Oct. 8, 1935. E. I. GREEN 2,016,427

VOLUME RANGE CONTROL

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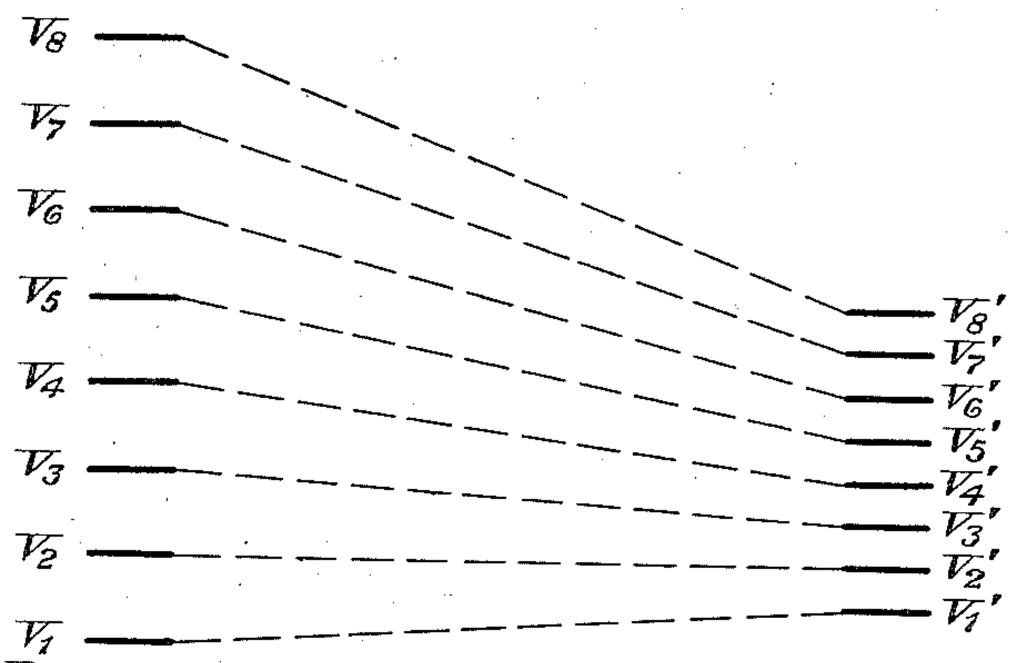

Fig. 1

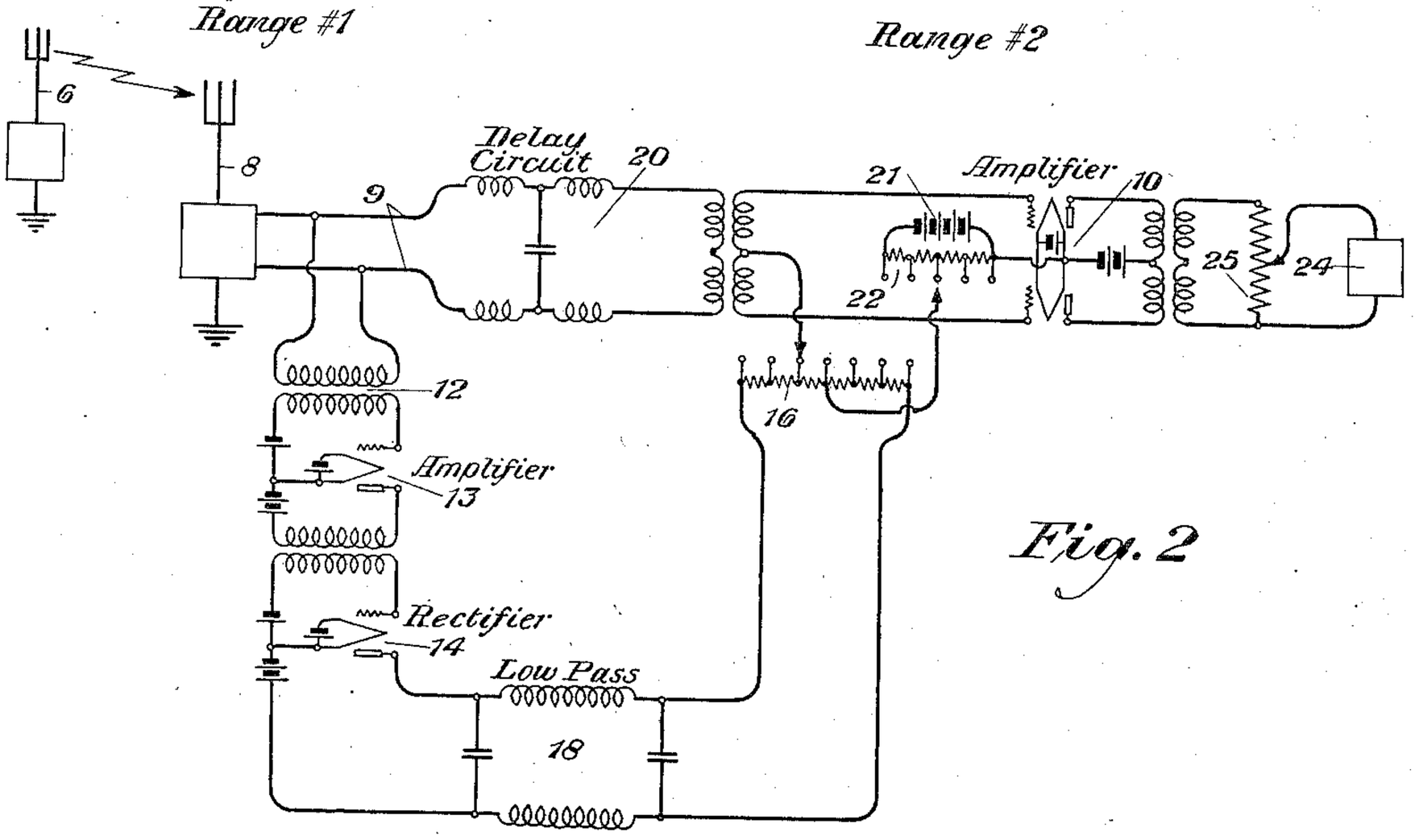

Fig. 2

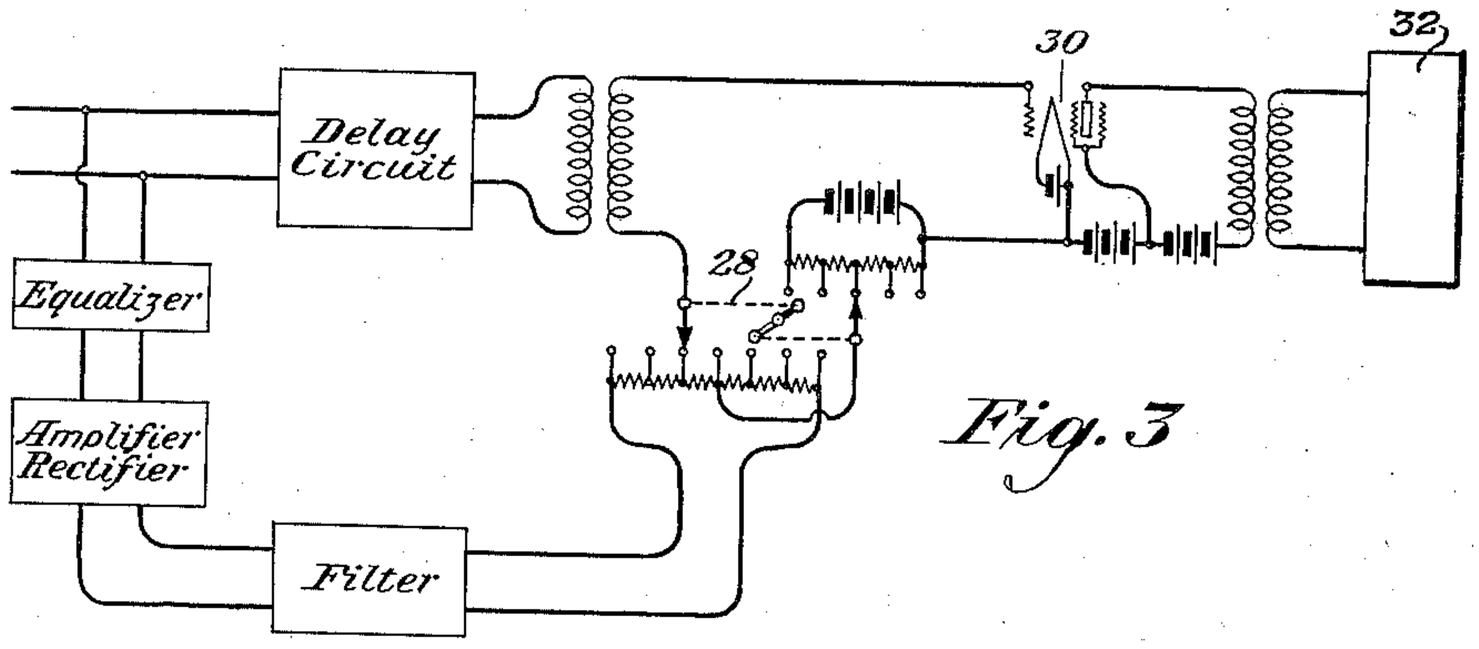

Fig. 3

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VOLUME RANGE CONTROL

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This invention relates to volume range control for such devices as loud speakers and telephone receivers for radio and other communications and is especially applicable in connection with the reception of broadcast programs, whether by radio or wire channels. Here the term, volume range, refers not so much to the volume or loudness of the program but to the ratio of the maximum to the minimum of the program volume.

The object of the invention is to provide means whereby not only the absolute volume but also the range of volume may be under the control of the listener. The former of these is common in the art and, generally, consists of means such as potentiometers in the input of an amplifier or other device by which the portion of the incoming program voltage to be applied to the amplifier or other portion of the receiving system may be increased or decreased, as desired. While such a device changes the loudness or absolute volume of the program, it affects all parts in the same way so that the ratio of maximum to minimum loudness of a given program, i. e. the volume range, is not altered.

The invention will be better understood by reference to the following specification and the accompanying drawing in which Figure 1 is illustrative of changes in volume range. Fig. 2 is a circuit embodying my invention, and Fig. 3 is a modification thereof.

In present broadcasting, the range of acoustic volume delivered to the transmitting system varies widely, depending upon the nature of the program but in some cases may amount to as much as 60 to 100 decibels, i. e. an energy ratio of maximum to minimum volume of 10^6 to 10^{10}. Here the decibel is a transmission unit defined by the relation $L=10 \log_{10} V_1/V_2$, where L is the number of decibels difference in volume of two acoustic outputs of energy of volume V_1 and V_2, respectively. It will be observed that it depends on the ratio and not on the difference of the volumes or loudness. The volume range which can be handled by the transmitting system (extending from pickup point to the transmitting antenna) is definitely limited, the maximum volume being fixed by the overload point of the apparatus and similar considerations and the minimum volume being limited by the noise or interference which enters in various parts of the system. The present broadcast transmission systems are limited to a range of something like 25 or 30 decibels, i. e. a ratio of maximum to minimum volume of about 10^3. In other words, if the volume range exceeds this amount, and the absolute volume is set so that the minimum volume still is sufficiently loud with respect to the noise inherent in the transmission system, then the maximum volume would be so large as to overload the system and produce distortions. On the other hand, if the absolute volume is reduced so that the maximum volume does not produce distortion then, at minimum volume, the ratio of noise to signal frequency will be too large.

According to present practice, whenever the range of acoustic volume exceeds the range which can be accommodated by the transmitting system, it is narrowed down to its limit. This narrowing process may be accomplished in various ways; the simplest being that in which an individual acting as a monitor decreases the volume when it becomes excessive and increases the volume when it becomes very low, using his best judgment as to when and how large the changes shall be. Obviously, such changes introduce a departure from faithful reproduction of the program at the receiving station unless some compensating device is brought in to restore the original relationships. It is apparent that in the manual adjustment by the monitor, mentioned above, the element of judgment which is involved in the time sequence of the changes which are introduced makes it difficult to introduce a subsequent correction of the distortion resulting from the manual adjustments. Such correction could best be made if uniform expansion or contraction of the volume range can be obtained. The term, uniform expansion or contraction of the volume range, will be better understood by reference to Fig. 1 which in one direction shows volume range contraction with reduction for maximum volume and increase for minimum volume. The various steps of volume in one range may be designated by V_1, V_2 * * * V_8, which, it will be assumed, are to be contracted into a range designated by the corresponding steps V_1', V_2' * * * V_8'. In passing from one of these volume ranges to the other, the volume range will be contracted or expanded uniformly if uniform increments of volume in the initial range remain uniform in the resultant range. This may be expressed in another way by saying that $V_n/V_m=V_n'/V_m'$. The shift of either range in its entirety along the volume scale is of no significance in this connection since such a shift means merely a relative gain or loss.

In order to obtain at least an approximation to such uniform expansion or contraction, various automatic arrangements have been proposed

such as that disclosed in my Patent No. 1,738,000 of December 3, 1929, in which automatic volume contraction is obtained at the transmitting end and compensating expansion is obtained at the receiving station. It may occur, however, that while contraction at the transmitting station was necessary in order to keep within the limitations of the transmission system, even after corresponding expansion at the receiving station one may not be working up to the limitations of the volume range of the receiving apparatus. This is quite likely to be the case for the reason that properly designed receivers will, in general, handle a wider volume range than is delivered to them at the present time.

Furthermore, the volume range which is desired by the listener will be different from time to time and may be wider or narrower than the volume range delivered to him by his receiver. The maximum volume which he desires will depend upon such factors as the nature of the program, his position with reference to the loud speaker, the possibility of annoyance to others, etc., while the minimum volume which is satisfactory will depend upon the room noise and similar factors. Accordingly, in my invention, I propose to provide the listener with some means of adjusting the volume range delivered by his reproducing apparatus so as to suit his requirements at any time.

An arrangement for accomplishing this result is shown in Fig. 2, which consists of an amplifier 10 which receives program signals from any source such as the radio transmitting station 6. It is to be understood that at the transmitting station 6 the program has been narrowed, if necessary, to such a volume as to come within the limits of the apparatus of that transmitting set. At the receiving station 8 there will be suitable detectors and amplifiers which then supply the amplifier 10 referred to above. In the part of the receiving circuit which precedes the amplifier 10 there may be included an automatic gain control arrangement, such as, for example, an arrangement in which the carrier current is rectified and the rectified voltage used to control the receiving circuit in such a manner as to compensate for changes in the efficiency of the transmitting medium. Such an arrangement is disclosed in United States Patent No. 1,511,015 to H. A. Affel. An arrangement of this type does not, of course, affect the volume range of the program.

In accordance with my invention, provision is made for automatically expanding or contracting the volume range delivered by amplifier 10 and, in addition, provision is made by which the listener may vary or control the degree of the expansion or contraction of the volume range. To this end, I bridge across the line circuit 9 a transformer 12 feeding into an amplifier 13 and from thence into a rectifier 14. The output of this rectifier contains a resistance 16, one point of which, preferably the midpoint, is connected to the filaments of the amplifier 10 which is here shown as a push-pull amplifier. The space current of rectifier 14 normally flowing through the resistance 16 introduces a certain bias to the grids of the amplifier 10 and as the volume of the incoming program changes, the size of this rectifier space current changes, thus altering the bias of the amplifier grids and therefore changing the gain of said amplifier. The extent to which the gain is controlled can be altered by using a larger or smaller portion of the resistance 16 and, to this end, I make the contact from the grids to the resistance element a variable one. Furthermore, it will be observed that such bias as is introduced on the grids from this rectifier output may be made positive or negative thus allowing for either contraction or expansion, as desired.

From the circuit as thus described, it will be observed that if the incoming program volume increases, the current through the rectifier increases and therefore the drop through any portion of the resistance 16 increases. With the circuit as connected in Fig. 2, it will be observed that such increase in volume will be accompanied by an increase in the negative biasing of the grids resulting in the decrease of the amplification of the amplifier 10 and thus a decrease in the volume output of said amplifier. On the other hand, as the volume decreases, the bias will correspondingly decrease and the gain of the amplifier will be greater. Such a connection then results in a contraction of the volume range and it may be said that the amplification factor is a power less than unity of the speech envelope. Furthermore, it will be observed that if the contact of the grids is shifted to the opposite side of the midpoint connection of resistance 16, then the reverse action takes place, namely, expansion of volume range and the amplification factor is a power greater than unity of the speech envelope. Having set the contact at any one point on the resistance 16, the contraction or expansion is automatic but the amount of such contraction or expansion may be altered at will by shifting the contact on the resistance 16.

It is desirable that the changes in volume range shall be in accordance only with the major or slow swings of the program volume. For this purpose, a low-pass filter 18 is introduced in the output of the rectifier 14. Also, it is desirable to correct for the time required for operation of the rectifier circuit 14 and, for this purpose, I introduce a delay network 20 in the main transmission channel, as shown.

It will be recognized that with a rectifier of the type shown in Fig. 2, there is normally a space current flowing through the rectifier and the resistance element 16 which gives a definite bias to the grids of amplifier 10 in addition to such changes in this bias as may result from volume changes arriving on the conductors 9. If now, one changes the position of the contact to the element 16, the amount of this bias will change, and in order that operation shall be kept at substantially the same point on the operating characteristic of the tubes 10, I find it desirable to make corresponding correction therefor. This may be accomplished by the potentiometer 22 and battery 21, and, in general, I find it convenient to gear together the adjustments on the resistances 16 and 22 in such manner as to automatically make the necessary compensation as the adjustment of 16 is changed. One mode for accomplishing this is shown at 28 in Fig. 3. In addition, the element 22 may be used for changing the absolute volume of the program by independent adjustment, although I prefer to have such volume control obtained by independent means such as the potentiometer 25 connected in front of the loud speaker 24, or other reproducing device.

In the event that sufficient contraction or expansion of volume range is not obtained by one stage, then it is possible to connect two such controls as shown in Fig. 2, in tandem, or as many more as may be necessary, it being evident from the nature of the circuit connections that there is no limit to the number of such circuits which may

be connected one after the other. This is illustrated by the element 32 in Fig. 3.

Fig. 3 shows a modification of Fig. 2 in which a single amplifier 30 is used instead of the push-pull arrangement of Fig. 2. Also, in this case, the tube shown is that known as a screen grid tube. Such a tube has the interesting property, when suitably designed, of having a variable amplification factor, the mutual conductance of the tube being an exponential function of the bias applied to the control grid. The amplification can be made proportional to the mutual conductance so that it also will be an exponential function of the control grid bias. The combination of this exponential amplification with the other controls shown is particularly effective. In the rectifier circuit there is also shown an equalizer to bring the frequency-amplitude response characteristic to any desired form. Otherwise the operation is as described above.

What is claimed is:

1. In a signaling system, a source of audio frequency telephone current waves varying in volume over a definite volume range extending from a maximum volume to a minimum volume during the communication of intelligence, the energy ratio of said maximum to said minimum volume being definite, means responsive to changes in volume of said telephone waves to uniformly change the volume range into a volume range having a different energy ratio of maximum to minimum, the volume ranges being so related that uniform increments of volume in the new range will correspond to uniform increments in the old range means for altering at will the amount of change in volume range, and means to restore the average volume to normal when the amount of change in volume range is altered.

2. In a signaling system, a source of audio-frequency telephone current waves varying in volume over a definite volume range extending from a maximum volume to a minimum volume during the communication of intelligence, the energy ratio of said maximum to said minimum volume being definite means responsive to changes in volume of said telephone waves to uniformly change the volume range into a volume range having a different energy ratio of maximum to minimum, the volume ranges being so related that uniform increments of volume in the new range will correspond to uniform increments in the old range, means for altering at will the amount of change in volume range, and means whereby the change in volume range may be made either an expansion or a contraction of the range as desired.

3. In a signaling system, a source of audio-frequency telephone current waves varying in volume over a definite volume range extending from a maximum volume to a minimum volume during the communication of intelligence, the energy ratio of said maximum to said minimum volume being definite, an amplifier for said telephone waves, a rectifier to rectify said waves, said amplifier and rectifier having their inputs connected in parallel and the output of said rectifier varying in accordance with the volume of said telephone waves, means for applying a voltage derived from the rectifier output to a control electrode of the amplifier in such manner as to uniformly change the volume range of the telephone currents applied to the amplifier into a volume range in the output having a different energy ratio of maximum to minimum, the volume ranges being so related that uniform increments of volume in the new range will correspond to uniform increments in the old range, means for altering at will the amount of change in volume range by altering the proportion of the rectifier output voltage applied to said amplifier, and means to alter the direction in which the voltage is applied to the amplifier so that the change in volume range may be made either an expansion or a contraction of the range as desired.

4. In a signaling system, a source of audio-frequency telephone current waves varying in volume over a definite volume range extending from a maximum volume to a minimum volume during the communication of intelligence, the energy ratio of said maximum to said minimum volume being definite, an amplifier for said telephone waves comprising a vacuum tube whose mutual conduction is an exponential function of its grid bias, a rectifier to rectify said waves, said amplifier and rectifier having their inputs connected in parallel and the output of said rectifier varying in accordance with the volume of said telephone waves, means for applying a desired fractional portion of the voltage derived from the rectifier output to a control electrode of the amplifier in such manner as to automatically change the volume range of the telephone currents applied to the input of the amplifier into a volume range in the output bearing an exponential relation to the input currents so that energy ratio of maximum to minimum volumes will be different in the two ranges, the volume ranges being so related that uniform increments of volume in the output range will correspond to uniform increments in the old range, means for altering at will the amount of change in volume range, and means to restore the average volume to normal when the amount of change in volume range is altered.

5. In a signaling system, a source of audio-frequency telephone current waves varying in volume over a definite volume range extending from a maximum volume to a minimum volume during the communication of intelligence, the energy ratio of said maximum to said minimum volume being definite, an amplifier for said telephone waves, a rectifier to rectify said waves, said amplifier and rectifier having their inputs connected in parallel and the output of said rectifier varying in accordance with the volume of said telephone waves, a resistance impedance in the output of said rectifier, variable tap connections to said resistance from the input of said amplifier to apply a portion of the voltage across said resistance to the control electrode of the amplifier in such manner as to uniformly change the volume range of the telephone currents applied to said amplifier into a volume range in the output having a different energy ratio of maximum to minimum, the volume ranges being so related that uniform increments of volume in the new range will correspond to uniform increments in the old range, said variable tap connections being so arranged as to permit of altering at will the amount of change in volume range by altering the proportion of the voltage in said resistance applied to said amplifier, said taps also being arranged to permit of altering the direction in which the voltage is applied to the amplifier so that the change in volume range may be made either an expansion or a contraction of the range as desired.

6. In a signaling system, a source of audio-frequency telephone current waves varying in volume over a definite volume range extending from a maximum volume to a minimum volume during

the communication of intelligence, the energy ratio of said maximum to said minimum volume being definite, an amplifier for said telephone waves, a rectifier to rectify said waves, said amplifier and rectifier having their inputs connected in parallel and the output of said rectifier varying in accordance with the volume of said telephone waves, a resistance impedance in the output of said rectifier, variable tap connections to said resistance from the input of said amplifier to apply a portion of the voltage across said resistance to the control electrode of the amplifier in such manner as to uniformly change the volume range of the telephone currents applied to said amplifier into a volume range in the output having a different energy ratio of maximum to minimum, the volume ranges being so related that uniform increments of volume in the new range will correspond to uniform increments in the old range, said variable tap connections being so arranged as to permit of altering at will the amount of change in volume range by altering the proportion of the voltage in said resistance applied to said amplifier, said taps also being arranged to permit of altering the direction in which the voltage is applied to the amplifier so that the change in volume range may be made either an expansion or a contraction of the range as desired, and a biasing potentiometer circuit in series with said resistance in the amplifier circuit to adjust the average volume in such manner as to compensate for a change in the average volume resulting from adjusting the tap connections to said resistance.

7. In a signaling system, a source of audio-frequency telephone current waves varying in volume over a definite volume range extending from a maximum volume to a minimum volume during the communication of intelligence, the energy ratio of said maximum to said minimum volume being definite, an amplifier for said telephone waves, a rectifier to rectify said waves, said amplifier and rectifier having their inputs connected in parallel and the output of said rectifier varying in accordance with the volume of said telephone waves, a resistance impedance in the output of said rectifier, variable tap connections to said resistance from the input of said amplifier to apply a portion of the voltage across said resistance to the control electrode of the amplifier in such manner as to uniformly change the volume range of the telephone currents applied to said amplifier into a volume range in the output having a different energy ratio of maximum to minimum, the volume ranges being so related that uniform increments of volume in the new range will correspond to uniform increments in the old range, said variable tap connections being so arranged as to permit of altering at will the amount of change in volume range by altering the proportion of the voltage in said resistance applied to said amplifier, said taps also being arranged to permit of altering the direction in which the voltage is applied to the amplifier so that the change in volume range may be made either an expansion or a contraction of the range as desired, and a biasing potentiometer circuit in series with said resistance in the amplifier circuit to adjust the average volume, the means for varying the resistance connections and the potentiometer connection being so geared together that the adjustment of the potentiometer will compensate for a change in the average volume resulting from adjusting to the tap connections to said resistance.

8. In a signaling system, a source of audio-frequency telephone current waves varying in volume over a definite volume range extending from a maximum volume to a minimum volume during the communication of intelligence, the energy ratio of said maximum to said minimum volume being definite, an amplifier for said telephone waves, a rectifier to rectify said waves, said amplifier and rectifier having their inputs connected in parallel and the output of said rectifier varying in accordance with the volume of said telephone waves, an impedance in the output of said rectifier, a connection from the filament of said amplifier to the midpoint of said impedance, a connection from the grid of said amplifier to adjustable taps on said impedance on either side of the mid-point thereof, whereby a portion of the voltage across said impedance may be applied to said amplifier to uniformly change the volume range of the telephone currents applied to said amplifier into a volume range in the output having a different energy ratio of maximum to minimum, the volume ranges being so related that uniform increments of volume in the new range will correspond to uniform increments in the old range, the connection of said taps at varying distance from the mid-point permitting of altering at will the amount of change of volume range by altering the proportion of the voltage in said impedance applied to said amplifier, and the connection of said grid to a tap on the one side or the other of said mid-point permitting of altering the direction in which the voltage is applied to said amplifier so that the change in volume range may be made either an expansion or a contraction of the range as desired.

9. In a signaling system, a source of audio-frequency telephone current waves varying in volume over a definite volume range extending from a maximum volume to a minimum volume during the communication of intelligence, the energy ratio of said maximum to said minimum volume being definite, an amplifier for said telephone waves including two vacuum tubes in push-pull relation, a rectifier acted upon by the incoming telephone waves and the output of said rectifier varying in accordance with the volume of said telephone waves, means for applying a voltage derived from the rectifier output in common to the grid of the amplifier tubes in such manner as to uniformly change the volume range of the telephone currents applied to said amplifier into a volume range in the output having a different energy ratio of maximum to minimum, the volume ranges being so related that uniform increments of volume in the new range will correspond to uniform increments in the old range, and means for altering at will the amount of change in volume range by altering the proportion of the rectifier output voltage applied to said amplifier.

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