Jan. 22, 1924. 1,481,284

R. W. DEARDORFF

MEANS FOR AND METHOD OF AMPLITUDE SELECTION

Filed Oct. 5, 1921 3 Sheets-Sheet 1

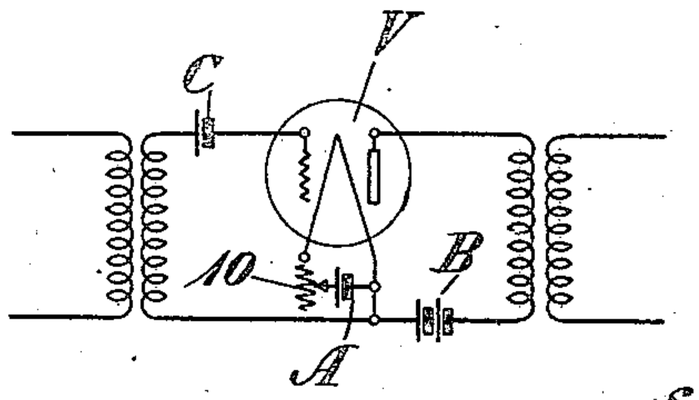

Fig. 1

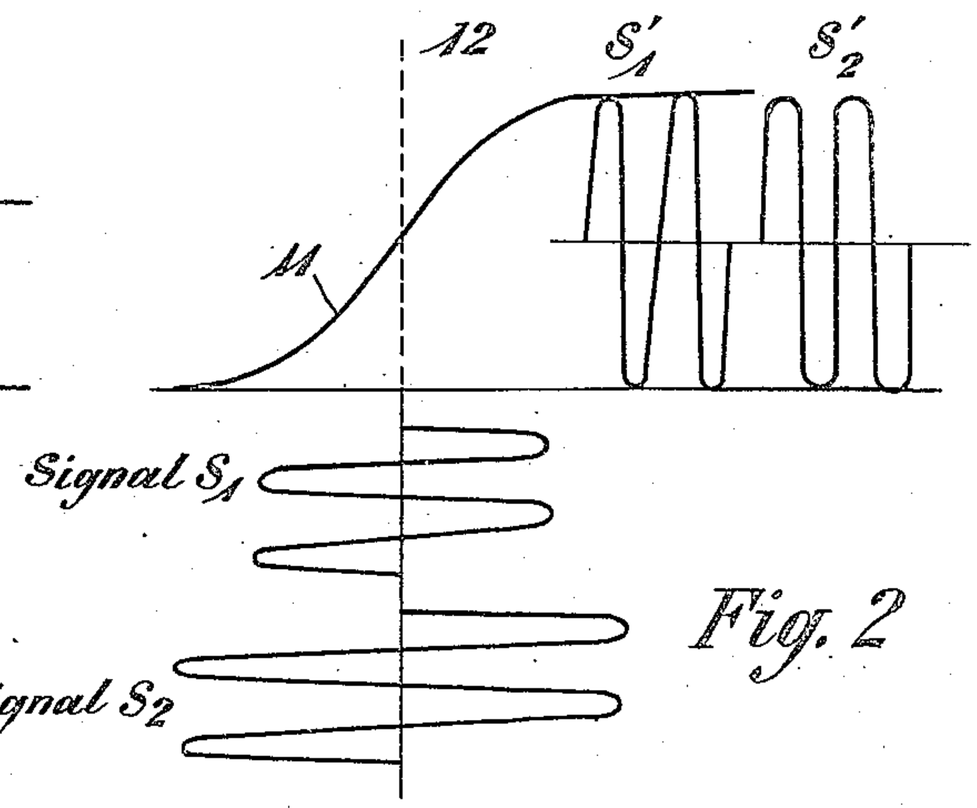

Fig. 2

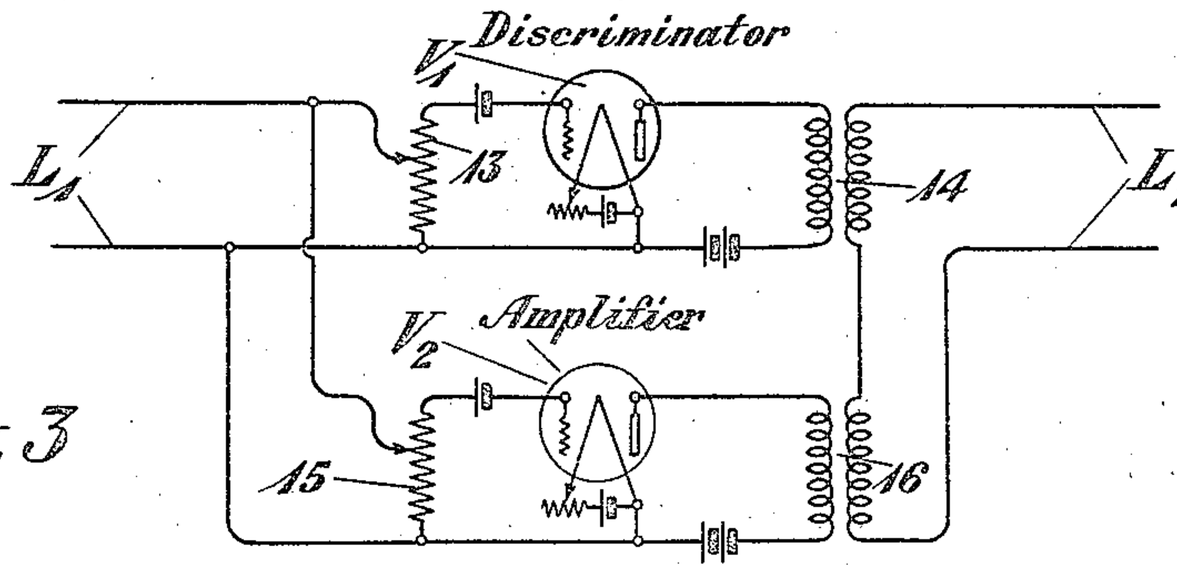

Fig. 3

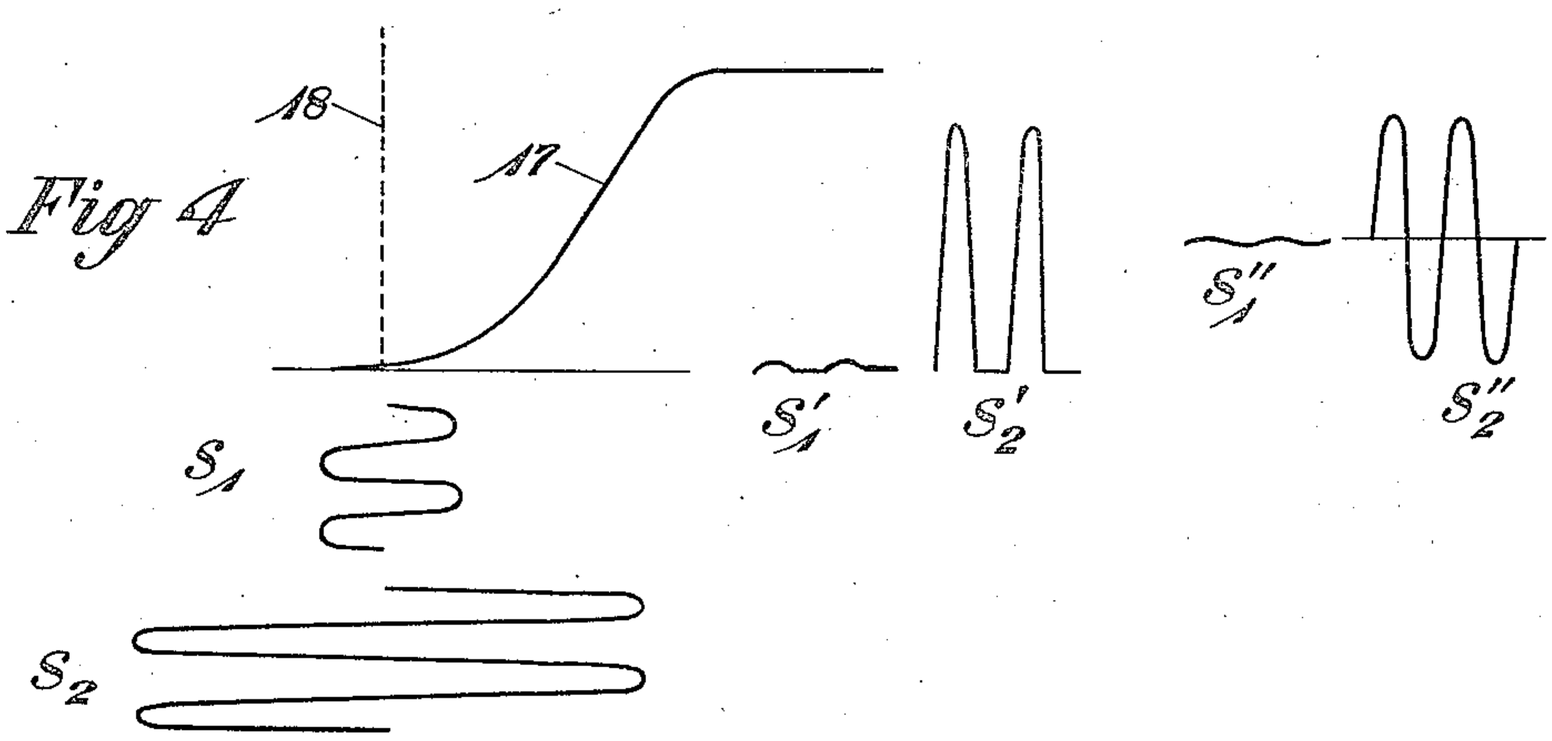

Fig 4

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MEANS FOR AND METHOD OF AMPLITUDE SELECTION

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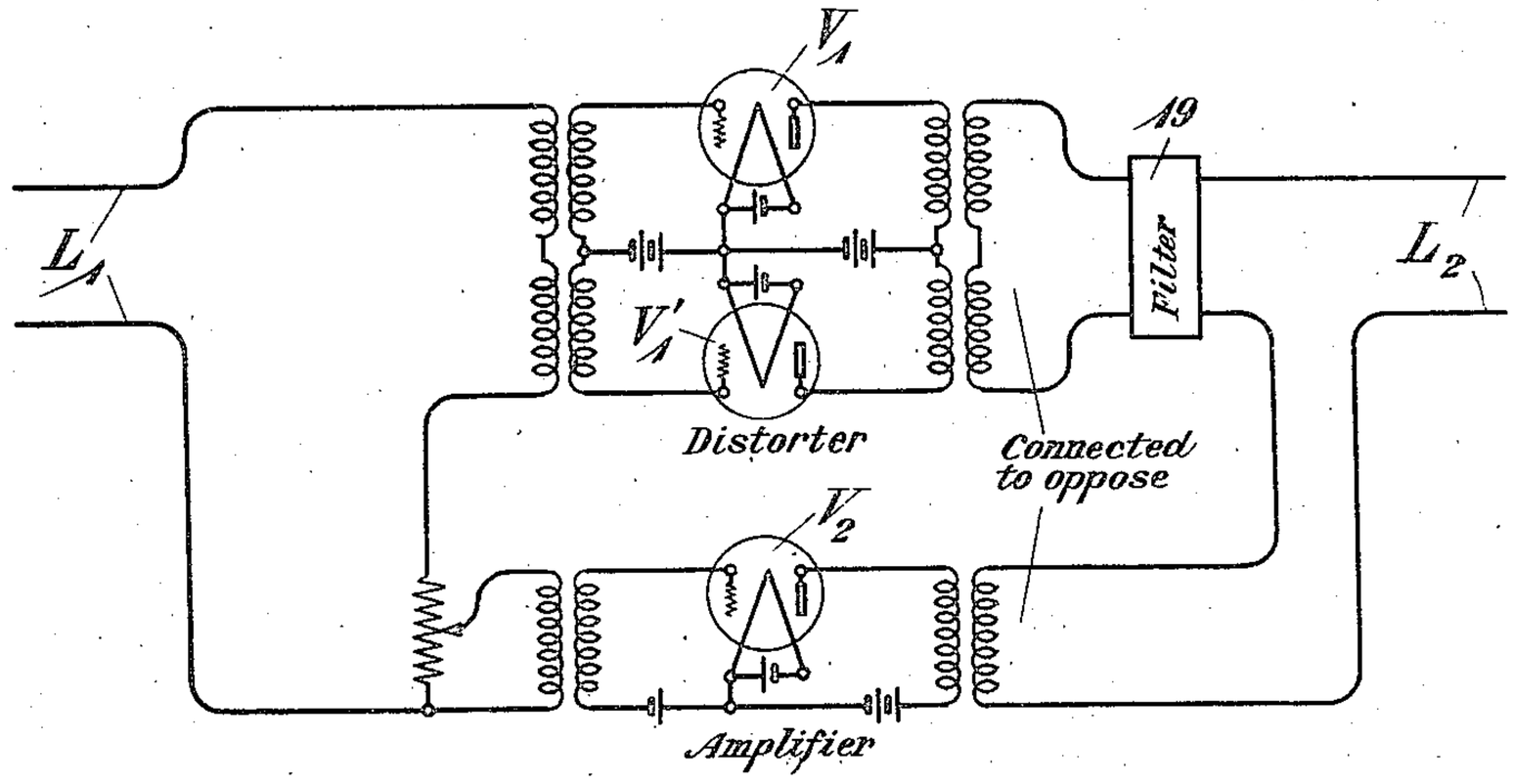


Fig. 5

Fig 6

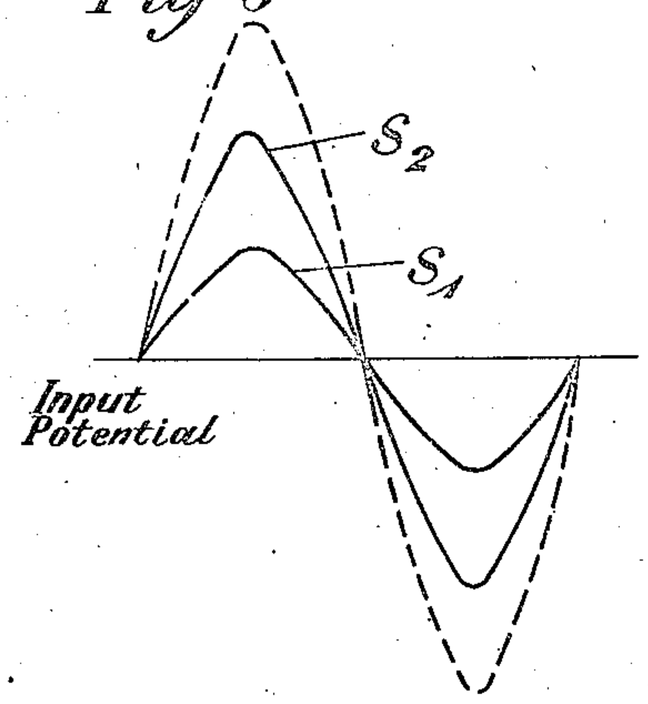
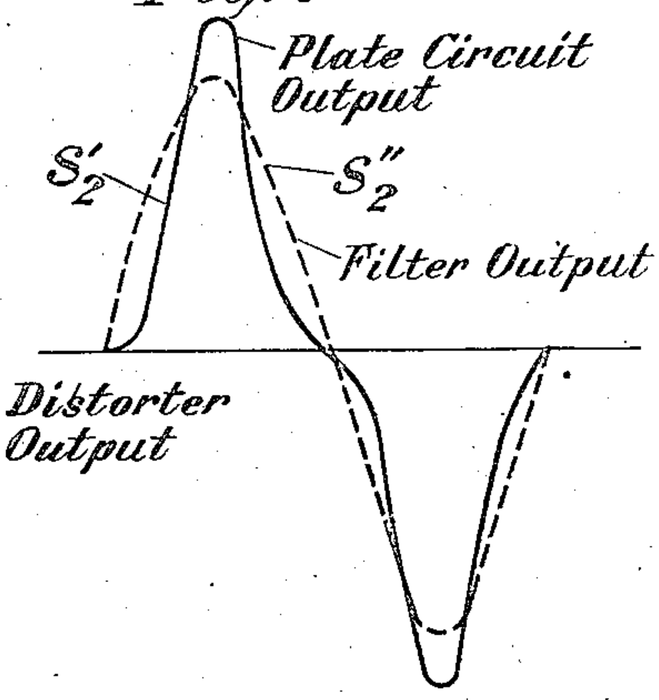


Fig. 7



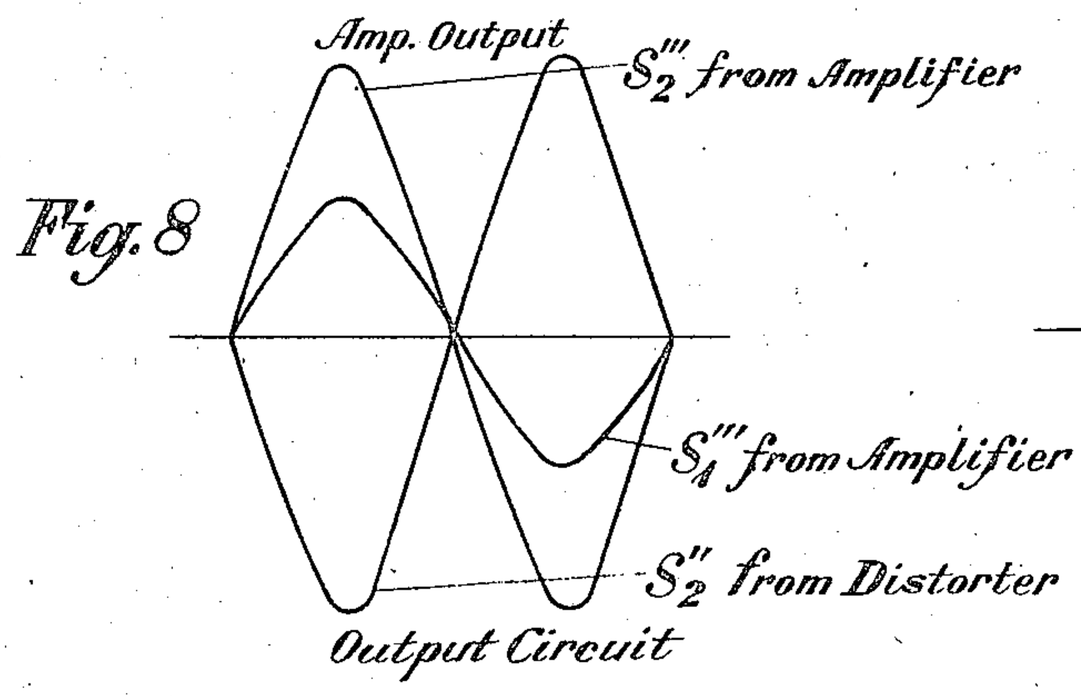


Fig. 8

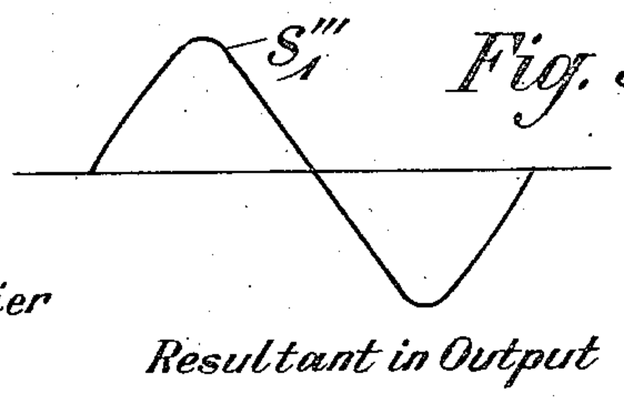


Fig. 9

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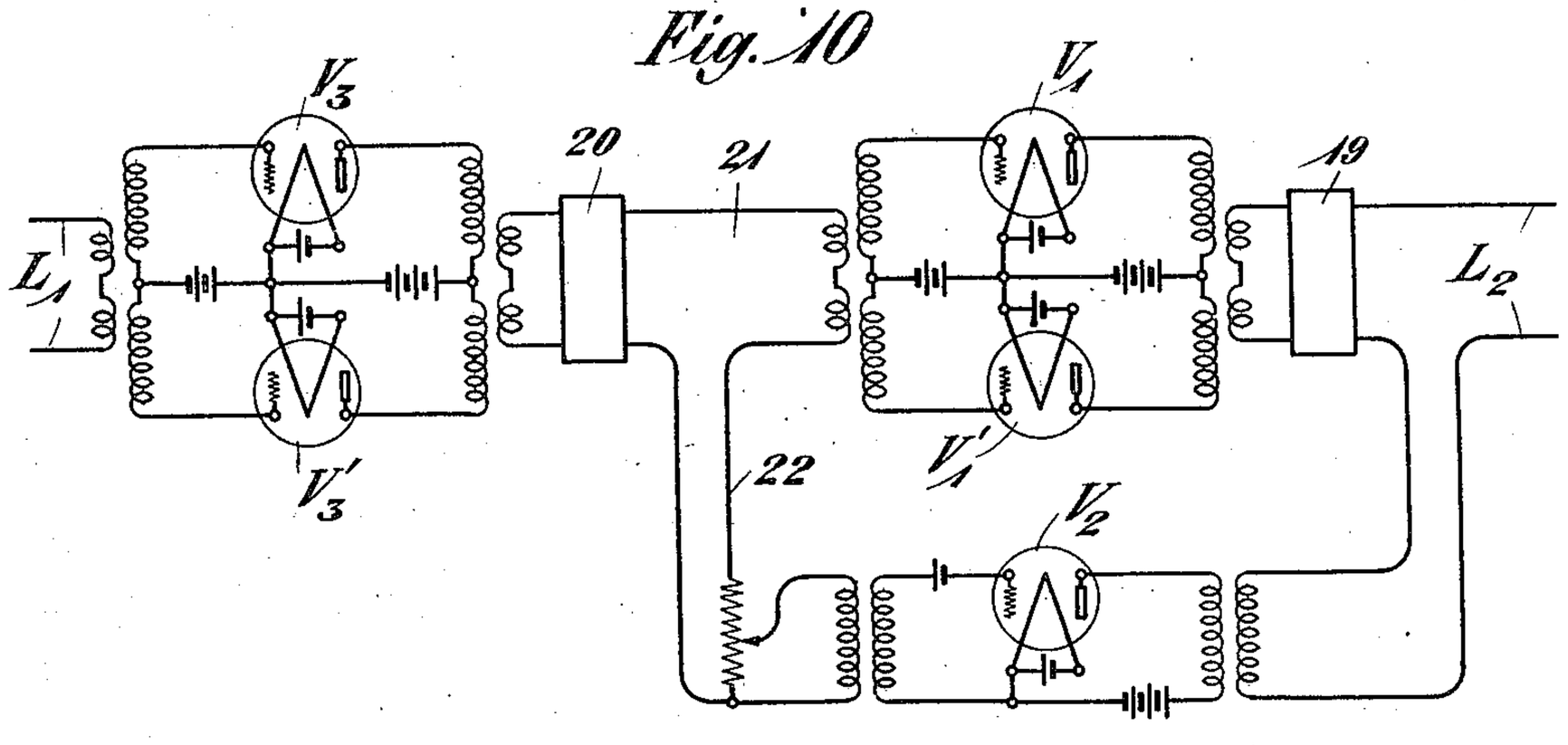
Fig. 10



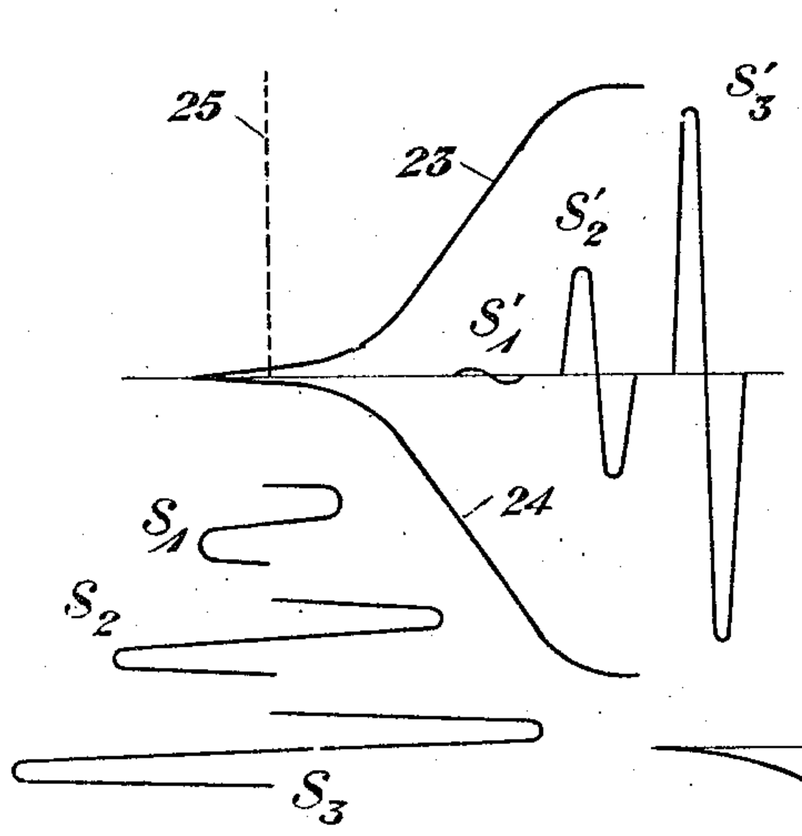


Fig. 11

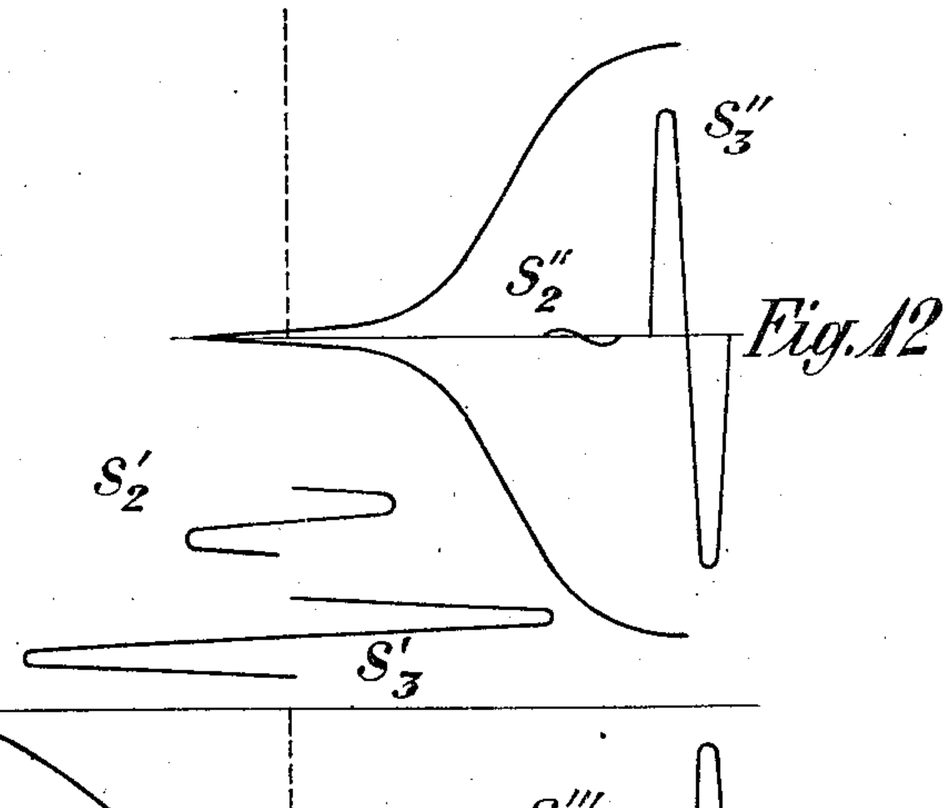


Fig. 12

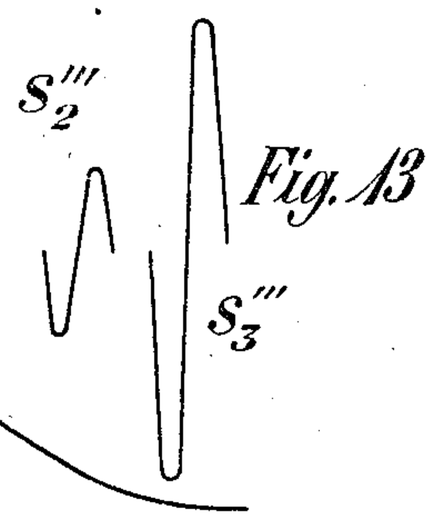


Fig. 13

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Patented Jan. 22, 1924. 1,481,284

UNITED STATES PATENT OFFICE.

RALPH W. DEARDORFF, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MEANS FOR AND METHOD OF AMPLITUDE SELECTION.

Application filed October 5, 1921. Serial No. 505,591.

To all whom it may concern:

Be it known that I, RALPH W. DEARDORFF, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Means for and Methods of Amplitude Selection, of which the following is a specification.

This invention relates to the art of signaling and more particularly to multiplex signaling.

In its broader aspects the invention relates to methods of and means for selecting between signaling currents of different characteristics. More specifically considered, the invention relates to the selection of a given signaling current from a number of superposed signaling currents by virtue of the difference between its amplitude and that of other superposed signaling currents. It also contemplates the elimination or suppression of undesired components having amplitudes above or below the amplitude range to which the device is selective.

In the selection of any given signaling current from a number of superposed signaling currents, it has long been known that if the various signaling currents have characteristic frequencies, a simple method of discrimination is at once available. Where, however, the distinctive characteristic of the several signaling currents is one of amplitude, the problem is not so readily solved. The three-element vacuum tube, however, has certain characteristics which render it available as an instrumentality for amplitude discrimination. In accordance with the present invention therefore, it is proposed to use certain combinations of vacuum tubes and circuits whereby the signaling currents of a given amplitude may be selected to the exclusion of any desired number of superposed signaling currents all having different amplitude.

The invention may now be more fully understood from the following description, when read in connection with the accompanying drawing in which:

Figure 1 is a diagram of a simple form of vacuum tube circuit adapted to be used in connection with the amplitude selection of signaling current;

Fig. 2 is a series of curves illustrating the characteristics of the vacuum tube of Fig. 1;

Fig. 3 is a diagram showing one form of vacuum tube selecting circuit for discriminating between signaling currents of different amplitudes;

Fig. 4 is a series of curves illustrating the operation of the arrangement of Fig. 3;

Fig. 5 is a diagram of a circuit arranged similar to that of Fig. 3, but having certain improved features not present in Fig. 3;

Figs. 6 to 9, inclusive, are curves illustrating the operation of the arrangement of Fig. 5;

Fig. 10 is a circuit diagram of a vacuum tube amplitude selecting organization capable of selecting by means of its amplitude charactertistic a given signaling current from any number of superposed signaling currents; and

Figs. 11 to 13, inclusive, show curves illustrating the operation of the arrangement of Fig. 10.

Referring to Fig. 1, V designates a vacuum tube of the usual type, having a filament, grid and plate. The input circuit includes the usual battery C for determining the grid potential, and the output circuit includes the usual battery B for supplying the plate current. A battery A is provided for heating the filament and the current supplied by this battery to the filament may be regulated by means of a resistance 10.

It is a well-known fact that in a circuit arrangement of this kind the maximum current which can possibly flow between the filament and the plate will be determined by the temperature of the filament, so that by adjusting the resistance 10 to a desired point, the saturation point of the tube, as it is called, may be determined. This will limit the current to be transmitted to the saturation value. An alternative way of limiting the current is by adjusting the plate voltages to some desired maximum value within the limits of saturation, the temperature of the filament being fixed at such a point as to obtain a sufficiently high saturation.

Referring to Fig. 2, for example, 11 designates a curve representing the variation of the plate current with the grid potential, the grid potential being plotted horizontally and space current being plotted vertically. It will be noted that the space current does not increase after a certain grid potential has

been reached, this being indicated by the flat part of the curve. By lowering the filament temperature, or lowering the plate voltage, this flat part of the curve may be lowered as much as desired.

If now the potential of the C battery be so chosen as to bring the normal potential of the grid to the point indicated by the dotted line 12 in the diagram, and an alternating signal, as indicated by the curve marked signal S_1 be superposed upon the grid potential, a variation in the space current will occur, as is indicated by the curve S_1'. If an alternating signal current S_2 of great amplitude be superposed upon the normal grid potential, a similar variation in the space current, as indicated by the curve S_2' will occur, and the maximum amplitude of this variation will be no greater than in the case of the signal S_1, owing to the saturation characteristic of the tube.

Referring now to Fig. 3, it will be shown how this principle may be employed in selecting either of two signals of different amplitude. The tube V_1 in Fig. 3 is a discriminating tube similar to that shown in Fig. 1, and its grid potential and filament temperature may be regulated, so that its characteristic curve will be similar to that of the curve 11. Signals from a line L_1 may be impressed upon this tube through a potentiometer 13, the potentiometer determining the amplitude of the variations impressed upon the grid due to the signal. The output circuit of the tube V_1 may be associated with an outgoing line L_2 through a transformer 14.

A second tube V_2 of construction similar to that of the tube V_1 may be connected with the line L_1 through a potentiometer 15. The filament temperature, plate voltage and the normal grid potential of the tube V_2 may be so adjusted or chosen that the tube will have the usual amplifying characteristic. In general its characteristic curve will be similar to that of the curve 11 of Fig. 2 and the saturation point will be sufficiently high and the potentiometer 15 so adjusted that for signals of amplitudes S_1 or S_2 the tube will operate along the straight portion of its characteristic on either side of the dotted line 12. This will result in reproducing in the output circuit of the tube V_2 in response to signals impressed on the input circuit, current variations similar in both form and relative amplitude to those impressed on the input circuit. The output circuit of the tube V_2 is associated with the line L_2 through a transformer 16 which is so wound that the effect produced in the circuit L_2 will oppose the effect produced by the transformer 14.

If, now, signals of two amplitudes S_1 and S_2 be impressed on the line L_1, both signals will have the same amplitude in the output of the tube V_1. By properly adjusting the potentiometers 13 and 15, however, these signals when passed through the amplifying tube V_2, will appear in the output circuit with such amplitudes that the amplitude of one of them, for example, the signal S_2, will be the same in the output of tube V_2 as the amplitude of the corresponding signal when passed through the discriminating tube V_1. The amplitude of the other signal (S_1 in the case assumed) will be less than that of the signal S_2. As a consequence, the signal in the output circuit of the tube V_2, corresponding to S_2, will balance out in the line L_2 the corresponding component in the output of the tube V_1. The two components corresponding to the signal S_1, however, will not balance, and consequently, the signal S_1 will be received in the line L_2 and the signal S_2 will be excluded.

If the potentiometers 13 and 15 are given a different relative adjustment, the amplitude of the signal S_1 in the output circuit of the tube V_1 may be made just equal to that of the component corresponding to S_1 in the output circuit of the tube V_1. In this case, the components corresponding to the signal S_1 will balance out in the line L_2, but the amplitude of the signal S_2 appearing in the output circuit of the tube V_2 will be greater than that of the corresponding component in the output circuit of the tube V_1, and the signal S_2 will accordingly be received in the line L_2.

It is also possible to utilize a single tube in such a manner as to select a current of greater amplitude to the exclusion of one of lower amplitude by employing a circuit such as that shown in Fig. 1. For example, let us suppose the characteristic of the tube V of Fig. 1 to be as shown at 17 in Fig. 4, and that the C battery be adjusted so that the normal grid potential will be that indicated by the dotted line 18, this potential being somewhat more negative than the point of the upper knee of the curve. If, now, a signal of amplitude S_1 be superposed upon the grid potential, the signal will be practically suppressed, owing to the fact that the curve at this point is almost flat. The variation in the direct current flowing in the output circuit will be as shown at S_1'. A signal of greater amplitude, such as S_2, will however, result in a rectified current in the output circuit, as indicated by S_2', because in this instance the positive halves of the signal wave bring the grid potential up on the slope of the characteristic curve. The signal variations S_1' and S_2', when passed through the output transformer, will cause alternating currents corresponding to the curves S_1'' and S_2'' to appear in the output circuit. It will be noted that the curve S_2'' will, except for a certain amount of distortion, correspond to that of the signal S_2, while the curve S_1'' represents a practically negligible current variation. Accordingly, the

signal S_1 is, for all practical purposes, suppressed.

It would also be possible to suppress the component of lesser amplitude by working beyond the upper knee of the curve. In order to suppress the component of greater amplitude, however, by use of the discriminating tube having a characteristic such as shown in Fig. 4, it will be necessary to use an additional tube as an amplifier, the tubes being connected in a circuit organization such as shown in Fig. 3. In this case it will be seen that only the signal S_2 will be passed through the tube V_1. By properly adjusting the potentiometers, the amplitude of the signal S_2 appearing in the output circuit of the amplifier V_2 may be made equal to the corresponding component in the output circuit of the tube V_1. These two components will accordingly balance out in the line L_2, but the signal S_1 of small amplitude will not be balanced out, due to the fact that it was transmitted through the tube V_2 but not through the tube V_1.

The arrangement just described is subject to the objection that only one half of the signal wave is transmitted and a certain amount of distortion of the signal wave occurs in the discriminating tube. These difficulties are overcome by means of the modified arrangement shown in Fig. 5. In this case the discriminating arrangement comprises two tubes V_1 and V_1' connected in a balanced circuit in such a manner that input waves of one sign will be rectified by the tube V_1 and the input waves of the other sign will be rectified by the tube V_1'. Consequently, both halves of an alternating input signal will be reproduced in the output side of the apparatus, except for the distortion, due to the fact that the tubes are operated below the knee of the curve. The normal grid potential may, of course, be adjusted as indicated in Fig. 4, so that for signals of small amplitude, practically no transmission will take place through the tubes V_1 and V_1', but in the case of signals of greater amplitude, both halves of the wave will be transmitted, subject, of course, to a certain degree of distortion. In order to eliminate the harmonics introduced by the distortion, a low pass or band filter 19 may be included between the line L_2 and the discriminating tubes V_1 and V_1'. By arranging the upper cut-off of this filter sufficiently high to pass the fundamental signaling frequency but to suppress harmonics of this frequency the distortion of the signal will be entirely eliminated and the signal will be restored to its normal sine wave form. The amplifying tube V_2 will, as in the case of Fig. 3, be so connected as to produce upon the line L_2 effects opposite to those produced by the output transformer of the discriminating device. This action is aided by the fact that the filter may in addition to suppressing undesired frequencies, be used as a phase shifting device.

The action of this arrangement in discriminating against current of greater amplitude may be understood from the curves shown in Figs. 6 to 9, inclusive. In Fig. 6, the curves S_1 and S_2 represent simple sine waves as applied to the input side of the tubes V_1 and V_1'. The wave S_1 is suppressed in the manner already described, but the wave S_2, being of greater amplitude, will be transmitted, and if the tubes are properly adjusted, will be amplified as indicated by the curve S_2' of Fig. 7, both halves of the wave being transmitted and both being similarly distorted. The action of the filter 19 upon the curve S_2' will be to produce a simple sine wave S_2'', of lesser amplitude than the wave S_2'. Fig. 8 shows the wave S_2'' passed by the filter 19 and superposed upon the waves appearing in the output circuit of the amplifier V_2 in opposite phase relation. In this diagram the curve S_1''' represents the signal wave S_1 after amplification by the amplifier V_2, while the curve S_2''' is a similar representation of the wave S_2 after amplification. This wave is just equal to, but opposite in sign, to the wave S_2'' supplied by the distorter. As a consequence, signal S_2 is suppressed and the wave S_1''' will appear in the line L_2, as indicated in Fig. 9.

Where it is desired to suppress the current of lower amplitude without distorting the current of greater amplitude only the distorting tube arrangement V_1—V_1' and the filter 19 will be used, the amplifying portion of the apparatus being omitted. This results in the production of the wave S_2'' as indicated in Fig. 7, which corresponds to the signal of greater amplitude.

The arrangements thus far described are only capable of selecting signals of one amplitude from superposed signals of two amplitudes. When it is desired to select any given signal from superposed signals of more than two amplitudes, the principle employed by the apparatus illustrated in Fig. 10 and the curves of Figs. 11 to 13, inclusive, may be employed. In Fig. 10 a discriminating tube arrangement V_1—V_1', with a filter 19 in its output circuit, is associated with the outgoing line L_2 in a manner similar to the corresponding apparatus in Fig. 5. An amplifying tube V_2 is also connected to the line L_2 in a manner similar to that shown in Fig. 5. The input branches 21 and 22 leading to the discriminating tube and the amplifying tube, respectively, are connected in this case, however, to a circuit including a filter 20 instead of being connected directly to the line L_1. The filter 20 is arranged upon the output side of a dis-

criminating arrangement similar to the discriminating arrangement $V_1—V_1'$, this discriminating arrangement comprising tubes $V_3—V_3'$.

Let us assume that signals of three amplitudes, S_1, S_2 and S_3 are being received over the line L_1 and it is desired to select the signal S_2 to the exclusion of the signals S_1 and S_3 of lesser and greater amplitude, respectively. The characteristic curves of the tubes $V_3—V_3'$ are indicated by curves 23 and 24, respectively, of Fig. 11, and the C battery is so adjusted that the normal grid potential will be at the point indicated by the dotted line 25. The result of the operation of these two tubes will be to suppress the signal S_1 in the output circuit of the tube but to pass two signals S_2 and S_3 of greater amplitude, these signals appearing as S_2' and S_3' in Fig. 11. The filter 20 eliminates the harmonics introduced by the distortion of the tubes, so that on the output side of the filter 20 the signals S_2 and S_3 will again appear as pure sine waves having the form S_2' and S_3'. When these waves are impressed upon a similar discriminating tube arrangement $V_1—V_1'$ having the characteristics indicated in Fig. 12, the component S_2' is eliminated and a wave S_3'', corresponding to the original signal wave S_3 will be transmitted, the harmonics being suppressed by the filter 19. The same waves, when impressed upon the amplifying tube V_2 having the characteristics indicated in Fig. 13, will result in the reproduction in the output circuit of said tube of both signals S_2 and S_3 as indicated by the curves S_2''' and S_3'''. The latter of these curves, it will be noted, is of the same form and amplitude as the component S_3'' appearing in the output circuit of the discriminating arrangement. Consequently, the component corresponding to the signal S_3 is balanced out in the line L_2, but a component S_2''', corresponding to the signal S_2, will be transmitted to the line L_2 and will be received. Thus it will be seen that we have an arrangement capable of receiving a band of amplitudes while suppressing those on either side of the received band.

If it is desired to suppress signals of all amplitudes except the signal of maximum amplitude S_3, the amplifying tube V_2 may be omitted, in which case only the signal indicated by the curve S_3'' of Fig. 12 will be transmitted. The same result may be obtained, however, by the use of one pair of discriminating tubes and one filter. For example, the tubes $V_3—V_3'$, together with the filter 20, may be used and the normal C potential so adjusted that currents of amplitudes S_1 and S_2 will fall upon the flat part of the characteristic of the two tubes. This may be done by adjusting the grid potential so that the dotted line 25 will be moved further to the left. This will result in suppressing signals S_1 and S_2 while the signal S_3 will be passed.

If it is desired to transmit to L_2 only the signal of lowest amplitude, such as S_1, the discriminating tubes $V_3—V_3'$, together with the filter 20, may be eliminated. The operating point of the tubes $V_1—V_1'$ will be so set that the signal S_1 will be suppressed by these tubes, while signals of amplitude S_2 and S_3 will be passed. The amplifier V_2 will transmit all three signals, however, and by properly adjusting its degree of amplification, the components corresponding to S_2 and S_3 will balance out the corresponding components passed by the discriminating tube, so that signals S_2 and S_3 will disappear while the signal S_1 will be transmitted through the amplifier V_2 to the outgoing line.

This principle may be extended to the selection of any desired current from currents of as many different amplitudes as desired provided tubes having proper operating characteristics are used. It will be readily seen, for example, from Fig. 10 and the associated curves that the first discriminating device $V_3—V_3'$ can be used to eliminate all amplitudes below the amplitude which it is desired to select. The amplitudes above this limit will then be transmitted to the next discriminating device $V_1—V_1'$ and its associated amplifier V_2. The discriminating device $V_1—V_1'$ may then be adjusted to eliminate in its output circuit the component corresponding to the signal of the desired amplitude, while passing all amplitudes above that which is to be selected. The undesired amplitudes will then be balanced out by means of the components appearing in the output circuit of the amplifier V_2, while the component corresponding to the desired amplitude will not be balanced out, owing to the fact that this component is transmitted by the amplifier V_2 but is not transmitted by the discriminating arrangement $V_1—V_1'$.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. The method of discriminating between currents of the same frequency but of different amplitudes, which consists in translating said currents without changing the relative amplitudes of the individual currents, translating said currents to produce a change in the relative amplitudes of the individual currents, and combining the resulting components so that components of certain amplitudes neutralize each other.

2. The method of discriminating between currents of the same frequency but of dif-

ferent amplitudes, which consists in translating said currents without changing the relative amplitudes of the component currents, translating said currents to produce a change in the relative amplitudes of the component currents while producing such change in the amplitude of the undesired component that it will be equal in amplitude but opposite in sign to the corresponding component resulting from said first mentioned translating action, and combining the components resulting from the action of both translating actions.

3. The method of discriminating between currents of the same frequency but of different amplitudes, which consists in changing the amplitudes of said component currents without disturbing the amplitude ratio between said component currents, changing the amplitudes of the component currents in such a manner as to produce a change in the amplitude ratio between the components, and combining the resultant components in such a manner as to neutralize undesired components.

4. The method of discriminating between currents of the same frequency but of different amplitudes, which consists in changing the amplitudes of said component currents without changing the amplitude ratio between the different components, changing the amplitudes of the component currents in such a manner as to produce a change in the amplitude ratio between the component currents as well as to bring undesired components to the same amplitude as the corresponding components resulting from the first mentioned operation, and combining the components resulting from both operations in such a manner as to neutralize the undesired components.

5. The method of discriminating between currents of the same frequency but of different amplitudes, which consists in amplifying all said component currents by the same factor, amplifying certain component currents by different factors, and combining the resultant components in such a manner as to neutralize undesired components.

6. The method of discriminating between currents of the same frequency but of different amplitudes, which consists in amplifying all said components by the same factor, amplifying the components by different factors so chosen as to produce currents of the same amplitude as regards certain components as the corresponding components resulting from the first mentioned operation, and combining the components resulting from both operations in such a manner that components of the same amplitude neutralize each other.

7. The method of discriminating between currents of different amplitudes, which consists in suppressing all currents having amplitudes lower than a desired minimum amplitude, translating the remaining components in such manner as to suppress all components having an amplitude greater than an upper limiting amplitude, and transmitting the remaining components.

8. The method of discriminating between currents of different amplitudes, which consists in suppressing components having amplitudes below a minimum desired amplitude, amplifying the remaining components without changing the amplitude ratio of such components, amplifying said components in such a manner as to change the amplitude ratio of the components, and combining the components resulting from the last two operations so that undesired components counteract each other.

9. The method of discriminating between currents of different amplitudes, which consists in suppressing components having amplitudes below a desired minimum amplitude, amplifying the remaining components without changing the amplitude ratio between the components, also amplifying said remaining components in such a manner as to change the amplitude ratio by bringing the amplitudes of undesired components to the same level as corresponding components resulting from the preceding operations, and combining the components resulting from both operations in such a manner that components having the same amplitude will neutralize each other.

10. The method of discriminating between currents of different amplitudes, which consists in suppressing components having amplitudes lower than a desired minimum amplitude, changing the amplitudes of the remaining components without changing the amplitude ratio between the different components, changing the amplitudes of said remaining components in such a manner as to change the ratio between the amplitudes of the different components, and combining the components resulting from the last two operations so that undesired components neutralize each other.

11. The method of discriminating between currents of different amplitudes, which consists in suppressing components having amplitudes below a desired minimum amplitude, amplifying the remaining components without changing the amplitude ratio between the components, amplifying said remaining components in such a manner as to change the amplitude ratio while bringing undesired components to the same amplitude level as corresponding components resulting from the preceding operations, and combining the components resulting from the last two operations in such a manner that the components of equal amplitude will be neutralized.

12. The method of discriminating between

currents of different amplitudes, which consists in translating the various components in such manner as to suppress components having an amplitude lower than a desired minimum amplitude, translating the remaining components without changing the relative amplitudes of the different components, translating said remaining components in such manner as to change the relative amplitudes of the components, and combining the components resulting from the last two operations in such a manner as to neutralize undesired components.

13. The method of discriminating between currents of different amplitudes, which consists in translating the various components in such manner as to suppress components having amplitudes lower than a desired minimum amplitude, translating the remaining components without changing the relative amplitudes of the various components, translating said remaining components to change the relative amplitudes of the various components in such a manner as to bring undesired components to the same amplitude as that of corresponding components resulting from the preceding operation, and combining the components resulting from both operations in such a manner that components of the same amplitude will be neutralized.

14. A system for discriminating between currents of the same frequency but of different amplitudes, comprising a translating device for changing the amplitudes of said various components without changing their ratio, a second translating device for producing a change in both amplitude and amplitude ratio of the various components, and means for combining the components resulting from the action of both translating devices in such a manner that undesired components will be neutralized.

15. A system for discriminating between currents of the same frequency but of different amplitudes, comprising means for amplifying said component currents without changing their amplitude ratio, means for amplifying certain components to a greater degree than others, and means for combining components resulting from both amplifying operations in such a manner as to neutralize undersired components.

16. A system for discriminating between currents of the same frequency but of different amplitudes, which comprises a vacuum tube circuit arrangement adapted to amplify all said components by the same factor, a second vacuum tube circuit arrangement adapted to amplify various components by different factors, and means to combine the components resulting from the action of both tubes in such a manner as to neutralize undersired components.

17. A system for discriminating between currents of the same frequency, but of different amplitudes, which comprises a vacuum tube arrangement for amplifying said components by the same factor, a second vacuum tube arrangement for amplifying components of different amplitudes by different factors so chosen that the amplitudes of certain components, when amplified, will be equal to the amplitudes of the corresponding components resulting from the action of the first vacuum tube arrangement, and means for combining the components resulting from the action of both vacuum tube arrangements in such a manner that components of equal amplitude will neutralize each other.

18. A system for discriminating between currents of different amplitudes, which comprises means for suppressing all components having an amplitude lower than a minimum desired amplitude, and means for suppressing currents having amplitudes greater than a maximum desired amplitude.

19. A system for discriminating between currents of different frequencies, which comprises means for suppressing components having amplitudes lower than a minimum desired amplitude, means for changing the amplitudes of the remaining components without changing their amplitude ratio, means for changing the amplitudes and amplitude ratio of said remaining components, and means to combine the components resulting from the last two actions in such a manner as to neutralize undesired components.

20. A system for discriminating between currents of different amplitudes, which comprises means for suppressing components having amplitudes lower than a desired minimum amplitude, means for amplifying all the remaining components by the same factor, means for amplifying said remaining components by different factors, and means for combining the components resulting from the last two operations in such a manner that undesired components will be neutralized.

21. A system for discriminating between currents of different amplitudes, which comprises means for suppressing components having amplitudes below a minimum desired amplitude, means for amplifying all the said remaining components by the same factor, means for amplifying said remaining components by different factors so chosen that certain components, when amplified, will have the same amplitude as corresponding components resulting from the previous operations, and means for combining the components resulting from the last two operations in such a manner that components of equal amplitude will be neutralized.

22. A system for discriminating between

currents of different amplitudes, which comprises means for suppressing components having amplitudes lower than a minimum desired amplitude, a vacuum tube arrangement for amplifying all of said remaining components by the same factor, a second vacuum tube arrangement for amplifying said remaining components by different factors, and means for combining the components resulting from the action of both vacuum tube arrangements in such a manner as to neutralize undesired components.

23. A system for discriminating between currents of different amplitudes, which comprises means for suppressing components having amplitudes below a minimum desired amplitude, a vacuum tube arrangement for amplifying the remaining components by the same factor, a second vacuum tube arrangement for amplifying said remaining components by different factors so chosen that certain components, when amplified, will have the same amplitude as corresponding components resulting from the action of the first vacuum tube arrangement, and means for so combining the components resulting from the action of both vacuum tube arrangements that components having the same amplitude will neutralize each other.

In testimony whereof, I have signed my name to this specification this 1st day of October, 1921.

RALPH W. DEARDORFF.