

Jan. 28, 1941.

P. J. LARSEN

2,229,703

ELECTRIC TRANSLATION SYSTEM

Filed Jan. 22, 1938

4 Sheets-Sheet 1

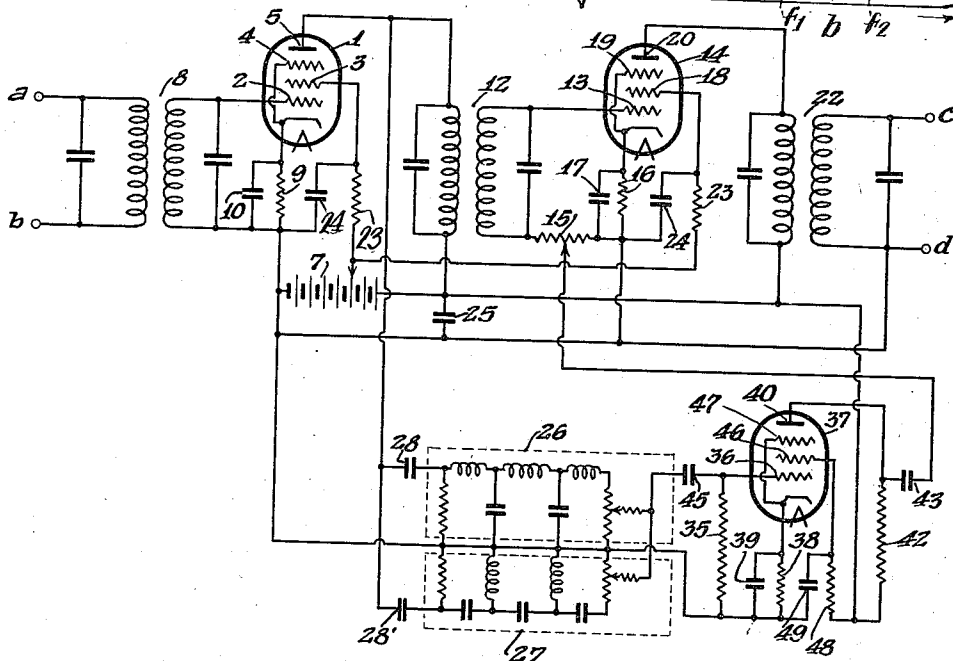
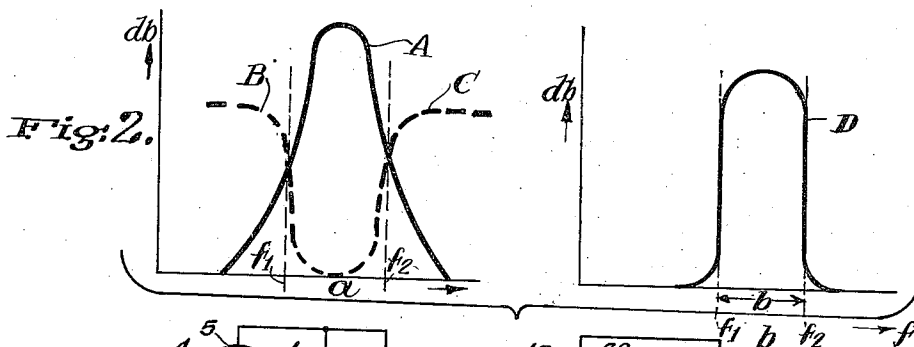


Fig. 1.

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4 Sheets-Sheet 2

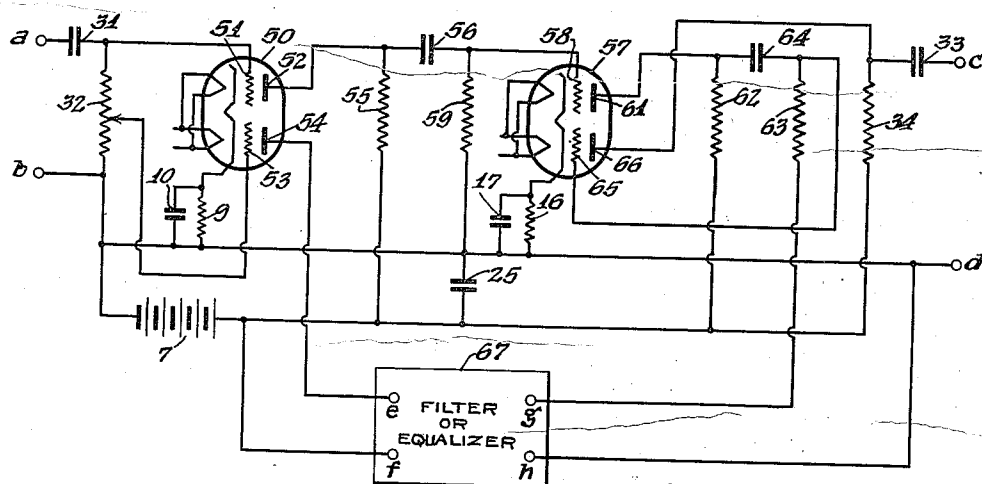


Fig. 3.

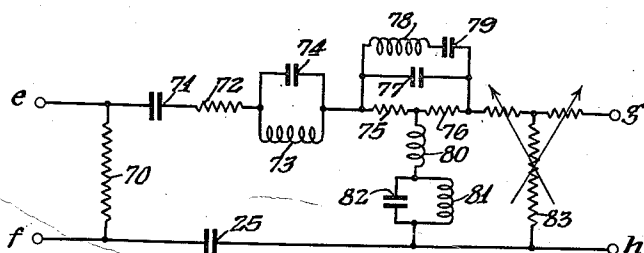


Fig. 4.

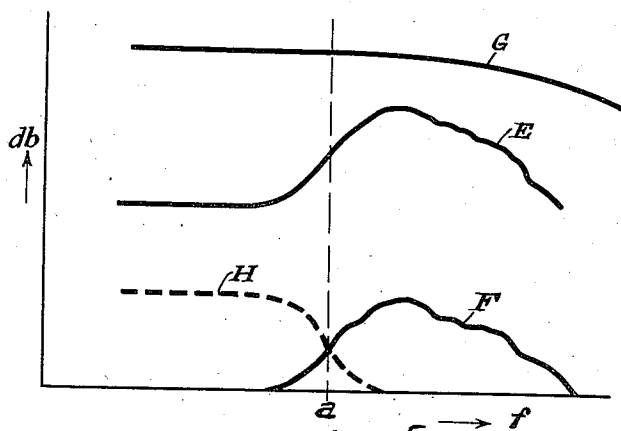


Fig. 5.

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4 Sheets-Sheet 3

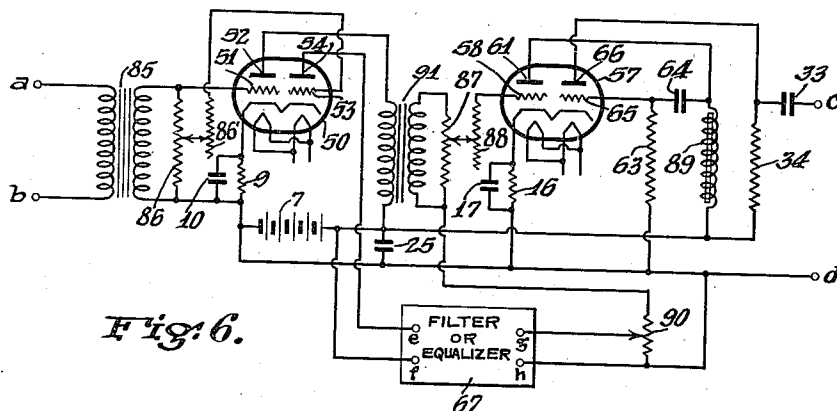


Fig. 6.

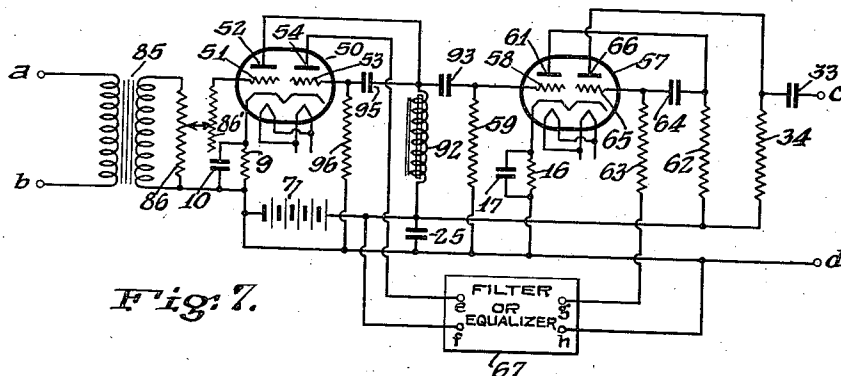


Fig. 7.

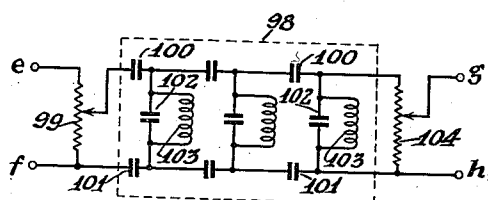


Fig. 8.

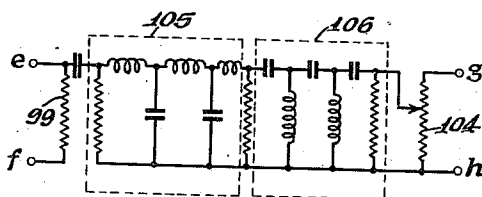


Fig. 9.

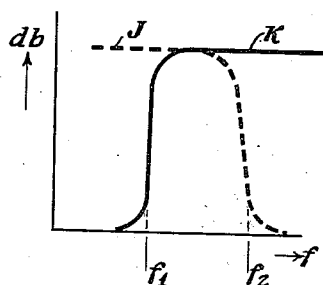


Fig. 10a.

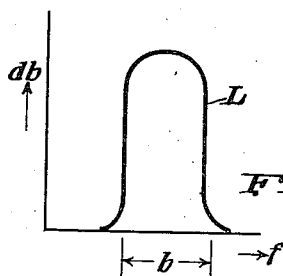


Fig. 10b.

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4 Sheets-Sheet 4

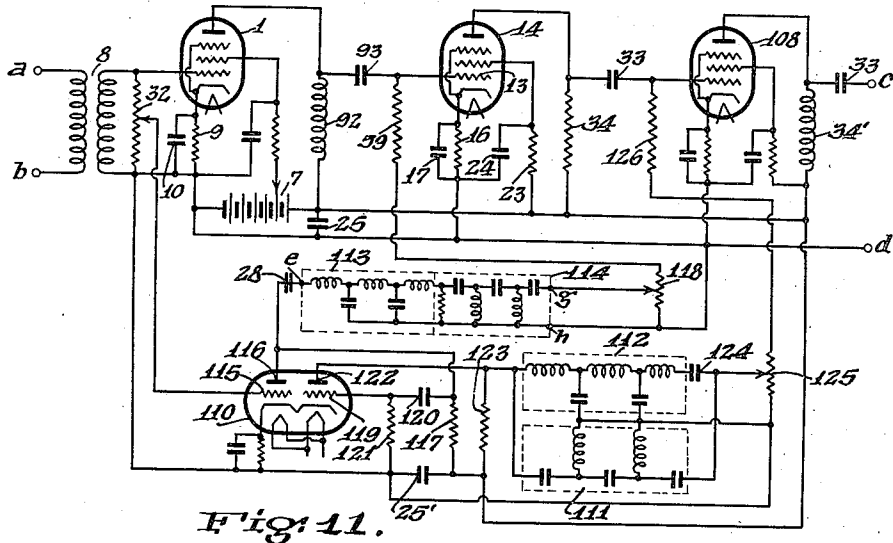


Fig. 11.

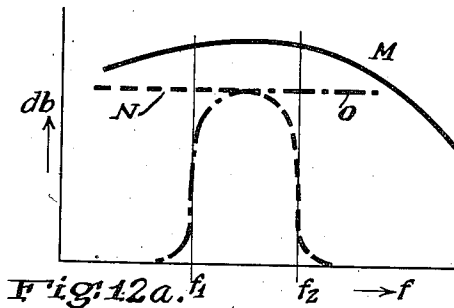


Fig. 12a.

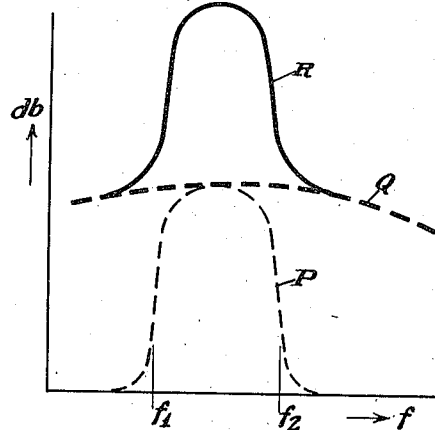


Fig. 12b.

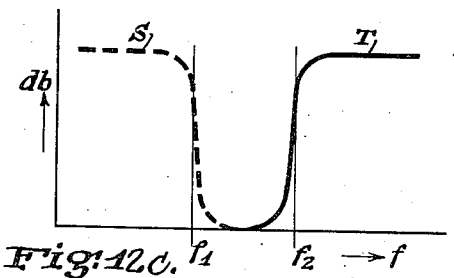


Fig. 12c.

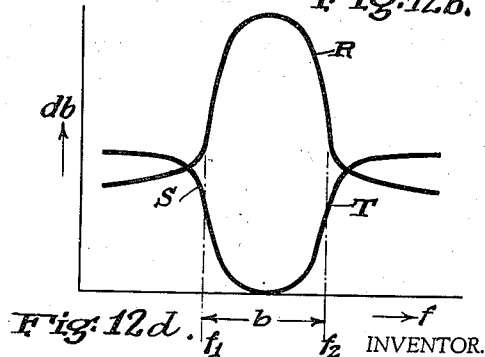


Fig. 12d.

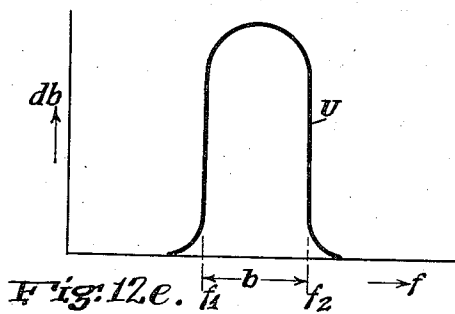


Fig. 12e.

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UNITED STATES PATENT OFFICE

2,229,703

ELECTRIC TRANSLATION SYSTEM

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Application January 22, 1938, Serial No. 186,371

2 Claims. (Cl. 179-171)

The present invention relates to wave translation systems, more particularly to improvements in and a method of translating or amplifying variable electric currents as used in the high frequency and low frequency arts such as in radio, carrier telephony, telephone, telegraph, talking picture, sound systems and the like. More specifically the invention herein is concerned with amplifiers having corrective wave translation networks for eliminating distortion characteristics of impressed input signal and/or to obtain band pass frequency characteristics from normally broad flat frequency response amplifiers and to obtain other advantages which will be further explained in the specification.

In my copending application, Serial No. 183,154, filed January 3, 1938, I have described an amplifier with one or more inverse feedback arrangements for stabilizing the operation, preventing distortion and to obtain band pass or other response characteristics.

The object of the present invention is to obtain frequency discrimination by utilizing selective networks or filters of predetermined frequency characteristic in a "feed forward" or parallel path to an amplifier from a lower to a higher amplification level thereof and superimposing the voltage derived therefrom upon the stage of higher amplification level of the amplifier to alter the amplifier output frequency characteristic or any other characteristic of desired shape in a simple manner substantially without affecting the overall gain of the amplifier such as is the case in inverse feedback systems and without the use of complicated or unstable circuits which may affect the otherwise stable characteristics of the amplifier.

Another object is the provision of an amplifier having a predetermined frequency response characteristic or band width suitable for amplifying and/or translating low frequency, intermediate frequency, and high frequency signal bands of any desired frequency range or band width and comprising coupling and frequency discrimination solely in the auxiliary "feed forward" control path for obtaining the said results.

A further object is to combine low pass and high pass wave filter elements as coupling networks in an amplifier circuit in such a manner as to obtain amplification of a desired frequency band or discrimination above or below a first predetermined cut-off frequency and to balance out or neutralize all the currents having frequencies above or below another predetermined frequency thereby to obtain a frequency response character-

istic of the band pass or band suppression type positioned at any desired point on the frequency scale extending from zero frequency to the low (audio), intermediate, and high frequency ranges employed in practice.

A still further object is to combine equalizer networks having predetermined frequency characteristics as coupling networks in an amplifier circuit in such a manner as to obtain a desired amplification or attenuation of predetermined characteristic by balancing out or neutralizing distinct frequencies or ranges or adding voltages to the input signal voltage, thereby to obtain a predetermined over-all frequency response characteristic of the amplifier.

Another object is to provide equalizing networks in an amplifier system, the equalizer network or networks having characteristics similar to the distortion characteristics of a transmission line or other transmission system preceding the amplifier in such a manner that the voltages derived from said equalizer neutralize or become cumulative to the control voltage of the amplifier, thereby correcting the response thereof resulting in a flat or any other predetermined total output frequency response of the amplifier.

These and further objects and advantages of the invention will become more apparent as the following detailed description proceeds taken with reference to the accompanying drawings illustrating several embodiments of the invention, and wherein:

Figure 1 shows a simple amplifying circuit having a band pass type frequency amplifying or transmission characteristic constructed in accordance with the invention.

Figure 2 shows the frequency response curves illustrative of the function and operation of the circuit according to Figure 1.

Figure 3 is a further modification of a circuit according to the invention embodying features such as twin-triode tubes to improve the overall efficiency and operation.

Figure 4 is a diagram illustrating a typical equalizer network for wave correction purposes.

Figure 5 shows a frequency response curve illustrative of the function and operation of the equalizer network of the type shown in Figure 4 when employed in the preceding amplifier circuits, Figures 1 and 3.

Figures 6 and 7 are further circuits showing modifications of the invention adapted to improve the overall gain of the amplifier.

Figures 8 and 9 show diagrams of typical band

pass filters which may be utilized in conjunction with the preceding circuits,

Figs. 10a and 10b show frequency response curves illustrative of the function and operation of the filter of Figure 9 in conjunction with the circuits according to the previous figures,

Figure 11 is a further modification of the invention for obtaining a band pass characteristic from an amplifier with a normally broad and flat frequency characteristic by both neutralization of the undesired frequencies and strengthening of the desired frequencies according to the invention,

Figures 12a-12c show frequency response curves illustrative of the function and operation of the circuit constructed in accordance with the circuit of Figure 11.

Similar reference characters identify similar parts throughout the different views of the drawings.

Referring to Figure 1, wherein is shown a simple amplifying circuit having a predetermined frequency characteristic of the band pass type positioned at any desired point of the frequency scale including the audio, intermediate and high frequency ranges, numeral 1 represents an amplifying valve of standard construction, in the example shown, a valve of the pentode type having a cathode, an input or control grid 2, a screen grid 3, a suppressor grid 4, and a plate or anode 5. The suppressor grid 4 is directly internally connected with the cathode in a manner well known. The screen grid 3 is shown connected through a resistance 23 to a suitable tap point of the high tension source 7, which may be a battery as shown or a potentiometer resistance and by-passed by a condenser 24 as well understood by those skilled in the art. Numeral 8 represents an input transformer having a tuned primary and secondary being preferably resonant to the desired frequencies to be transmitted by the amplifier.

The input terminals *a b* are connected directly across the primary of transformer 8, the secondary thereof being connected to the grid 2 and to the cathode of the valve 1 through grid biasing resistor 9 in the cathode lead shunted by a condenser 10 in a manner well known. The plate 5 of the valve is connected through the primary of tuned or untuned inter-stage transformer 12 to the plate supply 7. The secondary of the inter-stage transformer 12 is connected to the input grid 13 of a succeeding amplifier valve 14 through a coupling resistance 15 and biasing resistance 16 shunted by condenser 17. Valve 14 being similar to valve 1 of the pentode type has a screen grid 18, a suppressor grid 19, and a plate or anode 20. The anode 20 of this valve is connected through the primary of the output transformer 22 to the plate supply 7. The inter-stage transformer 12 in the example shown as well as the output transformer 22 are provided with condensers across their primaries and secondaries similarly to transformer 8 and are preferably tuned to the same frequency as the latter or broadly to the frequencies to be transmitted through the amplifier. The secondary of transformer 22 is connected to the output terminals *c, d*. The suppressor grid 19 of valve 14 is directly internally connected with the cathode in a manner well known. The screen grid 18 is shown connected in a known manner through a voltage drop resistance 23 to the high tension source 7 and is by-passed to the cathode by a capacity 24. There is provided further a shunting condenser 25, across the high tension source 7. As is understood the tuning condensers for the transformers

8, 12 and 22 may be omitted and the latter designed to be resonant to the desired frequency or band of frequencies by virtue of the inductances and distributed capacities thereof.

Normally the amplifier as above described will amplify in a known manner the frequencies to which the transformers 8, 12 and 22 are tuned which will be of a band pass character having sloping sides and which without a high regenerative effect in the amplifier itself will, as in the case of an intermediate amplifier, be broader than the frequency band desired in such a manner that interfering signals from adjacent carrier waves will be transmitted and amplified. To eliminate such interfering signals, there are provided, in accordance with the improvement of the invention, filter networks 26 and 27 connected between the plate 5 of valve 1 and the input circuit of valve 14. As is known, the voltage variations on the plate 5 of tube 1 and grid 13 of valve 14 are 180° out of phase with the input voltage impressed upon the grid 2 of tube 1, provided the primary and secondary of transformer 12 are connected with the proper polarity, or if a resistance-capacity coupling network of known construction is employed in place of the transformer 12. The voltage variations derived in the example shown from the plate 5 are impressed through the coupling condensers 28 and 28' upon the multiple networks 27 and 26. Network 26 is a low pass filter network which type of network, as is known, is effective in preferred passing currents having frequencies below a predetermined cut-off frequency and of suppressing currents having frequencies above said cut-off frequency. Network 27 is connected in parallel to network 26 in the same circuit and is of the high pass type effective in preferred passing currents having frequencies above a predetermined cut-off frequency and of suppressing currents having frequencies below said cut-off frequency. Networks 26 and 27 have been illustrated solely as one particular type of network to perform the function desired. More complex or more simplified filters of any desired construction may be employed in place of those illustrated to suit any special requirement. Likewise, one half section terminating filters may be employed at the input as well as the output end of each of the filters with or without corresponding terminating resistance, so as to maintain the impedance of all circuits to which they are connected constant.

The outputs of the low pass filter 26 and high pass filter 27, as shown are connected in parallel through a gain control resistance network and coupled through coupling condenser 45 to the grid 36 of valve 37; the latter grid being provided with a grid leak or coupling resistance 35. Valve 37 represents an amplifying valve of the pentode type similar to valves 1 and 14 having a cathode, an input or control grid 36, a screen grid 46, a suppressor grid 47 and a plate or anode 40, the suppressor grid 47 being directly internally connected with the cathode in a well known manner. The screen grid 46 is connected through a voltage drop resistance 48 to the high tension source 7 and shunted to ground or cathode by a condenser 49. The output of valve 37 is shown connected from the plate or anode 40 through coupling resistance 42 to the high tension source 7 and through coupling condenser 43 to a point on the coupling resistance 15 in the grid input circuit of valve 14. The voltages of the frequencies to be discriminated as selected by the filters 26 and 27 being applied across coupling resistance 15

in the input circuit of valve 14, are 180° out of phase with the voltages of the same corresponding frequencies impressed upon this input circuit through the transformer 12, and therefore the

voltages of these frequencies will be neutralized and will not be further transmitted or amplified.

There is thus formed one auxiliary "feed forward" circuit path from a stage other than the last one in the propagation direction of the amplifier to any following stage in that direction, modifying in a desired manner the input potential at that following stage so as to obtain a desired final output response characteristic of the amplifier. In order to obtain an exact balance, phase shifting networks may be suitably arranged in the circuit, such as a resistance capacity series network. As is understood, any other type of phase-shifting or phase-rotating device or circuit known in the art may be employed for this purpose and the phase rotation or correction may be also affected in the main amplifier path for the signal currents passed through the latter such as in or preceding to the grid circuit of the valve 14.

Figure 2 shows the characteristic curves (output response in db. or any other unit plotted against frequency) of the above described amplifier circuit of Figure 1. The curve A therein represents the normally transmitted frequency band through the amplifier without the neutralizing or balancing circuit according to the invention. As will be noted, this curve having sloping ascending and descending branches extends beyond the desired frequency band f_1 — f_2 and it is these portions of the characteristic curve which effect or cause interfering signals such as in the case of an intermediate frequency amplifier as employed in superheterodyne receivers or the like. The curve B represents the characteristics of the low pass filter 26 of Figure 1 having a cut-off point at the frequency f_1 . Curve C represents the characteristic curve of the high pass filter 27 of Figure 1 having a cut-off at frequency f_2 . It is apparent therefore that the only frequencies which will be transmitted through these filter networks 26 and 27 will be the frequencies below f_1 and the frequencies above f_2 . Therefore the voltage derived from these frequencies above and below the desired band f_1 to f_2 , will oppose the signal voltages of corresponding frequencies impressed upon the grid 13 of valve 14 thereby causing neutralization thereof. As a result there is obtained in the output circuit or across the primary of transformer 22 a characteristic with a sharper cut-off than would have been possible without this novel arrangement.

The curve D in Figure 2b represents the resulting characteristic curve obtained by the use of the invention and as will be noted the slopes at the lower and upper part of this curve are steeper than in the original curve A of Figure 2. Thus, by this arrangement the over-all selectivity of the amplifier is considerably increased resulting in the elimination of interference from adjacent signal channels. As is understood from the foregoing the inventive circuit, among various other uses, has great advantages when embodied in the intermediate section of a superheterodyne radio receiver in enabling a substantial increase of receiver selectivity without affecting the fidelity of reproduction. The filter 26 and 27 may be designed to have the requisite critical or cut-off frequencies f_1 — f_2 , by proper dimensioning of the capacity and in-

ductance units in relation to each other and to the impedance of the associated input and output circuits connected to the input and output terminals of the filters.

In the above description of the operation of Figure 2 and in the description of the circuits described hereafter, it is apparent that the voltages derived from the parallel filter network or "forward feed" circuit in the case of Figure 1 must, to suppress the undesired frequencies, have voltages exactly 180° out of phase with the voltages developed in the grid circuit to which the output of the filter network is connected so as to obtain complete neutralization of these undesired frequencies. In other circuits wherein, instead of neutralizing the undesired frequencies the filter networks form a correcting or equalizer circuit for equalizing distortion of a line or the like and where these voltages superimposed upon the voltages in the grid circuit of the tube must be in phase, phase shifting devices such as Wheatstone resistance capacity networks or other well known phase shifting devices or systems may be employed in connection with the filter or equalizer systems so as to obtain the proper phasing of the superimposed voltages. Likewise when employing transformers such as the transformer 12 of Figure 1, reversal of phases may also be obtained by reversing the connections or the direction of winding of the primary or secondary of the transformer.

Figure 3 is illustrative of another embodiment of the invention. According to this modification twin-triode valves are employed connected in a cascade arrangement with one of the triode units in one of the valves being employed as an amplifier for the currents passing through the wave discriminating networks. In the figure, numeral 50 represents an amplifier valve of the twin-triode type of standard construction having a dual cathode, an input or control grid 51 and a plate or anode 52, comprising one of the triode units, and the cathode further control grid 53 and the other plate or anode 54 comprising the other triode unit in this valve. A line or a preceding amplifier or transmission circuit is connected to the input terminals a, b and the signals therefrom are applied through coupling condenser 31 to grid 51, the latter being provided with its usual grid coupling resistance 32, and the well known biasing means, resistance 9 and condenser 10. The plate 52 of this triode unit is connected on the one hand through plate load resistance 55 to the high tension source 7 and through a coupling condenser 56 to the input circuit of the first triode unit of a second twin-triode valve 57, the input circuit thereof comprising the grid 58 coupling resistance 59 and biasing resistance 16 shunted by condenser 17. The output or plate 61 of this triode unit is connected through a known resistance capacity coupling network comprised of resistances 62 and 63 and a capacity 64 to the input grid 65 of the second triode unit of this valve, the output or plate 66 of this triode unit being connected on the one hand through plate load resistor or impedance 34 to the high tension source 7 and through coupling condenser 33 to output terminal c, the other output terminal d being connected to the common ground 70 or zero potential point of the system. The grid 53 of the second triode unit of valve 50, which triode unit is used as the amplifier in the "forward feed" circuit including the wave discriminating networks, derives its potential from the input

coupling resistance 32, which may be adjustable so as to vary the input-signal level to be applied to the discriminating networks. The output or plate 54 of this triode unit is shown connected to the filter or equalizer 67, through terminals *e* and *f* to the high tension source 7, the output of filter 67 being applied through terminals *g* and *h* in series with resistance 63 to the input circuit of the second triode unit of valve 57.

The cascade amplifier consisting of the three triode units that is the units having input circuits connected to grids 51, 58, 65, form a three stage resistance coupled amplifier having normally a fairly flat frequency characteristic depending upon the constants of the load resistances and the coupling condensers 55, 62, 34 and 56, 64 and 33, respectively. To obtain a band pass frequency characteristic of a desired band width from such a resistance coupled amplifier, filter networks similar to the previously described low pass filter 26 and high pass filter 27, may be employed in the filter unit 67, provided with the usual load resistance for plate circuit 54 and coupling condenser 28 as shown in Figure 1. In such an arrangement as described, there may be impressed upon the input circuit of grid 65 in series with the resistance 63 voltage variations of the frequencies selected by the filters, 180° out of the phase with the voltage variations of the same frequencies impressed upon the input circuit from the line through coupling condenser 64, thereby neutralizing or annulling these voltage variations and producing in the output or plate circuit 66 amplified voltage variations of the desired frequencies between *f*₁ and *f*₂, as shown in the curves of Figures 2*a* and 2*b*.

The arrangements described heretofore all relate to means for obtaining a band-pass frequency characteristic from broadly tuned or flat frequency response amplifier circuits or for obtaining improved band pass characteristics from band pass characteristic amplifiers. It is apparent, that by selecting other types of filters such as band pass filters, as shown in Figure 8 later referred to, or any other type of equalizing or wave correcting network any desired frequency response, band pass characteristic or band elimination characteristic may be obtained.

Figure 4 represents a typical equalizer or wave correcting network which may be employed in connection with any of the previous described figures and especially in connection with the circuit of Figure 3. Normally, when the main amplifier portion of the circuit of the type shown in Figure 3, that is the three stage resistance coupled cascade amplifier is connected to a transmission channel, such as a telephone or carrier current line, the distortion characteristic of the line will affect signals transmitted by the line in such a manner as to attenuate certain frequencies thereof, which frequency attenuations will be repeated by the amplifier and will produce in the output of the amplifier a response characteristic similar to the distortion characteristic of the line. Methods have been employed in the past to equalize these distortion characteristics by employing equalizer networks in the amplifier proper, however such equalizers have the disadvantage of introducing losses into the circuits thereby decreasing the overall gain of the amplifier system. By the novel method disclosed such distortion characteristics of the transmission channel may be readily compensated or neutralized by the em-

ployment of an equalizer or wave correcting network without impairing the efficiency of the amplifier system. Figure 5 shows a curve representing by way of example the transmission characteristics of a transmission circuit or apparatus and the curve of an equalizer employed in a neutralization circuit of the invention to obtain a response in the output circuit of the amplifier in which the distortion characteristics of the line are not repeated.

As shown in Figure 5, curve E illustrates the frequency response of a circuit or translating device connected to the input terminals *a*, *b* of Figure 3, through the usual coupling means. As will be noted, frequencies below *a* have been attenuated, and frequencies above *a* are, therefore, impressed upon the input of the amplifier with increased amplitude over the attenuated frequencies. In order to prevent such distortion the equalizing or wave correcting network as illustrated in Figure 4, connected to the usual plate load resistance 70, and coupling condenser 71, should be so designed that the output response from the plate 66 of valve 57 corresponds to curve G of Figure 5. The equalizer as shown in Figure 4 consists of series elements, comprising a resistance 72, resonant circuit inductance 73 shunted by condenser 74, resistances 75 and 76, shunted by condenser 77 and by inductance 78 and condenser 79 in series therewith and a shunt element connected from the junction point of the resistances 75 and 76, and consisting of inductance 80 in series with a shunt resonance circuit comprising inductance 81 and condenser 82. The output of the equalizer includes a coupling resistance 83 connected to the output terminals *g*, *h*, corresponding to the terminals of equalizer 67 of Figure 3. The constants of the component elements of such an equalizer are well known and any desired equalization, or attenuation, for any desired frequency or frequency band, and having any desired sharpness or cut-off, can be obtained by proper selection of the component elements.

Curve F of Figure 5 shows the frequency response characteristics of the equalizer of Figure 4 and it will be noted that the frequencies below *a* are attenuated by the equalizer, whereas the frequencies above *a* are transmitted with varying attenuation through the equalizer according to a characteristic similar to the response characteristic E. Therefore, the voltage variations derived across the coupling resistance 83 of Figure 4, corresponding to the frequency response as represented by curve F in Figure 5 when impressed upon the input circuit of the grid 65 through terminals *g*, *h* of Figure 3, will equalize the corresponding voltage variations of corresponding frequencies impressed upon the input circuit of grid 65 from the line through coupling condenser 64, resulting in a frequency response corresponding to curve G of Figure 5, in the output circuit of plate 66 and across output terminals *c*, *d* of the amplifier. It will be apparent that such equalizer networks, or filters, should be designed to meet the specific problem involved in any particular case so as to produce in the output circuit of the amplifier, a predetermined frequency response.

Heretofore the circuits described have embodied the novel feature of the invention of impressing upon an amplifier system at a point of higher amplification level variations corresponding to frequencies or frequency bands to be equalized derived from a point of lower amplification

level and neutralizing or annulling by opposing the corresponding frequency voltage variations impressed upon the amplifier from an input circuit or line. Another modification of the invention is to utilize the frequencies to be transmitted through the amplifier and superimposing voltages of the desired frequencies upon the amplifier to become additive to the signal voltages in the amplifier, thereby to increase the overall gain of the amplifier so as to obtain a band pass characteristic or any desired shape or output frequency response.

Figure 6 is a modification employing this additive feature, wherein the voltages of the predetermined frequency or frequencies passed by the filters or equalizer are superimposed upon the signal voltages in phase therewith, thereby producing a cumulative increase in the voltages impressed upon the grid for the frequency or frequencies selected by the filter or equalizer networks. In general, the amplifier proper of Figure 6 is similar to the amplifier previously described in connection with Figure 3. The input *a*, *b* from a line or a preceding amplifier is coupled through the input transformer 85 in the example shown an iron-core audio or low frequency transformer the secondary of which is shunted by a coupling resistance 86, and connected to the input grid 51 of the first triode unit of the twin-triode tube 50. The output or plate 52 thereof is coupled through a transformer 91 to the grid 58 of the first triode unit of the second twin-triode 57, through a shunt resistance 87 placed across the secondary of the transformer 86, and a grid series resistance 88. The resistances 87 and 88 form a constant impedance input and output network. The output or plate 61 of this triode unit is connected on the one hand through plate load impedance 89 in the example shown an iron-core choke coil to the high tension source 7 and through coupling condenser 64 and grid leak resistance 63 to the input grid 65 of the second triode unit, the output or plate 66 thereof being connected to the high tension source 7 through the plate load resistance 34 and to the output terminal *c* through coupling condenser 33. The signal energy for the filter or equalizer 67 is applied from the coupling resistance 86 through series grid resistance 86' to the grid 53 of the second triode unit of the first twin-triode valve 50. The output or plate 54 thereof, is connected to the filter or equalizer network 67 through terminals *e* and *f* to the high tension source 7, the output terminals *g* and *h* of the filter or equalizer network 67 being connected to a coupling resistor 90, the latter being in series with the grid resistors 87 and 88 in the input circuit of grid 58 of the first triode unit of the valve 57. As will be apparent from the above, the voltage derived across the coupling resistance 90 from the filter or equalizer networks 67 will be in phase with the voltage impressed upon the grid 58, from the transformer 91. Therefore the voltage variations of the frequencies selected by the filter or equalizer network 67 will become additive to the voltage variations of the same corresponding frequencies repeated by the transformer 91 causing a cumulative resultant thereof which is then applied to the grid 58, producing in the output or plate 61 an amplified response of these selected frequencies, which will be further repeated and amplified by the succeeding amplifier.

To illustrate the operation, and performance, of the circuit of Figure 6, there may be employed

in the filter or equalizer 67 an equalizer or wave corrective network similar to the type shown in Figure 3 but having a characteristic response corresponding to curve H of Figure 5, wherein it will be noted that the frequencies below *a* will be transmitted through the equalizer and the frequencies above *a* will be attenuated. The characteristics of the equalizer or wave correcting network should correspond to the attenuated portion of the impressed input signal as shown by curve E in Figure 5. It is apparent, that these voltage variations of the frequencies transmitted through the equalizer or wave correcting network being impressed upon the grid input 58 of Figure 6 in phase with the impressed voltage variations of the input signals impressed thereon from transformer 91 and of the same approximate amplitude that the attenuated frequencies discriminated by the line or amplifier, are equalized and the result will be a curve as represented by G in Figure 5. As explained in connection with Figures 3, 4, and 5 previously, other types of equalizer or filter networks may be employed to obtain any predetermined frequency response from the amplifier.

Figure 7 represents a modification of the circuit arrangement of Figure 6. The input *a*, *b* is coupled through transformer 85 to the grid 51 of the first triode unit of valve 50, through impedance correcting grid resistance 86' and coupling resistance 86 shunted across the secondary of the transformer. The output or anode 52 of this triode unit, is connected on the one hand through plate impedance 92 to the high tension source 7 and through coupling condenser 93 to the grid 58 of the second twin-triode valve 57. The grid 53 is provided with a grid leak resistance 59 in connection with the usual grid biasing resistance 16 and by-pass condenser 17. The output or plate 61 of this triode unit is coupled as previously described in connection with Figure 5, through resistance 62 to the high tension source 7 and through coupling condenser 64 to grid 65, the latter being provided with the coupling resistance 63. The output or plate 66, is connected through the plate load resistance 34 to the high tension source 7 and through coupling condenser 33 to the output terminal *c*. The amplifier for the filter or equalizer network, in this case, is connected from the output or plate 52 of the first triode amplifier unit in valve 50 through coupling condenser 95 to the grid 53 of the second triode unit in valve 50, the grid 53 being provided with the usual resistance grid leak 96 and biasing means 9 and 10. The output thereof or plate 54 is connected to the filter or equalizer 67 through terminals *e* and *f* to the high tension source 7. The output or terminals *g* and *h* of the filter or equalizer are connected in series with the grid resistance 63 in the input circuit of the last triode unit. It will be apparent from the above description that the voltage variations derived from the output of the filter or equalizer will be in phase with the voltage variations impressed upon the grid 65 through the coupling condenser 64. Therefore the voltage variations of the predetermined frequency or frequencies transmitted by the filter or equalizer will become cumulative to the voltage variations of the same frequencies impressed upon the grid 65 through coupling condenser 64, resulting in producing in the output or plate circuit an increased voltage amplitude of the frequencies selected by the filters or equalizers.

For equalizing or wave correction, equalizers

or wave correction networks as previously described in connection with Figures 3, 4, 5, may be employed. For band pass characteristics or where increased amplitude of a predetermined frequency band is desired, band pass filters may be employed in place of the equalizer or wave correcting networks.

Figures 8 and 9 are illustrative of band pass filter networks adapted to transmit frequencies of any desired band width dependent upon the constants of the component elements thereof.

In Figure 8 there is shown a band pass filter which may be arranged in the "feed forward" auxiliary circuit in any of the preceding illustrations. This filter proper shown at 98 derives its input from the coupling resistance 99 connected across the terminals *e* and *f*, the filter itself consisting of a number of sections and comprising as series elements capacities 100 and 101 and shunt elements consisting of an inductance 103 shunted by condenser 102. The output of filter terminates across the load or variable coupling resistance 104, in the output terminals *g* and *h*. This filter may be used in the circuit in Figure 7 in which case the voltage variations transmitted therethrough will be applied in phase with the voltage variations impressed through the coupling condenser 64 upon the grid 65. It is obvious that where such a band pass characteristic is desired that the coupling means in the amplifier proper such as the input transformer 85, the intercoupling elements 92, 93, 59' and 62, 63, 64 may be replaced with transformers broadly tuned to the frequency band desired or the intercoupling elements may be similar band pass characteristic networks designed to transmit the same frequency band as the additive filter system. In this latter case the additive system will compensate for the attenuation losses through the intercoupled networks and in turn will provide increased selectivity in addition to this increased gain.

Figure 9 represents another type of band-pass filter consisting of a low-pass filter network 105 in series with a high-pass filter network 106, the filters obtaining their potential from coupling resistance 99 connected to input terminals *e* and *f* and the output thereof being connected through the coupling or load resistance 104 to the output terminals *g* and *h*. Each filter illustrated may consist of any number of similar sections and each may be provided with input and output half section filters, and/or may be provided with input, intercoupling and output terminating resistance so designed as to maintain proper impedance characteristic for the adjacent circuits to which these filters are connected.

Figure 10a illustrates the characteristic curve of a typical filter such as illustrated in Figure 9. As noted, the cut-off points of the respective low-pass and high-pass filters are overlapping, that is, the low-pass filter 105 of Figure 9, as illustrated by curve J in Figure 10a, is designed to have a cut-off at frequency f_2 whereas the high-pass filter 106 of Figure 9 is designed to have a cut-off as illustrated by curve K, at frequency f_1 . Figure 10b represents the transmission curve L of the combined filters 105 and 106 of Figure 9. Curve L comprises a frequency band *b* between frequencies f_1 and f_2 corresponding to the cross over cut-off points as represented by curves F and A of Figure 10a, as the frequency band transmitted by the combined filters.

Figure 11 represents a further modification and

improvement of the invention and as illustrated, combines the two methods disclosed namely the neutralizing and the additive or cumulative methods into a single system to produce a band-pass characteristic amplifier for any desired band width having sharp or steep cut-off points at the upper and lower extremities of the frequency band to be transmitted and in which no sacrifice of gain of the amplifier proper is made.

In Figure 11, the amplifier proper comprises three stages embodying pentode valves 1, 14 and 108. The input circuit of the valve 1 obtains its signal voltage through input transformer 8, the primary of which is connected across input terminals *a* and *b*. The secondary of the transformer is provided with a shunt coupling resistance 32 from which the input signal voltage for the filter network system is derived. All of the other elements of the amplifier proper, have been previously described in connection with the other figures and therefore the description thereof will not be repeated. The neutralizing and additive system comprises the twin-triode valve 110, the filters 111, 112, 113 and 114 and associated circuits. The grid 115 of the valve 110 of standard construction, derives its input potential from the input coupling resistance 32.

For the additive system, that is, the system in which the selected frequency voltage variations are superimposed in phase on the signal voltage variations, only this single triode unit is employed as the amplifier. The output or anode 116 thereof is connected through plate load resistance 117 to the high tension source 7, and to the band-pass filters 113 and 114 through terminal *c*. The filter 113 is a low pass filter and 114 is a high pass filter and both may be similar in construction to the band pass filters previously described in connection with Figures 8 and 9 and should be designed to pass the band of frequencies desired as for example a band between frequency f_1 to f_2 as represented in Figure 10b. It is apparent therefore, that the output of the filters connected to terminals *g* and *h* will furnish to the coupling resistance 118, voltage variations of the frequencies of the band *b*. The coupling resistance 118 as shown, is connected in series with the coupling resistance 59 in the grid circuit of valve 14. The voltage variations supplied by the band-pass filters to the coupling resistance 118 being in phase with the signal voltage variations impressed upon the grid 13 of valve 14 through coupling condenser 93, will therefore become cumulative thereto.

For the neutralizing system as shown in this Figure 11, the output from the plate 116 of the valve 110, is coupled to the grid 119 of the second triode unit thereof, through coupling condenser 120, the grid 119 being provided with the usual grid leak or coupling resistance 121, the output or plate 122 of this triode unit being coupled through plate load resistance 123 to the high tension source 7 and to the parallel connected band discriminating networks 111 and 112. It will be apparent, that there will be supplied to these filter networks a greatly amplified signal corresponding to the signal impressed upon the cascade amplifier proper through the input coupling transformer 8. The filter discriminating networks 111 and 112 correspond to the similar filter discriminating networks 26 and 27 described in connection with Figure 1, the low-pass filter 112, having a cut-off point at frequency f_1 , as shown by the curve B in Figure 2a or at the

same frequency at which the high-pass filter 114 has its cut-off point as shown by curve K in Figure 10a, and the high pass filter 111 having its cut-off point at frequency f_2 as shown by curve C in Figure 2a, or at the same frequency at which the low-pass filter 113 has its cut-off point as shown by curve J in Figure 10a. It is apparent therefore, that the low pass filter 112 and high pass filter 111 will pass all frequencies below frequency f_1 and all frequencies above frequency f_2 thereby discriminating for the band of frequencies between f_1 and f_2 . The output of the low pass filter 112 coupled through the blocking condenser or coupling condenser 124, and the output from the high pass filter 111 are connected to the coupling resistance 125 which latter is connected in series with the coupling resistance 126 of grid of the last pentode tube 108. The voltage variations of the frequencies passed by the filters 111 and 112 will be 180° out of phase with the signal voltage variations of the same frequencies impressed upon the grid of the valve 108 through the coupling condenser 33 from the preceding amplifier valve 14. It is apparent, therefore, that the voltage variations of these frequencies will be neutralized and will not be repeated through the pentode amplifier valve 108.

Figure 12 shows curves illustrating the function of the circuit of Figure 11. In Figure 12a curve M represents the typical response characteristic of the three stage cascade amplifier and may also represent the input signal impressed upon the input terminals a, b thereof. Without the novel features of the invention this input signal would be repeated by the amplifier and would produce a similar amplified frequency response in the output thereof. Curve N represents the transmission characteristic of the low pass filter 113 having a cut-off at frequency f_2 . Curve O represents the transmission characteristic of the high pass filter 114 having a cut-off at frequency f_1 . In Figure 12b curve P represents the transmission characteristic of the frequencies between f_1 and f_2 passed through the filters 113 and 114, the voltage variations of which are applied across the coupling resistance 118. Curve Q thereon represents the characteristic curve of the voltage variations of the input signal applied through the coupling condenser 93 from the preceding amplifier valve 14 upon the grid 13 of amplifier valve 14. As the voltage variations represented by curve P across the coupling resistance 118 are in phase with the input signal voltage variations there will be applied to the grid 13 the resultant or a cumulation of these voltage variations as shown by curve R in Figure 12b, which voltage variations will then be repeated or amplified by the valve 14 and accordingly impressed on the grid of the succeeding valve 108, through coupling condenser 33. As only the voltage variations of the frequencies in the band between frequency f_1 and f_2 are desired in the output of the amplifier proper, the voltage variations of the frequencies below frequency f_1 and voltage variation above the frequency f_2 , which would be repeated through the amplifier valve 108, as shown on the curve R of Figure 12d can be eliminated by the use of the neutralizing system of Figure 11. As explained in the following Figure 12c S represents the transmission characteristic of the low pass filter 112 having a cut-off at frequency f_1 and curve T represents the transmission characteristic of the high pass filter 111 having cut-

off at frequency f_2 . In Figure 12d curves S and T represent the voltage variations of the frequencies below f_1 and above f_2 which are applied across the coupling resistance 125 and as previously explained as these voltage variations are 180° out of phase with the voltage variation applied to the grid of amplifier valve 108 through coupling condenser 33 as shown by curve R, these impressed voltage variations will neutralize or oppose the voltage variations of the frequencies below frequency f_1 and above frequency f_2 , resulting in imposing on the grid of valve 108 only the voltage variations between frequencies f_1 and f_2 . These voltage variations will be repeated and amplified by valve 108 producing in the output or plate circuit thereof a band pass characteristic corresponding to curve U in Figure 12e.

Many other modifications may be made to the circuit of Figure 11 such as employing wave correcting networks without departing from the scope of the invention. I do not wish to be limited solely to the devices illustrated as employed in connection with this invention.

It is understood that any other type of network, filters, equalizers, etc., for producing the effects such as for obtaining high pass, low pass, band pass, equalization, band discrimination or wave correction may be employed with equal advantage and without departing from the spirit of the invention. It is further understood that the invention may be equally employed for translating or amplifying both low frequency and high frequency signal waves such as audio or speech currents, as well as, intermediate frequency, high frequency, or ultra-high frequency waves or currents.

While I have shown particular combination of elements to illustrate ways of carrying out the invention, I want it clearly understood that any one of these elements can be used by itself, or with any other element, besides those shown and illustrated without departing from the scope of the invention.

It will further be evident from the above that the invention is not limited to the specific arrangements of parts and circuits shown and methods disclosed herein for illustration, but that the novel thought and underlying principle of the invention, is susceptible of numerous variations and modifications coming within the broad scope and spirit of the invention as defined in the appended claims.

The specification and drawings are accordingly intended to be regarded in an illustrative, rather than a limited sense.

I claim:

1. In the system for translating electric wave energy, an electron tube amplifier comprising a plurality of amplifying stages in cascade normally having a relatively broad input-output frequency response characteristic, means for deriving wave energy from a stage of relatively lower order of said amplifier, a first band-pass type frequency discriminating network having an input and an output and cutoff frequencies separated from each other by a predetermined range corresponding to the wave band to be transmitted by said system, means for impressing said derived energy upon the input of said network, further means for impressing wave energy from the output of said network upon the input circuit of an amplifier stage of relatively higher order in substantially like phase relation to the wave energy being transmitted through said input circuit, means for deriving further wave en-

ergy from an amplifying stage of relatively lower order, a second band-elimination type frequency discriminating network having cutoff frequencies substantially coinciding with the cutoff frequencies of said band-pass network, means for impressing said further derived energy upon the input of said band-elimination network, and further means for impressing output energy from said band-elimination network upon the input circuit of a stage of relatively higher order of said amplifier in phase opposition to the energy being transmitted to said last input circuit.

2. In a system as claimed in the preceding claim comprising amplifying means connected in the path of said band-pass and band-elimination networks, and means for controlling the amplitude of the energies impressed upon said amplifier from said networks to obtain a resultant band-pass type input-output frequency response characteristic of said system having a band width defined by the cutoff frequencies of said first and second network.

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