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EXPANDER AND LIMITER CIRCUITS

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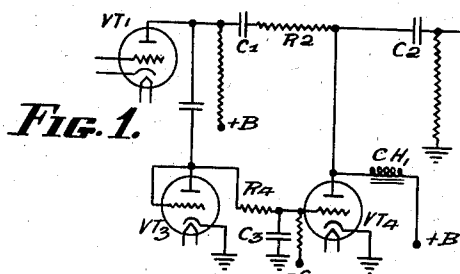


FIG. 1.

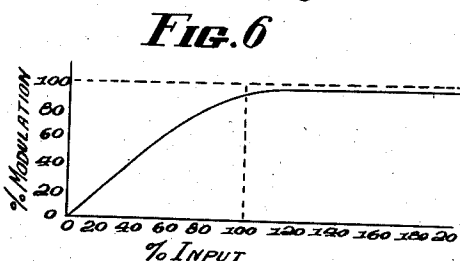


FIG. 6

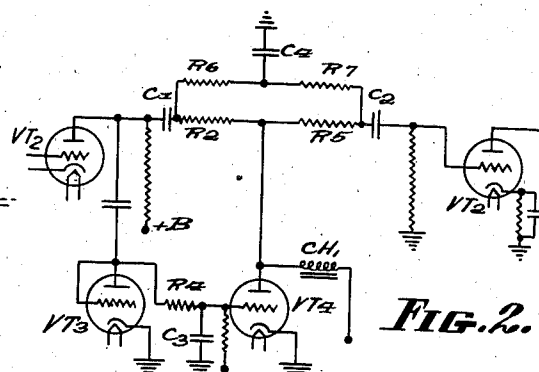


FIG. 2.

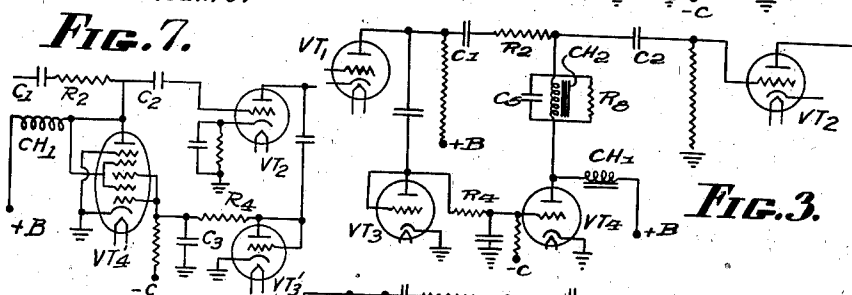


FIG. 3.

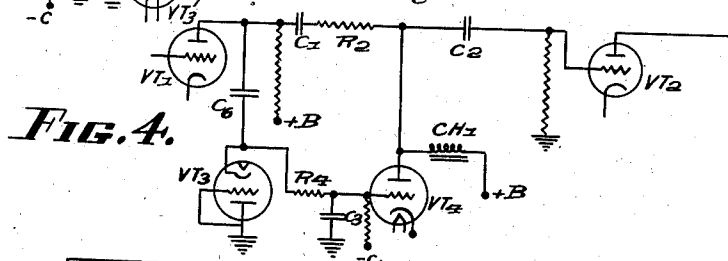


FIG. 4.

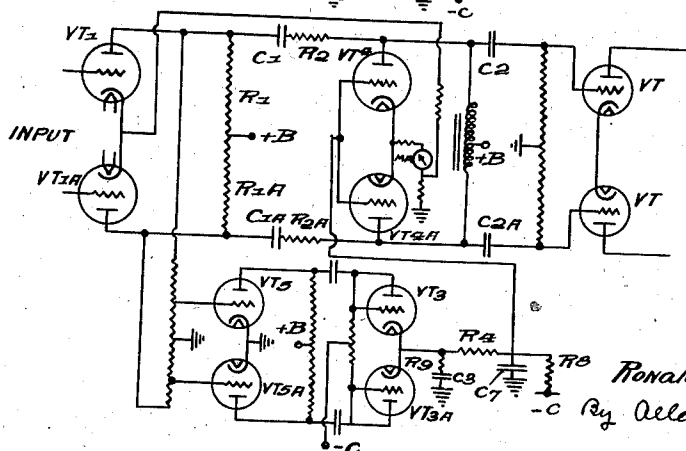


FIG. 5.

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EXPANDER AND LIMITER CIRCUITS

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1 Claim. (Cl. 179—171)

My invention relates primarily to the problems inherent in the broadcasting and reproducing of music or other intelligence. These problems arise due to the necessity for the avoidance of over-modulation in broadcasting. For this reason musical compositions, by way of example, have to be compressed in volume scale during broadcasting. This may be done in several ways. The hand-monitoring of broadcast music is a common procedure. A preferable way comprises the rewriting or revision of musical scores so as to give them a compressed scale. This avoids, of course, arbitrary volume distortions. But either of these methods has its disadvantages; and it is one object of my invention to provide automatically acting means for compressing the volume range of any broadcast intelligence to a range suitable for proper modulation of a carrier wave.

Since, however, the volume range of broadcast intelligence must be artificially compressed for broadcasting purposes, it follows that in the reproduction of such broadcast intelligence in a radio receiving set the volume range will not be the natural range before compression. As a consequence, there is need in a receiving set for an automatically acting means for lengthening the volume range. Accordingly it is a second main object of my invention to provide a volume expander to meet this need.

Volume range must, of course, be distinguished from general volume level. A radio receiving set may be capable of reproducing speech, for example, with a natural volume range, i. e. the ratio of the softest volume of sound in such speech to the loudest volume of sound therein, may be the ratio of that obtained in the original speech. But the speech may be reproduced with a general volume or power softer or louder than the power of the original. Broadcast intelligence is seldom reproduced at exactly the same general volume level as characterized in the original. But certain types of apparent distortion occur when there are great changes either in general volume level or in volume range. In particular, at low volume levels, there is an apparent loss in the power and effect of low-frequency reproduction. In a receiver capable of reproducing low frequencies, the reverse is frequently found at high volume levels. A third main object of my invention therefore is the provision of means for automatic compensation.

Other and ancillary objects of my invention will be set forth hereinafter or will be apparent to one skilled in the art upon reading this speci-

fication, wherein I set forth certain exemplary embodiments of my invention. Reference is made to the drawing wherein:

Fig. 1 is a circuit diagram showing a simple form of expander circuit embodying my invention.

Fig. 2 is a circuit having by-pass means for the purpose of bass compensation.

Fig. 3 shows a circuit in which bass compensation is effected by tuned means in one of the arms of the potentiometer.

Fig. 4 is a simple contractor circuit.

Fig. 5 is a limited contractor arranged for a broadcast transmitter in which contraction is obtained only at or near the point of full modulation thus presenting over-modulation distortion.

Fig. 6 illustrates the non-linear characteristics of amplification above approximately 90% modulation; and

Fig. 7 is a circuit diagram showing the employment of a different type of control tube and also the obtaining of the control voltage to be rectified from the audio amplifier after the potentiometer.

Arranged as a volume expander, my circuit operates as a potentiometer in an output circuit or between stages in an audio amplifier chain. The plate resistance of a control tube forms one arm of the potentiometer and a high fixed resistance the other. The audio signal is rectified to produce a D. C. voltage which, of course, varies with the volume level of the speech or music from which it is derived. This voltage is applied to the grid of the control tube and varies the plate resistance of the tube. Thus the loss introduced into the system by this variable vacuum tube potentiometer varies as the volume varies to expand the volume range.

In Fig. 1 VT₁ and VT₂ are the tubes in successive stages of an audio amplifier. In the coupling between the two stages I have added a series resistor R₂ of high resistance. A tube VT₃ is operated, as well known in the art, so as to serve as a diode rectifier for converting a portion of the alternating current plate voltage of the tube VT₁ into direct current voltage, the value of which will vary as the output of the tube VT₁. This voltage is preferably partially filtered by a resistance and capacity filter comprising the resistance R₄ and C₃ which, assuming proper circuit constants also provides the necessary time delay to prevent expansion taking place too rapidly, and then is applied, as shown, to the grid of the control tube VT₄ so as to serve as the negative bias for that tube.

The plate of the control tube VT_4 is connected into the coupling between the tubes VT_1 and VT_2 beyond the resistance R_2 . The tube VT_4 thus constitutes the arm of a potentiometer, the other arm being the resistor R_2 . As the signal increases in the output circuit of the tube VT_1 the plate resistance of the controlling tube VT_4 increases. Thus less of the signal is by-passed through the tube VT_4 and there will be an increase in the over-all gain or amplification in the amplifier cascade comprising tubes VT_1 and VT_2 . The choke CH_1 shown in Figs. 1, 2, 3 and 4, is used to feed plate voltage to VT_4 , and is preferable to a resistance feed because it does not load the tube, thereby imposing no limit on the impedance of the shunt leg of the potentiometer.

It is found that tubes having exponential characteristics, or in other words, variable μ tubes are preferable for use in this circuit. The recently developed dual control grid tube (6L7) is found to serve the purpose very nicely as the control tube. When such a tube is being used, the screen is connected to the plate and the rectified audio voltage is applied to both the oscillator grid and the signal grid as shown by the connection of the tube VT_4 in Fig. 7.

In a system of this character the audio voltage which is to be rectified to produce the control bias for the control tube is preferably taken off the circuit before the potentiometer structure which constitutes the expander proper. In this way very nearly linear volume expansion is obtained with an exponential tube. Where the output voltage of tube VT_1 is very small it is within the scope of my invention to amplify it in a separate amplifier stage before rectifying it. In Fig. 5 I have shown separate amplifiers VT_3 and VT_{5a} for this purpose. This also serves to reduce the distortion brought about by the diode VT_3 which is directly tied to the signal channel consisting of VT_1 and VT_2 , as shown. It is thus preferable to isolate the diode by means of an amplifier.

It is impossible to take the voltage to be rectified off the audio amplifier after the potentiometer, for example, by connecting the rectifier tube VT_3 shown in Fig. 7 to the output of the amplifier tube VT_2 . The magnitude of the voltage in this case is usually ample. However, since the effect of the control voltage is to increase the volume, and since an increase in the volume increases the control voltage, a derivation of the control voltage from the circuit after the potentiometer is likely to produce an expansion curve which has a rather steep slope over a small volume range and very little expansion over the rest of the range. Attention to the choice of circuit constants may correct this condition to some extent. However, I prefer as indicated, to derive the control voltage from a point in the audio chain preceding the potentiometer.

The action which I have described occurs substantially to the same degree at all audio frequencies, assuming proper circuit constants have been chosen. For reasons which I have set forth hereinabove, it is desirable to provide accentuated bass response during the softer passages to compensate for the apparent fading of the bass at low volume levels.

This can conveniently be accomplished in an automatic way by the circuit shown in Fig. 2. Here like index numerals have been given to like parts. To this circuit has been added additional resistances R_5 , R_6 and R_7 . The latter two resistances occur in a branch circuit which serves

selectively to by-pass the potentiometer hereinabove described. Intermediate the resistances R_6 and R_7 in the by-pass circuit there is a connection to ground through a capacity C_4 . The various resistances are chosen with such values that under a high excitation of the tube VT_1 , the potentiometer arm which is the plate resistance of the tube VT_4 has a very high resistance with respect to the other potentiometer arm, namely the resistance R_2 . Therefore, the gain is at a very high value through the normal coupling circuit and very little of the bass is by-passed through the by-pass circuit. However, at low excitation of the tube VT_1 , where the potentiometer circuit serves to by-pass to ground a considerable amount of the output of the tube VT_1 , a relatively large amount of the low frequencies will get through the by-pass circuit comprising the resistances R_6 and R_7 . The bass compensation may be accentuated by using a reactor in the place of resistance R_6 or resistance R_7 , or both. Essentially in this aspect of my invention I am employing a by-pass filter circuit which at low volume levels by-passes in the sense of impressing them on the grid VT_2 , only such frequencies as are not shunted to ground by the capacity C_4 , namely the bass frequencies whereas at high volume VT_4 assumes a high resistance thereby rendering more effective the normal coupling between VT_1 and VT_2 , and cutting down the effect of the by-pass circuit. The filter itself may be of any type, such as resistance and capacity, inductance and capacity and the like.

A similar effect may be secured in the circuit shown in Fig. 3, where instead of the by-pass circuit which I have described above, I provide a tuned circuit in that branch of the potentiometer arm which includes the plate resistance of the tube VT_4 . Here I have shown such a tuned circuit comprising the inductance CH_2 and the condenser C_5 in parallel. This serves to increase the impedance of the arm of the potentiometer including the plate resistance of the tube VT_4 at low frequencies tending in this way to provide less volume loss at low frequencies. A damping resistance R_8 may be provided if desired to limit the impedance at resonant frequencies.

If the action of the rectifying tube VT_3 is reversed and if the tube VT_4 is biased nearly to zero plate current when no signal is impressed in VT_1 then the circuit operates to contract the volume range rather than to expand it. This is illustrated in Fig. 4 where the plate of the tube VT_3 is now connected to ground as shown; whereas the lead from the plate circuit of the tube VT_1 is connected to the cathode of VT_3 through an isolating capacity C_6 , the circuit being otherwise like that shown in Fig. 1. In this circuit the gain is at a maximum when the output of the tube VT_1 is at a minimum, since the tube VT_4 is biased to a high plate impedance and therefore by-passes very little of the signal. When greater excitation is applied to VT_1 , however, positive rather than negative bias is applied to the grid of VT_4 , as will be understood, thus lowering its impedance and resulting in a by-passing of considerable of the signal voltage resulting thus in a reduction in the gain of the signal channel comprising tubes VT_1 and VT_2 essentially inversely proportional to the strength of the signal applied to VT_1 . The circuit of Fig. 4 is useful in radio transmission to raise the average modulation percentage thus increasing the effective transmission distance, and increasing the ratio of signal to noise. It is preferable, of course, to

use an expander such as that shown in Figs. 1, 2 and 3 at the receiving station, so as to counteract the effect of the automatic compressor at the transmitting station.

A very effective modulation limiter results from the circuit of Fig. 4 by providing contraction only at levels above 80 or 90 per cent modulation. This prevents over modulation with its inherent distortion. A suitable circuit is shown in Fig. 5, the various thermionic means being arranged in push-pull, so as to reduce circuit distortion still further. Here the tube VT_1 is arranged in push-pull with a corresponding tube VT_{1a} and the other tubes in the circuit are likewise duplicated in push-pull, as will be readily understood from the diagram. The action of the circuit of Fig. 5 is as follows: For the excitation of the tubes VT_1 and VT_{1a} from zero to say 80 or 90 per cent of the maximum (the maximum being 100 per cent modulation for the transmitter) rectifier tubes VT_3 and VT_{3a} remain biased to cut-off. These tubes are isolated by means of amplifier tubes VT_5 and VT_{5a} . That is to say, the negative potential is just sufficient to permit rectification at a point where the excitation of the tubes VT_1 and VT_{1a} becomes 80 or 90 per cent of the maximum. Above this the bias is overcome by the grid excitation furnished by the tubes VT_5 and VT_{5a} to such an extent as to apply a positive potential to the grids of the control tubes VT_4 and VT_{4a} which results in a reduction of the gain. This circuit will be seen to differ from the circuits heretofore described in this respect.

This results in an action such as graphically shown in Fig. 6, where the percentage modulation in accordance with variations of input follows a non-rectilinear curve so as to avoid over modulation, as hereinabove set forth.

In Fig. 5 I have shown a filter and time delay means comprising the series resistance R_4 , a pair of shunting condensers C_3 and C_7 the first of which has a resistance R_6 in series with it. Sudden overloads, in this arrangement, result in essentially immediate volume limitation or reduction of amplification, as governed by R_4 C_7 , whereas sustained overloads result in a gradual return of amplification to normal by charging condenser C_3 which is of high capacity in this instance.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent, is:

15 An automatic means for expanding volume range in a radio receiver which comprises, in an amplifier circuit, a potentiometer having a series arm of fixed resistance in said circuit and an arm shunting said circuit, said shunting arm comprising a vacuum tube, and means for varying the plate resistance of said tube in accordance with the signal strength impressed on said amplifier circuit, said last mentioned means comprising means for rectifying a portion of the voltage in said amplifier circuit and for impressing said rectified voltage upon the grid of said tube so as to vary said plate resistance in accordance with variations of the signal strength, in combination with means for automatic bass compensation comprising a circuit to by-pass the fixed resistance leg of said potentiometer and having low attenuation for low frequencies at low volume levels and becoming ineffective as a by-pass at high volume levels upon the increase of said plate resistance in the shunt leg of said potentiometer.

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