

Aug. 27, 1935.

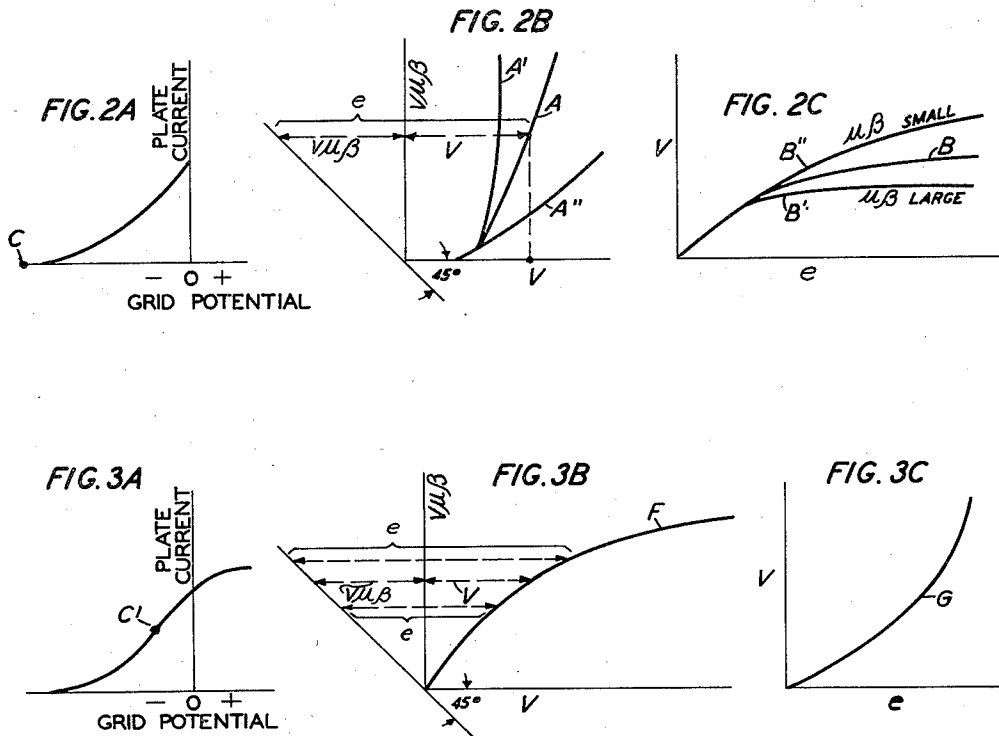
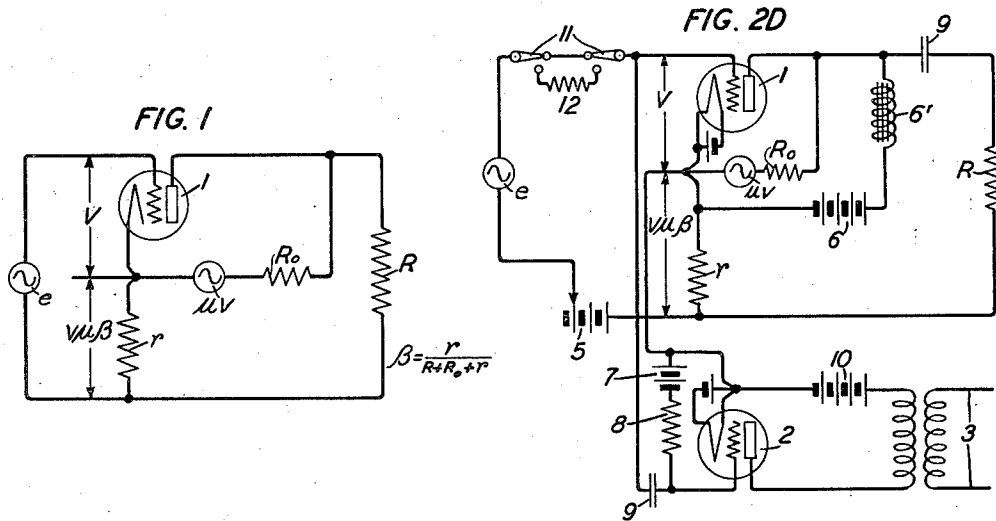
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2,012,286

WAVE TRANSLATION SYSTEM

Filed Jan. 29, 1932

4 Sheets-Sheet 1



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WAVE TRANSLATION SYSTEM

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FIG. 4

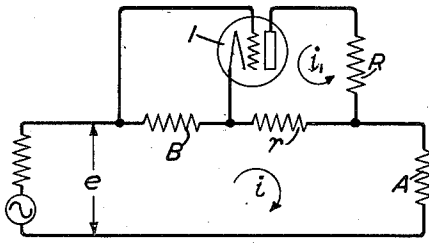


FIG. 5

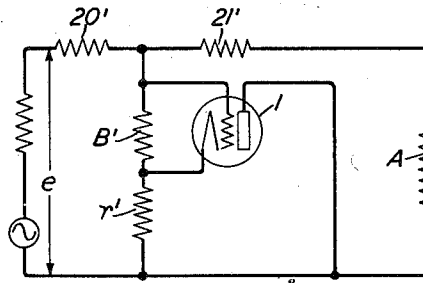


FIG. 6

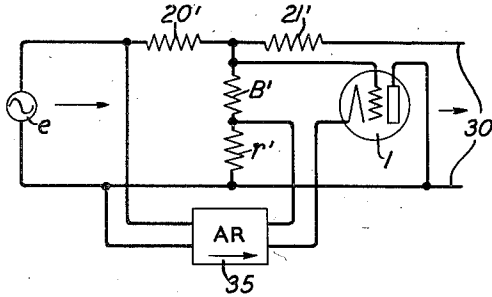


FIG. 7

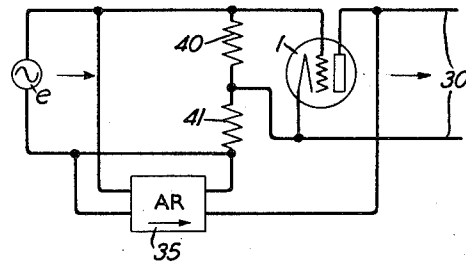


FIG. 8

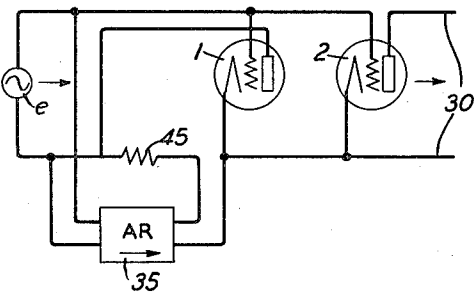
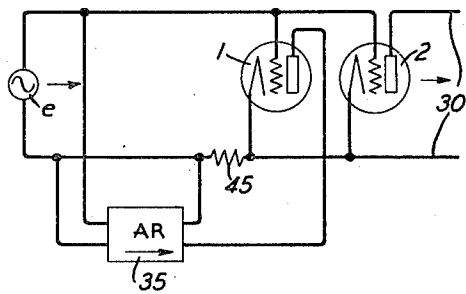


FIG. 9



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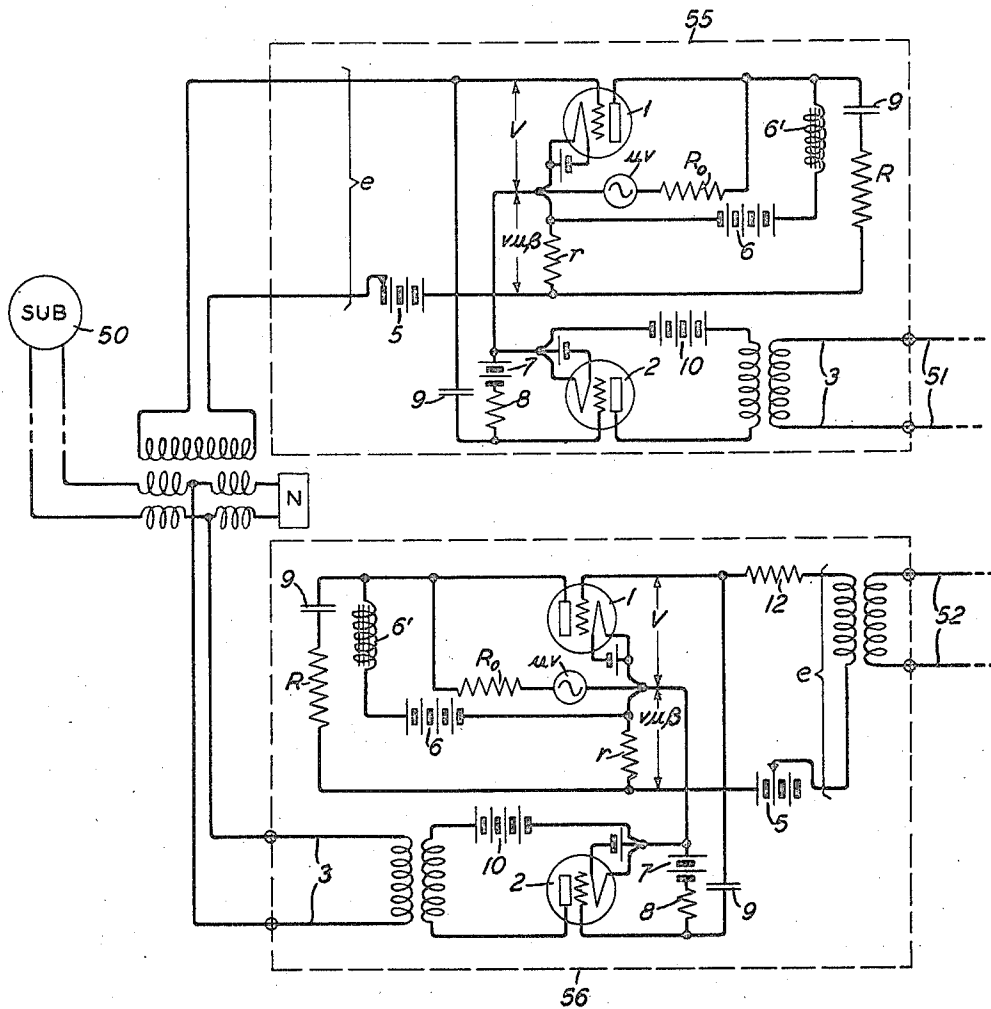
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WAVE TRANSLATION SYSTEM

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4 Sheets-Sheet 3

FIG. 10



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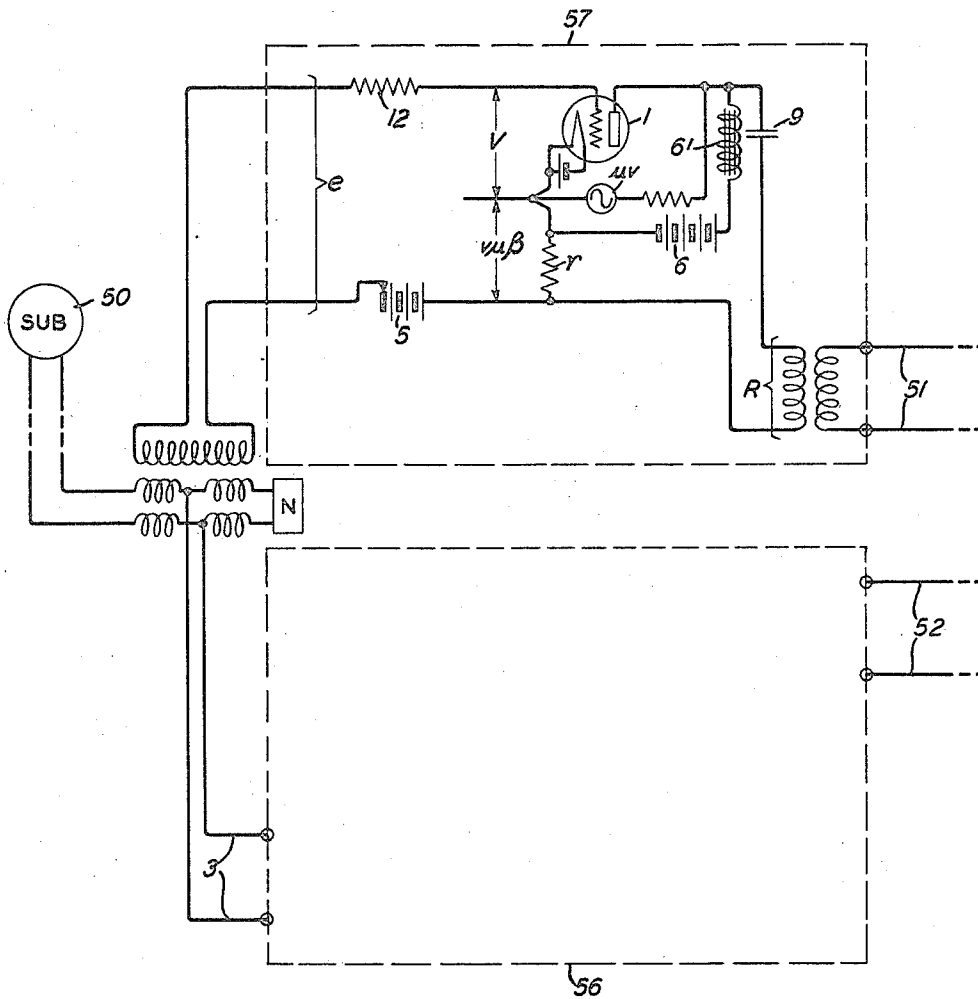
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FIG. 11



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2,012,286

WAVE TRANSLATION SYSTEM

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Application January 29, 1932, Serial No. 589,594

22 Claims. (Cl. 178-44)

This invention relates to wave transmission, and has as objects distortion reduction and transmission volume control.

Other objects are to effect volume control without introducing unnecessary distortion in the transmission and to facilitate obtaining the desired range of volume control.

Automatic volume control devices or circuits may be classified according to their speed of operation, some acting instantaneously and others involving delay. In some cases the device may be required to operate instantaneously while in others varying amounts of delay may be tolerated, or even required. Instantaneously acting devices are usually associated with amplitude distortion, and therefore with the accompanying new frequencies, but delayed control circuits may be so arranged as to minimize modulation. By using degenerating circuits in volume control work certain advantages can be realized. In the instantaneous devices distortion can be reduced, while in the delayed devices the desired gain variations can be more easily obtained through the multiplying action of a degenerating circuit.

Other objects and aspects of the invention will be apparent from the following description and claims.

In the drawings:

Figs. 1, 2A, 2B, 2C, 3A, 3B, and 3C are diagrams for facilitating explanation of the invention;

Fig. 2D is a limiter circuit or volume compressor embodying one form of the invention, and includes also a cross-talk reducing circuit embodying a form of the invention, and the circuit of this figure can also be adjusted to be a volume expander embodying a form of the invention, and including a volume limiter embodying a form of the invention; and

Figs. 4 to 11 show schematically other forms of the invention.

Before discussing the various types of control circuits in detail some of the properties of degenerating circuits will be noted by reference to the simplest form of degenerating circuit, the alternating current paths of which are shown in Fig. 1. Here the degenerating resistance r is common to both plate and grid circuits of an amplifier tube 1. The circuit equation is

$$v + \mu v \beta = e \quad (1)$$

$$v = e / (1 + \mu \beta)$$

or

where

$$\beta = \frac{r}{R + R_0 + r}$$

hold good. When reactances are introduced in circuit, β becomes a complex quantity.) The grid voltage v is therefore less, in the case under consideration, than the applied generator E. M. F. e by the degenerating factor $1/(1 + \mu \beta)$. In order to raise the grid potential to that existing when the feed-back is removed, the generator voltage can be increased by the reciprocal of that factor. The flow of modulated products may be attributed to fictitious generators in the plate circuit, the amplitudes of which depend upon the fundamental plate current. The degenerating factor operates on these E. M. F.'s so that the ratio of modulation to fundamental is correspondingly decreased. Thus, Equation (1) applies to the fundamental and also to the distortion products so that at a definite fundamental output distortion is smaller with the degenerative circuit by the amount of the degenerating factor.

It is evident from (1) that by varying $\mu \beta$ the grid potential may be made to vary correspondingly. The fundamental plate generator voltage E,

$$E = \mu v = \frac{\mu e}{1 + \mu \beta} \quad (2)$$

reduces to e/β when μ is large, so that the output current is independent of the μ in this case. When μ or β are functions of v the equations become non-linear and in some cases of involved form. A simple graphical construction to exhibit the relation between v and e is always possible however, when, as will be assumed, $\mu \beta$ involves no phase angle. For example, with the grid biased to negative potential below that corresponding to plate current cut-off, such as the potential at c in Fig. 2A, which shows the usual static characteristic of tube 1, a relation such as that given by curve A of Fig. 2B is obtained between the fundamental component of grid potential v and the fundamental voltage component $v \mu \beta$ across the resistance r of Fig. 1. Both v and $v \mu \beta$ are plotted to the same scale. Drawing the 45° line indicated through the origin, the generator potential is given to scale by the horizontal distance between the point on the curve A corresponding to a definite v and the 45° line so that the relation between v and e is definite. Apparently the grid voltage v is limited the more sharply as $\mu \beta$ is increased, approaching an asymptotic maximum as $\mu \beta$ becomes infinite; for example, for curve A' the values of $\mu \beta$ are larger and for curve A'' they are smaller than the corresponding values for curve A. The $e-v$ relation is plotted directly in Fig. 2C in which curves B, B', and B'' correspond to curves A, A', and A'', respectively, of Fig. 2B. Each of curves B, B', and B'' has a linear range up to the point at which the control tube is actuated, and beyond

(If the generator e were transferred from the grid to the plate circuit, the equation would still

which a limitation on the maximum output is imposed to a degree depending upon the value of $\mu\beta$. Thus, the circuit acts to limit the grid potential so that a limiter circuit is formed by connecting an additional amplifier 2 between the grid and cathode of tube 1 and a load circuit 3 as shown in Fig. 2D. In a sense the circuit of Fig. 2D acts as a compressor, with respect to transmission from e to 3, since the gain to the fundamental is reduced as the amplitude is increased. Transmitting through the tube 1, however, (i. e., considering R as the load circuit) gives a device of the expander or cross-talk reducer type since there is a large loss at low inputs and a low loss (or a gain) at high inputs. In Fig. 2D grid battery 5 biases the grid of tube 1 to the voltage at c in Fig. 2A. Space current for tube 1 is supplied from battery 6 through choke coil 6'. Grid bias for tube 2, which may operate as an ordinary amplifier, is supplied from battery 7 through high resistance 8. Stopping condensers 9 of low reactance isolate the grids of tubes 1 and 2 from each other as regards direct current bias and prevent battery 6 from sending current through resistance R. Battery 10 supplies plate potential for tube 2.

The circuit of Fig. 2D can be used as a volume expander for transmission passing from source e to load circuit 3, or as a volume limiter for transmission from source e to load circuit R, by employing for the circuit of tube 1 a static characteristic such as that shown in Fig. 3A (instead of that shown in Fig. 2A) and operating about the point c' in Fig. 3A, so as to obtain a $v\mu\beta$ characteristic such as F of Fig. 3B instead of A of Fig. 2B. This can be done, for example, by operating switches 11 to include resistance 12 in the input circuit of tube 1 so as to produce the bend in the upper portion of the characteristic of Fig. 3A and adjusting battery 5 to bias the grid of tube 1 to the voltage at c' in Fig. 3A. The $e-v$ relation can be obtained by the same construction as before, and is shown as curve G of Fig. 3C.

The same sort of effects may be obtained by using the degenerative circuit as an impedance element in series or in shunt connection as shown in Fig. 4 and Fig. 5. This comes about from the fact that the impedance across the terminals of the circuit rises as the degeneration is increased. From Fig. 4 in which the degenerative circuit of tube 1 is connected in series between source e and load resistance A

$$\left. \begin{aligned} e &= (A+B+r)i + ri_i \\ \mu\beta i &= (R+R_0+r)i_i + ri \end{aligned} \right\} \quad (3)$$

from which we get for $\mu\beta \gg r$,

$$\frac{e}{i} = (A+B+r) + \mu\beta \left(\frac{r}{R+R_0+r} \right) = (A+B+r) + \mu\beta B.$$

That is, the resistance B is multiplied by the factor $(1+\mu\beta)$ which may be made large (as for example by using an amplifier in the feed-back path). Thus, with the degenerative characteristic of Fig. 2B the series connection of Fig. 4 gives us a compressor or a limiter, while with that of Fig. 3B, the series connection gives us an expander or a cross-talk reducer. These functions are interchanged when the connection is changed from series to shunt, as in Fig. 5, wherein B' and r' correspond respectively to B and r of Fig. 4 and resistances 20' and 21' control the effect of the shunt-impedance element on the re-

mainder of the circuit, as regards change of gain with level. In Figs. 4 and 5, and also in Figs. 6 to 9 about to be described, the requisite means for supplying cathode energizing current, steady grid biasing voltage and unidirectional space current have been omitted to simplify the disclosure, as they can readily be supplied in the general manner indicated in Fig. 2D or in usual and obvious manner by those skilled in the art.

The circuits so far described are instantaneously acting circuits in which the degenerative circuit offers the advantage of minimizing distortion in the process of volume control. Where time delays are permissible or required the degenerative circuit may be applied to provide an effective amplification of the variable resistance used to regulate transmission, for example as shown in Figs. 6, 7, 8, and 9. Fig. 6 shows tube 1 connected in a degenerative circuit which is like that of Fig. 5 and which is similarly used as a shunt across the transmission path that is to be regulated i. e., the path from source or input circuit e to load circuit 30 in Fig. 6. Here an amplifier-rectifier 35, which involves the desired delay, is used to provide a bias which controls the amount of regeneration.

With the degenerative characteristic of Fig. 2B the shunt connection of Fig. 5 and of Fig. 6 gives an expander or cross-talk reducer (i. e., as e increases, $\mu\beta$ increases and the amount of degeneration and the shunt resistance increase); and in Fig. 6, increase of e moreover causes amplifier-rectifier 35 to render the grid bias of tube 1 less negative, and consequently causes further increase of $\mu\beta$ and of the amount of degeneration and of the shunt resistance; and by this further increase of the shunt resistance the volume expanding or cross-talk reducing effect is increased.

With the degenerative characteristic of Fig. 3B the shunt connection of Fig. 5 and of Fig. 6 gives a volume compressor or limiter, (i. e. as e increases, $\mu\beta$ decreases and the amount of degeneration and the shunt resistance decrease); and in Fig. 6, increase of e moreover causes amplifier-rectifier 35 to render the grid bias of tube 1 less negative, and consequently causes further decrease of $\mu\beta$ and of the amount of degeneration and of the shunt resistance; and by this further decrease of the shunt resistance the volume compressing or limiting effect is increased. In Figs. 6 to 9 the arrows indicate the direction of transmission in the portions of the circuit at which the arrows are placed.

In Fig. 7 transmission from source or input circuit e passes through tube 1 to load circuit 30. The tube is connected for degeneration, resistance 40 across the grid and filament being shunted by the path through resistance 41 and source e in series so that the resistance 41 is common to the input circuit extending from the filament through resistance 41 and source e to the grid and the plate circuit extending from the filament through resistance 41, output side of amplifier-rectifier 35 and plate-filament space path of tube 1. Resistance 41 corresponds to resistance r of Fig. 1 in being common to an input circuit and an output circuit of the tube 1 so as to cause degenerative feed-back. In Fig. 7, amplifier-rectifier 35 which, as noted above, involves the desired delay, effects volume control by changing the resistance (of the last tube of the amplifier-rectifier) in the feed-back path.

Transmission from e to circuit 30 in Fig. 7 corresponds to transmission from e to circuit R in

Fig. 2D, and the remarks above as to that transmission in Fig. 2D apply also to this transmission in Fig. 7, wherein, however, there is involved the delay arising in the action of the amplifier-rectifier.

In Figs. 8 and 9, tube 1 is connected in a degenerative circuit, resistance 45 being common to the input and plate circuits of the tube, and the voltage across the grid and filament of the tube is applied across the grid and filament of main line amplifier 2, as in Fig. 2D.

In Fig. 8, volume control of the transmission passing from source *e* to load circuit 30 is obtained by having amplifier-rectifier 35 change the grid bias on the control tube 1 in the same manner as in Fig. 6; and in Fig. 9, volume control of transmission passing from source *e* to load circuit 30 is obtained as in Fig. 7 by having amplifier-rectifier 35 change the resistance (of the last tube of the amplifier-rectifier) in the feed-back path. That is, in Fig. 9 the resistance of the last tube of the amplifier-rectifier is a function of the input amplitude, and this variable resistance is in series with the feedback path and so changes the amount of feed-back; whereas in Fig. 8 the amplifier-rectifier provides a variable bias on the grid of the first tube shown, which causes the resistance of the first tube to change and so modifies the feed-back. Thus, the same kind of effect is involved in both figures, although the mechanism is somewhat different.

The transmissions from *e* to circuit 30 in Figs. 8 and 9 correspond to transmission from *e* to circuit 3 in Fig. 2D, and the remarks above as to that transmission in Fig. 2D apply also to these transmissions in Figs. 8 and 9, wherein, however, there is involved the delay arising in the action of the amplifier-rectifier.

Fig. 10 shows a part of a telephone system wherein a two-wire portion and a four-wire portion are connected by a bridge transformer (hybrid coil) and line balancing network N in usual manner. The two-wire portion includes a telephone station or subscriber's telephone set 50. The four-wire portion includes outgoing circuit or transmitting channel 51 and incoming circuit or receiving channel 52. These two channels may be of any desired type, as for example land lines or radio channels. It will be understood that the one-way channels 51 and 52 form a link, as for example a wire or radio link, for connecting the two-way two-wire circuit including telephone set 50 with a corresponding remote two-way line. The remote terminal of the four-wire portion of the system may be, for example, like the terminal shown.

In this figure, block 55 is a voltage limiter or volume compressor circuit like that of Fig. 2D, for voice waves or other transmission passing from source *e* to circuit 3 (or in other words from telephone set 50 to line 51 in Fig. 10). Therefore, in block 55 the resistance 12 of Fig. 2D is omitted and the battery 5 is adjusted for operation of the circuit in this block as indicated by the curves 2A, 2B and 2C described above.

Block 56 is a volume expander like that of Fig. 2D for transmission from source *e* to circuit 3, (or in other words from line 52 to telephone set 50 in Fig. 10). Therefore, in block 56 the resistance 12 and battery 5 are adjusted for operation of the circuit of this block as indicated by the curves 3A, 3B and 3C described above. The circuit of block 56 is adjusted to expand the volume of transmission passing from 52 to 50, for example to compensate for volume compression

produced at the remote end of the four-wire portion of the system by the voltage limiter or volume compressor corresponding to that shown in block 55.

Fig. 11 shows a system such as that of Fig. 10, except that the circuit of block 57 is used in place of the circuit of block 55 of Fig. 10. In Fig. 11, resistance 12 is included in the circuit of block 57 and battery 5 is adjusted for operation of the circuit of block 57 as indicated by the curves 3A, 3B and 3C described above. Then the circuit of this block is a voltage limiter like that of Fig. 2D for transmission passing from source *e* to circuit 51 (or in other words from telephone set 50 to line 51 in Fig. 11). The expander of block 56 can then compensate for volume control produced, for example, at the remote end of the four-wire system by a limiter corresponding to that just described.

Systems with feed-back reducing gain, for example for gain stabilization or distortion reduction, are claimed broadly in a copending application of H. S. Black, Serial No. 606,871, filed April 22, 1932, for Wave translation system, which is generic to the present application as to such subject-matter.

What is claimed is:

1. A wave translating system comprising means for producing feedback in said system of waves that reduce the magnitude of its output waves, and means for rendering the input-output characteristic of said system with feedback non-linear with respect to its operating amplitude range.
2. A wave translating system comprising means for rendering its degenerating factor small compared to unity, and means for rendering the input-output characteristic of said system with degeneration non-linear with respect to its operating amplitude range.
3. A wave translating system comprising an electric space discharge device having anode, cathode and discharge control means, means for producing feedback in said device of waves that reduce the magnitude of its output waves, and means causing said control means to render the input-output characteristic of said device non-linear with respect to its operating amplitude range.
4. A wave translating system comprising an electric space discharge device, means for normally reducing space current of said device to substantially zero value, and means for producing feedback in said device of waves that reduce the magnitude of its output waves below their value without feedback.
5. A wave translating system comprising an electric space discharge device having anode cathode and discharge control means, means for normally causing said control means to reduce anode current of said device to a value approximately as low as zero, and means for producing feedback in said device of waves that reduce the magnitude of its output waves below their value without feedback.
6. A wave translating system comprising an electric space discharge device having anode, cathode and grid structure, means for rendering said device degenerative and rendering its degenerating factor small compared to unity, and means for biasing said grid structure to a potential that reduces space current of said device to substantially zero value.
7. A wave translating system comprising an electric space discharge device, means for normally reducing space current of said device to

substantially zero value, means for producing feedback in said device of waves that reduce the magnitude of its output waves below their value without feedback, and means for preventing feedback of unidirectional voltage with said first mentioned waves.

8. A wave translating system comprising an electric space discharge device having anode, cathode and discharge control means, means for normally causing said control means to reduce anode current of said device to a value approximately as low as zero, means forming with said device a closed feedback loop for feeding back in said device waves that reduce the magnitude of its output waves below their value without feedback, and means for preventing propagation of direct current around said loop.

9. A wave translating system comprising an electric space discharge device, means for normally reducing space current of said device to substantially zero value, means for rendering said device degenerative and rendering its degenerating factor small compared to unity, and means for preventing feedback of direct current in said device.

10. A wave translating system comprising an electric space discharge device having anode, cathode and discharge control means, means for supplying to said control means steady negative biasing potential sufficient to reduce space current of said device to approximately zero value, means for transmitting direct current to the substantial exclusion of alternating current connecting said cathode and anode means, other means for transmitting alternating current to the substantial exclusion of direct current connecting said cathode and anode means, and means for feeding back from said other means to said control means waves, to the exclusion of unidirectional voltage that reduce the magnitude of the output waves of said device below their value without feedback.

11. A wave translating system comprising an electric space discharge device, a source of input waves therefor, means for interrupting space current of said device during a considerable portion of the negative swing of the waves from said source, and means for producing feedback in said device of waves that reduce the magnitude of its output waves below their value without feedback.

12. A wave translating system comprising an electric space discharge device having anode, cathode and grid structure, a source of input waves for said device, means for rendering said device degenerative, and means for normally biasing said grid structure to a potential that causes extinction of anode current of said device during a considerable portion of the negative swing of the waves from said source.

13. A wave translating system comprising an electric space discharge device having anode, cathode and grid means, a source of input signal waves for said device, means for rendering said device degenerative, and means for normally biasing said grid means to such potential as to render anode current of said device extinct during a considerable portion of the negative swing of the signal waves from said source, said means for rendering said device degenerative rendering the degenerating factor small compared to unity for reducing distortion of the signal output.

14. A wave transmission system comprising a wave source, a load, an electric space discharge device having anode, cathode and grid structure, with its input and its output connected respec-

tively to said source and said load for transmission through the device from the source to the load, means for supplying to said grid structure potential for causing said device to transmit portions only of the waves supplied thereto from said source, and means feeding back in said device waves that reduce the distortion caused by the transmission of portions only of the input waves.

15. A transmission volume limiter comprising a degenerative circuit including a vacuum tube having an anode, a cathode and a discharge control element, an output circuit connected across said cathode and control element, and means supplying to said control element a negative biasing potential substantially greater than that required to reduce the anode current to zero value.

16. A transmission volume expander comprising a degenerative circuit including a vacuum tube having an anode, a cathode and a discharge control element, an output circuit connected across said cathode and control element, and means for supplying to said control element a biasing potential of such value as to operate said vacuum tube about a point substantially midway between the upper and the lower knees of its input-output characteristic.

17. A wave transmission system comprising a resistance for controlling the transmission efficiency of the system, and a degenerative circuit including said resistance for increasing the impedance of said resistance to transmission in the system, said degenerative circuit comprising a vacuum tube having means for normally reducing its space current to zero value.

18. A volume control circuit comprising a resistance in series in said circuit for controlling the transmission efficiency of the circuit, and a degenerative circuit including said resistance for increasing the impedance of said resistance to passage of transmission therethrough, said degenerative circuit including a vacuum tube having an anode, a cathode and a discharge control element, with said resistance connected between said cathode and said control element and with means biasing said control element to a potential that normally reduces anode current of said tube to zero value.

19. A volume control circuit comprising a resistance in shunt to said circuit for controlling the transmission efficiency of the circuit, and a degenerative circuit including said resistance for increasing the impedance of said resistance to passage of transmission therethrough, said degenerative circuit including a vacuum tube having an anode, a cathode and a discharge control element, with said resistance connected between said cathode and said control element and with means biasing said control element to a potential that normally reduces anode current of said tube to zero value.

20. In a wave transmission system, a degenerative circuit for controlling the transmission efficiency of said system, means responsive to changes of transmission level for controlling operation of said degenerative circuit, and means for producing delay in the action of said second mentioned means.

21. In a wave transmission system, a resistance for controlling the transmission efficiency of the system, a degenerative circuit in effect multiplying the value of said resistance, means responsive to changes in transmission level for varying the

amount of degeneration in said degenerative circuit, and means for delaying action of said first mentioned means.

22. The combination of a wave translating device for discriminating between waves of different amplitudes by virtue of non-linearity of its input-output characteristic in its operating

range, and means for rendering said device degenerative and rendering its degenerating factor small compared to unity, said device comprising a vacuum tube having means for normally reducing its space current to zero value.

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