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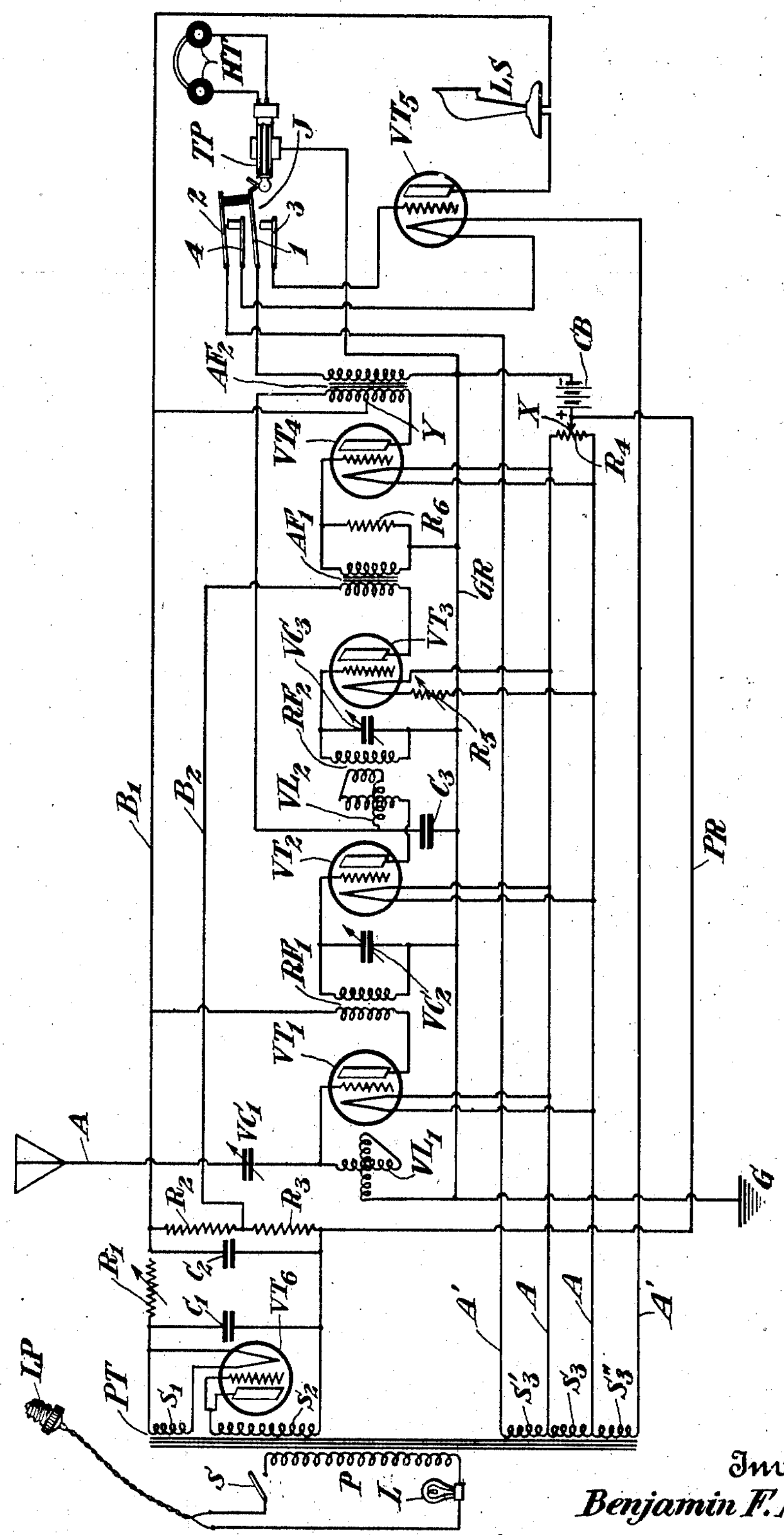

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ELECTRICAL SIGNAL AMPLIFYING AND REPEATING SYSTEM.

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While my invention relates generally to electrical signal amplifying and repeating systems, it is described herein more particularly with reference to such systems used in the reception of radio signals wherein three-electrode vacuum tubes are employed as the amplifying and repeating devices.

An object of my invention is to improve upon the results which have been heretofore obtained when other than steady sources of potential have been employed for energizing the amplifying and repeating devices to render them operative, particularly where other than steady sources of potential are used for energizing the filament and plate circuits of three-electrode vacuum tubes. I have particularly in mind the use of alternating currents from ordinary house-lighting circuits as the energizing source.

This invention constitutes an improvement over that described in my co-pending application Serial No. 29,859 of May 13, 1925, in which I illustrated and described a system for amplifying and repeating electrical signals wherein a plurality of three-electrode vacuum tubes were energized from a source of alternating current, together with means and procedure for eliminating the "hum" that usually results from the use of such currents. I have found that substantial improvement is obtained by certain further procedure with properly chosen and co-ordinated apparatus, which further improvements are the subject of my present invention.

My invention will be best understood by reference to the figure in the accompanying drawing which illustrates diagrammatically a complete radio receiver employing five vacuum tubes whose plate and filament circuits are energized from a source of alternating current, with means for eliminating hum as hereinafter more fully described. VT^1 and VT^2 indicate two tubes arranged for radio frequency amplification, VT^3 indicates a detector tube, and VT^4 and VT^5 indicate two tubes arranged for audio frequency amplification. The plate circuits of these tubes are energized by unsteady direct current derived from rectifying and filtering preferably 60 cycle alternating current, the arrangement comprising an ordinary lamp plug LP connecting the primary of a power transformer PT through a switch S and an indicating lamp and safety fuse L to the source of supply. An ordinary three-electrode vacuum tube VT^6 is converted in effect into a two-electrode tube for rectification purposes by connecting the grid and plate elements together as shown. A secondary winding S^1 energizes the filament of the rectifying tube. A secondary winding S^2 provides the currents to be rectified by the vacuum tube VT^6 and filtered by the combination comprising the two parallel condensers C^1 and C^2 and the series resistance R^1, preferably made variable for proper control of the energy supply to the plate circuits of the operating vacuum tubes. The resistances R^2 and R^3 divide the rectified and filtered energy into two potentials, one usually high for the amplifier tubes of the system, and supplied thereto by the line B^1, and one usually low for the detector tube of the system, and supplied thereto by the line B^2. The line PR provides a plate return for connection to the several filaments.

The secondary winding S^3 and lines AA supply unrectified alternating current for heating the filaments of the first four vacuum tubes of the system. The extension secondary windings $S^{3\prime}$ $S^{3\prime\prime}$ and the lines A′ A′ supply unrectified alternating current of higher potential to the fifth vacuum tube VT^5, which tube is intended to operate the loud speaker LS, and is a more powerful tube than the preceding ones. Good detector action is a little more critical to filament current adjustment than amplifier tube action, so that the filament circuit of detector tube VT^3 includes a current control resistance R^5.

The grids of all of the vacuum tubes are connected to a common grid return or line GR, which line includes a grid biasing battery CB, and which is connected to the filaments through a variable contact X associated with a resistance or potentiometer connected across the filament supply lines AA.

Being thus energized from a source of alternating current, the operation of the system is as follows: Radio signals are collected on the antenna A and resonantly passed to the first radio frequency amplifier VT^1 through the action of variable condenser VC^1 and variable inductance or variometer VL^1. The amplified high frequency currents are selectively transferred from tube VT^1 to tube VT^2 through radio frequency transformer with the assistance of variable condenser VC^2. The high frequency currents, twice amplified, are selectively passed to the detector tube VT^3 through radio frequency transformer RF^2 aided by variable condenser VC^3. The primary of radio frequency transformer RF^2 includes a variable inductance or variometer VL^2 to permit of adjusting the coupling for best results with variation of frequency of received radio signals. The detected currents are passed to vacuum tube VT^4 through audio frequency transformer AF^1, which transformer has a high resistance R^6 in shunt to its secondary winding for the purpose of lessening its tendency to assist production of oscillations in the system. The audio frequency amplified currents are passed from vacuum tube VT^4 to vacuum tube VT^5 through association of the lower half of the primary winding of audio frequency transformer AF^2 with the secondary winding of this transformer. The audio frequency currents, finally highly amplified in the more powerful tube amplifier VT^5, are converted into sound in the loud speaker LS. An arrangement is shown whereby the audio frequency currents can be stopped short of the vacuum tube VT^5 and directed instead into head telephones HT. It will be seen that when the telephone plug TP is inserted in the telephone jack J, the head telephones are connected directly across the secondary winding of audio frequency transformer AF^2 through the plug making contact with the lever 1 connected to one side of the secondary winding and through the jack connected to the other side of the secondary winding. Also that levers 1, 2, 3 and 4 cooperate to open the filament circuit and the grid circuit of vacuum tube VT^5. It is very important to open up the grid circuit of vacuum tube VT^5 and de-energize the tube when the telephones are connected to the first stage of audio frequency amplification because, if left connected and energized, stray fields from the alternating current system in the receiver will be picked up by the circuits of this last and free tube and amplified to create considerable annoyance from the loud speaker.

With the plate and filament circuits of the tubes energized with the form of unsteady current shown at least three sources for creating annoying hum exist as follows: (1), the impure currents resulting from rectification and filtration supplied to the plate circuits; (2), the alternating current supply for heating the filaments periodically varies the potential across the terminals of the filaments alternately positive and negative, and, since the grids must be connected to some point of the filament, there results a varying potential upon the grids; and (3), the temperatures of the filaments vary somewhat in consonance with the alternating currents heating the filament, resulting in a varying electron emission by the filaments at double the frequency of the alternating currents. Since the usual frequency of available alternating current supply is 60 per second, it will be seen that the disturbing currents resulting from the conditions I have outlined above are of an extremely low frequency compared to the radio frequency signal currents handled by the radio frequency portion of my receiver, and are also low in frequency compared to the great majority of signal currents handled in the audio frequency portion of my receiver. Very little or no difficulty therefore arises in vacuum tubes VT^1 and VT^2 and their associated circuits because the radio frequency transformers which convey the currents through and beyond these tubes pass to a negligible degree the disturbing currents. The trouble begins in the detector tube VT^3 where the audio frequency transformer AF^1 more or less efficiently passes forward disturbances arising in this tube. These disturbances are subject to double amplification in vacuum tubes VT^4 and VT^5. Similarly, disturbances arising in vacuum tube VT^4 are more or less efficiently passed on to vacuum tube VT^5 and amplified. It will be seen that disturbances arising in vacuum tube VT^5, the last tube, are not subject to further amplification, and may, under proper conditions, not become practically annoying.

It will be seen that I provide in the output circuit of my radio frequency amplifier tube VT^2 a high frequency path through the variable inductance VL^2, forming the primary of radio frequency transformer RF^2, and condenser C^3, and a low frequency path through the upper half of the primary of audio frequency transformer AF^2. The result is that high frequency signal currents passing through this tube continue on in regular manner to the detector tube, while low frequency currents resulting from the disturbing conditions I have outlined act on audio frequency transformer AF^2. By making the windings of the primary of AF^2 opposite in action, disturbing currents arising in VT^2 are made to oppose disturbing currents arising in or conveyed by VT^4, thereby neutralizing disturbing currents without neutralizing low frequency signal currents because no appreciably low frequency signal currents exist in the upper half of the winding. Such a system I have fully described in my co-pending application 29,-859 of May 13, 1925, together with how such a system might be extended to provide neutralization of disturbing currents arising in the last tube, if neutralization to a high degree is desired. It is readily apparent that with the radio receiver shown, vacuum tube VT^1 is available for neutralizing effect on vacuum tube VT^5 in the same manner that neutralization is carried out between vacuum tube VT^2 and VT^4. It is, of course, not necessary that the neutralizing tubes be a part of the radio receiving system. Separate tubes could be employed in the manner described and illustrated, but such procedure would be an unnecessary duplication of material where the radio frequency tubes in a system such as I have shown are available and can be made to serve the dual capacity.

Existing types of vacuum tubes have arrived at designs of filaments best suited to operation from battery sources of energy. Battery construction, life and maintenance compel developing the necessary filament power consumption through small current supplied at a correspondingly high voltage. The ratio of voltage to current has so far not been less than 5 to 1. The demand for low current has further brought about the use of filaments of small diameter and small mass, operated at extremely high temperatures for high rates of electron emission, resulting in an arrangement of very low temperature inertia, and therefore most susceptible to varying electron emission when heated by alternating currents. The high voltage across the filaments of existing tubes is most undesirable for alternating current heating, because the wide variation in potential across the filament increases the tendency to impress a varying potential on the grid through its necessary connection to the filament. It is customary, in trying to minimize the effect on the grid, to connect the grid return to a theoretical mid-point of a potentiometer connected across the filament supply line, or to a theoretical mid-point or center tap of the filament transformer secondary winding. At best, the mid-point connection is only theoretical, and it is readily apparent that the greater the total difference of potential across the filament, the greater will be the disturbance arising from an imperfect mid-point connection.

It is readily appreciated that in supplying filament current through an alternating current transformer, it makes no substantial difference in the source of supply how large the current may be in order to reach a low voltage characteristic desirable for alternating current operation. For instance, a present efficient vacuum tube requires approximately 1½ watts in the filament supplied at about 6 volts with ¼ ampere of current. I find that a similar vacuum tube having this power consumption in the filament supplied at 1 volt and 1½ amperes of current is much more desirable in characteristics for use in an alternating current energized system. Such a tube would necessarily have a much larger diameter filament than now in use, thereby increasing its mass and increasing its heat inertia. Also in view of the availability of large currents in alternating operation, the filament could be further increased to obtain larger surface for lower temperature operation without sacrificing total electron emission, thus still further increasing the desirable heat inertia characteristic.

In the system shown and described by me the first four vacuum tubes have the low voltage and high inertia temperature filaments discussed by me, and I find that the arrangement is most effective in combination with the neutralizing arrangement described in the patent application I have referred to towards complete hum elimination, and my present invention refers particularly to a system embodying this added feature.

It will therefore be seen that the use of alternating current for heating filaments lends itself particularly well to using tubes having different filament characteristics in the same system. For instance, by extending secondary winding S^3 somewhat on each side to include the additions $S^{3'}$ and $S^{3''}$, I am enabled to use the more powerful vacuum tube VT^5 in the last stage for operating a loud speaker, the filament voltage for this tube being considerably higher than for the other tubes.

While I depend for hum elimination to a large extent upon the neutralizing arrangement and the use of low voltage and high heat inertia filaments, I have introduced another factor which I find of particular value in eliminating the disturbance in the last and unneutralized stage of audio frequency amplification. It will be seen that I provide a variable contact X for the grid returns of the vacuum tubes to the potentiometer R^4 across the filament supply circuit. Considering now the audio frequency transformer AF^2, if there is a complete balance of the disturbing currents in the two halves of the primary winding so that no disturbing currents are transferred to the vacuum tube VT^5, there will be nothing to neutralize the disturbing currents arising in this tube. However, if disturbing currents should be introduced into the grid circuit of this tube out of phase with those arising in the tube, they may be utilized for neutralization. By varying the contact X from one side to the other of the theoretical mid-point of the potentiometer R^4 I am enabled to vary not only the degree of the disturbing currents in audio frequency transformer AF^2, but their phase as well, and in this way am enabled to neutralize disturbing currents arising in the last tube. As before pointed out, disturbances arising in preceding tubes are amplified, so that the low intensity disturbances due to the low voltage, low temperature, high thermal inertia filaments of the tubes preceding the last stage are, because of amplification, capable of effectively opposing the greater intensity of disturbances of the high voltage filament of the power tube of the last stage.

While I have utilized a radio receiver for the purpose of illustrating and describing my invention, other applications thereof will be readily appreciated by those skilled in the art, and I do not intend to limit my invention to the system chosen for illustrative purposes.

Having fully described my invention, I claim:

1. A system including three-electrode vacuum tube amplifiers of alternating currents having grid, filament and plate electrodes, means for impressing the alternating currents to be amplified upon said system, means for passing the amplified currents from one tube to another including connections between the grids and filaments of said tubes, means for operatively energizing said tubes including means for heating the filaments of said tubes from unsteady sources of potential, the filaments of said tubes being adapted to consume energy for heating at a rate determined by a predominant current component, means for uniformly distributing the potential and phase variations in said filament heating system due to said unsteady currents, and means connecting said grids to such a point of said distributed potential and phase as to cause variations of potential to be impressed on said grids in such a manner as to neutralize variations in the amplified plate current in the last of said tubes caused by the unsteady filament heating currents.

2. A system including three-electrode vacuum tube amplifiers of alternating currents having grid, filament and plate electrodes, means for impressing the alternating currents to be amplified upon said system, means for passing the amplified currents from one tube to another including connections between the grids and filaments of said tubes, means for operatively energizing said tubes including a transformer supplying alternating current to said filaments, the filaments of said tubes being adapted to consume energy for heating at a rate determined by a predominant current component, means for uniformly distributing the potential and phase variations in said filament energizing system due to said alternating currents, and means connecting said grids to such a point of said distributed potential and phase as to cause variations of potential to be impressed on said grids in such a manner as to neutralize variations in the amplified plate current in the last of said tubes caused by the unsteady filament heating currents.

3. In an electrical amplifying system, a plurality of vacuum tubes, each having a plate, filament and grid, circuits for supplying alternating heating current to different filaments at different potentials, said circuits having a common point which is substantially neutral to each of said circuits, a connection between each of said grids and said point, a single source of potential, and plate circuits connected to said source, said circuits including a connection from said source to said point.

4. Means for supplying alternating current at different voltages to the filaments of different three-electrode vacuum tubes of an amplifying system and for providing a connection between the grid circuits of the tubes and the filament supply system, said means consisting of a transformer having a primary and a secondary winding, a pair of filament supply taps connected to intermediate points of the secondary winding at opposite sides of the neutral point of the secondary winding, an impedance connected across the taps and a grid-connection tap connected to an intermediate point of said impedance.

5. Means for supplying alternating current at different voltages to the filaments of different three-electrode vacuum tubes of an amplifying system and for providing a connection between the grid circuits of tubes and the filament supply system, said means consisting of a transformer having a primary and a secondary winding, a pair of filament supply taps connected to intermediate points of the secondary winding at opposite sides of the neutral point of the secondary winding, a resistance connected across said taps and a grid-connection tap adjustable to different points of said resistance.

6. A system including three-electrode vacuum tube amplifiers of alternating currents, having grid, filament and plate electrodes, means for impressing the alternating currents to be amplified upon said system, means for passing the amplified currents from one tube to another including connections between the grids and filaments of said tubes, means for operatively energizing said tubes including means for heating the filaments of said tubes from an unsteady source of potential, the filaments of said tubes being adapted to consume energy for heating at a low operating temperature at a rate determined by a predominant current component, means for uniformly distributing the potential and phase variations in said filament heating system due to said unsteady currents, and means connecting said grids to such a point of said distributed potential and phase as to cause variations of potential to be impressed on said grids in such a manner as to neutralize variations in the amplified plate current in the last of said tubes caused by the unsteady filament heating currents.

7. The system as claimed in claim 1

wherein a transformer is provided, which transformer has a secondary winding from which are supplied the currents for heating the filaments at different voltages and wherein connections are provided for supplying the higher or highest voltage from the secondary winding and for supplying the lower voltage or voltages from a central section or central sections of the secondary winding.

8. In a signal current amplifying system a plurality of three-electrode vacuum tubes arranged for multi-stage amplification of signaling current, the filaments of one or more of the tubes in advance of the last tube being massive and heated by current of relatively low voltage and the filament of the last tube being adapted for heating by current of relatively high voltage, means for energizing said filaments from a common source of alternating current energy whereby periodic disturbing variations are created in the plate circuits of said tubes, and means for passing to the grid circuit of the last tube some of the disturbing energy of a preceding tube of phase after amplification to oppose the disturbing energy in the plate circuit of the last tube.

9. In a signal current amplifying system a plurality of three-electrode vacuum tubes arranged for multi-stage amplification of signaling current, the filaments of one or more of said tubes being massive and heated by large current at low voltage and the filament of another tube being adapted to be heated by current at relatively higher voltage, means for heating all of said filaments from a common source of alternating current, whereby disturbing periodic variations are produced in the plate circuits of said tubes, and means for passing to the grid circuit of the higher voltage filament tube some of the disturbing energy of said one or more massive filament tubes of phase after amplification to oppose the disturbing energy in the plate circuit of said higher voltage filament tube.

10. In a signal current amplifying system employing a plurality of three-electrode vacuum tubes arranged for multi-stage amplification, some of said tubes having cathodes producing relatively small periodic disturbing variations in their plate circuits when energized by alternating current and one of said tubes having a cathode producing relatively large disturbing variations in its plate circuit when energized by alternating current, means for energizing the cathodes of all of said tubes from a common alternating current source, and means for passing to the grid circuit of said tube having relatively large disturbing variations some of the disturbing energy in the plate circuits of the other of said tubes of phase after amplification to oppose energy in the plate circuit of said tube having relatively large disturbing variations.

11. A signal current amplifying system including a pair of three-electrode vacuum tubes connected in cascade relation, one of said tubes having a cathode producing relatively small and the other of said tubes having a cathode producing relatively large disturbing variations when energized with periodically fluctuating current, means for energizing the cathodes of both of said tubes from a common source of periodically fluctuating current, said tubes being so associated in said system that the disturbing energy of the first of said tubes is introduced into the grid circuit of the second of said tubes in a phase to oppose the disturbing energy in the plate circuit of the second said tube.

12. In a cascade system for amplifying signal current of high frequency modulated at audible frequency including a three-electrode vacuum functioning as a detector followed by one or more three-electrode vacuum tubes functioning as audio amplifiers, means for energizing the cathodes of all of said tubes from a common source of audible frequency periodically fluctuating current, the cathode of said detector tube producing relatively small disturbing variations by reason of said fluctuating current energizing and the cathode of a following audio amplifier tube producing relatively larger disturbing variations by reason of said fluctuating current energizing, and means for introducing some of the disturbing energy of said detector tube into the grid circuit of said following tube of phase after amplification to effectively oppose the disturbing variations in said following tube.

13. In a system for amplifying and translating signal current the combination of a loud-speaking translating device, a three-electrode vacuum tube of substantial power for operating said translating device, said tube having a cathode which when energized with alternating current produces substantial disturbing current variations in the plate circuit thereof, one or more less powerful amplifying tubes preceding said output tube having cathodes which when energized with alternating current produce relatively small disturbing current variations in the plate circuits thereof, means for energizing the cathodes of all of said tubes from a common source of alternating current, and means for passing to the grid circuit of said power tube some of the disturbing energy of said preceding tube or tubes of phase after amplification to oppose disturbing energy in the plate circuit of said output tube.

In testimony whereof I affix my signature.

BENJAMIN F. MIESSNER.