

**Nov. 24, 1936.**

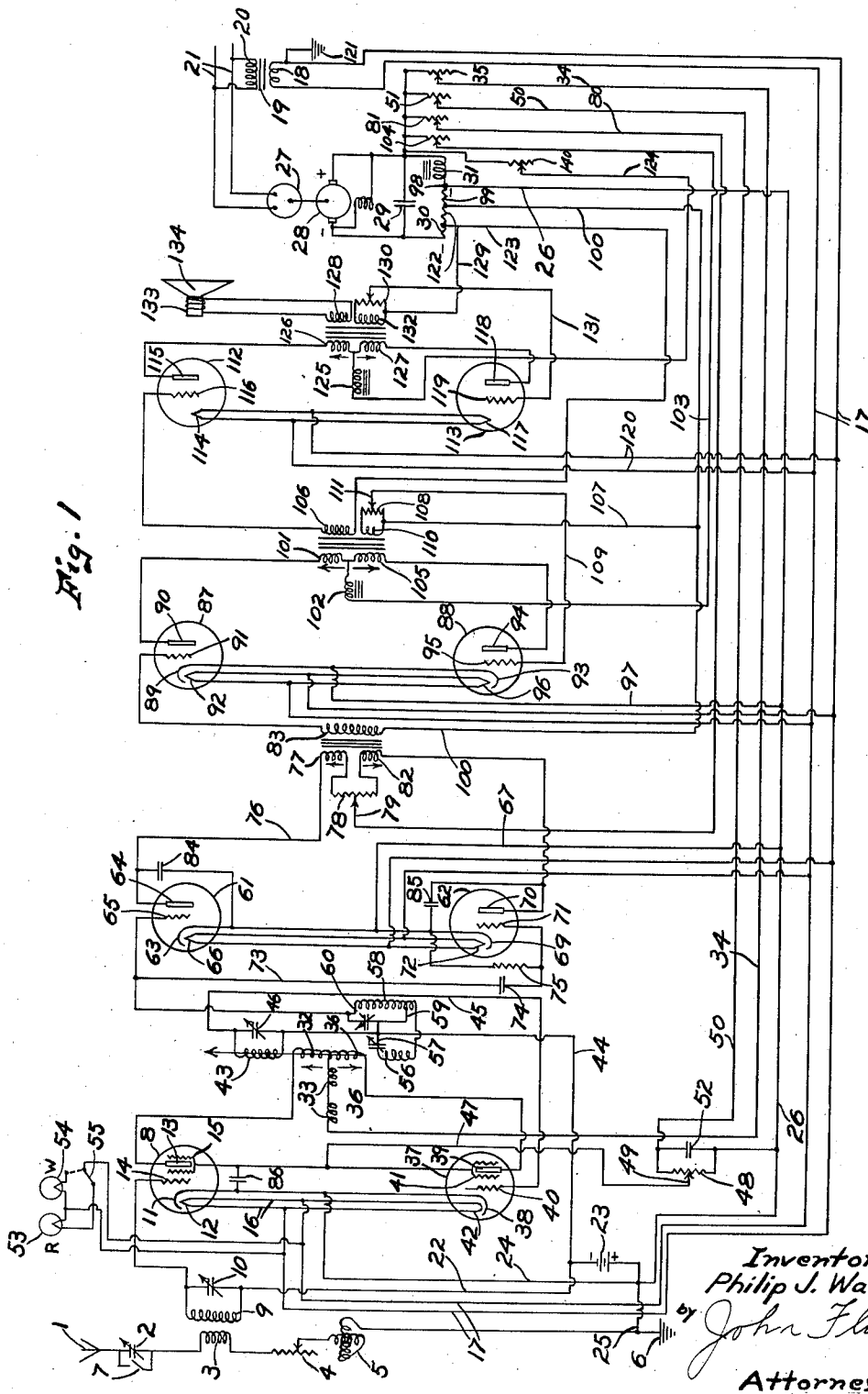
P. J. WALSH

**2,061,602**

# AMPLIFYING SYSTEM

Filed June 2, 1930

2 Sheets-Sheet 1



Nov. 24, 1936.

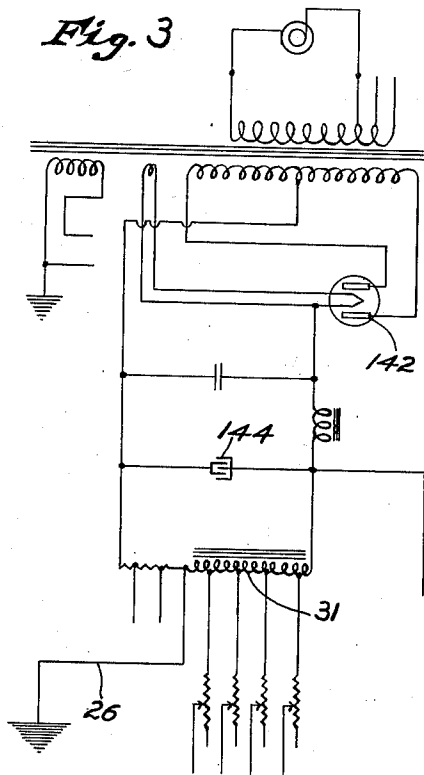
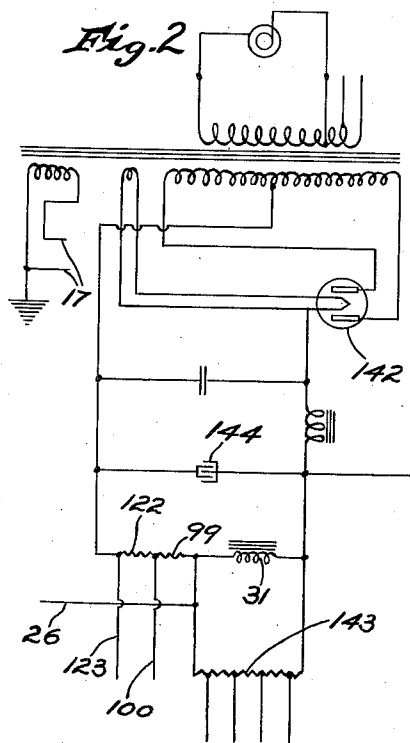
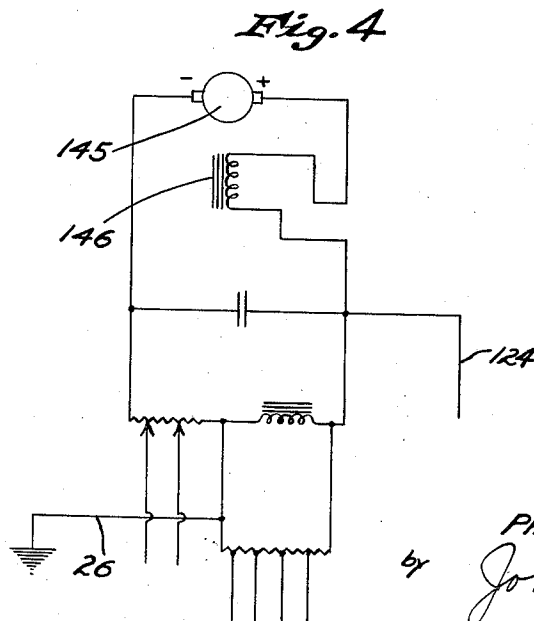
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AMPLIFYING SYSTEM

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2 Sheets-Sheet 2



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## UNITED STATES PATENT OFFICE

2,061,602

## AMPLIFYING SYSTEM

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Application June 2, 1930, Serial No. 458,975

5 Claims. (Cl. 179—171)

This invention relates to a system for treating minute electrical impulses into amplified impulses capable of utilization by a translating device.

More particularly, the invention relates to a system of radio communication, and especially to the amplification and detection of radio signals.

In my prior application, Serial No. 296,140, filed July 30, 1928, Patent No. 1,857,901 and entitled Constant current amplifier system, I describe a scheme for securing generally the same results as I do with the present system; and my present system is a variation of the invention disclosed in said prior application.

In my system, I utilize electronic emission devices for amplification and for detection. Such devices usually include an evacuated vessel in which are enclosed several electrodes. One electrode is an electron emitting electrode, or cathode, such as a heated filament. This electrode may be directly heated by the aid of an electric current, or may be indirectly heated by conduction from a source of heat. The electrons thus emitted are received at a plate or anode also enclosed in the vessel. This anode, in order that it attract the electrons, is kept at a potential positive with respect to the cathode, as by the aid of an external circuit connecting the two electrodes.

The "space current" in the vessel formed between the two electrodes can be very delicately controlled; and it is upon this phenomenon that amplification and detection are based. Thus if a control electrode is interposed to affect the space in the vessel, relatively minute variations in the potential difference between the cathode and control electrode cause correspondingly large variations in the space current. These large variations of course also flow through the output circuit that connects the cathode and anode, and they may be again amplified or utilized in any desired manner.

In the case of radio communication especially, the received signaling impulses are apt to be of a complex nature; first because the impulses are in the form of modulated radio frequency energy; and second because the modulations or impulses are often in the nature of sound waves that are composed of a large number of constituent frequencies. In order to make it possible to utilize the audio frequencies, it is necessary to delete the effect of the radio frequency component, as by the aid of "detectors". These detectors can also be of the electron emitting type, but so arranged, (as is well understood), that the audio frequency im-

pulses are passed through it in readily perceptible form capable of affecting a translating device.

This can be accomplished by so arranging the relay action of the detector tube that it passes impulses much more readily in one direction than in the other, as by impressing a biasing potential on the control electrode or "grid" as it is usually termed. Another method for accomplishing the same result is by the aid of a condenser inserted in the grid-cathode circuit, which condenser is shunted by a very high "grid leak" resistance.

In my prior application I explain how it is possible to utilize two electronic emission devices in such a manner that the sum of their space currents is constant, whereby a change in the space current of one device causes a corresponding but opposite change in the other device. Furthermore, this change is emphasized or rendered greater by causing the impedance of the second device to be altered in accordance with this unbalance.

It is one of the objects of my invention to provide a novel and improved system for securing these results in general.

In receiving signals from any of a large number of broadcasting stations, it is advisable to provide a system for adjusting or controlling the volume, so that the signals received from nearby or powerful stations can be toned down to a pleasing volume, and the signals from distant or weak stations can be brought in with greater amplification as desired and within the limits of the system. In accomplishing this result, I make use of a screen grid, supplementing the other electrodes in the vessel, in conjunction with a device for adjusting the potential of the grid.

It is also another object of my invention to provide a detecting system that is more effective than other types, and particularly by utilizing two detector tubes operating on opposite phases of the signalling impulses.

It is another object of my invention to reduce the cost of construction, due to the fact that no expensive shielding cans need be used, and no neutralization schemes that require careful adjustment.

It is another object of my invention to make it possible to use electron emission tubes in parallel in a radio receiving system which do not have to be matched. This is due to the provision of adjusting devices compensating for tube inequalities.

It is a further object of my invention so to arrange the tubes in pairs that they are not sensitive to interfering stations, electrical noises or

mechanical vibrations, whereby they are quiet in operation. This, I believe, is due to the fact that the paired tubes, operating in the same instant and in the same phase instead of in opposite phases as in prior systems, are similarly affected so that in the output circuits these disturbing effects are cancelled out.

It is another object of my invention to provide an extremely selective receiving system, in spite of elimination of all shields.

It is another object of my invention to provide a stable receiving set that cannot be disturbed by the proximity of the body of the user.

It is another object of my invention so to arrange the tubes used in the system as to make it possible to use a simplified form of power supply, and yet without the existence of any hum.

It is still another object of my invention to improve the tone and quality of reproduction.

It is still another object of my invention so to arrange the detector stage that this cannot be overloaded, and is not critical, as in prior systems.

My invention possesses many other advantages, and has other objects which may be made more easily apparent from a consideration of one embodiment of my invention. For this purpose I have shown a form in the drawings accompanying and forming part of the present specification. I shall now proceed to describe this form in detail, which illustrates the general principles of my invention; but it is to be understood that this detailed description is not to be taken in a limiting sense, since the scope of my invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is a schematic diagram of one form of my invention; and

Figs. 2, 3, and 4 are diagrams of modified forms of the power unit used in connection with my system.

In the present instance, I show my invention as embodied in a radio receiving system, having a pick-up circuit, such as an antenna 1, a condenser 2, a coupling coil 3, an adjustable resistance 4, a variable tuning inductance 5, and a ground connection 6. The condenser 2 can be short-circuited and is used for adjusting the period of the antenna 1. The short-circuiting switch is indicated at 7. Condenser 2 can be of the order of .0001 microfarad maximum capacity.

For broadcast range reception, coupling coil 3 can be of the order of ten turns, and resistance 4 can be of the order of 5000 ohms. This resistance I find does not appreciably broaden the tuning, but rather it increases the selectivity by reducing the pick-up of the antenna circuit.

Coil 3 is rather closely coupled to the input circuit of a tube 8, as by being placed close to a coil 9 of about seventy or eighty turns. This coil forms one element of a tunable circuit, which includes a variable condenser 10 of about .0005 microfarad capacity. This condenser can be used for tuning circuit 9-10.

Electronic emission device 8 is shown in this instance as having a cathode 11 that is adapted to be heated to an electron emitting temperature, as by an element 12. It also has the anode 13 as well as a control electrode or grid 14. A screen grid 15 for stabilizing the operation of the tube 8 in a well-understood manner, can also be used. The input circuit of tube 8 connects to the cathode 11 and electrode 14 so as to affect the flow of electrons between cathode 11 and

anode 13, which is kept at a potential positive with respect to the cathode. Before tracing the input circuit in detail, I shall describe how element 12 is energized to heat cathode 11.

Element 12 is shown as connected by conductors 16, 17 to the secondary 18 of a transformer 19. The primary coil 20 of this transformer can be fed from a source of electrical energy, as through leads 21.

The input circuit of tube 8 includes control electrode 14, circuit 9-10, connection 22, grid bias battery 23, and connection 24 to cathode 11. A connection 25 can be employed to ground cathode 11, as is customary in radio systems, and a lead 26 can, in fact, be used to provide a common ground return for all of the other cathodes used in the system.

Before tracing the output circuit for tube 8, I shall explain how the plate or anode potentials are secured. In the present instance I show a motor-generator set for securing these potentials. Thus a small motor 27 can be arranged to drive a small direct current generator 28, and which is wound to deliver a comparatively high potential, such as 250 volts, across its brushes. A large condenser 29 can be connected across the brushes to absorb most of the pulsations, and can be of the order of 4 microfarads. The load on the generator 28 is formed by a resistance 30 and a coil 31, the purpose of which will be explained hereinafter.

As in my prior application, the space current in tube 8 is caused to vary in an opposite sense from that in another tube which is paired with it, by providing for a constant current to be passed through both tubes in parallel. The output circuit of tube 8 can now be traced, and the full explanation of the constant current effect will be completed when the circuits for the other tube of the pair will be explained.

Beginning with anode 13, the output circuit of tube 8 includes the upper half of a coil 32-36, an inductance 33, lead 34, an adjustable resistance 35, positive side of generator 28, negative side of this generator, common lead 26, and connection 24 to cathode 11. The lower half 36 of coil 32-36 forms, with the section 32, a complete coil of about 34 turns wound to about three inches in diameter. Inductance 33 is of high value, and can be formed of a pair of chokes, each of 250 millihenrys. This inductance maintains the current constant in lead 34, which connects to another output circuit as will now be described, and which together with that just traced, will receive a combined current flow that is constant.

Thus, as explained in my prior application, I utilize another electron emission device 37 having a cathode 38, an anode 39, a control electrode 43, a screen grid 41, and a heater 42 for the cathode 38. The output circuit of this tube 37 can be traced as follows: anode 39, lower half 36 of coil 32-36, said lower half bucking the upper half 32, inductance 33, lead 34, resistance 35, generator 28, lead 26, and lead 24 back to cathode 38. Due to the constancy of the current in lead 34, a variation in space current in tube 8 causes an equal and opposite variation in space current in tube 37. To enhance this effect, the impedance of tube 37 can be made to vary oppositely to that of tube 8, as by the aid of an input circuit the activity of which is directly dependent upon the degree of unbalance between the two space currents.

Thus the input circuit for tube 37 is coupled to coil 32-36, so as to be affected by the unbal-

ance in the two sections 32 and 36. While no signals are being received, the coil sections 32 and 36 neutralize each other. As soon as signals are received, the impedance of tube 8 is varied and causes unbalance in the distribution of the total current passing through the inductance 33.

In order to utilize this unbalance for creating an increased unbalance, there is shown a coil 43 variably coupled to coil 32—36. This coil 43 is included in the input circuit of the tube 37. This circuit can be traced as follows: cathode 33, connection 24, battery 23, connection 44, coil 43, connection 45, to control electrode 40.

Thus, as the impedance of tube 8 decreases so that greater current flow exists in section 32 than in section 36, the input circuit just traced is so affected by this unbalance as to cause an increase in the impedance of tube 37. This enhances or emphasizes the unbalance already existing between the two paths through the tubes 8 and 37. I find that coil 43, when using the system for broadcast reception, can be about 50 turns wound on about a three inch diameter tube, said tube being arranged to be directly in alignment with the axis of coil 32—36, or out of alignment therewith. The degree of coupling forms a controlling means whereby the degree of amplification secured by this first stage is adjustable. In order to provide maximum amplification, coil 43 may be tuned by a variable condenser 46 that bridges this coil 43.

In order to stabilize this first stage of radio frequency amplification, it is sometimes desirable to provide such screens as indicated at 15 and 41, which are maintained at a potential intermediate between that of the cathode and the anode. In the present instance both grids 15 and 41 are connected together.

A lead 47 impresses a positive potential upon these grids, as by the aid of a potentiometer resistance 48 that is provided with an adjustable tap 49. This resistance 48 has one of its terminals connected to the common return 26, and its opposite terminal to a lead or connection 50, that connects to an adjustable resistance 51 and thence to the positive side of the generator 28. It is apparent that by moving the tap 49 upwardly on resistance 48, the positive potential impressed upon the grids 15, 41 is increased, and a reverse effect takes place when the tap 49 is moved downwardly. The maximum screen grid voltage can be of the order of 75 volts. Resistance 48 can be shunted by a condenser 52 of about one microfarad.

I have found it convenient to control the volume of the system by adjusting the tap 49, and especially for the nearby stations. The volume can also be controlled, especially for distant or weak stations, by adjusting coil 43 with respect to coils 32 and 36. Preferably, the arrangement is such that only one of these two forms of volume control can be utilized at a time. An indicator scheme shows which one of these two means is being used. Thus, in the present instance I show a red pilot light 53 and a white pilot light 54, which are alternately energized from leads 17 and in accordance with the position of a switch 55. During the period that the volume is controlled by the tap 49, the lever 55 is in the dotted line position, whereby the pilot 54 is energized. When the limit of volume control is reached by moving the tap 49 up as far as it will go, then the mechanism is such that coil 43 can be shifted from its minimum coupled position toward its maximum coupled position with respect to coil

32—36. When this movement of coil 43 is rendered possible, the switch 55 is thrown to the full line position, in which the red pilot light 53 is energized.

I find that for usual broadcast reception only a single stage of radio frequency amplification as just described is sufficient, since the building up coil 43 can greatly increase the effectiveness of the amplification. However, additional stages can, if desired, be included but they are omitted herein for the sake of simplicity.

The amplified impulses are transferred by the aid of the unbalanced currents in coil sections 32 and 36 to another coil 55 which is coupled to coil 32—36. This coil forms a part of a complete link circuit which couples the amplifier stage to a detector stage. Coil 56 can be of about 45 turns, wound on a tube about 3 inches in diameter, and in fact can be wound on an extension of the same tube upon which coil 32—36 is wound. The link circuit further includes in this instance, a tuning element such as variable condenser 57 that may have a maximum capacity of .0005 microfarads. The link circuit is in series with a large coil 58 of about 110 turns wound on a tube of about two inches diameter. Only a portion of this coil is included in the link, as determined by the tap 59. The number of turns included in the link circuit is of the order of 22 turns. The remaining portion of the coil 58 can be tuned by a variable condenser 60 having about the same maximum capacity as condenser 57. It is across this condenser 60 that the detector tubes 61 and 62 are coupled in a manner now to be described.

Tube 61 includes a heated cathode 63, an anode 64, a controlling electrode or grid 65, and a heater element 66. The heater element is connected to leads 17 for its supply of heating current. The input circuit of tube 61 can be traced as follows: cathode 63, connection 67, common negative lead 26, battery 23, lead 44, coil 58, and control electrode or grid 65. Due to the provision of the grid bias battery 23, the detector action is secured by causing tube 61 to operate below the straight portion of the tube characteristic.

The other detector tube 62 operates in conjunction with tube 61 and in such a way as to be oppositely affected by the potential differences existing across the condenser 60, which serves as a tuning condenser for the input circuits of both tubes 61 and 62. Tube 62 is provided with electrodes, such as cathode 69, anode 70, control electrode 71 and a heater element 72. The heater element 72 is supplied with heating current in parallel with heating element 66 of tube 61. The input circuit of tube 62 can be traced as follows: cathode 69, lead 67, common negative lead 26, battery 23, connection 44, condenser 60, lead 73, grid condenser 74, to grid or control electrode 71. This circuit is bridged by the grid leak resistance 75 of about one megohm. The grid condenser 74 is of the order of .00025 microfarad. When the grid 65 of tube 61 swings positive, the grid 71 of tube 62 swings negative, due to the interposition of the grid condenser 74 in the input circuit of tube 62. Thus a seesaw effect is secured while yet maintaining full potential difference simultaneously across both input circuits. Thus the effectiveness of the arrangement is increased.

The output circuits of tubes 61 and 62 are also in parallel, and are so arranged that the sum of the space currents is maintained substantially constant, just as in the amplifier stage. Thus the output circuit of tube 61 can be traced as follows: anode 64, connections 76, coil 77, upper

portion of resistance 78, tap 79, connection 80, resistance 81, of about 150,000 ohms, generator 28, lead 26, connection 67 to cathode 63. Resistance 81 keeps the current to both detectors substantially constant. The output circuit of tube 62 is in parallel with the circuit just traced, and may be traced as follows: anode 78, coil 82, lower portion of resistance 78, tap 79, lead 99, resistance 81, generator 28, connection 28, and connection 67 to cathode 69. The two coils 77 and 82 are in opposition, so that when the current flow therein is balanced from tap 79, the coil 83 has no induced electromotive force, said coil being coupled to both coils 77 and 82. Tap 79 can be adjusted to equalize the magnetic effects in coils 77 and 82 when no signals are being received.

Resistance 78 can be of the order of 25,000 ohms and coils 77 and 82 taken as one complete coil on the large iron core have an inductance of two hundred henrys (200), and about 7,600 turns. Coil 83 has about 26,000 turns.

In order to by-pass any residual or radio frequency in the space currents in the detectors, the condensers 84 and 85 can be used to bridge the coils 77 and 82. These can be of the order of .00025 microfarad. In general, it may be stated that such by-pass condensers can be utilized in other parts of the system, as, for example, in connection with tubes 8 and 37. A condenser 86, of about one microfarad capacity can be connected between the cathodes and screen grids of these two tubes.

When a signal transmitted to the detector 61 causes a variation in current flow in coil 77, a corresponding but opposite variation in current flow is present in coil 82, causing unbalance, and a corresponding induction of an electromotive force in coil 83.

Coil 83 affects the input circuit of an audio frequency amplifier stage, this stage including the vacuum tubes 87 and 88. Vacuum tube 87 has a cathode 98, an anode 93, a control or grid electrode 91, and a heater 92. Vacuum tube 88 has a cathode 93, an anode 94, a control or grid electrode 95, and a heater 96. The heaters 92 and 96 are fed with heating current from leads 17. The input circuit of the amplifier tube 87 can be traced as follows: cathode 98, connection 97, connection 26, negative point 93, negative bias resistance 99, connection 100, coil 83, and electrode 91. The resistance 99, being included in series with coil 31 across the generator 28, provides a negative bias of proper value to control electrode 91. The output circuit of tube 87 can be traced as follows: anode 93, coil 101, inductance 102, lead 103, adjustable resistance 104, generator 28, to the common negative lead 26.

The output circuit of tube 88 is in parallel with the output circuit of tube 87, and can be traced through coil 102, where the currents join, in the following manner: anode 94, coil 105, coupled to coil 101, coil 102, lead 103, resistance 104, generator 28, back to the negative lead 26.

As before, inductance 102 which is in the common position of the paths, serves to maintain the sum of the currents flowing in the two paths substantially constant, so that coils 101 and 105 are neutralized when no signal is received. However, as soon as signals are received a variation in impedance of tube 87 produces an unbalance in the two circuits and consequently an electromotive force is induced in coil 106, coupled to coils 101 and 105. This unbalance is further utilized to emphasize the unbalance still more by

oppositely affecting the impedance of tube 88, as by controlling its input circuit. Thus the input circuit of tube 88 can be traced as follows: cathode 93, connection 97, lead 26, grid bias resistance 99, lead 100, lead 107, portion of potentiometer resistance 108, and lead 109 to control electrode 95. The potentiometer resistance 108 bridges the secondary coil 110 coupled to coils 101 and 105 so as to respond to the unbalance therein. The degree of building up is thus controlled by the position of tap 111 on the resistance 108. Coils 101 and 105 are of the same order of magnitude as coils 77, 82; and coil 106 has about 16,000 turns. Coil 110 can have about 900 turns.

Coil 106 affects a power amplifier stage including the power tubes 112 and 113. Power tube 112 has the heated filament or cathode 114, the anode 115, and a control electrode or grid 116. The power tube 113 has a heated filament or cathode 117, anode 118, and control or grid electrode 119. The filaments 114 and 117 can be heated directly by current supplied from leads 120 connected to leads 17. Since power tubes usually require a large grid bias, the input circuit of tube 112 includes such a bias and this circuit will now be traced as follows: cathode 114, connections 120, connections 17, ground connection 121, ground connection 6, connections 25 and 26, resistances 99 and 122, lead 123, coil 106, and control electrode 116. Resistances 99 and 122 provide the proper grid bias.

The output circuit of both tubes 112 and 113 are supplied in parallel as follows: from the positive terminal of generator 28, resistance 140, lead 124, heavy inductance 125, whence the current divides through the tubes 112 and 113. One divided circuit includes the plate or anode coil 126, anode 115, cathode 114, leads 120, leads 17, ground 121, ground 6, and connections 25 and 26 to the negative point 93. The other space current circuit leading from coil 125 includes the plate or anode coil 127, anode 118, cathode 117, connections 120, connections 17, ground connections 121 and 6, and connections 25 and 26 to negative point 93. As before, the current is maintained substantially constant by the large choke coil 125, and upon transmission of an audio frequency signal to the input circuit of tube 112, there is an unbalance between the two coils 126—127 (which together have about 4400 turns and an inductance of about 70 henrys) causing the induction of an electromotive force in secondary coil 128 coupled to coils 126 and 127. This degree of unbalance is again emphasized by reversely affecting the impedance of tube 113 by the aid of its input circuit. This input circuit can be traced as follows: cathode 117, leads 120, leads 17, ground 121, ground 6, connections 25 and 26, resistances 99 and 122, lead 129, a variable tap on potentiometer resistance 130, and lead 131 to the control electrode 119. The potentiometer resistance 130 is connected across another secondary coil 132 of about 1200 turns, coupled to coils 126 and 127, so as to be affected by the degree of unbalance of the currents between these two coils. The potentiometer resistance 130, as well as the resistance 108 can be of the order of one-half megohm.

The secondary coil 128, which can be of about 88 turns, can be connected to a translating device to supply it with the amplified audio frequency impulses; for example, the moving coil 133 of the electrodynamic speaker 134. This electrodynamic speaker has a field coil, and for this

purpose the coil 31 heretofore mentioned can be used.

The operation of the system is apparent from the foregoing. Of course, a wide latitude may be permitted from the values heretofore given for the circuit constants, depending upon the character of the signals to be received and amplified. All the amplifier and detector stages work substantially on the constant current principle set forth in my prior application heretofore mentioned, and in the patents referred to in said application. Tuning or selection of the stations can be accomplished by ganging all of the tunable elements, such as the variable condensers 10, 46, 57, and 60, and variometer 5; and the volume control is effected by varying the potential of the screen grids 15 and 41, or the position of the build-up coil 43. I have noticed in the operation of this system that best results are obtained when the tunable circuit 60—58 in the input of the detector tubes 61 and 62 is tuned slightly off the resonance point of the other tunable circuits. I merely note this fact and do not desire to be bound by any explanations of theory involving such use of the circuits. Experience shows that this departure from coincidence with the other circuits is advantageous.

In operation, the system performs with little or no background noises, which I attribute to the utilization of the constant currents in the various stages. Coil 43 can be so loosely coupled to coil 32—36 as to prevent instability even when the system is operating at a high degree of amplification.

In Fig. 2, I use a tube rectifier 142 in place of a motor generator set 27—28. Furthermore, the resistance 143 is bridged across field coil 31 for providing the taps for the various leads to the output circuits. A very large condenser 144 can be used to by-pass disturbances. This can be an electrolytic condenser of as much as 50 or more microfarads.

Fig. 3 is quite similar to Fig. 2, except that the taps for the various leads for the output circuits are made directly to the field coil 31, just as in Fig. 1.

In Fig. 4, I use a series wound generator 145 for the supply source; the series coil 146 in this case helping to reduce fluctuations.

I claim:

1. In a system of the character described, means defining a pair of electrical paths, means affecting the impedance of one of said paths, means for supplying a current to each of said paths so that the sum of these currents remains substantially constant, and means for adjustably affecting the impedance of the other of said paths in a sense opposite to that of the first mentioned path, comprising means responding to the difference in current flow in the two paths, and a tapped resistance connected across said responding means.

2. In a system of the character described, means defining a pair of electrical paths, means affecting the impedance of one of said paths, means for supplying a current to each of said paths so that the sum of these currents remains substantially constant, and means for adjustably affecting the impedance of the other of said paths in a sense opposite to that of the first mentioned path, comprising a transformer having a primary coil responsive to the unbalance in the currents, as well as a secondary coil, and a potentiometer resistance bridging said secondary coil.

3. In a system of the character described, means defining a pair of electrical paths, each of said paths including an electronic emission device, means for supplying a current to each of said paths so that the sum of these currents remains substantially constant, means affecting the impedance of one of said electronic emission devices, and means for adjustably affecting the impedance of the other electronic emission device in a sense opposite to that of the first mentioned device, comprising means responding to the difference in current flow in the two paths, and a tapped resistance connected across said responding means.

4. In a system of the character described, means defining a pair of electrical paths, each of said paths including an electronic emission device, means for supplying a current to each of said paths so that the sum of these currents remains substantially constant, means affecting the impedance of one of said electronic emission devices, and means for adjustably affecting the impedance of the other electronic emission device in a sense opposite to that of the first mentioned device, comprising a transformer having a primary coil responsive to the unbalance in the currents, as well as a secondary coil, and a potentiometer resistance bridging said secondary coil and affecting the input of the said other electronic emission device.

5. In a system of the character described, a pair of electronic devices, each having a cathode, an anode and a control electrode, means for supplying the space current to both devices in parallel, in such a way as to maintain the sum of these space currents substantially constant, a pair of opposed coil sections, one in each of the space current paths, and a link circuit coupled to the sections for transmitting amplified impulses, said link circuit including a coil coupling it to the coil sections, a variable condenser, a coil of greater turns than said coupling coil, a small portion thereof being in series with the coupling coil and the condenser, and a condenser bridging the other portion thereof.

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