Feb. 5, 1935. R. A. BRADEN 1,990,062

REDUCTION OF HARMONICS IN AMPLIFIERS

Original Filed May 13, 1930

Fig. 1

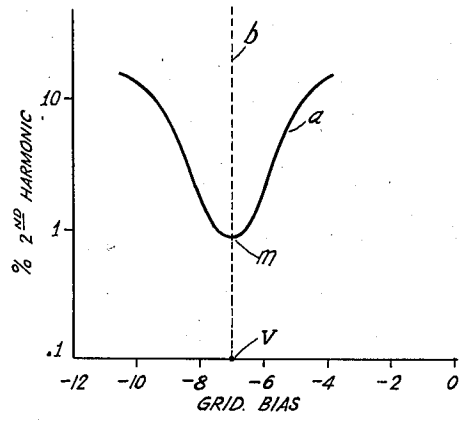


Fig. 2

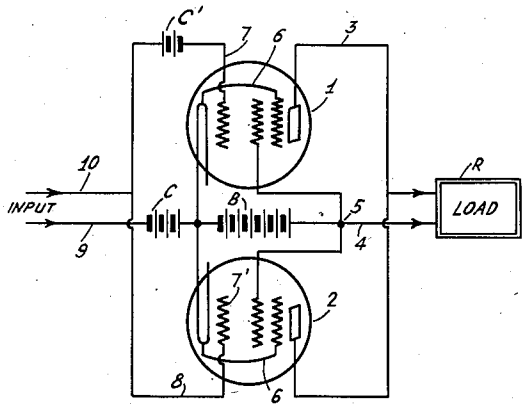


Fig. 3

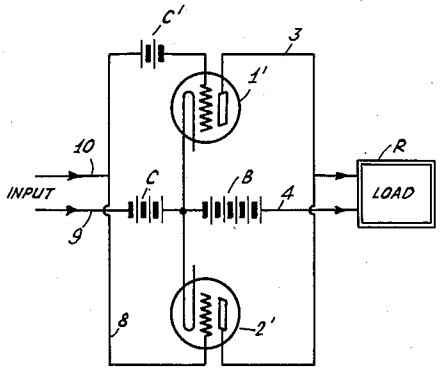
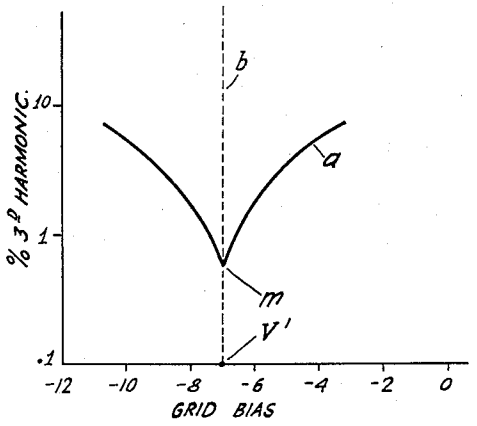


Fig. 4



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REDUCTION OF HARMONICS IN AMPLIFIERS

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Application May 13, 1930, Serial No. 451,915
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7 Claims. (Cl. 179—171)

My present invention relates to amplifier circuits, and more particularly to methods of, and means for, substantially eliminating harmonics in the output circuits of multi-electrode electron discharge tubes.

Experience has shown that ideal amplifier performance is at best approximated. Distortionless performance of an amplifier often depends upon success in eliminating, or substantially suppressing, harmonics in the output or load circuit of an amplifier, as for example the power stage of a radio receiver. It has been the practice, when employing triodes in radio receivers, to provide a push-pull arrangement in the power stage for eliminating distortion in so far as the latter is produced by even harmonics of the signal voltage. It has been more difficult to eliminate, or substantially suppress, the odd harmonics, and particularly the third harmonic.

Again, with the introduction of the electron discharge device of the pentode type, it has been found that the amount of second harmonic produced in the output circuit is much greater, with some adjustments, than is obtained with triodes, and in general it has been found difficult to keep the distortion due to harmonic production within permissible limits. It has been found that the second harmonic output of a pentode tube working into a resistance load varies with the grid bias in such a manner that a minimum percentage production of second harmonic exists at a certain value of grid bias, an increase in percentage of second harmonic occurring as the bias is changed from the said value. However, it was additionally found that the second harmonic was subjected to a phase reversal whenever the grid bias was changed from one side of the aforementioned value to a point above or below the value.

Now, I have discovered a method of, and devised means for, utilizing the aforementioned experimental observations in eliminating, and substantially suppressing, the production of harmonics in the output circuits of electron discharge tubes connected to function as amplifiers. In carrying out the method, electron discharge tubes are connected in parallel, and the bias on the control electrode of one tube is made greater than that value of bias which produces a minimum percentage of second harmonic in the case of pentodes (and a minimum percentage of third harmonic in the case of triodes) and the control electrode bias of the other tube is made less than the aforementioned minimum value of bias, the percentage of harmonic appearing in the output or load circuit then being the difference between the amounts of harmonic generated in the two connected tubes. In this way a very substantial reduction in the amount of second harmonic can be secured when pentode tubes are employed, the same method being applied to triodes to reduce the amount of third harmonic in the output circuit.

Accordingly, it is one of the main objects of the present invention to provide a method of greatly reducing the appearance of second and third harmonics in the load circuits of pentodes and triodes respectively, the method consisting in connecting a pair of pentodes, or a pair of triodes, in parallel, and then biasing one of the tubes to a greater extent than the other tube, one of the biases being greater than a predetermined value of grid bias which produces a minimum percentage of harmonic, and the other tube having a grid bias less than said minimum grid bias, whereby the amount of second harmonic appearing in the load circuit of pentodes, and the amount of third harmonic appearing in the load circuit of triodes, represents the difference between the amounts of harmonic generated in the two tubes.

Another important object of the invention is to provide a method of substantially suppressing the appearance of harmonics in the output or load circuits of electron discharge devices connected in parallel in the power stage of an amplifier, the method consisting in biasing the control electrode of one of the electron discharge devices to a greater value than that value of bias which will allow a minimum percentage of harmonics in the load circuit, and then biasing the control electrode of the other device to a value as much below the aforementioned minimum bias value as the bias on the first tube is above that value.

Another object of the invention is to provide a power stage for radio receivers, which power stage includes a pair of pentodes connected in parallel, the control electrodes of the two pentodes being differently biased, the value of the control electrode bias of one of the pentodes being so chosen with respect to the control electrode bias of the other pentode that the second harmonics produced in each of the pentode output circuits are in phase relation whereby the amount of harmonic appearing in the common load circuit of the two tubes will be the difference between the amounts of second harmonic generated in the two tubes.

Other objects of the invention are to improve generally the efficiency of amplifiers, and to provide radio receiver power stages utilizing pentodes which are not only durable and reliable in operation, but which approximate ideal performance with respect to suppression of harmonics in the load circuits thereof.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims, the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawing,

Fig. 1 graphically shows the relation between harmonic output of a pentode with respect to its control electrode bias,

Fig. 2 diagrammatically discloses a circuit embodying the invention,

Fig. 3 diagrammatically shows a modified form of the invention,

Fig. 4 is a graphical representation of the invention as embodied in the modification of Fig. 3.

Referring to the accompanying drawing in which like characters of reference indicate the same parts in the different figures, there is graphically demonstrated in Fig. 1, the fact that the second harmonic output of a pentode tube working into a resistance load varies with grid bias in a predetermined manner. The curve in Fig. 1 is secured by logarithmically plotting "% 2nd harmonic" as ordinates against "grid bias" as abscissæ. It may be inferred from this curve that if the grid bias is changed from a value less than V to a value greater than V, the second harmonic undergoes a phase reversal with respect to the fundamental frequency, and experimental tests show this is the case.

It will be noted that as the grid bias on the control electrode of a pentode is varied in a more negative direction from the point V, which point is about —7 volts, the percentage of second harmonic produced increases to a value above 10% at which latter value increase in the grid bias negatively does not increase the percentage of second harmonic. This same phenomena is observed when the grid bias is negatively decreased, or when the pentode grid is made more positive, from the value V, it being only noted that the second harmonic in this case undergoes a phase reversal, this fact being noted by the change in direction of the curve *a*. The dotted line *b* passes through the minimum second harmonic value *m*, and thus divides the curve *a* into symmetrical portions.

In Fig. 2 there is shown a circuit for taking advantage of the characteristic curve shown in Fig. 1. Two pentode tubes 1, 2 are connected in parallel, the anodes of the two tubes being connected by a common conductor 3 to one terminal of the load circuit, this latter being a loud speaker or any other utilization means well known to those skilled in the art. The cathodes of the two tubes are connected through a source of anode potential B and a conductor 4 to the other terminal of the load circuit, it being noted that the screen grid element of each tube is connected to a point 5 on the cathode lead 4.

As is well known to those skilled in the art of constructing pentodes, the cathode of each tube has connected to it an additional electrode 6, the additional electrode being disposed between the screen grid electrode and anode in each tube. The control electrode 7 in tube 1 has connected in series therewith a biasing battery C', while the control electrode 7' of the tube 2 is connected in series by a lead 8 to the positive terminal of the biasing battery C'. A main biasing battery C is provided for equally biasing the control electrode 7 and 7', the positive terminal of the battery C being connected to the cathodes of both tubes 1 and 2, the negative terminal of the battery C being connected to a lead 9. A second lead 10 is connected to lead 8, leads 9 and 10 having the input energy to be amplified impressed thereacross.

If the two pentode tubes are connected in parallel as shown in Fig. 2, and the bias on the control electrode of one of the tubes (as for example the control electrode 7 of tube 1) is greater than the value V, and the bias of the control electrode in the other tube (control electrode 7' and tube 2) is less than the value V, then the amount of second harmonic appearing in the load circuit will be the difference between the amounts of second harmonic generated in the two tubes 1 and 2.

It is for this reason that the two biasing batteries C and C' are provided, the main biasing battery C being provided to bias the control electrodes 7 and 7' equally, while the auxiliary biasing battery C' is employed, to additionally bias the control electrode of one of the tubes to a point beyond the value V. It will, of course, be understood that the percentage of second harmonic appearing in the common load circuit of both tubes is the difference between the amounts of harmonic generated in the two tubes because the second harmonics produced in the output circuit of each tube are in phase opposition relation.

Since the position of the value V shifts slightly with changes in the load circuit R, and since, in general, the load impedance is a function of frequency, it will be realized that an exact balance to eliminate completely the second harmonic at all frequencies cannot be obtained. However, a substantial reduction in the amount of second harmonic produced in the load circuit R is readily secured.

The method disclosed in Fig. 2 can be applied to triodes to reduce the amount of third harmonic in the common load circuit R, the relation between grid bias on the control electrode of each tube and percentage third harmonic produced being graphically demonstrated in Fig. 4 by a curve similar to the curve given in Fig. 1. In Fig. 4 it is shown that there is a phase reversal of the third harmonic with respect to the fundamental frequency at a bias value generally denoted as V', the minimum point on the curve *a* corresponding to the value *m*, and being below 1%. Here, again, the dotted line *b* passes through the minimum point *m* and the value V' divides the curve *a* into two symmetrical portions, each portion representing the amount of third harmonic above or below the critical value V'.

In this case since there is a phase reversal of the third harmonic with respect to the fundamental frequency at the bias value V', one tube 2' in Fig. 3 has a bias smaller than, that is to say more positive than, the value V', and the other tube 1' has its control electrode biased by an auxiliary biasing battery C' to a value larger than, that is to say more negative than, V'. In this way, the percentage amount of third harmonic appearing in the common load circuit R of the triodes will be the difference between the amounts

of third harmonic generated in each of the two triodes 1', 2'.

It is to be pointed out that it is possible to pair a pentode with a triode, biasing the pentode with a bias voltage greater than V, the triode having a characteristic somewhat similar to that of the pentode with a bias less than V.

Furthermore, while I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications in the circuit arrangements, as well as in the electron discharge devices employed, may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. The method of greatly reducing the appearance of harmonics in the common load circuit of a pair of multi-electrode tubes which consists in connecting a pair of multi-electrode tubes in parallel, biasing the control electrode of one of the tubes to a greater extent than the control electrode in the other tube, one of the biases being greater than a predetermined value of control electrode bias which produces a minimum percentage of harmonic, and the other tube having a control electrode bias less than said minimum control electrode bias, whereby the amount of harmonics appearing in the said common load circuit will be the difference between the amounts of harmonic generated in the two tubes.

2. The method of greatly reducing the appearance of second harmonics in the common load circuit of a pair of pentodes which consists in connecting a pair of pentodes in parallel, biasing the grid of one of the tubes to a greater extent than the grid in the other tube, one of the biases being greater than a predetermined value of grid bias which produces a minimum percentage of second harmonic, and the other tube having a grid bias less than said minimum grid bias, whereby the amount of second harmonics appearing in the said common load circuit will be the difference between the amounts of second harmonic generated in the two tubes.

3. The method of greatly reducing the appearance of third harmonics in the common load circuit of a pair of triodes which consists in connecting a pair of triodes in parallel, biasing the grid of one of the tubes to a greater extent than the grid in the other tube, one of the biases being greater than a predetermined value of grid bias which produces a minimum percentage of third harmonic, and the other tube having a grid bias less than said minimum grid bias, whereby the amount of third harmonics appearing in the said common load circuit will be the difference between the amounts of third harmonic generated in the two tubes.

4. A method of substantially suppressing the appearance of second harmonics in the common load circuit of pentodes connected in parallel in the power stage of an amplifier, which consists in biasing the grid of one of the pentodes to a value greater than the value of the grid bias which will allow a minimum percentage of second harmonics in the common load circuit, and then biasing the grid of the other pentode to a value as much below the aforementioned minimum grid bias value as the bias on the grid of the first tube is above that value.

5. A power stage for radio receivers, comprising a pair of pentodes connected in parallel, the control electrodes of the two pentodes being differently biased, the value of the control electrode bias of one of the pentodes being so chosen with respect to the control electrode bias of the other pentode that the second harmonics produced in each of the pentode output circuits are in phase opposition relation whereby the amount of second harmonic appearing in the common load circuit of both pentodes will be the difference between the amounts of second harmonic generated in each of the two tubes.

6. The method of reducing the percentage of second harmonics in the common load circuit of a pair of pentodes consisting in biasing the control electrode of one of the pentodes to a greater extent than the control electrode of the other pentode, and biasing the control electrode of the latter in such a manner that second harmonics produced in said common load circuit by said pentodes are in phase opposition.

7. An electrical wave amplifier comprising at least two electron discharge tubes, a source of waves to be amplified, a load circuit, connections between the source and the input electrodes of the tubes, connections between the load circuit and the output electrodes of the tubes, said tubes having normal characteristics such that second harmonics are substantially repeated into the load circuit, and means for differentially biasing space current control electrodes of said tubes in such a manner that said second harmonics are produced in the load circuit in phase opposition.

RENE A. BRADEN.