Nov. 3, 1931. E. PETERSON 1,830,240

ELECTRIC WAVE LIMITING DEVICE

Filed May 18, 1929

FIG. 1.

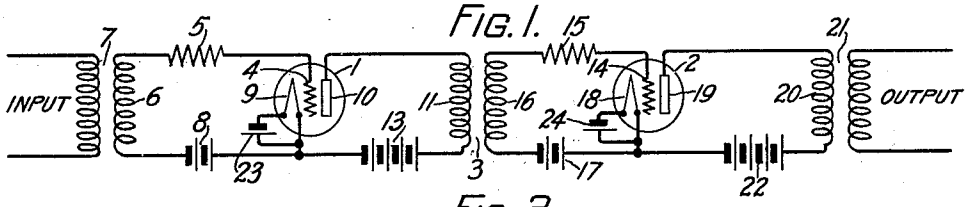


FIG. 2.

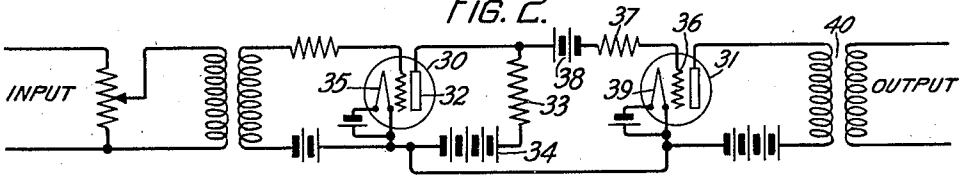


FIG. 3.

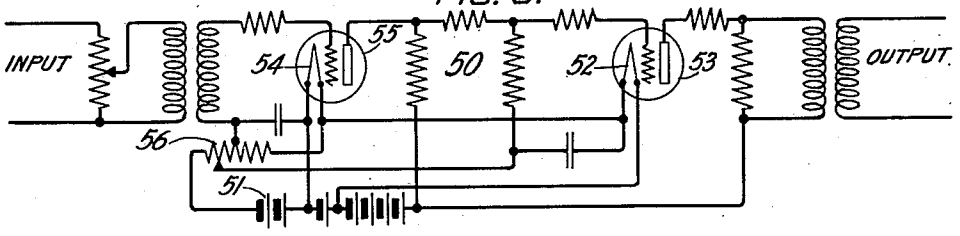


FIG. 5.

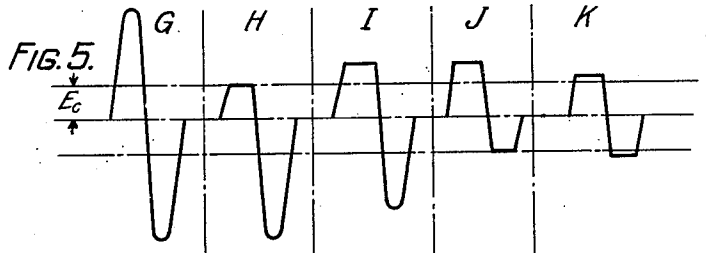


FIG. 6.

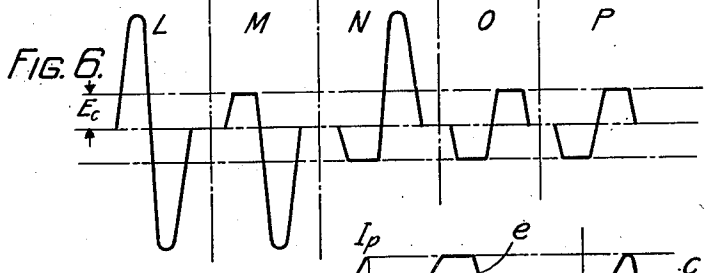
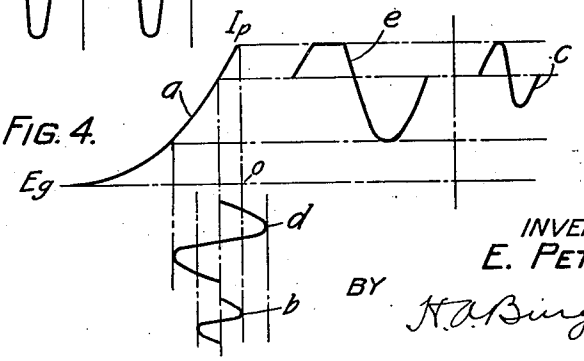


FIG. 4.



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UNITED STATES PATENT OFFICE

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ELECTRIC WAVE LIMITING DEVICE

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This invention relates to wave transmission systems and more particularly to means for limiting disturbances in amplifier circuits.

In order to obtain high efficiency and maximum power from high power amplifiers it is desirable to keep the input voltage as large as possible without overloading the tubes or producing excess distortion. Provision must be made, however, for transients or other unavoidable disturbances which when they occur might produce undesirable results.

An object of the invention is to limit the peak voltages impressed upon a vacuum tube amplifier which are in excess of normal signal voltages.

Another object of the invention is to produce a sharp or abrupt limitation of both positive and negative voltage peaks.

In accordance with the present invention two amplifier tubes are connected in cascade. Each tube has a resistance in the input circuit which prevents any increase in the plate current when the potential upon the grid of the tube exceeds a predetermined value. When a wave is impressed upon the voltage limiting device, it is faithfully repeated until a certain value is reached beyond which any increase in potential of either polarity is unaccompanied by further increase of output current. The two stages in cascade are connected so that limitation of one polarity takes place in the first stage while the other polarity is limited in the succeeding stage. The circuit thus permits both halves of the wave to have grid circuit limitations which results in much sharper cut-off than if plate circuit limitations were used.

A better understanding of the invention may be had from the following description and the accompanying drawings, of which Figs. 1 to 3 are different circuits embodying the invention and Figs. 4 to 6 are curves illustrating their operation.

Referring to Fig. 1, a pair of vacuum tubes 1 and 2 having similar input and output circuits are seen connected in cascade through an interstage transformer 3. The input circuit of the tube 1 may be traced from the grid 4 through resistance 5, the secondary winding 6 of the input transformer 7, and the source of grid potential 8 to the filament 9 of the tube. The output circuit of tube 1 may be traced from the plate 10 through primary winding 11 of the interstage transformer 3 and a source of plate potential 13 to the filament 9 of the tube. Similar circuits may be traced for the vacuum tube 2. Thus, the input circuit of the tube 2 may be traced from the grid 14 through the resistance 15, the secondary winding 16 of the transformer 3, and the source of grid potential 17 to the filament 18 of the tube. The output circuit may be traced from the plate 19 through the primary winding 20 of the output transformer 21, and the source of plate potential 22, back to the filament circuit 18. The filaments 9 and 18 are energized, respectively, by the sources of energy 23 and 24.

The operation of the circuit may be readily understood by reference to Fig. 4. The curve *a* is the grid-potential plate-current characteristic of one stage of the amplifier. When a normal voltage wave, such as that represented by *b* is applied to the grid of tube 1, it is amplified and appears as a current wave *c* in the plate circuit of the tube. When a voltage wave, represented by *d*, exceeds a certain value determined by the biasing potential on the grid, the latter element becomes positive and grid current flows. However, when the grid is positive, the internal resistance between filament and grid is low, and resistance 5 is so large compared with it that practically all of the potential drop occurs across this resistance, the grid potential going only slightly above its zero value. For this reason the plate current does not follow the variations of the input wave when the positive cycle of the latter exceeds the negative grid potential 8 but is chopped off as shown by curve *e*. The same phenomenon occurs in the input circuit of the tube 2, but the windings of the interstage transformer 3 are poled so that in this circuit the other half cycle of the wave is limited.

Fig. 5 illustrates the phenomena which take place in different parts of the circuit when the input wave is in excess of the normal value. Thus G represents the input voltage

as a sine wave having peak values greatly in excess of the grid biasing voltage, which is represented by E_c. This wave is cut off in the manner heretofore described so that the voltage impressed on the grid of tube 1 is shown by H. The voltage appearing at the high side of the transformer 3 has the DC component removed and is shown by I. This wave has the same shape as that shown by H, but is moved up so that the area of the positive half cycle of the wave is equal to the area of the negative half cycle. On account of the amplification occurring in tube 1, this wave, I, would have a greater amplitude than the grid wave, H, but for simplicity in explaining the action, the effect of the amplification has been neglected in these curves. The voltage wave impressed upon the grid of the tube 2 with the negative portion of the wave limited is shown by J. The portion of the wave that is limited in this stage is the negative portion of the original input wave although as regards the tube 2 the part of the wave limited in its grid circuit is positive on account of the shift in phase occasioned by the transformer 3. The final output wave is represented by K and has the DC component introduced in the plate circuit of the tube 2 removed.

In order to repeat waves of the shapes indicated in Fig. 5, the interstage and output transformers of Fig. 1 should have good transmission characteristics over the frequency band including all of the important components represented by the flat topped waves, and should also have a zero or a small phase shift over this range.

In the case of a radio transmitter, the power limiter of the invention would be used to prevent damage to the high power transmitting tubes by preventing excessive voltages from reaching them through the input circuit. The circuit of Figs. 1, 2 or 3 would be placed in the input circuit leading to the high power tubes. In this case the antenna would preferably have a relatively narrow band frequency characteristic, incapable of transmitting the wide range of components which the transformers of Fig. 1 (or the Figs. 2 and 3 circuits) are designed to transmit, and this will reduce to a harmless amount the distortion arising from the flattening of the peaks of the waves as shown in Figs. 5 and 6.

Fig. 2 shows another embodiment of the invention in which the two tube stages are resistance coupled, thereby permitting both halves of the waves to be limited without removing the DC components. This circuit permits both halves of the waves to be cut off in exactly the same manner. In Fig. 2 the input of the tube 30 is the same as the input circuit of tube 1 of Fig. 1, while the output circuit of tube 31 is similar to the output circuit of tube 2. The output circuit of tube 30 may be traced from the plate 32 through the resistance 33, the source of plate potential 34 to the filament 35. The input circuit of tube 31 may be traced from the grid 36, through the resistance 37, source of grid potential 38, the resistance 33, and source of potential 34 to the filament 39.

In the operation of this circuit the potential which appears in the output of the tube 30 is opposite in phase to the voltage impressed upon its grid. The voltage appearing across resistance 33, containing a DC component from the plate circuit of tube 30, is limited in the input circuit of the tube 31. By means of this circuit both halves of the wave may be limited by precisely the same amount thus giving a somewhat better result than that obtained by the circuit of Fig. 1. The phenomena which take place in different parts of this circuit are illustrated by Fig. 6. For instance, L represents the input voltage as a sine wave. After limitation occurs in the input circuit of the tube 30 in the manner heretofore described, the voltage impressed upon its grid is shown by M. The voltage in the output circuit of this tube due to the voltage upon its grid is shown by N and is exactly the same shape although opposite in phase to M. When limitation is effected in the grid circuit of tube 31 the resultant voltage is shown by O and since the DC component from the plate circuit of the tube 30 was present at the time that limitation was effected both half cycles of the resultant wave are equal and symmetrical. The wave appearing in the output of this circuit is shown by P. In the case just described the resistance 33 of Fig. 2 may be apportioned so that the input levels of tubes 30 and 31 are equal.

Fig. 3 shows another type of voltage limiter also employing resistance coupling. In this circuit an attenuating circuit 50 is connected between the tube stages, in order that the AC voltage applied to the grid of the second tube may exactly equal that applied to the first tube. This permits the limitation of both halves of the wave to be effected at zero gain, so that both halves of the waves are cut off in exactly the same manner. The filaments of the tubes 53 and 55 are connected in series by a circuit which may be traced from the source of potential 51 through the filament 52, the filament 54, and back to the source 51. Since the grid potential of the tube 53 is obtained partly from the voltage drop through the filament of the tube 55, the biasing potentials upon the grids of both tubes may be equalized by tapping off different portions of the potential across the resistance 56 as shown. The grid limitation in tubes 53 and 55 is effected in the same way as in the circuits heretofore described. The curves of Fig. 6 are equally applicable to the

operation of the circuit of Fig. 3 and of Fig. 2.

Although this invention has been described with reference to several particular embodiments thereof, it is capable of broad interpretation within the spirit of the invention and is to be limited, therefore, only by the scope of the appended claims.

What is claimed is:

1. In a voltage limiting device, means for limiting voltage peaks of both polarities in successive stages, said means comprising a plurality of space discharge devices connected in tandem relation, and means in the input circuits of said devices for preventing the voltages impressed upon the input circuit of said devices from exceeding a predetermined value.

2. A voltage limiting device comprising space discharge devices in a plurality of stages, a resistance in the input circuit of each of said devices for limiting only the positive voltage peaks impressed upon the input circuits thereof to a predetermined value, and means for associating said tubes with each other in such a manner that both peaks of the voltage wave impressed upon said limiting device are subjected to the limiting action.

3. An electric wave limiting device comprising grid control space discharge devices in a plurality of stages, a resistance in the input circuit of each of said devices for limiting only the positive wave peaks impressed upon said input circuits and means for connecting said space discharge devices in such a way that the wave is impressed upon the grids of said devices in phase opposition.

4. An electric wave limiting device comprising grid control space discharge devices in a plurality of stages, a source of biasing potential in the input circuit of each of said devices, means comprising a resistance for preventing the grids of said tubes from becoming positive when the wave applied to the input of said limiting device exceeds a predetermined value, and interstage coupling means for said space discharge devices for permitting that portion of a wave to be limited in one stage which was not limited in a preceding stage.

5. In a voltage limiting device a pair of vacuum tubes connected in tandem relation, means in the input circuit of one of said tubes for providing a negative potential upon the grid with respect to the cathode thereof, means for impressing voltage waves upon said input circuit, means therein for preventing said grid from becoming positive with respect to said cathode, corresponding means in the input circuit of the other of said tubes, and means for impressing the voltage wave as limited by said first tube, upon the input circuit of said second tube in opposite polarity to said first tube.

6. In a voltage limiting device, a pair of vacuum tubes connected in tandem relation, means in the input circuit of one of said tubes for providing a negative potential upon the grid with respect to the cathode thereof, means for impressing a voltage wave upon said input circuit, a resistance therein having a value sufficient to provide a negative grid bias when current flows in said input circuit equivalent to the voltage by which the positive voltage wave exceeds the absolute value of said first mentioned grid bias, and corresponding means in the input circuit of the other of said tubes, and means for impressing the voltage wave as limited by said first tube upon the input circuit of said second tube in opposite phase relation to said first tube.

7. In a communication channel, a peak voltage limiting device comprising a three-electrode vacuum tube having in the input circuit thereof a resistance many times as great as the input impedance of said tube at zero grid bias and a negative grid biasing voltage approximately equal to the maximum voltage of the signals normally transmitted, and a second voltage limiting device in tandem therewith, poled to limit the voltage peaks not subject to the limiting action of said first device.

8. In a signal channel, a voltage limiting circuit comprising a three-electrode vacuum tube having an input circuit comprising a resistance large in comparison with the input impedance of said tube when grid current starts to flow, and a grid biasing voltage proportioned to the maximum voltage to be carried normally by said channel to limit the positive peaks transmitted to substantially said maximum normal voltage, and a second voltage limiting circuit in tandem therewith poled to limit the peaks not subject to the limiting action of said first circuit.

In witness whereof, I hereunto subscribe my name this 16th day of May, 1929.

EUGENE PETERSON.