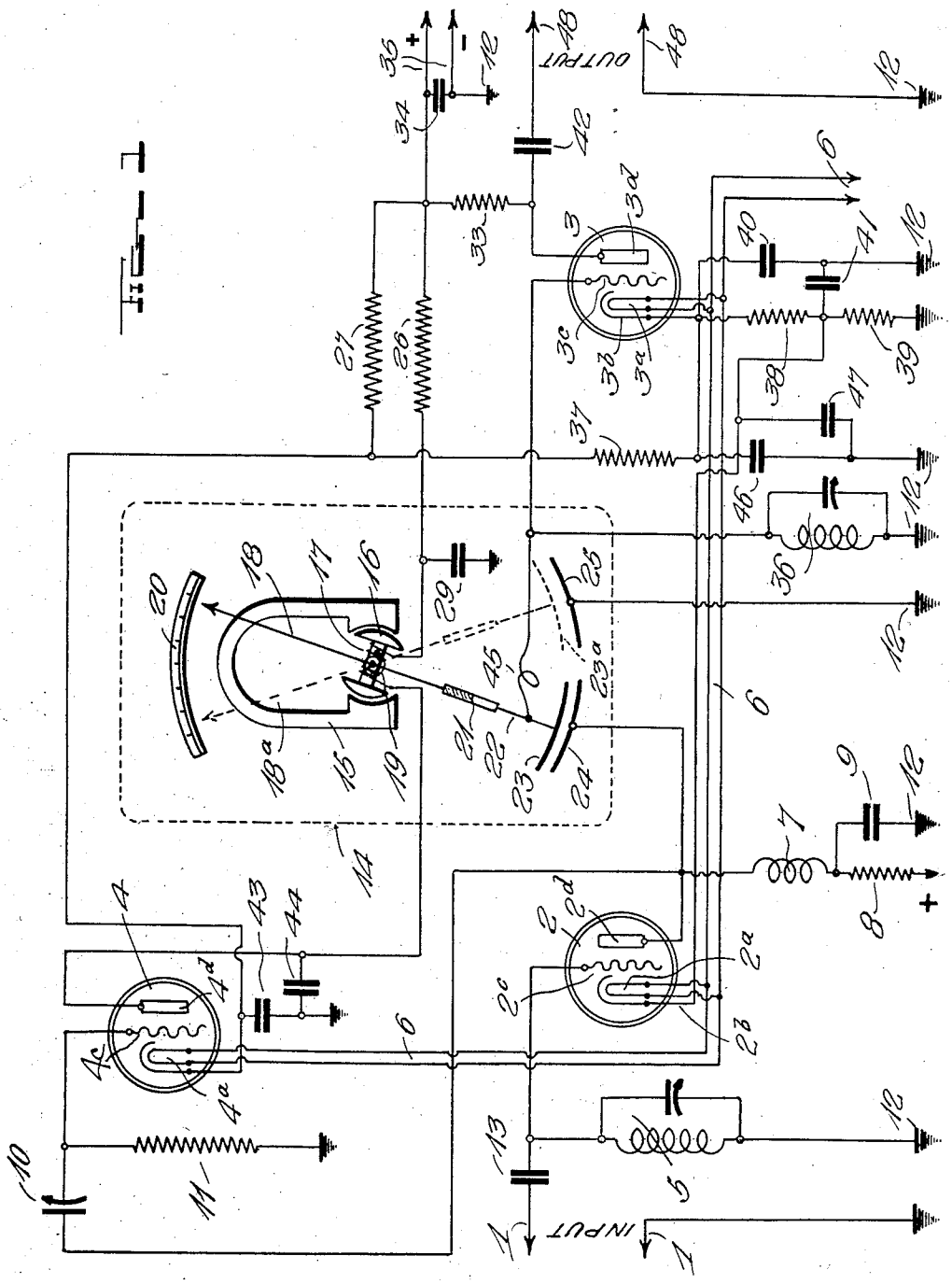
Aug. 6, 1935. G. P. ADAIR 2,010,002

VOLUME CONTROL SYSTEM

Filed July 3, 1931 6 Sheets-Sheet 1

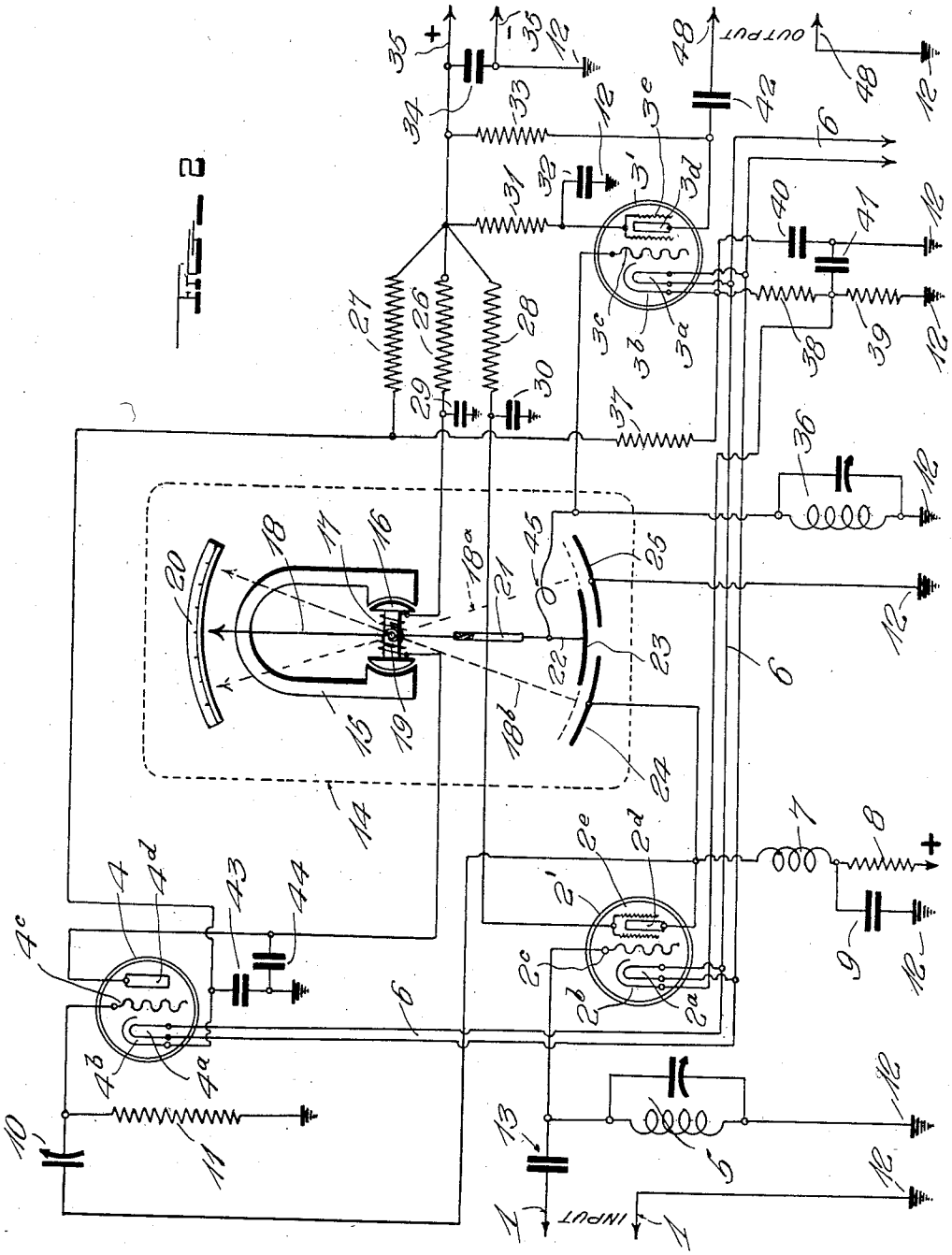


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VOLUME CONTROL SYSTEM

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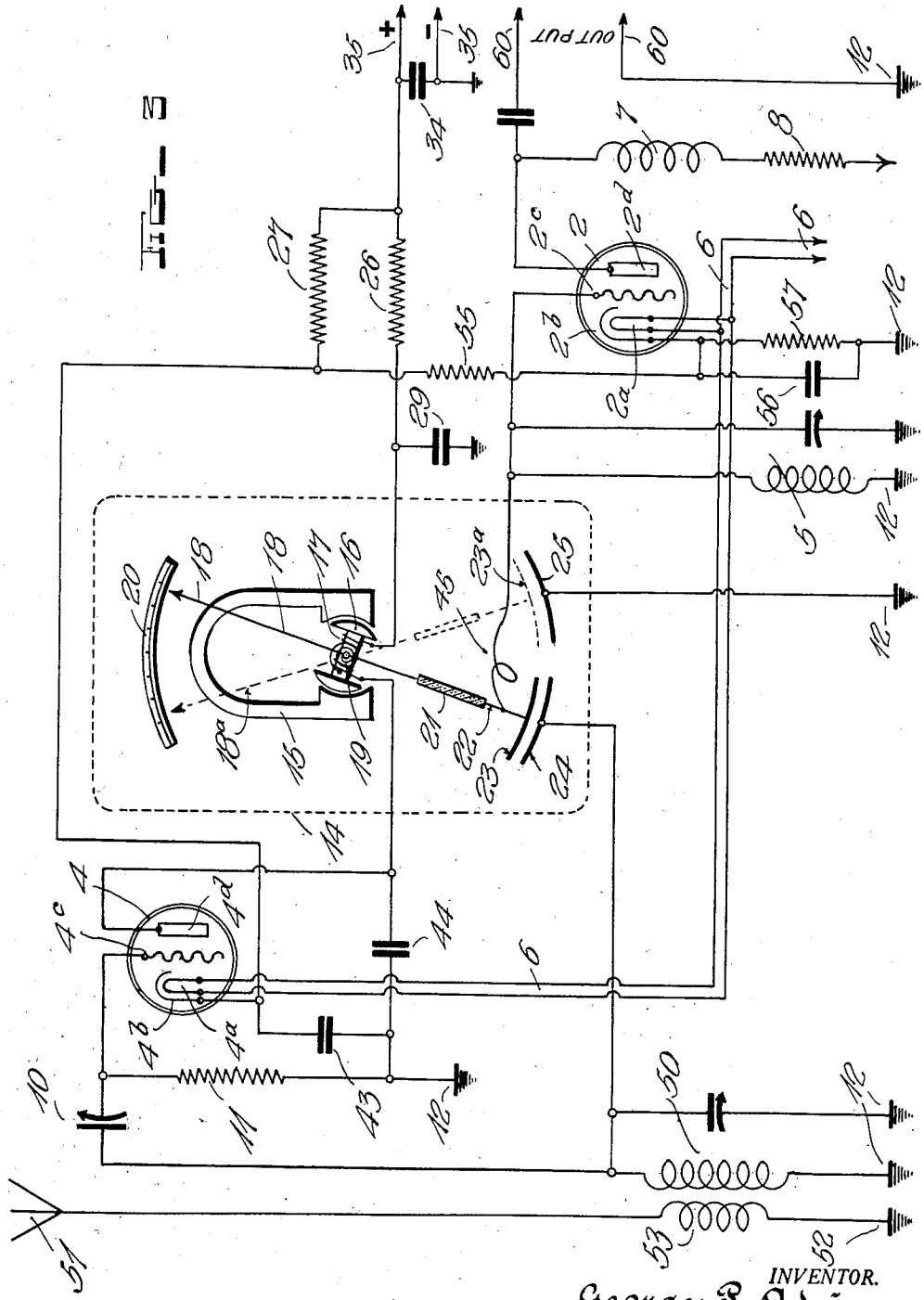
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VOLUME CONTROL SYSTEM

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FIG. 3

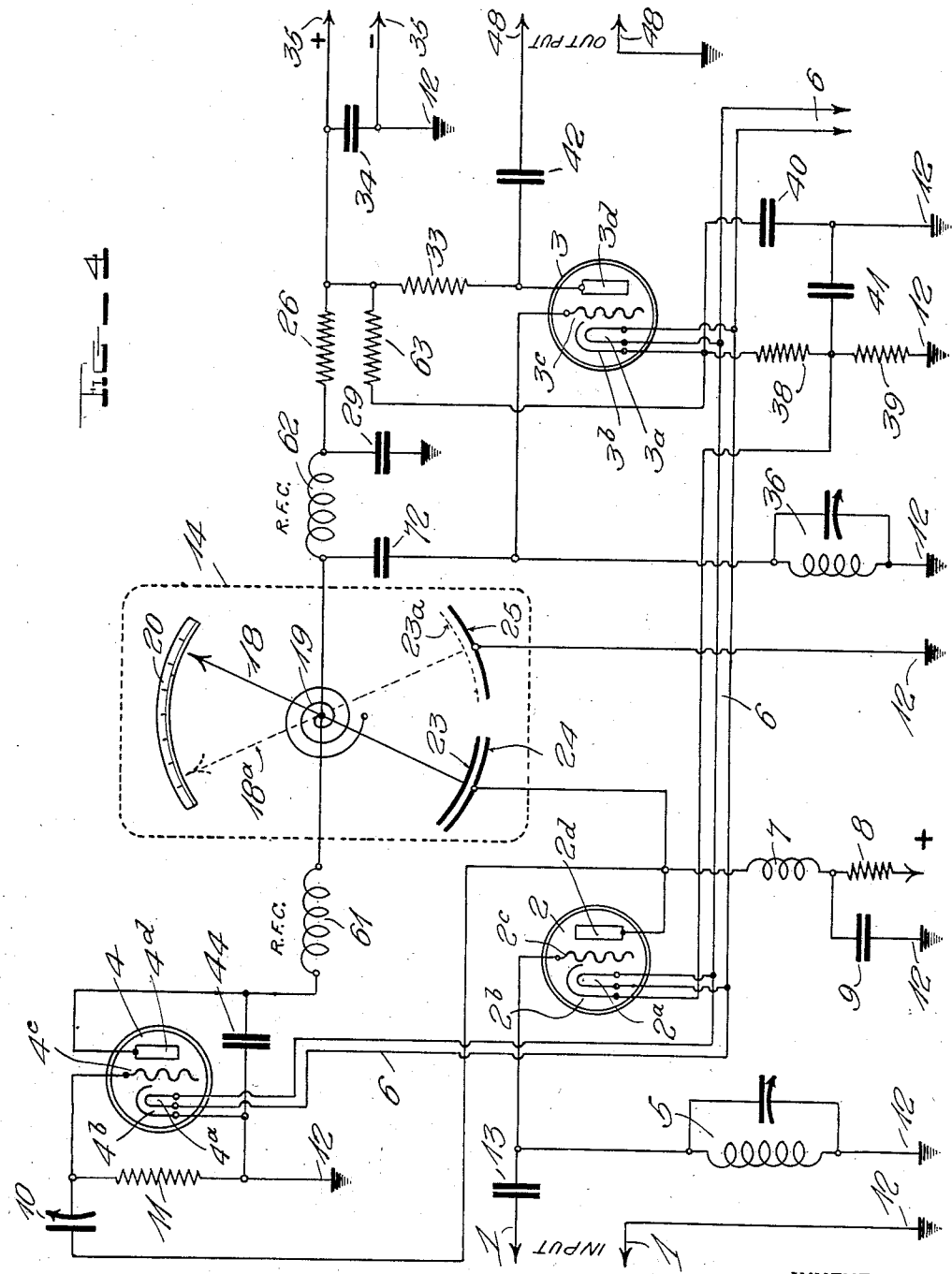


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VOLUME CONTROL SYSTEM

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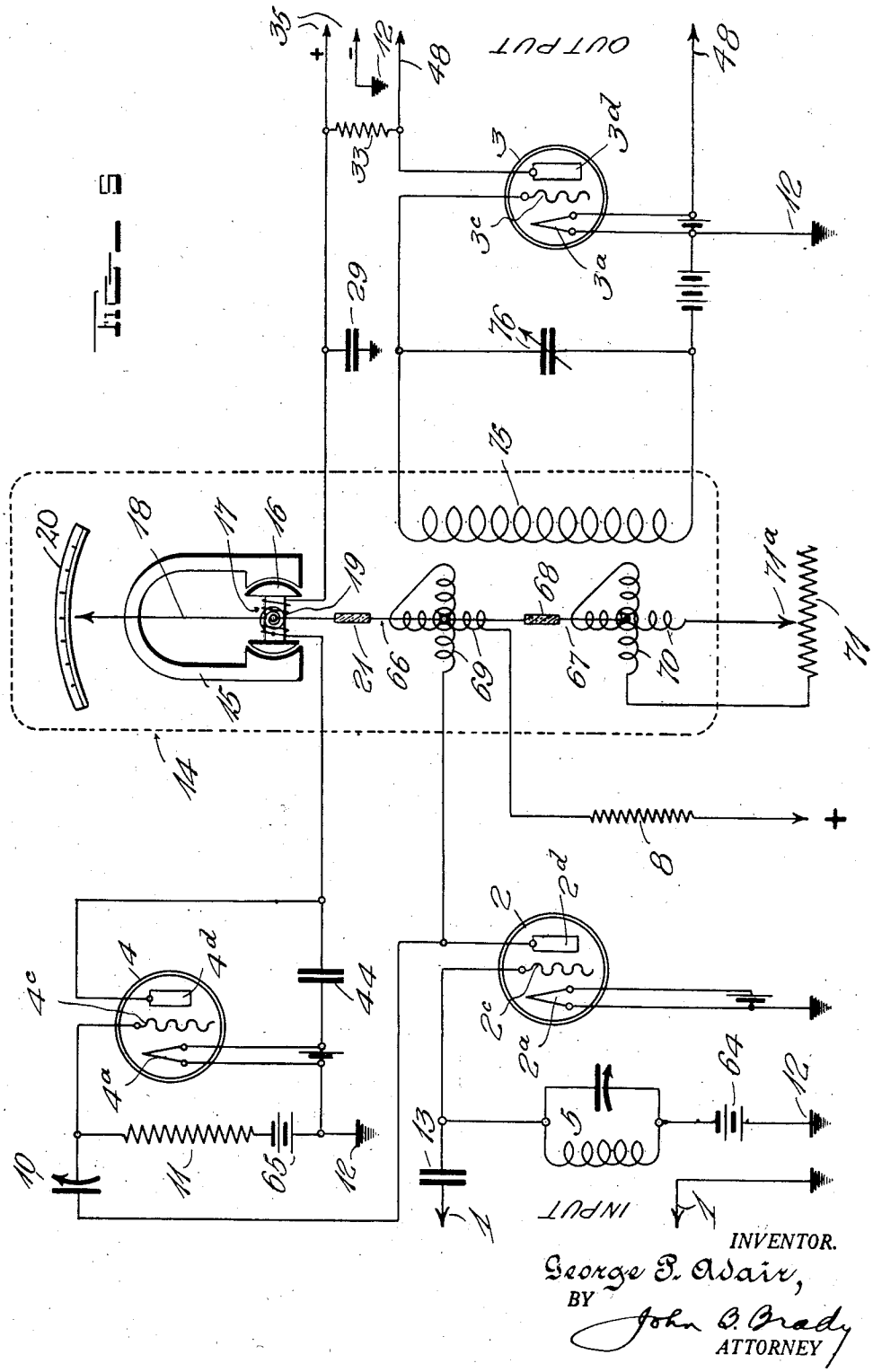


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VOLUME CONTROL SYSTEM

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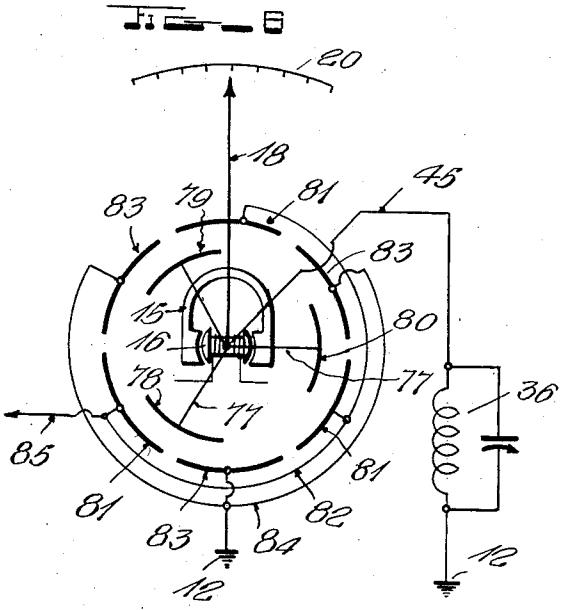


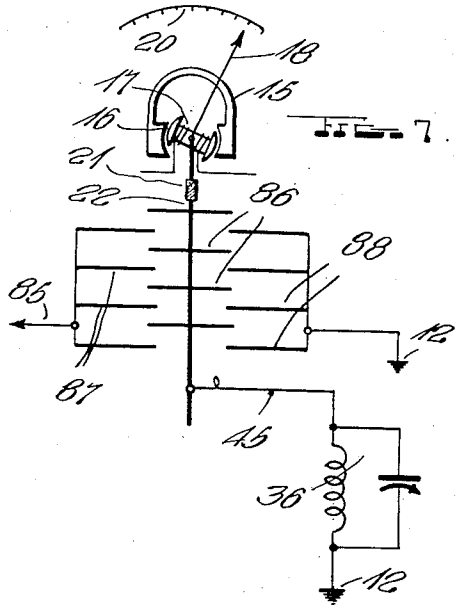
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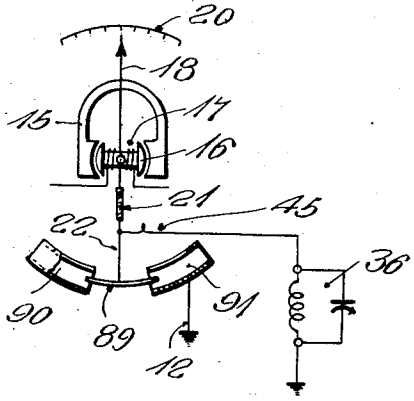
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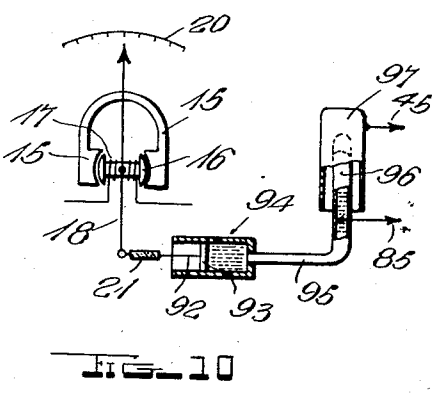
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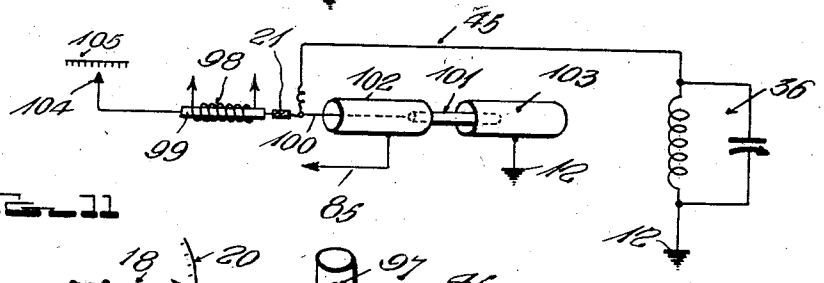
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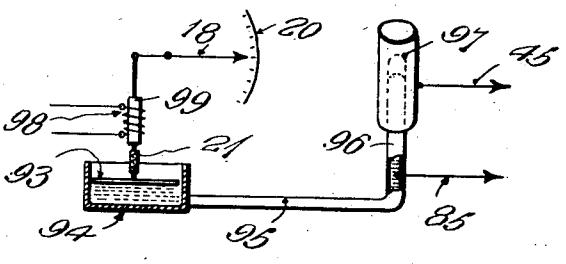












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Patented Aug. 6, 1935

2,010,002

UNITED STATES PATENT OFFICE

2,010,002

VOLUME CONTROL SYSTEM

George P. Adair, San Antonio, Tex.

Application July 3, 1931, Serial No. 548,695

6 Claims. (Cl. 250—20)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

My invention relates broadly to volume control systems and more particularly to a circuit arrangement for automatically controlling the coupling of the electrical circuits in a radio receiving system for correspondingly controlling the volume of the reproduced sound.

One of the objects of my invention is to provide a circuit arrangement for reducing fading effects in radio broadcast receiving circuits by automatically controlling the coupling of the circuits in the receiver in accordance with the amplitude of the incoming signaling energy.

Another object of my invention is to provide a volume control circuit for radio broadcast receivers which operates independent of frequency for maintaining the volume of sound reproduced by the radio broadcast receiver constant independent of fading effects.

Still another object of my invention is to provide a device for controlling the coupling of the circuits in a radio broadcast receiver at the same time indicating conditions of resonance of the receiving circuit for the reproduction of sound at constant volume independent of fading effects.

A further object of my invention is to provide a construction of mechanical actuator for controlling the volume of reproduced sound in accordance with variable conditions of fading in the circuits of the radio broadcast receiver wherein the parts are arranged to avoid appreciable wear and to give gradual control over the entire range of the receiving apparatus.

Other and further objects of my invention reside in the circuit arrangement for and the construction of the variable coupling device used in association with the amplifier circuits of a radio broadcast receiver as set forth more fully in the specification hereinafter following by reference to the accompanying drawings, in which:

Figure 1 illustrates one circuit arrangement for a radio broadcast receiver equipped with a volume control circuit in accordance with my invention; Fig. 2 shows a modified form of variable coupling system employed in interstage relationship in an amplifier system embodying my invention; Fig. 3 shows a simplified form of radio receiving circuit including a variable coupling device for controlling the transfer of energy through the amplifier in accordance with my invention; Fig. 4 illustrates an electrostatic control apparatus for varying the coupling between the stages of an amplifier system in accordance with my invention; Fig. 5 shows an arrangement of automatic coupling control apparatus in which the inductive association of the coupling coils in an amplifier system is variably controlled in accordance with the amplitude of the incoming signaling energy; Fig. 6 is a schematic view showing a modified form of coupling control mechanism which may be employed in the control system of my invention; Fig. 7 illustrates a further modified form of coupling control mechanism embodying the principles of my invention; Fig. 8 illustrates another form of variable capacity device operative in accordance with changes in amplitude of signaling energy for correspondingly controlling the amplification characteristics of the receiving apparatus for governing the volume of the reproduced sound; Fig. 9 shows a further form of coupling control mechanism which may be employed in the circuits heretofore described; Fig. 10 illustrates a still further modified form of variable capacity mechanism controllable in accordance with the operation of the signal receiving circuits in the system of my invention; and Fig. 11 shows a further modified construction of variable capacity control device employed in the fading compensator of my invention.

The volume control system of my invention is adaptable for installation in existing types of radio broadcast receivers. The coupling control mechanism may be assembled as a separate unit and incorporated in existing equipment at very reasonable cost. The control circuit of my invention may be built into the radio receiving apparatus as part of the production program thereof at very reasonable cost. The control mechanism of my invention comprises a variable impedance device, the effective value of which is electromagnetically or electrostatically controlled in accordance with the amplitude of the incoming signaling energy. The operation of the variable impedance device is so damped that there is no tendency toward amplitude distortion. The effective variation in impedance may be made as fast as desired to meet special conditions. I may arrange the variable impedance device intermediate the stages of amplification or the variable impedance devices may be arranged between the antenna and the amplification circuit of the receiver, or between the amplifier system and the sound reproducing circuit.

In applying the volume control system of my invention to existing types of receiving circuits, all voltages and currents of the high frequency cascade circuit remain unchanged so that they may be adjusted for maximum efficiency thereby reducing to a minimum signal distortion and so called "cross-modulation" due to improper ad-

justment of tube voltages which is inherent in voltage changing control circuits. In applying the variable impedance system of my invention to existing receiving circuits there is no tendency for the receiving circuit or amplifier to oscillate or flutter as is the case with other systems of volume control. The system of my invention provides automatic control over a much wider range of signal strength than has been possible with previous volume control systems. The volume control device of my invention operates independent of frequency of the actuating signal.

Referring to the drawings in more detail, reference character 1 designates the input terminals of the receiving apparatus which includes a high frequency amplifier stage 2, the output of which is connected to the high frequency rectifier stage 3 through a variable coupling system. The output circuit of the high frequency amplifier tube 2 connects to the input circuit of a control tube 4 as will be hereinafter described in detail. The coupling system enclosed within the dotted line 14 is actuated under control of the control tube 4 for variably controlling the transfer of energy to the high frequency rectifier tube 3.

The input circuit 1 connects through coupling condenser 13 and selectively tuned circuit 5 to the control grid 2c and the cathode element 2b through the ground connections 12. The output circuit of tube 2 connections from anode 2d to the input circuit of control tube 4 through condenser 10 to control grid 4c. The anode potential for tube 2 is supplied through choke coil 7 and regulating resistance 8 which leads to the positive terminal of the anode potential. A by-pass condenser 9 connects across the anode potential source to ground 12 as shown. A suitable biasing potential is supplied to the grid of control tube 4c through resistance 11. The heater cathodes 2a of tube 2, 4a of tube 4, and 3a of tube 3, are supplied with heating current through circuit 6 from any suitable potential source. The output circuit of control tube 4 connects from anode 4d to the winding 17 on the rotatable armature 16 of the electromagnetic device forming part of the control apparatus within the dotted line 14. The armature 16 is pivotally mounted for rotation between the magnetic pole pieces of the magnetic system 15. Rotatable armature 16 carries the movable pointer or indicator 18 which is normally biased by means of the spring 19 to occupy the full line position shown in Fig. 1. The pointer or indicator 18 has one end thereof movable over a graduated scale 20. The other end of the indicator or pointer 18 carries the plate member 23 by means of arm 22 in insulated relation to the indicator or pointer 18 through insulated joint 21. The plate 23 is electrically connected through flexible conductor 45 with the control grid 3c of the high frequency rectifier tube 3. The plate member 23 may be capacitatively related to either fixed plate 24 or fixed plate 25. The capacity area 25 is connected to ground 12 as shown while capacity area 24 connects to the output circuit of high frequency amplifier tube 2 at the anode 2d as illustrated. The input circuit of high frequency rectifier tube 3 is selectively tuned by circuit 30 one end of which is connected to control grid 3c and to the movable capacity area 23 through flexible lead 45 and the other end of which is connected to ground, completing the circuit to the cathode 3b of the high frequency rectifier tube 3. In order to furnish the required operating potential on the several electrodes of the tubes, I provide the resistance elements 26, 27, 33, 37, 38 and 39 as shown. I also arrange suitable capacities 29, 40, 41, 43, 44, 46 and 47 as shown. The anode potential for the tubes 3 and 4 is supplied from terminals 35 across by-pass condenser 34. The output from the high frequency rectifier tube 3 leads from anode 3d through condenser 42 to output terminals 48 as shown.

In the operation of my volume control system as illustrated in Fig. 1, variations in the amplitude of the incoming signaling energy due to fading conditions are caused to slowly modify the amplitude level of the space discharge in the tube 2. This in turn, reacting upon the condenser 10 produces variations in the potential applied to the grid of the tube 4, thereby controlling the flow of current in the armature winding 17 which is in the output circuit of tube 4. At the extreme of fading conditions the output signaling energy from tube 2 is for the most part transferred to the grid 3c of the detector tube 3. This is accomplished when the armature 16 is in the position shown in the figure and when the capacity area 23 is opposed to the capacity area 25. As the amplitude level of the incoming signal rises, however, more and more current flows through the armature winding 17, thereby causing the capacity area 23 to move toward its position shown in dotted lines, whereat the coupling between the capacity areas 23 and 24 is diminished and the strength of the signal applied to the grid 3c is controlled.

In Fig. 2 I have shown the application of the circuit arrangement of my invention to a screen grid amplifier and high frequency rectifier circuit. In this arrangement high frequency amplifier tube 2' includes a screen grid 2e which is biased from the potential source 35 through regulating resistance 28 having a by-pass circuit to ground through condenser 36. High frequency rectifier tube 3' includes the screen grid element 3e which is biased from potential source 35 through resistance 31 having a path to ground through condenser 32 connected therewith as shown. The high frequency amplifier tube 2' has its grid 2c biased to such value through resistances 27, 37, 38 and 39 that the tube 2' operates on the lower knee of the characteristic plate current curve. When a signal of a value greater than that required to give the desired output is impressed on the system the plate current in the output of tube 4 is increased thereby increasing the energization of actuating winding 17 and decreasing the capacitative coupling between high frequency amplifier tube 2' and high frequency rectifier tube 3' by shifting capacity area 23 out of juxtaposition with capacity area 24 thereby maintaining the output the same as it was originally or as nearly so as desired. The degree of control depends upon the adjustment of the condenser 10 and the bias on grid 4c of control tube 4 through bias resistance 11. The control also depends on the shape, dimensions and characteristics of the coupling device. In order to secure extreme accuracy in operation of control tube 4, a manual adjustment may be provided at the input circuit of control tube 4 for obtaining the most satisfactory results from the system as a whole. The use of the grounded capacity area 25 is for the purpose of making the rate of change of coupling greater and also preventing signal pick-up from any source other than through tube 2'.

While I have shown the grounded capacity area 25 I realize that other modifications may be employed and I do not intend that my invention be limited to the precise arrangement shown.

In Fig. 2 the dotted line position 18b of the indicator 18 shows one extreme condition where maximum coupling between the output of high frequency amplifier tube 2' and the input of high frequency rectifier 3' exists. The dotted line position 18a of the indicator represents a condition where minimum coupling exists between the output of high frequency amplifier tube 2' and the input of high frequency rectifier tube 3'.

Fig. 3 shows a simplified arrangement of volume control circuit where the control tube 4 connects directly in the input circuit to the receiver. The input circuit of the first radio frequency amplifier stage 2 is capacitatively coupled through the relatively movable plates 23 and 24 with the tuned input circuit 50 of the receiver. I have illustrated the receiver connected to antenna 51 and ground 52, the antenna circuit including primary winding 53, electromagnetically coupled with a secondary winding forming part of the tuning circuit 50. A tap is taken from the tuned input circuit 50 to the variable condenser 10 in circuit with the grid 4c. The winding 17 of the electromagnetic device is connected as heretofore described in the output circuit of control tube 4. The fixed plate 24 of the variable capacity system connects to one side of the tuned circuit 50. The fixed plate 25 connects to ground 12 as shown. The flexible lead 45 connects the movable capacity area 23 to the control grid 2c of the high frequency amplifier tube 2 as shown. The desired potentials for the tube electrodes are obtained by means of resistors 26, 27, 55 and 57. Condenser 57 is connected in shunt with resistor 56 as shown. The tuned circuit 5 is connected to the input of the high frequency amplifier tube 2 as shown. The maximum coupling condition is shown in full line position. When the signal strength increases the plate current for control tube 4 increases thereby shifting arm 18 and decreasing the capacity coupling between electrical circuit 50 and tuned circuit 5. Plate potential for tube 2 is obtained through impedance elements 7 and 8 which lead to the source of plate potential. The output terminals 60 lead to the succeeding stage of high frequency amplification or to a high frequency rectifier.

In Fig. 4 I have shown a modified form of circuit embodying my invention in which the electrostatic attraction and repulsion between plates 23—24 is utilized for changing the effective coupling between the output of high frequency amplifier tube 2 and the input of high frequency rectifier tube 3. In this arrangement the arm 18 is pivotally mounted and biased by means of spring 19 and carries movable plate 23 which may be shifted from juxtaposition with respect to fixed plate 24 to a position adjacent fixed plate 25. The circuit from the output of control tube 4 leads through radio frequency choke coil 61 to the indicator or pointer 18 to which movable plate 23 is directly connected. The plate potential for control tube 4 is supplied tnrough resistance 26 and radio frequency choke coil 62 from the source of potential 35. Condenser 72 is disposed in series between one side of the choke coil 62 which connects with arm 18 and movable capacity area 23 and the tuned circuit 36. The required operating potential for cathode 3b is supplied through resistance 63. Under conditions of fading the signal strength varies in the output circuit of high frequency amplifier 2. The bias is arranged on 4c so that the control tube 4 is operating on the upper knee of the characteristic curve and an increasing signal reduces the plate circuit. As the signal strength increases above a predetermined value, the plate current or tube 4 decreases and the charge on movable condenser plate 23 increases in like polarity to the charge on fixed plate 24, resulting in the repulsion of plate 23 which moves to the dotted line position 23a thereby decreasing the capacity between plates 23 and 24 and decreasing the coupling between high frequency rectifier tube 3 and high frequency amplifier 4. When the current strength rises in the plate circuit of tube 4 the charge of plate 23 is smaller, thereby decreasing the repulsion force and enabling the plate 23 to automatically resume the full line position shown, restoring the normal coupling relationship.

In Fig. 5 I have shown a modified form of the circuit of my invention in which an electromagnetic coupling system is employed. In this arrangement I have shown the input circuit of high frequency amplifier tube 2 completed through suitable potential source 64 for supplying predetermined bias potential on the grid 2c of tube 2. The control tube 4 has the grid electrode 4c thereof biased from suitable potential source 65. The output circuit of control tube 4 connects in the manner heretofore described through winding 17 of the magnetic actuator. The indicator arm 18 of the magnetic actuator and the shafts 66 and 67 are mechanically coupled one to another by electrically insulating couplings 21 or 68 as shown. The shaft 66 carries variometer windings 69 which are inductively related to the inductance 75 which connects to the input of the high frequency rectifier tube 3. The shaft 67 carries variometer windings 70 inductively related to the inductance 75. A control circuit including shunt connected impedance 71a connects across the inductance 70 for effecting adjustment of and compensating for changes in inductance in the coupling system. The output circuit of high frequency amplifier 2 is completed through the inductances comprising variometer 69. By varying the spacial relation of the sets of inductances 69 and 70 with respect to inductance 75 the coupling between the output of high frequency amplifier 2 and the input of high frequency rectifier 3 is varied. Condenser 76 is employed to tune inductance 75. As the current in the plate circuit of control tube 4 increases the coupling between inductances 69 and 70 and inductance 75 is decreased, thereby maintaining the output current at terminals 49 substantially constant.

The variable capacitative device which I have heretofore described for controlling the coupling between different portions of the circuit may take many different forms. I have illustrated a number of such forms in Figs. 6 to 11. In Fig. 6 the rotatable armature 16 carries a shaft member to which there is attached a spider 77 carrying separate capacity areas 78, 79 and 80 displaced approximately 120° and adapted to shift angularly within set of stationary capacity areas displaced 60° apart. Each stationary capacity area is displaced 60° from the adjacent stationary capacity area. The adjacent capacity areas belong to different sets. One set of stationary capacity areas is indicated by reference character 81 connected to bus connector 84. The output circuit of one of the coupling systems connects between terminal 85 and ground 12. The succeeding circuit 36 to which energy is to be transferred is connected between ground 12 and the capacity areas 78, 79 and 80. The motive mechanism for driving the sets of movable plates is actuated in the manner heretofore described.

In Fig. 7 I have shown a multiple set of rotor plates 86 mounted upon shaft 22 extending from insulated coupling 21 which plates are adapted to be variably interleaved with oppositely disposed sets of multiply arranged stator plates. One set of stator plates is represented at 87 connected with the circuit from which energy is to be transferred through lead 35. The other set of stator plates is represented at 88 connected to ground 12. By moving shaft 22 so that plates 86 overlap to a maximum extent with plates 87, the transfer of energy to tuned circuit 36 is increased to a maximum. However by moving rotor plates 86 to a position where the overlap is a minimum the transfer of energy is a minimum. The plates 86 are automatically actuated in the manner heretofore described.

In Fig. 8, I have shown a form of variable capacity device wherein the movable capacity area is in the form of a rod member 89 curved about the center of angular movement as shown. The stationary capacity areas are shown at 90 and 91 in the form of tubes concentrically disposed about the movable capacity area 89. The actuation of the movable capacity area is brought about in the manner described in connection with the previous figures.

In order to increase the stability of the variable capacity coupling device I may employ an arrangement as shown in Fig. 9, wherein a movable indicator arm 13 is linked through insulated coupling 21 with the connecting rod 92 which connects with piston 93 in cylinder 94. Cylinder 94 connects through tube 95 with the riser 96 which is concentrically surrounded by the tubular capacity area 97 in spaced relation to riser 96. Movement of indicator arm 13 by reason of the actuation of the electromagnetic mechanism tends to displace the mercury in cylinder 94 to variably fill the riser 96 thereby controlling the effective capacity between the coupling connection 35 leading from the input system and the coupling connection 45 leading to the output system.

In lieu of the rotary electromagnetic actuating mechanism I may employ a solenoid actuator having an actuating coil 98 as shown in Fig. 10, the actuating coil being connected in the output circuit of the control tube in a manner similar to the connection of the winding 17. Armature 99 is operated by solenoid winding 98 to move longitudinally extending shaft 100 to the right or left, thereby displacing the tubular capacity area 101 with respect to the fixed concentric cylinders 102 and 103. The amount of displacement is measured by indicator 104 operative over scale 105. The input system is connected through lead 35 with capacity area 102. The output system is connected through lead 45 with tuned circuit 36. Maximum transfer of energy occurs between leads 35 and 45 when capacity area 101 is shifted concentrically within capacity area 102. Minimum transfer of energy occurs when capacity area 101 is shifted concentrically within cylinder 103.

Fig. 11 shows a further modified form of solenoid actuator in which the solenoid winding 98 operates upon armature 99 through insulated link 21 to displace piston 93 operative upon the top of a pool of mercury within the cylinder 94.

The control system is provided with all required electrical shielding in order to avoid undesired interference with the operation of the circuits. I realize that other forms of variable impedance systems may be used for controlling the coupling between different circuits in accordance with conditions existing in the circuits. I have found the system of my invention as described herein highly practical and while I have described my invention in certain preferred embodiments, I desire that it be understood that modifications may be made and that no limitations upon my invention are intended other than are imposed by the scope of the appended claims.

The invention herein described may be manufactured and used by and for the Government of the United States of America, for governmental purposes, without the payment of any royalties thereon.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. In a signal receiving system, the combination of a signal receiving circuit, an electron tube system, a control tube connected with said signal receiving circuit, variable coupling means interposed between said signal receiving circuit and said electron tube system, and electrostatic means controlled from the output of said control tube for actuating said variable coupling means in accordance with conditions existing in the output of said control tube for variably controlling the transfer of energy from said signal receiving circuit to said electron tube system.

2. In a signal receiving system, a signal receiving circuit, an electron tube system, a control tube operated from said signal receiving circuit, and electrostatic means controlled by the output of said control tube for varying the coupling between said signal receiving circuit and said electron tube system in accordance with conditions in said signal receiving circuit.

3. In an amplifier system, a plurality of electron tubes each having input and output circuits, a control tube connected to the output circuit of one of said electron tubes, a movable actuator operated by said control tube, a resonance indicator controlled by said movable actuator, a movable condenser plate shiftable to different positions by said movable actuator and connected with the input circuit of a succeeding electron tube, a stationary condenser plate connected with the output circuit of the preceding electron tube, an independent stationary condenser plate positioned opposite said first mentioned stationary plate and connected to ground potential, said movable actuator operating to shift said movable condenser plate through positions adjacent or intermediate said stationary condenser plates for controlling the transfer of energy from the preceding electron tube to the succeeding electron tube in accordance with the characteristics of the signaling energy in the circuits of the preceding electron tube.

4. An amplifier system comprising a plurality of electron tubes each having input and output circuits, control means connected with the output circuit at one of said electron tubes, a movable actuator operated by said control means, said movable actuator carrying a resonance indicator and a movable capacity area shiftable to either of two limiting positions, the stationary capacity areas disposed adjacent each of the limiting positions of said movable capacity area, one of said stationary capacity areas being connected to the output circuit of one of said electron tubes and said movable capacity area being connected to the input circuit of the succeeding electron tube, the other of said stationary capacity areas being connected to ground, said mov-

able actuator operating to variably shift said movable capacity area into juxta-position with either of said stationary capacity areas in accordance with the operation of said control means for variably controlling the coupling between said electron tubes.

5. In an amplification system, a plurality of electron tubes each having input and output circuits, a control circuit connected with the output circuit of one electron tube, a pivotally mounted arm carrying a capacity area connected in the output of said control circuit and shiftable to either of two limiting positions, a stationary capacity area disposed adjacent the path of said movable capacity area at the opposite limits of movement of said movable capacity area, one of said stationary capacity areas being connected with the output circuit of one of said electron tubes, the other of said stationary capacity areas being connected to ground and said movable capacity area being connected to the input circuit of the succeeding electron tube, means for applying charges of the same polarity to said first mentioned stationary capacity area and said movable capacity area, the magnitude of said charges being varied in accordance with the operation of said control means in correspondence with the characteristics of signaling currents in the circuits of said preceding electron tube for repulsively controlling the spacial relation between said movable capacity area and said first mentioned stationary capacity area and correspondingly controlling the coupling between said electron tubes.

6. In a volume control system for radio receiving circuits having a plurality of successively coupled stages, means for impressing upon one of said stages incoming signaling energy the amplitude level of which varies according to existing fading conditions, means controlled by amplified output energy derived from the particular stage last described for varying the coupling between said stage and a succeeding stage, said last mentioned means comprising a stationary capacitive element connected with the output circuit of one of the stages, a movable capacitive element connected with the input circuit of the succeeding stage and a stationary grounded capacitive element adjacent the first said stationary capacitive element for maintaining a substantially uniform reactance between said movable capacitive element and the stationary capacitive elements in different positions of said movable capacitive element.

GEORGE P. ADAIR.