

Jan. 3, 1933.

E. PETERSON

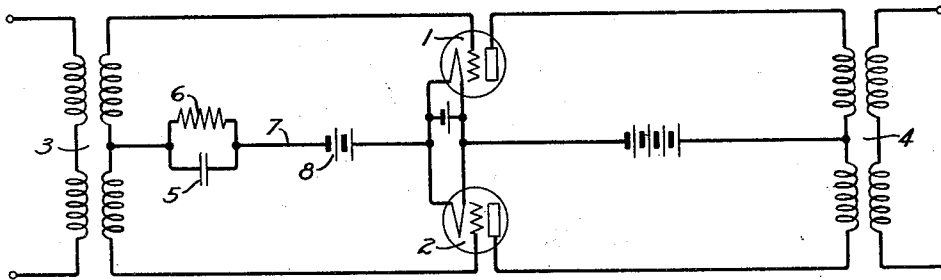
1,893,302

METHOD OF AND MEANS FOR CONTROLLING ELECTRIC WAVE AMPLIFIERS

Filed June 20, 1928

2 Sheets-Sheet 1

FIG. 1



INVENTOR
EUGENE PETERSON
BY *J.P. Neville*

ATTORNEY

Jan. 3, 1933.

E. PETERSON

1,893,302

METHOD OF AND MEANS FOR CONTROLLING ELECTRIC WAVE AMPLIFIERS

Filed June 20, 1928

2 Sheets-Sheet 2

FIG. 2

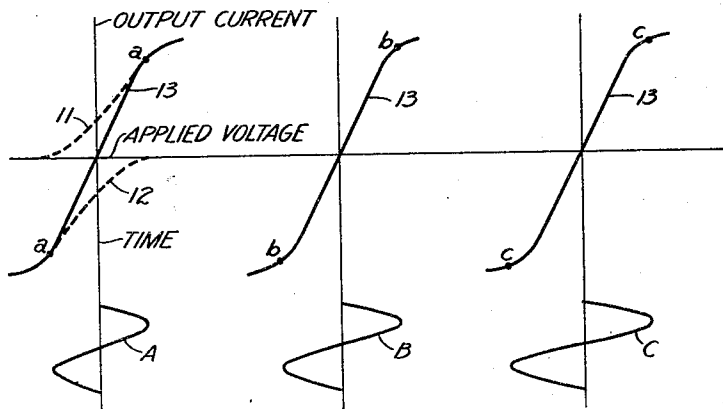


FIG. 3

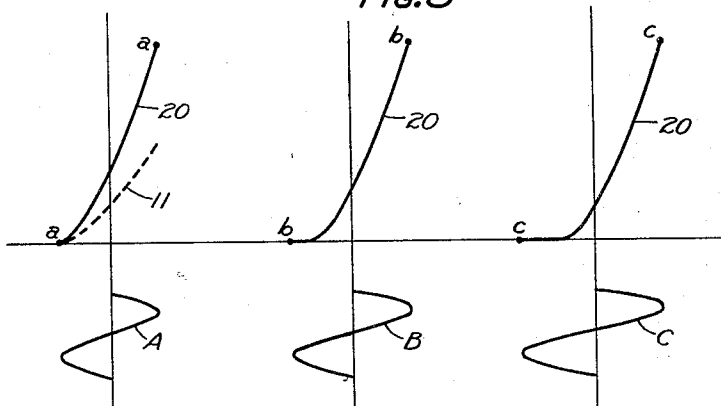
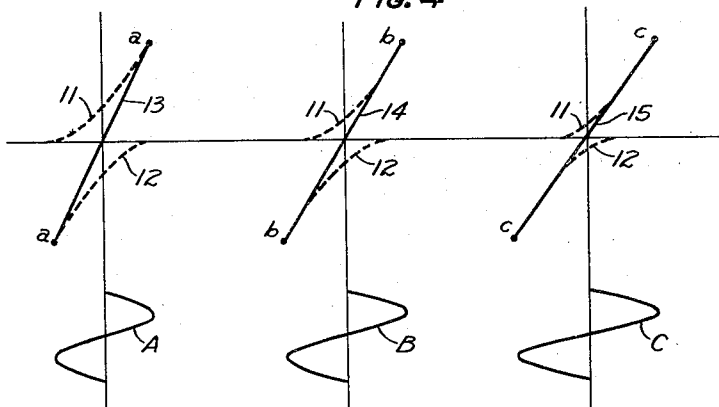


FIG. 4



INVENTOR
EUGENE PETERSON
BY *J. P. Neville*
ATTORNEY

UNITED STATES PATENT OFFICE

EUGENE PETERSON, OF NEW YORK, N. Y., ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

METHOD OF AND MEANS FOR CONTROLLING ELECTRIC WAVE AMPLIFIERS

Application filed June 20, 1928. Serial No. 286,772.

This invention relates to a method of and means for reducing modulation effects or distortion in amplifiers and controlling the gain thereof, particularly in space discharge amplifying tubes connected in push-pull relation.

Amplifiers employing space discharge tubes are commonly operated with a "C" battery or other source of constant negative grid bias.

It has also been proposed to employ, in connection with space discharge amplifier tubes operating singly or in parallel, a grid condenser and resistance combination for accumulating and maintaining a charge derived from the grid current, thereby providing a grid biasing potential without the use of a "C" battery and proportional at every instant to the envelope of the wave to be amplified.

It has been proposed, further, to employ a grid condenser and resistance combination to supplement a "C" battery, thereby providing added negative grid bias, when momentarily high potentials are impressed upon the amplifier, to prevent distortion of the wave.

When a grid condenser and resistance combination is employed in conjunction with tubes operated singly or in parallel, the amplifier may be operated without material distortion provided the amplitude of the input wave does not exceed a more or less definite value. When, however, the amplitude of the input wave is increased beyond a certain value, the amount of distortion progressively increases. The same result has been observed in an amplifier including push-pull connected space discharge tubes having their grids biased with respect to their cathodes by the application of a constant negative voltage.

When, however, a grid condenser and resistance combination is employed in conjunction with amplifying tubes connected in push-pull relation, the useful range of input values is materially extended. That is, the range of amplitude of the input wave which the amplifier can satisfactorily amplify without increasing distortion, is materially widened.

An object of the present invention is to de-

crease wave distortion due to changes in the input impedance of a space discharge amplifying system when grid current flows in its external input circuit.

Another object is to cause, in a substantially distortionless amplification system, a decreasing gain when the value of the input increases beyond a predetermined value.

Many transmission systems in common use are limited by economic, engineering or other practical considerations to a restricted range of amplitude values for the wave applied to the input electrodes of the amplifier. The feature of the invention whereby the gain of the amplifier decreases with the amplitude of the applied wave is particularly useful for compressing waves, having amplitudes varying over a wide range of values, into a restricted range without material distortion of the wave form.

The invention may be more fully understood from the following detailed description when read in conjunction with the drawings, wherein

Fig. 1 represents an embodiment of the invention,

Figs. 2 and 3 show typical operating characteristics of amplifying systems heretofore proposed, and

Fig. 4 shows corresponding characteristics of an amplifier embodying the present invention.

In Fig. 1, space discharge devices 1 and 2 are shown connected in push-pull relation between an input transformer 3 and an output transformer 4. An impedance network, consisting of a condenser 5 and a resistance 6 in parallel, is inserted in the common input lead 7 for producing a grid bias supplementary to that supplied by a grid battery 8, as will be more fully explained hereinafter.

If input waves of insufficient intensity to produce grid current in either of devices 1 or 2 are applied to the primary winding of input transformer 3, the system will operate in the usual manner of a push-pull amplifier to supply amplified waves to a load circuit, which may be connected to the secondary winding of output transformer 4. As no grid current flows, there will evidently be no

charge accumulated on condenser 5. The operation of the system in response to such applied waves is therefore substantially unaffected by the presence of condenser 5 or resistance 6.

The application of input waves, a portion of which, by virtue of sufficient amplitude of the whole, is effective to produce grid current flow in either or both of devices 1 and 2 and hence through the external input circuit, will, by causing a charge to be accumulated upon the plates of condenser 5, increase the negative grid bias of both devices and thus tend to decrease the grid current. The grid current automatically adjusts itself until it is exactly sufficient to counterbalance the leakage of the charge from condenser 5 through resistance 6 and thus the circuit maintains a constant grid bias as long as the amplitude of the applied wave remains unchanged.

Any change in the amplitude of the applied wave will be immediately followed by a variation of the grid bias until, at a slightly different value of grid current, a new condition of equilibrium is reached or until grid current ceases to flow.

The fractional value of the portion of the applied wave effective to produce grid current depends inversely upon the ratio between the resistance of element 6 and the internal grid-to-cathode resistance of the space discharge device. In a given case, by increasing the value of resistance 6 the portion of the wave effective on the grid can be made as small as may be desired, within practical limits. In this way the maximum value of grid current produced by applied waves of the largest amplitude for which the amplifier is intended may be made negligibly small.

When the amplifier is operated in the above described manner, the resulting fluctuations in the internal grid-to-cathode resistance of the tube may be maintained relatively small. Consequently, the wave distortion, or grid current modulation, introduced by the grid-to-cathode resistance variations is minimized.

While the equilibrium value of the grid current in any specific case is determined primarily by the relative values of resistance 6 and the internal grid-to-cathode resistance of the device, the time required for the system to change from one condition of equilibrium to another is dependent upon the time constant, or product of resistance by capacity, for the impedance network comprising condenser 5 and resistance 6.

Fluctuations in the amplitude of the applied waves which take place over periods that are long, in comparison with the time constant, will be fully responded to by the network and a complete and substantially instantaneous adjustment of grid bias will occur. Faster fluctuations are compensated

less quickly and completely, or, if too fast, they are not compensated at all.

For the amplification of modulated carrier waves, a network having a time constant of a few hundredths of a second has been used with good results.

In any given case a suitable value for the time constant of the network 5, 6 may readily be found either by computation or experiment.

If desired, any one of a plurality of suitable impedance networks may be used to couple input transformer 3 to devices 1 and 2. Aside from efficiently transmitting the applied wave to the input terminals of the discharge devices, the essential requirements for an alternative network are that it provide a conductive path and additional electrostatic capacity between the terminals of the discharge devices, unless the internal capacity is found to be already of a suitable value before insertion of the network. The values of leakage resistance and time constant for an alternative network are to be determined in accordance with the rules hereinbefore stated for network 5, 6.

The process hereinbefore described, whereby the grid bias is adjusted in response to changes in the amplitude of the applied wave when the amplitude exceeds a certain moderate value, results in a change in the operating characteristic curve of the combined discharge devices which is beneficial to this operation as an amplifier. The nature of the change in the operating characteristic is shown graphically by comparing Figs. 2 and 3 with Fig. 4.

In Figs. 2 to 4, the operating characteristic curves 11 to 15 and 20 are plotted with output currents as the ordinates and applied voltages as the abscissæ. Curves A, B and C are applied sinusoidal waves plotted with values of time as the ordinates and applied voltages as the abscissæ. The applied waves represented by A, B and C are of increasing amplitude in the order named.

The amplitude of wave A is such as to traverse the segment $a-a$ of any characteristic 13 to which it is applied in Figs. 2 to 4. Similarly, wave B traverses segment $b-b$ and wave C traverses segment $c-c$. The amplitudes of waves A, B and C in the respective figures are equal.

Fig. 2 shows typical operating characteristics for a push-pull amplifier of the type heretofore proposed and now well known in the art, such, for example, as might be represented by the amplifier of Fig. 1, omitting network 5-6.

Curves 11 and 12 are the characteristics of the individual devices comprising the push-pull amplifier. Curve 13 is the combined characteristic obtained by algebraic addition of the corresponding ordinates of curves 11 and 12.

Segment *a-a* of curve 13 is substantially rectilinear. Therefore, as is well known, the operation of the device over the segment will result in amplification of the applied wave substantially without distortion.

Segments *b-b* and *c-c* depart progressively from rectilinearity by including the curved portions shown at either side of the straight part of curve 13. Consequently the waves B and C will be amplified with increasing amounts of distortion.

Fig. 3 shows typical operating characteristics for an amplifier comprising two discharge devices similar to those shown in Fig. 1 but connected in parallel instead of in push-pull relation and provided with a network such as network 5—6 for supplying additional negative grid bases when waves of large amplitude are applied. Curve 11 is identical with the similarly numbered curve in Fig. 2 and, as before, is the characteristic of an individual discharge device.

In curve 20, which represents the characteristic of two such devices in parallel, each ordinate is twice as large as the corresponding ordinate of curve 11. As before, the segment of the characteristic over which each applied wave operates is designated by small letters indicating the terminal points of the segment. With this circuit arrangement there is a certain amount of distortion when wave A is applied and the amount of the distortion progressively increases with increase of the amplitude of the applied wave.

Fig. 4 illustrates the manner in which the device of the invention permits the amplification of waves of increased amplitude without material distortion due to curvature of the characteristic.

On account of the additional grid bias provided by the operating characteristic of the network 5—6 the individual characteristics 11 and 12 are displaced horizontally by an amount proportional to the increase in the amplitude of the applied wave and are thus combined in a manner which depends upon the amplitude of the applied wave.

Characteristics 13, 14 and 15, which are effective for applied waves A, B and C respectively, differ from each other in slope but are nevertheless all substantially rectilinear. Waves A, B and C are therefore amplified substantially without distortion. Due to the difference in the slope of the characteristics, the applied waves A, B and C, are all reproduced as output waves which are substantially equal in amplitude. In other words, in spite of the difference in the amplitudes of the impressed waves A, B and C, the amplitudes of the waves repeated by the device are limited to a substantially fixed value. This is due to the fact that within a range of amplitudes sufficiently large to produce grid current, the gain of the ampli-

fier is caused to vary inversely with the amplitude of the applied wave. While this is true also of the amplifier operating in accordance with Fig. 3, the operation of the amplitude limiting function in that case is accompanied by pronounced distortion, as noted above.

A comparison of Figs. 2, 3 and 4 shows that the invention effects a material extension of the range of applied waves which can be amplified without distortion.

What is claimed is:

1. An amplifier of alternating current comprising a plurality of space discharge devices connected in push-pull relation, each of said space discharge devices having a cathode, an anode and a control electrode, input and output circuits for said space discharge devices, means for supplying a substantially constant negative biasing potential to said control electrodes, said means being of such voltage as to prevent conduction of grid current through said space discharge devices when said amplifier is actuated by alternating current within an extended range of normal operating intensities, and a grid leak and condenser in said input circuit for supplying a second biasing potential to said control electrodes responsive to grid current whereby said amplifier is prevented from causing appreciable amount of grid current modulation when actuated by alternating current of intensities in a second extended range of intensities beyond said first mentioned range.

2. An amplifier of alternating current comprising a plurality of space discharge devices connected in push-pull relation, each of said space discharge devices having a cathode, an anode and a control electrode, input and output circuits for said space discharge devices, means for supplying a substantially constant negative biasing potential to said control electrodes, said means being of such voltage as to prevent conduction of grid current through said space discharge devices when said amplifier is actuated by alternating current within an extended range of normal operating intensities, and a grid leak and condenser in said input circuit for supplying a second biasing potential to said control electrodes responsive to grid current whereby said amplifier is prevented from causing appreciable amount of grid current modulation when actuated by alternating current of intensities in a second extended range of intensities beyond said first mentioned range, said grid leak and condenser combined having a value of time constant which is large compared with the alternation period of the current amplified.

3. An amplifier of alternating current comprising a plurality of space discharge devices connected in push-pull relation, each of said space discharge devices having a cathode, an

anode and a control electrode, input and output circuits for said space discharge devices, means for supplying a substantially constant negative biasing potential to said control electrodes, said means being of such voltage as to prevent conduction of grid current through said space discharge devices when said amplifier is actuated by alternating current within an extended range of normal operating intensities, and a grid leak and condenser in said input circuit for supplying a second biasing potential to said control electrodes in response to and in proportion to an increase in the intensity of the alternating current beyond said above mentioned range of intensities whereby said amplifier is prevented from causing appreciable amount of grid current modulation when actuated by alternating current of intensities in a second extended range of intensities beyond said first mentioned range.

4. An amplifier of alternating current comprising a plurality of space discharge devices connected in push-pull relation, each of said space discharge devices having a cathode, an anode, and a control electrode, input and output circuits for said space discharge devices, means for supplying a substantially constant negative biasing potential to said control electrodes, said means being of such voltage as to prevent conduction of grid current through said space discharge devices when said amplifier is actuated by alternating current within an extended range of normal operating intensities, and a grid leak and condenser in said input circuit for supplying a second biasing potential to said control electrodes responsive to grid current whereby a reduction is effected in the transmission gain of the amplifier when actuated by alternating current of intensities in a second extended range of intensities beyond said first mentioned range while the amplifier is prevented from causing appreciable amount of grid current modulation.

5. An amplifier of alternating current comprising a plurality of space discharge devices connected in push-pull relation, each of said space discharge devices having a cathode, an anode and a control electrode, input and output circuits for said space discharge devices, means for supplying a substantially constant negative biasing potential to said control electrodes, said means being of such voltage as to prevent conduction of grid current through said space discharge devices when said amplifier is actuated by alternating current within an extended range of normal operating intensities, and a grid leak and condenser in said input circuit for supplying a second biasing potential to said control electrodes responsive to grid current whereby a reduction is effected in the transmission gain of the amplifier when actuated by alternating current of intensities in a sec-

ond extended range of intensities beyond said first mentioned range while the amplifier is prevented from causing appreciable amount of grid current modulation, said grid leak and condenser combined having a value of time constant which is large compared with the alternation period of the current amplified.

6. An amplifier of alternating current comprising a plurality of space discharge devices connected in push-pull relation, each of said space discharge devices having a cathode, an anode and a control electrode, input and output circuits for said space discharge devices, means for supplying a substantially constant negative biasing potential to said control electrodes, said means being of such voltage as to prevent conduction of grid current through said space discharge devices when said amplifier is actuated by alternating current within an extended range of normal operating intensities, and a grid leak and condenser in said input circuit for supplying a second biasing potential to said control electrodes in response to and in proportion to an increase in the intensity of the alternating current beyond said above mentioned range of intensities whereby a reduction is effected in the transmission gain of the amplifier when actuated by alternating current of intensities in said second extended range of intensities beyond said first mentioned range while the amplifier is prevented from causing appreciable amount of grid current modulation.

In witness whereof, I hereunto subscribe my name this 16th day of June, 1928.

EUGENE PETERSON.