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VOLUME CONTROL SYSTEM FOR RADIORECEIVERS

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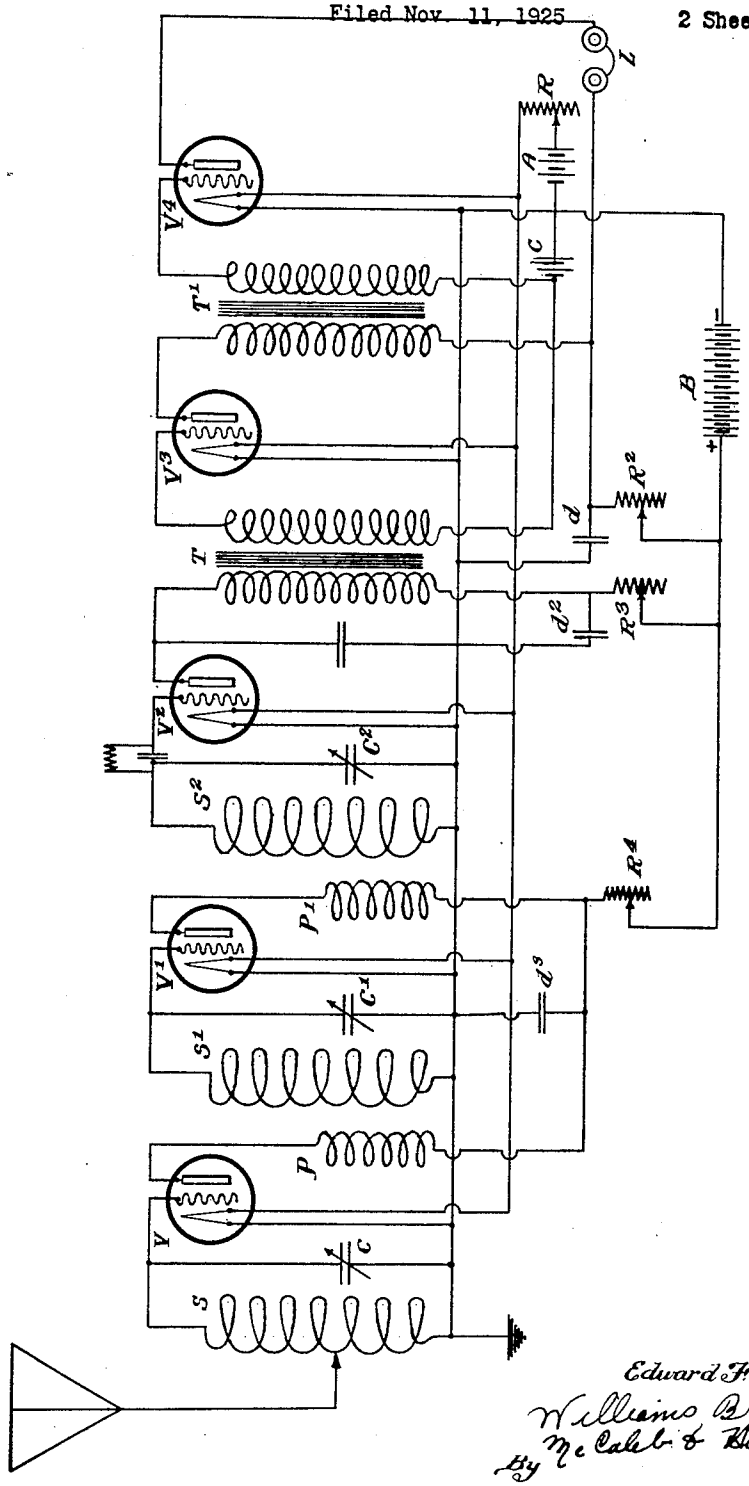



Fig. 1.

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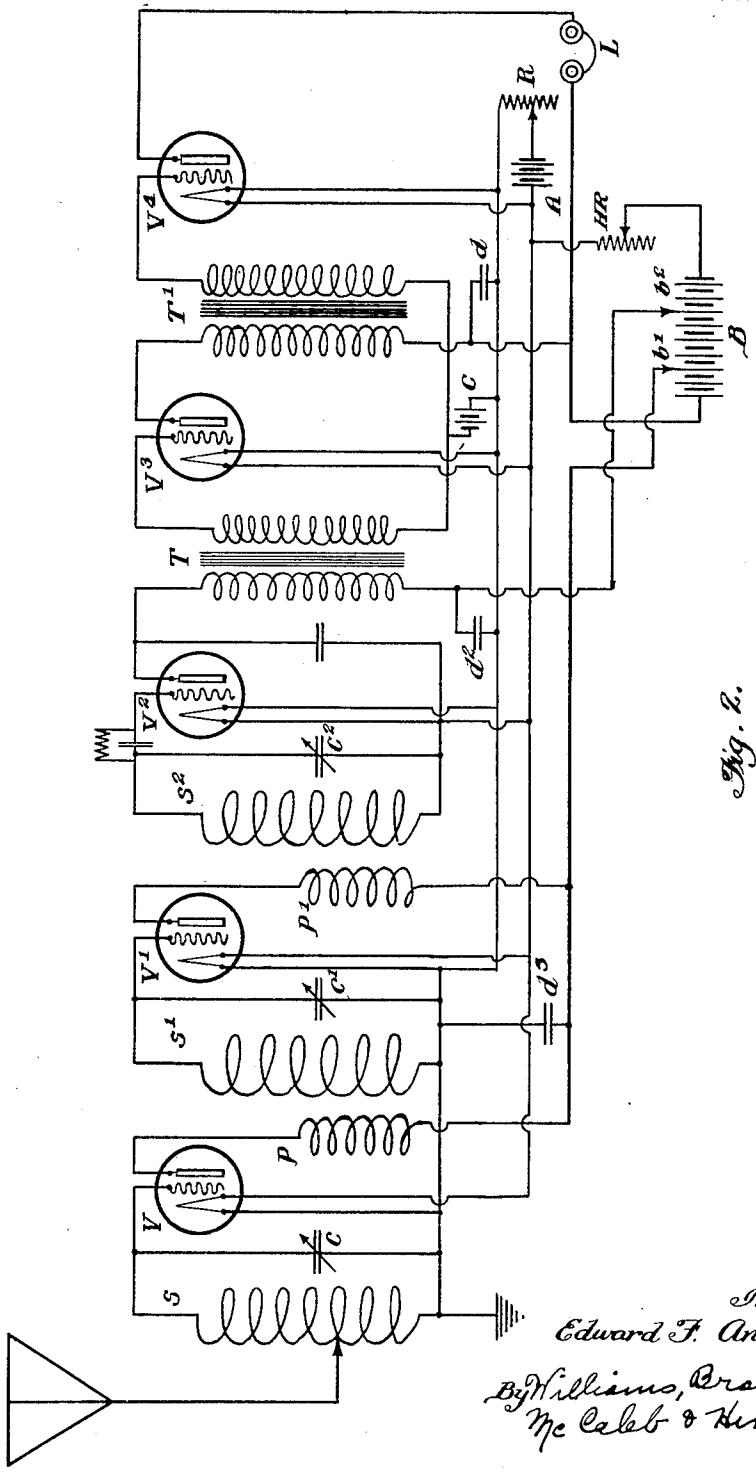



Fig. 2.

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# UNITED STATES PATENT OFFICE.

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## VOLUME-CONTROL SYSTEM FOR RADIORECEIVERS.

Application filed November 11, 1925. Serial No. 68,254.

This invention relates to means of volume control for thermionic tubes and associated circuits.

The objects of my invention are primarily to provide a volume control means which permits of the ready and satisfactory adjustment of volume without distortion or oscillation. It is customary to regulate the degree of radio frequency amplification by the regulation of filament excitation in the radio frequency tubes and in the detector. This method of regulation is not generally satisfactory because by this method the tubes cannot be operated with the filament excitation at which relatively small distortion occurs. For this reason it has been customary in the past to operate radio frequency tubes and detectors with filament excitations less than or different from that at which the least distortion occurs to reduce or increase the volume or to limit the effect of undesired signals such as static.

My invention is in part a continuation of the invention disclosed in my application Serial No. 743.511, filed October 14, 1924, wherein the use of extremely high resistances located in the plate circuits of thermionic tubes is shown and described for the purpose of preventing objectionable oscillation in transformer coupled radio frequency sets. It has been through the continued experimentation with and the expansion of the system disclosed in my above named application that I have developed the very great advantage and superiority of volume control by the method set forth in my present application.

In accordance with this method, one or more variable resistances extending to the extremely high maximum of ten million ohms are included in the circuits between the B voltage source and the plates of one or more of the thermionic tubes, by means of which the B current may be regulated and reduced to control the degree of amplification without necessitating any adjustment of the filament current away from that at which it provides the minimum distortion.

In order to avoid adding any resistance to the oscillatory plate circuit a by-pass condenser is included in such a position as to supply a return for the high frequency current to the filament of the tube without passing through the resistance. The variable resistance is also proportioned in such a way that a gradual variation of resistance occurs at the minimum resistance end and the resistance increases more rapidly toward the maximum end. The low resistance end can be used for the control of oscillation and the high resistance end of the same variable resistance for the control of volume, thus effecting these two controls with the same manual adjustment.

When my invention is applied to the plate circuit of thermionic tubes used for radio frequency amplification the variable resistance is placed between the primary of the radio frequency transformer and the B-battery there being a by-pass condenser connected between the end of the resistance remote from the battery and one terminal of the tube filament.

An increase in the variable resistance has two distinct effects, one is to lower the voltage applied to the plate of the tube, while the other is to increase the impedance of the plate circuit to the passage of unidirectional current of rapidly changing magnitude. This increase in impedance does not materially affect the radio frequency alternating currents in the oscillatory circuit. Neither does it increase the damping of this oscillatory plate circuit nor the tuned grid circuit to which it is coupled as would be the case if the by-pass condenser were omitted. The effect obtained by the use of my invention differs from and is superior to the effect which would be secured by a mere change in the voltage of the B-battery used.

The principal differences are: The lowering of the voltage of the B-battery places a definite limit on the plate voltage, relatively independent of the current flowing in the plate circuit whereas when the resistance which is a part of my invention is employed the voltage applied to the plate varies with the current flowing in the plate circuit. When the current flow is greatest the voltage drop across the resistance is also great-

est and therefore the voltage applied to the plate is less. When the plate current is small the voltage drop in the resistance is also small and a higher voltage is therefore impressed upon the plate.

Also, the use of my invention definitely increases the impedance of the plate circuit as the variable resistance is increased which increases the impedance encountered by the unidirectionally fluctuating currents in the plate circuit thus decreasing both the amplification and the tendency of the tube to oscillate. Even if it were assumed that the voltage at the terminals of the B-battery were increased to an amount just sufficient that with the addition of resistance the voltage applied to the plate remains constant, the effective amplification and the tendency of the tube to oscillate would still be reduced by reason of the presence of the high resistance in the circuit.

As pointed out in my application above referred to, the fact above mentioned serves to effectually prevent objectionable sustained oscillation and at the same time to permit the tubes to be operated at a very high degree of relay amplification.

The result of my invention which is a marked advantage particularly in portable radio sets using small dry batteries for supplying the B current energy, is that the draft upon the B battery is very greatly reduced, thus very greatly prolonging the life of the B-battery.

This invention used as a volume control, also makes it possible to hold down the plate current consumption in radio frequency amplifiers without the use of a C-battery, which besides constituting an additional battery, considerably complicates the circuit. The use of the resistance makes it possible to reduce the plate current to a surprisingly small fraction of what is would be without the resistance and still receive powerful signals. When it is desired to receive distant stations the plate resistance can be reduced to give greater signal strength, but when high amplification is not desired, increasing the resistance will effect a great saving in B energy. As a result of the fact that radio sets are used mostly for listening to relatively strong signals, the maximum saving of B energy can be had at practically all times. As pointed out in my prior application, no damping is added by the use of this resistance to the plate circuit of the radio tubes as the by-pass condenser returns the alternating current in the plate circuit directly to the filament of the tube without passing through the resistance. Only the pulsating direct current in the plate circuit which is fed to this circuit from the B-battery passes through the resistance. This does not affect that portion of the plate circuit which is resonant, or semi-resonant to the signal being received.

Two modifications of my invention are illustrated in the accompanying drawing. That of Figure 1 illustrates substantially the arrangement shown in my co-pending application above referred to, while that of Figure 2 illustrates a modification of that arrangement in which a single controlling resistance is used in the B-battery circuits of the radio frequency tubes, the detector and the audio frequency tubes, the plate circuits of each of these tubes being tapped in at different voltages in the B-battery source so that the tubes will be subjected to different maximum voltages during the low current draft periods in the operation of the tubes.

With this brief general description, Figure 1 is a diagrammatic illustration of a radio frequency receiving set comprising two stages of radio frequency amplification, a detector and two stages of audio frequency amplification together with three separate resistances for controlling the plate currents, one resistance for the radio frequency tubes, one for the detector tube, and one for the audio frequency tubes, it being understood that the operating devices for the three resistances may be mechanically connected so that the control of the three resistances will be automatically caused to operate simultaneously and in a definite relation with one another, or the resistances for controlling the current in the detector and in the audio frequency tubes may be either omitted or made permanent and the whole volume control and oscillation adjustment may be obtained through variation of the resistance in the radio frequency tube circuits. In fact, the latter arrangement has been found to be entirely practicable and entirely satisfactory in its commercial application.

Figure 2 is a diagrammatic illustration of a receiving set provided with two radio frequency amplifying tubes, a detector tube and two audio frequency amplifying tubes, and in which a single variable resistance is provided for regulating the plate current in all of the tubes, the circuits of the three different classes of tubes being connected to different voltages at the B battery current source.

In the accompanying Figure 1 the vacuum tubes V, $V_1$ and $V_2$, are the radio frequency amplifiers and detector, and the vacuum tubes $V_3$ and $V_4$ are the audio frequency amplifying tubes in a two stage radio amplifying circuit. The radio frequency amplifying circuits are tuned by means of variable condensers C, $C_1$ and $C_2$ in parallel circuits with the secondary coils S, $S_1$, and $S_2$, it being understood that the movable parts of the condensers C, $C_1$ and $C_2$ may be mechanically connected together so

that the adjustment of all three of these condensers may be made by the movement of a single operating member, or the three adjustable condensers may have separate controls as desired without departing from the functional operation in the circuits.

The plate or output circuit of the detector $V_2$ extends through the primary of an audio frequency transformer T, the secondary of which is connected with the grid or input circuit of the audio amplifying tube $V_3$. The plate circuit of the tube $V_3$ is connected with the primary of the audio frequency transformer $T_1$, the secondary of which is connected to the grid circuit of the audio amplifying tube $V_4$, the plate circuit of which extends to the loud speaker or other receiver L. The filaments of all of the tubes are shown in circuit with the A-battery marked A controlled by a single resistance R, which it is to be understood may be replaced by individual resistances, though this is not necessary in my system since with the use of similar tubes for radio and audio amplification and for detection, the same filament excitation may be maintained for all tubes and may be adjusted for the best current so far as distortion in the tubes is concerned. In fact, the resistance R may be replaced by an automatic so-called "ballast resistance" in the form of an iron wire operating at a critical temperature, and at which the resistance very rapidly increases with increase in temperature and decreases with decrease in temperature, which form of device will serve to maintain the filament current of all of the tubes substantially constant throughout the usual variations in battery voltage.

In accordance with the disclosure of Figure 1, a B-battery marked B is provided for supplying the plate current for all of the tubes. One terminal of this battery is connected with the filaments of all of the tubes. The other terminal of the battery is connected through a resistance $R_2$ and through the receiving device with the plate of tube $V_4$, and through the primary of the transformer $T_1$ with the plate of the tubes $V_3$ and $V_4$, as before stated being the audio frequency amplifying tubes. In order that the high frequency currents will not pass through the resistance $R_2$ and battery B, a condenser $d$ is provided in a by-pass circuit which bridges the battery B and resistance $R_2$. The current from one pole of the B battery is conducted to the plate of the detector tube $V_2$ through a variable resistance $R_3$, a condenser $d_2$ being provided in the circuit of the radio frequency current emanating from the plate of this tube to obviate the necessity of this current passing through the resistance $R_2$ to the battery B. A terminal of the battery B is also connected through a resistance $R_4$ with the plates of the radio frequency amplifier tubes V and $V_1$, and here again a condenser $d_2$ is provided to by-pass the radio frequency alternating currents so that they will not pass through the resistance $R_4$ nor the battery B. With reference to the circuit of Figure 1 thus described, it will be understood, as before pointed out, that the movable elements of the high resistances $R_2$, $R_3$ and $R_4$ may be mechanically connected to one another so that by the movement of one adjusting arm the three resistances, or if desired, two of them may be simultaneously adjusted.

The resistances $R_2$ and $R_3$ may be permanently adjusted to provide the most desirable voltage for the plate circuits of the audio frequency and detector tubes. By the use of these resistances located within the radio receiving set, a multiplicity of conductors usually incident to impressing different B-battery voltages upon different classes of tubes of a set is avoided. Where the resistances $R_2$ and $R_3$ are used solely for obtaining the most desirable B-battery voltage on the audio frequency and detector tubes, the resistance $R_4$ in circuit with the radio frequency amplifying tubes should have a maximum value of about ten million ohms in order that the signal strength may be cut down to a whisper in either head phones or loud speaker. It sometimes occurs that because of the close proximity of the receiving set to a powerful sending station, the signal has such strength that it cannot be adequately cut down by means of the resistance in the radio frequency circuits. This is because the signal is received in part at least directly by the detector tube terminals and its connected conductors within the set. When such a powerful signal prevails it seriously interferes with the tuning of the receiving set because so far as the portion of the signal is concerned which is directly received by the detector tube, only one stage of tuning is available, that with which the detector tube circuit is tuned. By increasing the resistance in the detector and audio stages without increasing the resistance in the radio stages this effect can be minimized. By cutting down the volume of the local station with the detector or audio resistance without increasing the radio resistance, the interference of the local station can be reduced. The resistances $R_2$ and $R_3$ can also be used for decreasing the volume of desired signals sent from powerful local stations and for reducing the B-battery current consumption.

In the disclosure of Figure 2, the various tubes, coils and condensers are designated by the same characters as those used in the description of Figure 1, so that a further detailed description of the main portion of this figure will be unnecessary. The B-battery, however, in this figure marked $B_1$ is provided

with two taps. The full positive pole of the battery is connected with the plates of the audio frequency tubes $V_3$ and $V_4$ through respectively the primary of the transformer $T_1$ and the loud speaker or other receiver L. The battery tap $b$ is connected through the coils $s$ and $s_1$ with the plates of the radio frequency amplifiers V and $V_1$, and the lower voltage tap $b_1$ is connected through the primary of the transformer T with the plate of the detector $V_2$. The return circuit for all of these battery taps is carried to the negative point of the battery by a conductor connecting with the filaments of all of the tubes through a high variable resistance marked HR, this resistance having the function of varying the currents in all of the plate circuits simultaneously. As in Figure 1, so in this embodiment, high frequency by-pass condensers $d$ and $d_2$ and $d_3$ serve to complete paths for the high frequency currents to obviate the necessity of these currents passing through the resistance HR and the battery B. The details of the circuits of Figures 1 and 2 not specifically described are all common knowledge in the art to which this invention pertains, and will be understood by any one skilled in this art.

In the embodiment of Figure 2 the advantages of eliminating a multiplicity of B-battery taps are forfeited but with this structure a maximum saving of B-battery current consumption is obtained by the use of the single resistance HR. It will be understood that the principles of my invention may be applied to various forms of radio receiving circuits, that the principles may be applied to one tube only or to all of the tubes of the receiving circuit, or to one or more groups of tubes.

Some of the advantages accruing from the use of my invention, particularly when operating principally upon the radio frequency tubes, are: The volume is decreased on the input side of the detector, thereby lessening the input energy into the detector, which lessens the possibilities of detector distortion; it makes possible the use of a single control both for controlling oscillation and also for reducing volume down to a whisper if desired, while all other controls on the set are arranged for maximum reception efficiency. The fact that reducing the volume with this control when applied to the plate circuit of the radio frequency tubes, also brings the tubes further and further from oscillation, eliminates any tendency to distortion due to an oscillatory condition in the tubes at the time when the volume is not the maximum and there is accordingly no necessity for a close approach to oscillation in order to increase the signal strength.

I claim:

1. In an electric amplifying or rectifying system, a thermionic tube, a filament and a plate therefor conductively connected together to form a plate circuit, an impedance and a source of B power in said circuit, a variable resistance of relatively high value in said circuit between said impedance and said filament, and a capacity, one terminal of which is connected to the said plate circuit at a point between said impedance and said variable resistance and the other terminal of which is connected to said plate circuit at a point between the other terminal of said variable resistance and said filament.

2. In an electric current amplifier, a plurality of thermionic tubes, filaments and plates therefor conductively connected together to form plate circuits, impedances in the individual plate circuits, a source of B power in said plate circuits, a variable resistance of relatively high value in one or more of the plate circuits connected between one or more of said impedances and one or more of said filaments, and one or more capacities each having one terminal connected to one or more of said circuits at a point between said impedances and said variable resistance, and the other terminal of which is connected with the circuit at a point between the other terminal of said variable resistance and one or more of said filaments.

3. In a circuit for amplifying or rectifying electric currents, a thermionic tube, a relatively high variable resistance and a source of B power in the plate to filament circuit of said tube connected between the plate and the filament of said tube, and a capacity in the plate load circuit, one terminal of said capacity being connected to the plate circuit at a point lying between one terminal of said variable resistance and the plate of said tube, the other terminal of said capacity being connected to the plate filament circuit at a point lying between the other terminal of said variable resistance and the filament of said tube.

4. In a radio frequency amplifier, a thermionic tube, a filament and a plate therefor conductively connected together to form a plate circuit, a detector receiving energy from said amplifier, a coupling means associated with the plate circuit of said amplifier for transferring energy to said detector, a variable resistance of relatively high value and a source of B power in said plate circuit between the coupling means and the filament of said amplifier, and a capacity, one terminal of which is connected to the plate circuit at a point between said coupling means and said variable resistance and the other terminal of which is connected to said plate circuit at a point between the other terminal of said variable resistance and said filament.

5. In a radio frequency amplifying system comprising two or more stages of radio frequency amplification, a plurality of thermionic tubes, a filament and a plate for each

tube, the filament of each tube being conductively connected to the plate of that tube thus forming a plurality of plate circuit, one for each tube, coupling means in the plate circuit of each tube for coupling said plate circuit with the input circuit of the next succeeding stage, a single variable resistance of relatively high value and a single source of B power serially connected in circuit between all of said coupling means and all of said filaments, and one or more capacities connected between said filaments and points in said plate circuits between the coupling means and said resistance.

In witness whereof, I hereunto subscribe my name this 6th day of November, 1925.

EDWARD F. ANDREWS.