March 29, 1932. E. H. LOFTIN ET AL 1,851,587

AMPLIFIER SYSTEM, METHOD, AND APPARATUS

Filed July 22, 1927

Fig. 1.

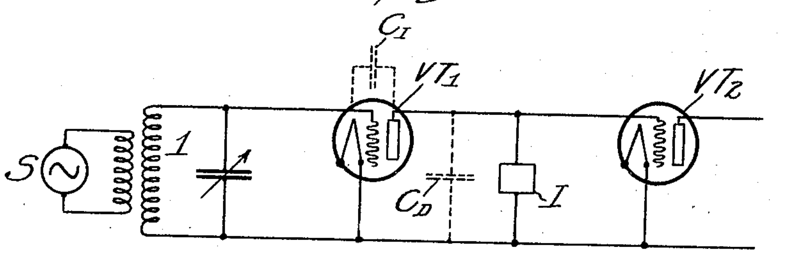


Fig. 2.

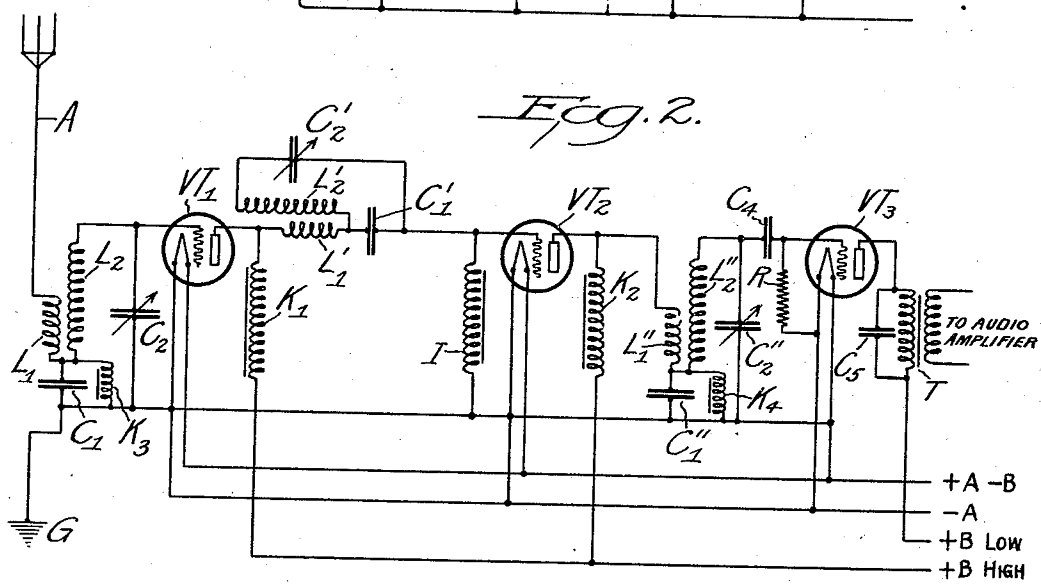
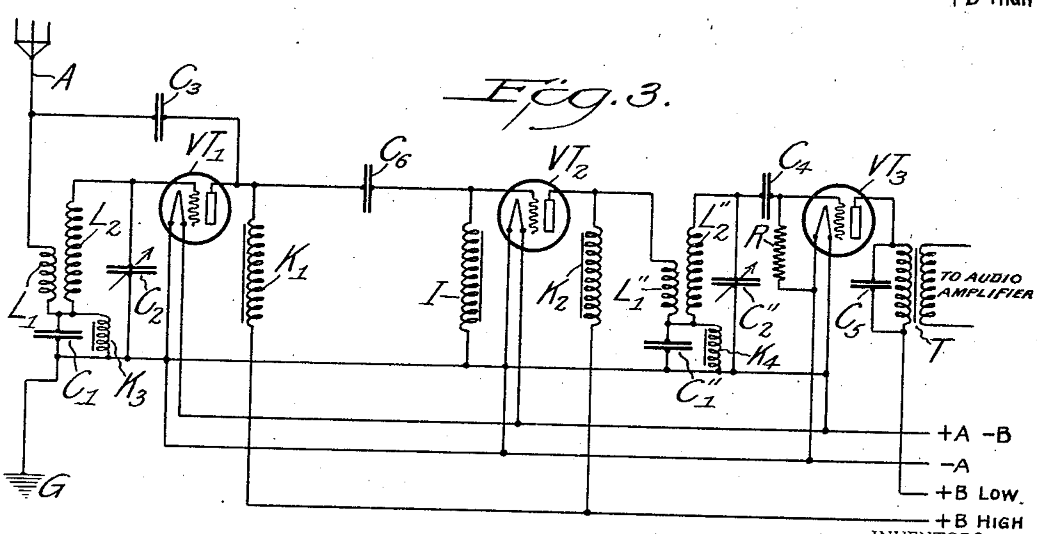


Fig. 3.



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UNITED STATES PATENT OFFICE

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AMPLIFIER SYSTEM, METHOD, AND APPARATUS

Application filed July 22, 1927. Serial No. 207,618.

While our invention relates generally to amplifier systems, it refers particularly to such systems including three electrode vacuum tube or like operating amplifiers, and has for a particular object the efficient amplification of alternating currents of more or less high frequency.

Another object is to choose and selectively amplify such currents over a wide band of frequencies while maintaining the amplification efficiency practically uniform with frequency, or to be able to vary the efficiency in any desired manner with frequency.

A further object is to provide an amplifying system that is oscillation proofed, and is free from troublesome reaction of the circuits of the system upon each other.

Still further objects are the simplification of selective control of amplification and the elimination of some of the difficulties that have heretofore been encountered in multiple stage amplification, particularly of the high frequency character.

Our invention will be best understood by reference to the figures of the accompanying drawings in which Fig. 1 is an explanatory diagram, and Figs. 2 and 3 are diagrammatic representations of two different embodiments of our invention shown employed for illustrative purposes in radio receivers. Like reference symbols in the several figures represent like parts.

In Fig. 1 the three electrode vacuum tube VT_1 is shown to have an input circuit including a tunable circuit 1 with which is associated a source of alternating currents S, it being assumed for explanatory purposes that the frequency of the alternating currents can be varied over a range, and circuit 1 can be tuned in consonance with such variations. The output circuit is shown coupled to a second tube VT_2 with the aid of an indicated non-selective impedance I, which impedance may be a more or less high resistance, a condenser, or a so-called choke or capacitively reacting coil. The capacity C_1 represented in dotted lines indicates the so-called internal or plate-to-grid capacity of tube VT_1, and the capacity C_D in dotted lines represents the distributed capacity of the leads and other elements of the output circuits. For simplicity means for energizing the tubes for operation have been omitted in this explanatory figure, it being understood that the operation to be explained refers to a properly energized system.

Considerable effort has been made in practice to couple amplifiers through fixed impedances in the manner shown in Fig. 1 with the hope that energy would be substantially equally well transferred for all frequencies, or in other words to make the system a so-called universal amplifier, but such poor results have been secured in high frequency work in the matter of securing efficient amplification that such systems have practically found no use in the art. The poor amplifying results come about by reason of the fact that no matter what may be the form of the fixed impedance there results an over-all plate circuit reactance that is capacitive in nature, so that the reaction of the plate circuit onto the grid circuit through the so-called grid-to-plate capacity of the tube, or inter-electrodal capacity indicated as C_1, has the well known effect of being of incorrect phase to assist the incoming energy in the grid circuit, but rather opposes it, so that the tube is caused to de-amplify from its normal amplifying ability. In fact, such an arrangement used in the kilocycle band of 500 to 1500 of radio broadcasting is practically worthless as an amplifier. In addition, the reactance is not constant with frequency so that the tube is caused to de-amplify to different degrees for different frequencies, with the result that the poor results are not uniform with frequency.

If the impedance I is in the form of a rather high resistance the overall reactance of the plate circuit is necessarily capacitive, because of the distributed capacity indicated at C_D. If the impedance is a condenser the overall reactance is necessarily capacitive. If the impedance is a so-called choke coil, to be effective as an impedance it must necessarily react capacitively, so that the overall plate circuit reactance is capacitive.

Our invention overcomes these difficult s, the first embodiment of it being shown n

Fig. 2, in which the element A is an ordinary radio receiving antenna connected to ground at G, the antenna being coupled to a variable period circuit L_2C_2 through a combined electromagnetic and electrostatic coupling including the inductive relation between coils L_1 and L_2 and coupling condenser C_1. The manner in which such a combined coupling can be made to transfer substantially constant energy with frequency, or vary the transfer in any predetermined manner with frequency, is fully disclosed in the copending application of S. Y. White, Serial No. 48,936, filed August 8, 1925. There is therefore provided an arrangement for selecting from the antenna any desired current frequency, and degree of it, for application to the input electrodes of three electrode vacuum tube amplifier VT_1. This first tube is coupled to a second amplifier tube VT_2 through a non-selective impedance I shown in the ordinary symbol employed to indicate a so-called choke coil.

There is shown coupled to the plate circuit of tube VT_1 a variable period circuit $L'_2C'_2$ through a combined electromagnetic and electrosatic coupling including inductive relation between coils L'_1 and L'_2 and condenser C'_1 common to the two circuits. With this arrangement, it is now possible, by reason of the reaction that can be produced by this variable period circuit onto the plate circuit of tube VT_1, to overcome the capacitive reaction of impedance I and the distributed capacities of the plate circuit to any desired degree for any selected frequency, this being because for any selected frequency there is an adjustment of the variable period coupled circuit which will cause its reaction onto the plate circuit to be inductive, which adjustment is somewhat removed from resonance. By adjusting the coupling to any desired amount, the degree of the inductive reactance can be controlled, and by adjusting the combined coupling to act with frequency in any predetermined way, the variation of inductive reactance can be controlled with frequency in any predetermined way. The manner in which these adjustments are obtained is more fully explained in copending application of S. Y. White, Serial No. 49,521, filed August 11, 1925, patented November 4, 1930, No. 1,780,611.

Thus with the arrangement outlined, it is possible to make the reaction of the plate circuit for any current frequency selectively applied to the input electrodes of tube VT_1 of any character and degree desired, so that the reaction through the inter-electrodal capacity can be made to lessen the degree of deamplification, to be neutral, or even to cause regenerative amplification. It is obvious that with increased amplification thus obtained the potential across impedance I is increased with resulting increased effect on the second tube VT_2, so that the system can now be made a most efficient amplifier over a wide range of frequencies.

Tube VT_3 is shown connected to act as a detector by reason of the grid condenser C_4 shunted by the grid leak resistance R, and having a grid return connected to the negative leg of the filament circuit, the plate circuit including an audio frequency transformer T, the primary being by-passed by a condenser C_5 as is usual practice. The detector tube is coupled to the second amplifier tube through an adjustable period circuit $L''_2 C''_2$ and a combined electromagnetic and electrostatic coupling involving the inductive relations between coils L''_1 and L''_2, and the coupling condenser C''_2, thus making it possible to continue the control of transfer of energy with frequency throughout the system. The vacuum tubes are indicated as energized in a conventional manner from sources of energy supply marked +A −B, −A, +B low, and +B high, the plates of the tubes being energized through choke coils K_1 and K_2 of low distributed capacity to confine high frequency current flow to the desired circuits of the system. It will be noted that the coupling condenser C'_1 serves the additional purpose of preventing the high potential applied to the plate of tube VT_1 from reaching the grid of tube VT_2.

The second embodiment of our invention is shown in Fig. 3, which in general arrangement is the same as the system of Fig. 2, but differs from the arrangement of Fig. 2 in the connections employed for overcoming the capacitive reaction of the coupling impedance and distributed capacities. In the second embodiment the connection is made from the plate circuit of tube VT_1 through a condenser C_3 back to the antenna A, the circuit of this connection being completed through coil L_1, coupling condenser C_1, and thence to the filament of the tube. This connection provides for the circuit L_2C_2 acting as the variable period circuit to control the reaction of the plate circuit of tube VT_1 with frequency, and therefore takes the place of variable period circuit $L'_2C'_2$ in the embodiment of Fig. 2. By this arrangement circuit L_2C_2 is utilized to serve a double function, namely acting as selective input to tube VT_1 and acting as a selective reactance controller for the output circuit of the same tube. While the coupling between the antenna and the secondary may not be just that desired for the proper degree of plate circuit reaction control, yet the reaction on the plate circuit can be controlled by proper selection of values of condenser C_3, so that all functions desired may readily be co-ordinated. In practice it is found that with this second embodiment tube VT_1 can be caused to amplify through neutral to regenerative amplification with a degree of coupling between the antenna and secondary circuit, that is entirely suitable for transfer of energy between these circuits. There therefore results a control of the potential developed across the coupling impedance I, and therefore on the input electrodes of second vacuum tubes VT_2.

This second embodiment has the advantage that substantially the same result as that obtained in the first embodiment of Fig. 2 is secured without the use of a second variable period circuit, and therefore greatly simplifies the construction and operation of the system. It will be noted that in the second embodiment, a condenser C_6 is employed to prevent the high potential applied to the plate of tube VT_1 reaching the grid of tube VT_2. It is desirable to make the capacity of this condenser sufficiently large to keep its reaction to currents of the frequencies being handled low. In other respects, except for the method of control of the reaction of the plate circuit, the system is the same as that described in detail in connection with Fig. 2.

A particular advantage of our system is a substantially complete isolation of the adjustable period circuits one from the other so far as influences which take place through the elements and circuits of the system are concerned, and this is particularly true of the embodiment of Fig. 3. In the common practice of multiple stage selective amplification when the several stages are directly connected through adjustable period circuit great difficulty has been had in keeping any degree of independency of the several circuits and several stages of amplification. In such systems the variation of one circuit, though it might be intended to influence but one stage in the system, by reason of the close relations and reactions introduced through the enormous effects on the amplifying abilities of the tubes, upsets the system as a whole, with the result that the greatest difficulty has been encountered in attempting to build multiple stage amplifying units having a fair degree of efficiency, and the problem has been rendered doubly difficult in trying to simultaneously operate all the controls from a common control element. In our system these difficulties are enormously reduced by reason of the substantially total independency of the several adjustable period circuits, and it is possible to employ as many units of this system in cascade as may be desired for any degree of amplification at one and the same frequency, as compared to the practical limits heretofore reached in the directly connected systems.

In the systems of both Figs. 2 and 3, it is preferable to employ choke coils K_2 of substantially different natural period from choke coils K_1, as if the two coils are of nearly the same natural periods, it is possible for K_2 to react on K_1 through the internal capacity of tube VT_2 to create an oscillating system at some arbitrary frequency, which would result in a parasitic undesirable effect.

While we have illustrated and described our invention in connection with radio receivers, we do not intend any limitations therein, as many applications are obvious to those skilled in the art.

We claim:—

1. The method of selectively amplifying alternating currents which comprises selectively impressing said currents upon a three electrode vacuum tube, non-selectively transferring the tube output of said currents to a second tube, and selectively controlling the amplifying ability of said first tube independently of said step of selectively impressing said currents upon a three electrode tube.

2. The method of selectively amplifying alternating currents which comprises selectively impressing said currents upon a three electrode vacuum tube, non-selectively developing and impressing on a second vacuum tube capacitively reacting potentials from the tube output of said currents, and selectively producing an inductive reactance in the output circuit of said first tube.

3. The method of selectively but uniformly amplifying alternating currents over a range of frequencies which comprises selectively impressing said currents upon a three electrode vacuum tube, non-selectively transferring the tube output of said currents to a second tube, and selectively but uniformly controlling the amplifying ability of said first tube with frequency independently of said step of selectively impressing said currents upon a three electrode tube.

4. The method of selectively but uniformly amplifying alternating currents over a range of frequencies which comprises selectively impressing said currents upon a three electrode vacuum tube, non-selectively developing and impressing on a second vacuum tube capacitively reacting potentials from the tube output of said currents, and selectively producing in the output circuit of said first tube an inductive reactance that varies with frequency in like manner to the reactance variation of said capactively reacting impedance with frequency.

5. The method of selectively highly amplifying alternating currents of a maintained one-frequency without deleterious reaction of succeeding selective circuits on preceding selective circuits which comprises selectively impressing said currents upon a three electrode vacuum tube, non-selectively transferring the tube output of said currents to a second tube, selectively controlling the amplifying ability of said first tube independently of said step of selectively impressing said currents upon a three electrode tube, selectively transferring said currents from said second tube to a succeeding like system and repeating the operation until the desired de-

gree of one-frequency amplification is obtained.

6. A system for the selective amplification of alternating currents including a three electrode vacuum tube having variable means for selectively impressing said currents thereon, a second tube, non-selective impedance means coupling the input of said second tube to the output of said first tube, and variable means other than said first mentioned variable means for selectively controlling the amplifying ability of said first tube with frequency.

7. A system for the selective amplification of alternating currents including a three electrode vacuum tube having variable means for selectively impressing said currents thereon, a second tube, non-selective impedance means coupling the input of said second tube to the output of said first tube, and variable means other than said first mentioned variable means for selectively changing with frequency the output circuit reactance of said first tube from that due to said impedance coupling.

8. A system for the selective amplification of alternating currents including a three electrode vacuum tube having variable means for selectively impressing said currents thereon, a second tube, non-selective impedance means coupling the input of said second tube to the output of said first tube, variable means other than said first mentioned variable means for selectively changing with frequency the output circuit reactance of said first tube from that due to said impedance coupling, and means for maintaining the changed reactance constant with frequency.

9. A system for the selective amplification of alternating currents including a three electrode vacuum tube having variable means for selectively impressing said currents thereon, a second tube, non-selective capacitively reacting impedance means linking the input of said second tube to the output of said first tube, and variable means other than said first mentioned variable means for selectively impressing with frequency an inductive reaction on said output circuit of said first tube.

10. A system for the selective amplification of alternating currents including a three electrode vacuum tube having means for selectively impressing said currents thereon, a second tube, a non-selective capacitively reacting impedance linking the input of said second tube to the output of said first tube, means for selectively impressing with frequency an inductive reaction on said output circuit of said first tube, and means for maintaining the relation of said inductive reaction to the capacitive reaction of said impedance consant with frequency.

11. A system for the selective amplification of alternating currents including a three electrode vacuum tube having variable means for selectively impressing said currents thereon, a second tube, non-selective impedance means linking the input of said second tube to the output of said first tube, and a circuit variable in period in consonance with the first said variable means coupled to the output circuit of said first tube.

12. A system for the selective amplification of alternating currents including a three electrode vacuum tube having means for selectively impressing said currents thereon, a second tube, a non-selective impedance linking the input of said second tube to the output of said first tube, a variable period circuit coupled to the output circuit of said first tube, and means for controlling the coupling between said variable circuit and said output circuit with frequency.

13. A system for the selective amplification of alternating currents including a three electrode vacuum tube, a variable period circuit connected to the input electrodes of said tube, a second tube, a non-selective impedance linking the input of said second tube to the output of said first tube, and a coupling between the output circuit of said first tube and said variable period circuit.

14. A system for the selective amplification of alternating currents including a three electrode vacuum tube, a variable period circuit connected to the input electrodes of said tube, a second tube, a non-selective impedance linking the input of said second tube to the output of said first tube, a coupling between the output circuit of said first tube and said variable period circuit, and means for controlling said coupling with frequency.

15. A system for the selective amplification of alternating currents including a three electrode vacuum tube, a variable period circuit connected to the input electrodes of said tube, a second tube, a non-selective impedance linking the input of said second tube to the output of said first tube, a coupling between the output circuit of said first tube and said variable circuit, and a condenser in series with said coupling for limiting the degree thereof.

16. In a system for the selective high amplification of alternating currents at a maintained one-frequency without deleterious reaction of succeeding selective circuits on preceding selective circuits which includes a multi-electrode vacuum tube having means for selectively impressing said currents thereon, a second tube, non-selective impedance means linking the input of said second tube to the output of said first tube, means for selectively changing the amplifying ability of said first tube, and a non-selective impedance in the output of the second tube of different natural period than said first impedance.

17. The method of selectively amplifying alternating currents which comprises selectively impressing said currents upon a multi-electrode electron discharge tube, non-selec-

tively transferring the tube output of said currents to a second tube, and selectively but independently controlling the amplifying ability of said tube in consonance with the selective impressing of currents thereon.

18. A system for the selective amplification of alternating currents including a multi-electrode electron discharge tube having a variable period circuit connected across the input electrodes thereof, a second tube, means for non-selectively transferring from the output of said first tube to the input electrodes of said second tube the first tube output of said currents, and means for selectively but independently controlling the amplifying ability of said first tube in consonance with selected tuning of said variable circuit.

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