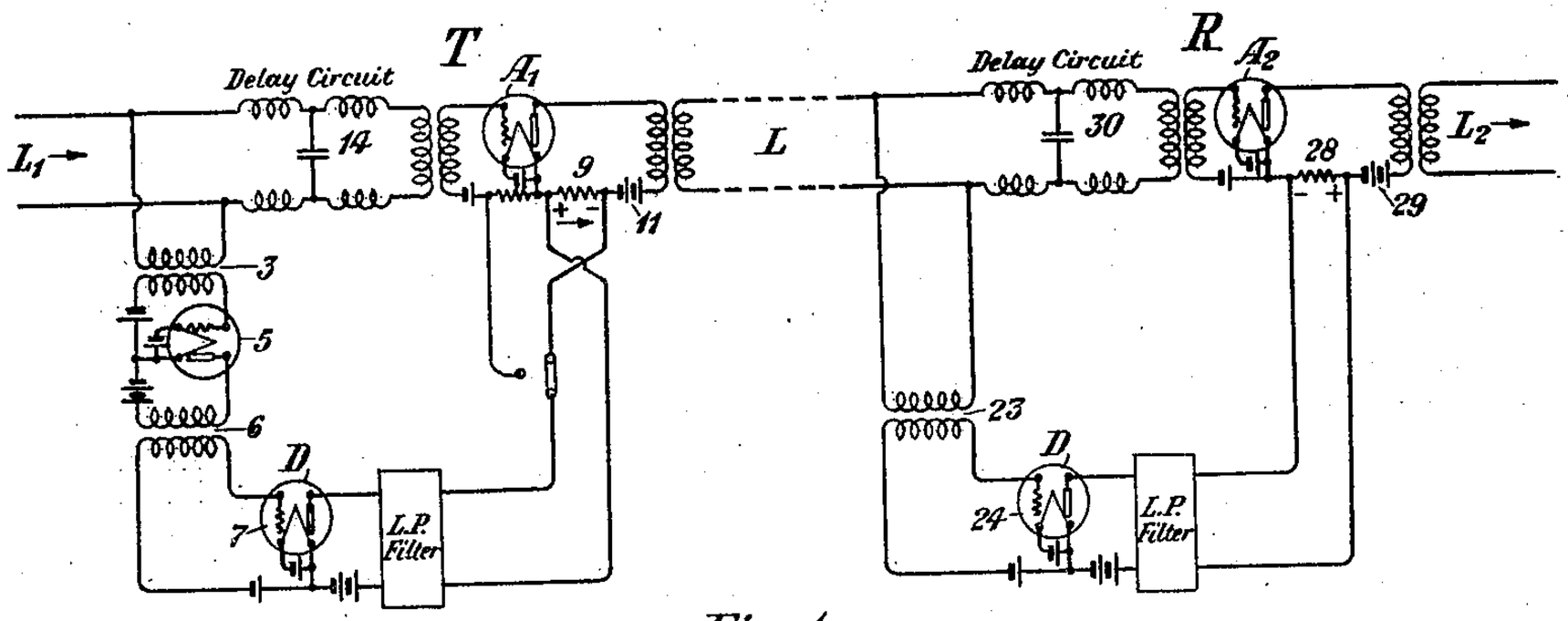

Fig. 1

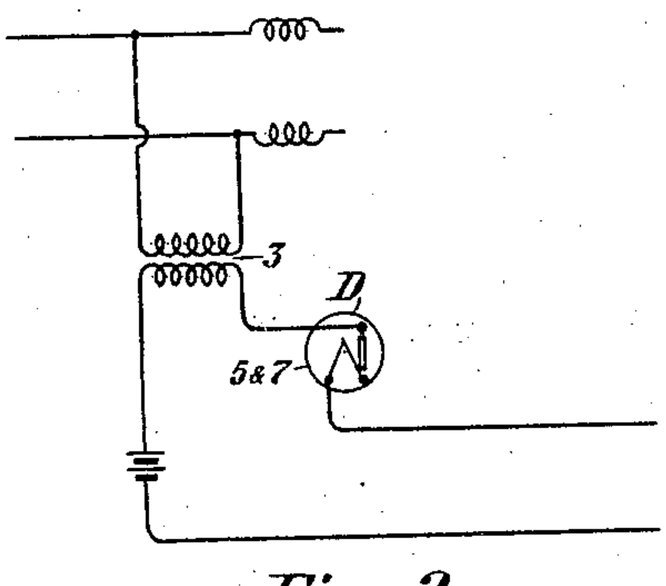

Fig. 2

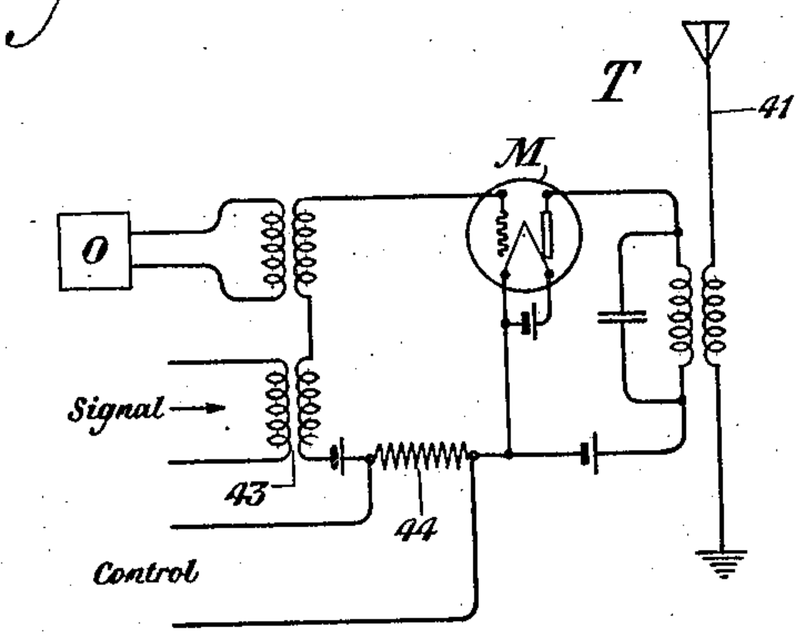

Fig. 3

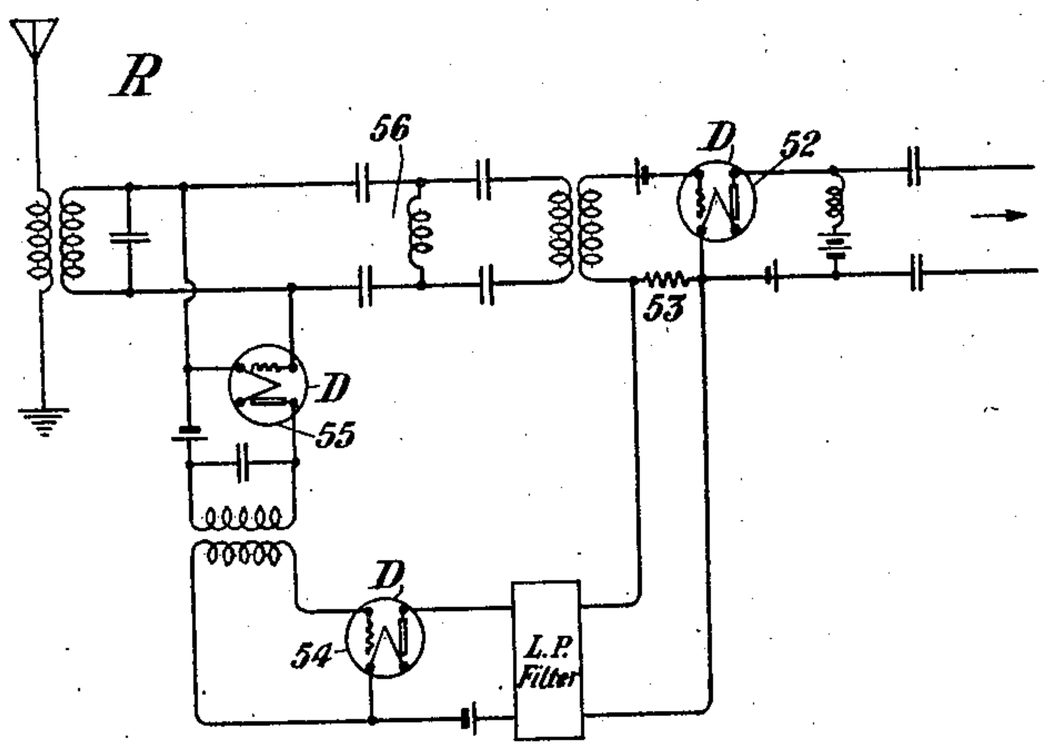

Fig. 4

INVENTOR
E. I. Green

BY

ATTORNEY

Patented Dec. 3, 1929 1,738,000

UNITED STATES PATENT OFFICE

ESTILL I. GREEN, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

MEANS FOR AND METHOD OF VOLUME CONTROL OF TRANSMISSION

Application filed August 5, 1926. Serial No. 127,394.

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 signal during transmission, and is related to such arrangements as are shown in application of Crisson, Serial No. 737,415, filed September 12, 1924.

In telephone transmission, and in other kinds of signaling as well, it is often desirable to transmit sounds, such as music, which have an extremely wide range of volume, over telephone circuits in which the volume range of currents which can be satisfactorily transmitted is limited on the one hand by interference from line noises, and on the other hand by the necessity of avoiding distortion due to overloading repeaters and interference on the other circuits. This is particularly true of such types of transmission systems as radio broadcasting circuits and public address systems.

In this invention, it is proposed to bring the signal within the volume limits of the transmission system by automatically changing the shape of the envelope of the signal wave, and I do this by taking advantage of the fact that the changes of volume in the voice or other signals occur at relatively low frequencies in comparison with the component frequencies of the signal. In other words, the changes of volume are very slow compared with the almost instantaneous changes of magnitude involved in alternating frequencies in the voice range, and by controlling the transmitted volume in accordance with the major swings in the voice current, the desired end may be attained.

More specifically, this is accomplished by applying the wave to a repeating or amplifying device, such as a thermionic amplifier, and modifying the amplifying factor in accordance with these relatively slow major changes in the energy level of the wave. The modification at the transmitting end obviously will be in such a direction as to reduce the energy level range, and in this invention I propose to make the amplifying or repeating factor proportional to some root or power less than unity of the envelope of the current wave. At the receiving end, the reverse condition is introduced, that is, the energy level or volume range is expanded in accordance with some power greater than unity, and preferably this power is the reciprocal of the power used for contraction at the transmitting end. By this method, it is possible to avoid very substantially the generation of numerous harmonics, such as will be the case if the amplifying factor is changed at a very high rate.

The invention will be better understood by reference to the following description taken with the accompanying drawing, in which Figure 1 shows one form of circuit for accomplishing this purpose, there being indicated a complete system comprising a transmitting and a receiving station. Fig. 2 is a modification of the transmitting station of Fig. 1. Figs. 3 and 4 show one manner in which the invention may be applied directly to radio communication.

Referring more specifically to Fig. 1, there is shown a line L_1 over which will come any suitable telephone current generated by speech or music. This telephone current wave passes through an amplifier A_1, and thence over a transmission line to the receiving station where it is again impressed upon an amplifier A_2, whence it passes over the line L_2 to a telephone receiver of any suitable form. In case the volume changes of the incoming message are very considerable, various undesirable effects may be produced as noted above, and to obviate these difficulties, I desire to narrow the volume range which the amplifier A_1 and the transmission line L must carry. Accordingly, across the line L_1 there is connected a transformer 3, the secondary of which is connected to the input circuit of a vacuum tube device 5, which device has a non-linear characteristic of such a form that the output is not proportional to the input, but is proportional to some root of that input, or, expressed in other words, is proportional to some power or exponent of that input, this power or exponent being less than unity. A very suitable value for this exponent to take, and one which it is convenient to use in visualizing this invention, is the exponent or power 5/10, in which case if an arbitrarily chosen portion of

the incoming wave is spoken of as having an energy amplitude of 1, and if another portion has an energy amplitude four times as great, then in the output of the device 5 the second portion of the wave will have an amplitude only two times as great as that of the first portion of the wave. This modified wave train is then passed on by transformer 6 to the input of a detecting or rectifying device 7, which is here shown as a thermionic device. In the output of this detector 7 there is a low-pass filter which will by-pass or suppress all currents except those of very low frequency, the cut-off value in this case being slightly above that corresponding to the frequency of the major swings in the telephonic wave train. The output of this detector 7 also includes a resistance 9, which resistance is at the same time included in the output circuit of the amplifier A_1, the polarity of connections from the detector 7 to the resistance 9 being as indicated on the drawing. Under these conditions, it will be seen that if the volume of the telephone current wave arriving on the line L_1 increases, the current flowing through the resistance 9 considered as a portion of the detector 7 would be increased, and the potential drop consumed therein would be correspondingly increased. The voltage from the battery 11, which is then available from the filament to plate portion of the amplifier A_1, is reduced, and the effective amplifying factor of the output circuit will be reduced. Thus, there results a compression of the volume range of the incoming signal message, the compression being in accordance with and controlled by the major swings in volume of that incoming message.

It is apparent that a certain amount of time has been consumed in transmitting the signal through the path 3, 5, 6 and 7, so that there is a certain delay in the arrival at the resistance 9 of the detected or rectified low frequency currents. On the other hand, the signal in being transmitted through the amplifier A_1, has not been subjected to a corresponding delay, and for the best results it is desirable that a corresponding delay should be introduced in order to bring the two effects into synchronism. To this end, there is shown in the input circuit of the amplifier A_1 a delay circuit 14, which may comprise inductances and capacities connected in a suitable manner to increase the time of transmission of signal, and thus introduce the necessary delay.

The signal, with the modified or contracted wave form, may now be transmitted over the line L to the receiving station R, at which it will ordinarily be desirable to reverse the process that is used for the previous contraction by applying a corresponding expansion. At this receiving station, there is shown an amplifier A_2 of the thermionic type, which in itself would naturally be chosen to have an approximately straight-line characteristic. In this case, also, however, the characteristic of the circuit as a whole may be modified by a side circuit consisting of a transformer 23 bridged across the incoming line L. The secondary of this transformer is connected to the input of a detecting or rectifying device 24, the output circuit of which includes a resistance element 28, which is included also in the output circuit of the amplifier A_2. Also included in the output circuit of the detector or rectifier 24 is a low-pass filter which is adapted to pass only those frequencies which are in the neighborhood of or below that corresponding to the major swings in volume of the incoming message. As a result, there would flow through the resistance 28, by virtue of its connection with the detector 24, a current which fluctuates in value in accordance with the envelope of the received contracted wave. In this case, the current from the detector D flows in such a direction that when variations occur in that current, the resulting potential difference across the resistance 28 will be in a direction to aid the battery 29, thus increasing the effective amplifying factor of the amplifier A_2 when the incoming current on the detector 24 increases. The amplifying circuit at the station R thus has a non-linear characteristic, the non-linearity being the reverse of that introduced at the transmitting station T, and, by proper choice of characteristics, may be made to completely neutralize the contraction introduced at the transmitting station so that a message with normal volume range will be transmitted over the line L_2.

Here, again, it will be desirable to introduce a delay in the arrival of the message at the input of the amplifier A_2 because of the time element involved in transmitting the message over the path 23, 24 and to the resistance element 28. Such a delay circuit is therefore shown at 30, this again being of any well-known form.

It is obvious that many variations may be introduced in this circuit arrangement without departing from the spirit of the invention. For example, the control may be obtained by placing the resistance element 9 in the input circuit of the amplifier A_1, as indicated in dotted lines, care, of course, being taken to have the connections properly poled. A similar change might be introduced at the receiver station. It is also apparent that instead of sending the message out on a line L, any suitable transmission channel might be used, such as a radio channel, in which case the amplifier A_1 could be connected to a suitable oscillation generator and modulation system connected to an antenna, this communicating with a corresponding receiving station. Also, it should be noted that the modifying characteristic of the tube 5 may be combined with the detecting or rectifying action of the tube 7, so that both functions are

performed by a single tube. Such a modification of that portion of the circuit is shown in Fig. 2, in which the transformer 3 is shown connected directly to a detector tube marked 5 and 7, this tube having the proper characteristic to perform both functions.

In some instances it may be found that the required compression of the volume range is so great that it cannot be conveniently accomplished through the control of a single amplifier as illustrated at A_1. Such cases may evidently be taken care of by the use of one or more additional compressors identical with or similar to the one shown at the transmitting side of Fig. 1, the several compressors being connected in series to perform the function desired. Correspondingly, additional receiving circuits connected in series may be used for the restoration of the original volume range.

In case this invention is to be used for carrier or radio circuits, or for radio broadcasting purposes, it may be desirable to control the extent of modulation of the carrier frequency, this control being exercised by the low frequency current arriving from the detector D. Similarly, at the radio receiving station it may be desirable to control the demodulating or detecting device in a corresponding manner. One method of accomplishing this is shown in Figs. 3 and 4, the first of which represents a radio transmitting station, and the second, a radio receiving station. In Fig. 3, there is shown the antenna 41, to which is connected a modulating tube M, this modulator being supplied with high frequency oscillations from the generator O, and with signal currents of normal wave form transmitted by the transformer 43. A suitable filter or tuned circuit may be inserted between the modulator M and the antenna 41 in order to eliminate the undesired products of modulation. In order to modify the extent of modulation in accordance with the volume arriving on the transformer 43, the efficiency of modulation would be controlled by the circuit 44 coming directly from the detector 7 and in effect serving as a variable, but slowly variable, bias on the modulating tube M. Similarly, at the receiving station R of Fig. 4, the demodulating or detecting efficiency of the detector 52 would be controlled by a corresponding slowly varying bias introduced in any suitable way, such as over the resistance 53, this slowly varying bias being derived from the detector 54, which in turn has received from the detector 55 the received signal frequency arriving on the receiving antenna. In this case, also, it might be desirable to introduce a delay circuit 56 in front of the detector 52 for the purposes already described.

Other methods of accomplishing the compression and expansion in carrier or radio circuits, such as, for example, the use of the control current to regulate the amount of the carrier current supply, will be readily apparent. Then again, in some cases it may be desirable to compress the volume range at the transmitting end without a corresponding expansion at the receiving end, and it is to be understood that all of these and other obvious modifications still come within my invention.

It should be pointed out that while in the description the element A_1 of Fig. 1 and the corresponding elements elsewhere are spoken of as amplifiers, the essential feature of the invention is that these elements shall be repeating elements adapted to compress the volume. While, in general, it will be convenient to have them increase the power, they may actually introduce a loss, corresponding to an amplification factor of less than unity and it is in this light that the term amplification factor should be interpreted in the specification and claims.

What is claimed is:

1. In a signaling system, a transmitting station, a source of a telephone current wave of varying volume, means for amplifying the wave, means associated with and adapted to modify the amplification factor of said amplifying means in accordance with a power of the envelope of the telephone current wave, said power being less than unity.

2. In a signaling system, a transmitting station, a source of a telephone current wave of varying volume, means for amplifying and transmitting the wave, means associated with and adapted to modify the amplification factor of said amplifying means in accordance with the envelope of the telephone current wave, means for receiving said modified wave, a translating device associated therewith comprising an amplifier and a detector operated upon directly by the received wave for modifying the amplification factor of the amplifier in accordance with the envelope of the received wave but in the reverse manner from that at the transmitting station.

3. In a signaling system, a transmitting station, a source of a telephone current wave of varying volume, means for amplifying and transmitting the wave, means associated with and adapted to modify the amplification factor of said amplifying means in accordance with the nth power of the envelope of the telephone current wave where n is less than unity, means for receiving said modified wave, a translating device associated therewith comprising an amplifier and means for modifying the amplification factor of the amplifier in accordance with a power of the envelope of the received wave, the power being the reciprocal of the power at the transmitting station.

4. In a signaling system, a source of a telephone current wave of varying volume, means for amplifying the wave, means associated

with and adapted to modify the amplification factor of said amplifying means in accordance with the envelope of the telephone current wave, said means comprising a vacuum tube with a non-linear characteristic and a rectifier connected to the output thereof and associated with the amplifier.

5. In a signaling system with a source of telephone current wave of varying volume, the method of signaling which consists in generating the signal wave comprising the wave in accordance with the nth power of the amplitude of the wave envelope where n is less than unity, transmitting the wave, receiving the wave and expanding it in substantial accordance with the $\frac{1}{n\text{th}}$ power of the amplitude of the received wave.

6. In a signaling system, a transmitting station, a source of a telephone current wave of varying volume, means for amplifying and transmitting the wave, means associated with and adapted to modify the amplification factor of said amplifying means in accordance with the envelope of the telephone current wave, means for receiving said modified wave, said means comprising a receiving amplifier, a translating device associated therewith and operated upon directly by the modified received wave and adapted to modify the amplification factor of the receiving amplifier in accordance with a power of the envelope of the received wave, said power being greater than unity.

In testimony whereof, I have signed my name to this specification this 3rd day of August, 1926.

ESTILL I. GREEN.