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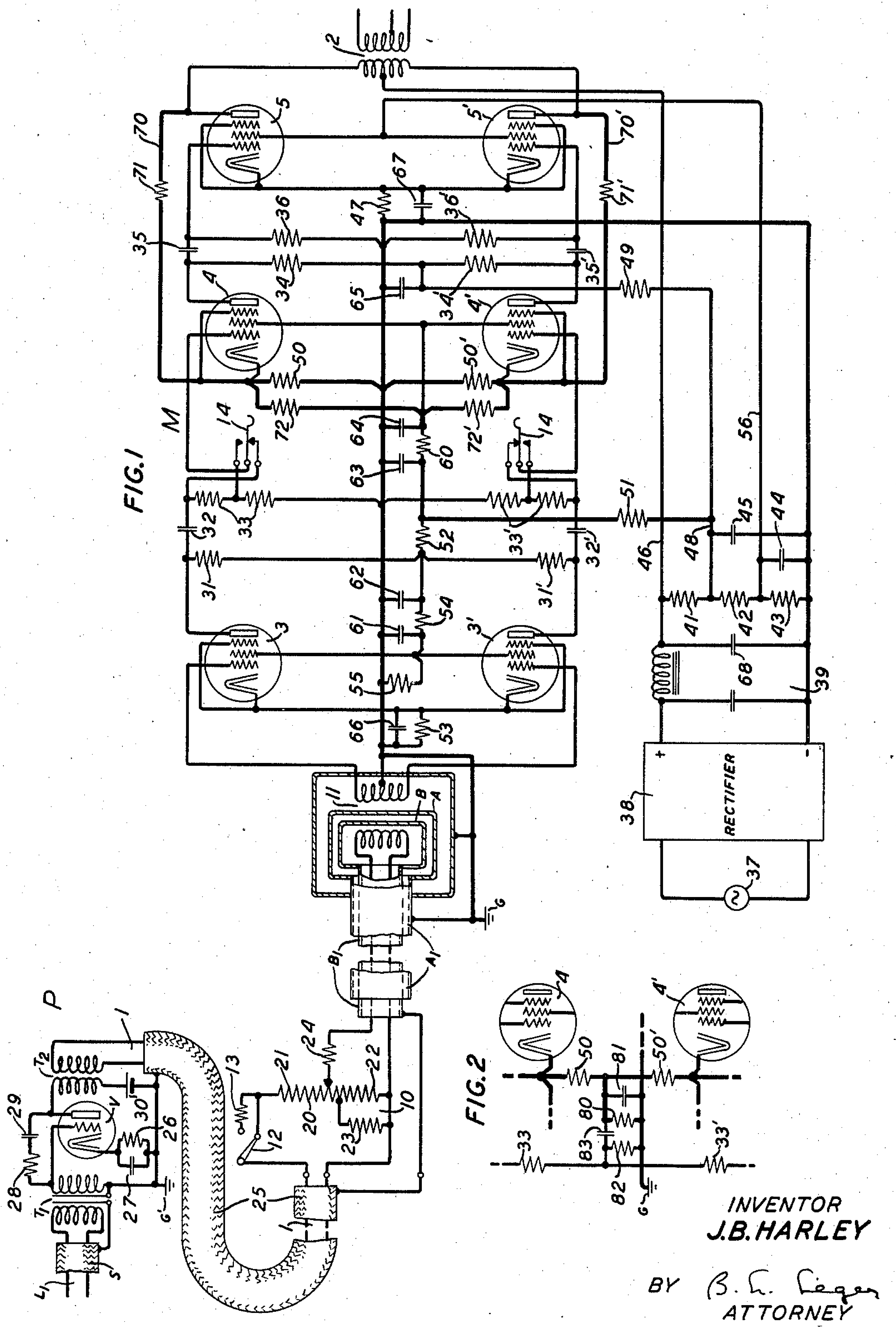

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ELECTRIC WAVE AMPLIFIER

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This invention relates to wave amplifying systems, as for example vacuum tube amplifiers.

Objects of the invention are to control transmission properties of the systems, as for example distortion introduced by the systems, to facilitate application of feedback in the systems, and to facilitate application of proper biasing potentials to grids of vacuum tubes in the systems.

In one specific aspect the invention is a negative feedback amplifier in which a negative grid biasing potential for a tube is obtained from two direct currents sent from the space current source in the same direction through a resistance in the grid-cathode circuit of the tube, one through the feedback path and the other through a connection from the space current source to a point between the resistance and the tube cathode. The tube may be the first tube of a two-stage, impedance-coupled amplifier, the resistance may be connected between the cathodes, and the feedback path may connect the second plate and the first cathode. Since the feedback path is utilized to transmit direct current for producing grid bias, no stopping condenser is required in that path. Omission of such condenser may be desirable not only for economy but for control of phase shift around the feedback loop, for instance to reduce singing tendency, especially at very low frequencies.

A feature of the invention is a push-pull vacuum tube circuit having a space current source and on each side of the push-pull circuit an amplifier comprising two impedance-coupled tubes with an alternating current and direct current connection from the plate of the last to the cathode of the first, for producing negative feedback that reduces modulation and noise in the amplifier and for transmitting direct current from the space current source through a resistance in the grid-cathode circuit of the first tube in the direction to produce negative biasing potential on the grid.

Other objects and features of the invention will be apparent from the following description and claims.

Fig. 1 of the drawing is a schematic diagram of an amplifier circuit embodying the specific form of the invention referred to above; and

Fig. 2 indicates a modification of the circuit of Fig. 1.

The amplifier circuit of Fig. 1 is shown as comprising a preliminary amplifier P and a main amplifier M. The preliminary amplifier comprises a vacuum tube V, shown by way of example as a heater type triode, amplifying waves received from line or circuit L_1 through input transformer T_1 and delivering them through output transformer T_2 and connection or circuit 1 to the main amplifier. The waves may be, for example, audio frequency signals such as speech or music.

The main amplifier is shown as a three-stage, balanced or push-pull amplifier for amplifying the waves received from incoming circuit 1 and transmitting them to an outgoing circuit connected to output transformer 2. The outgoing circuit may be, for instance, a 500-ohm circuit connected across the secondary winding of transformer 2, or an 8-ohm circuit connected across a portion of the winding. The first stage of the main amplifier comprises two similar vacuum tubes 3 and 3'. The second stage comprises vacuum tubes 4 and 4', which are also alike. The third stage comprises vacuum tubes 5 and 5', which are also alike. All of these tubes are shown as heater type pentodes, the circuits for the heaters being omitted from the drawing since they may be of any usual or suitable type.

The incoming circuit 1 is connected to the tubes 3 and 3' through potentiometer 10 and input transformer 11. With switch 12 closed on its lower contact as shown, circuit 1 is connected to potentiometer 10 directly. With the switch 12 closed on its upper contact the connection is through a resistor 13, whose resistance may be 10,000 ohms, for example. The direct connection may be used when the impedance of the incoming circuit 1 has approximately the value, for example 30 ohms, from which the main amplifier (with the direct connection) is designed to work for maximum gain and the best possible frequency characteristic. The connection through resistance 13 adapts the main amplifier for operation as a bridging amplifier across any impedance of a wide range, as for example the range between 1 ohm and 20,000 ohms.

The maximum gain of the main amplifier when operated between a sending impedance of 30 ohms and a receiving impedance of 8 ohms or 500 ohms may be 100 decibels, for example. Between the first two stages of the amplifier a switch 14 is shown by which the gain can be reduced 15 decibels, for instance, and the potentiometer 10 may give 40 decibels gain variation, for example.

The resistance element 20 of potentiometer 10 may be designed so that, without resistor 23, resistor 20 would provide a uniform resistance change with respect to the rotation of the contactor. A uniform resistance change is the condition most easily obtained in the manufacture of wire wound and carbon composition potentiometers. A potentiometer with a uniform resistance change would often be undesirable due to the progressive crowding of the useful part of the control toward one end of the rotation of the contactor. The ideal potentiometer for use in an amplifier of this type, which would eliminate this crowding, would introduce a loss in decibels directly proportional to the rotation of the contactor. By providing a fixed tap at a suitable point along the uniform potentiometer resistance 20 (say two-thirds of the distance from the off-position of the contactor) and a fixed resistance 23 connected between this tap and the end of the potentiometer as shown in Fig. 1, the loss introduced by a rotation of the contactor is spread more evenly over the entire rotation and may be designed to approach very closely the ideal condition in which the loss in decibels is directly proportional to the rotation.

The potentiometer comprises a resistance 20 divided into two sections 21 and 22 by a fixed tap connection, a resistor 23 shunting the resistor 22, and a resistor 24 in series in the variable tap conductor. Resistances 21, 22, 23, and 24 may have, for example, values of 40 ohms, 60 ohms, 6 ohms and 15 ohms, respectively. Resistance 24 maintains the input terminating impedance of the primary winding of transformer 11 above a definite value which closely approaches the value of resistance 24 for certain settings of the potentiometer control. This maintains the input terminating impedance of transformer 11 between definite limits, for preventing frequency discrimination.

The input transformer 11 has two electrostatic shields A and B between its secondary winding and its primary winding, shield A being connected to the amplifier ground G and shield B being connected to the conducting sheath 25 of the incoming circuit as in the case of the system shown in Crisson Patent 1,786,412, December 23, 1930. The sheath 25 may be grounded at the amplifier ground G′ of the preliminary amplifier P, which may be, for example, on the chassis of the preliminary amplifier. This ground G′ may be at a potential materially different from that of ground G of the main amplifier. The ground G may be, for example, on the chassis of that amplifier, and the double shielding serves to reduce noise as explained in the Crisson patent.

As shown in Fig. 1 the leads from potentiometer 10 to the primary of transformer 11 are protected by a shield B_1 connected to the inner box shield B. These shielded leads are further protected for the greater part of their length by a second shield A_1 connected to the chassis ground G. This outer shield isolates the wiring of the amplifier from unwanted potentials which may exist on the inner shield.

As indicated by the two shields shown in transformer T_1 this transformer may be doubly shielded as in the case of transformer 11, the shield for the secondary winding of transformer T_1 being shown grounded at G′, and the shield for the primary winding being shown connected to the conducting sheath S of circuit L_1. This sheath S may be grounded at the ground connection of the condenser transmitter (not shown) or other source that supplies signal waves to circuit L_1. This latter ground may be at a potential materially different from that of ground G′, and the double shielding of transformer T_1 serves to reduce noise as in the case of the double shielding of transformer 11. If the preliminary amplifier be omitted, the sheath 25 of circuit 1 may be grounded at the condenser transmitter (not shown) or other source used to supply signal waves to circuit 1.

The ground G′ of the preliminary amplifier is shown at the junction of the negative terminal of space current supply source 30 and the negative end of grid bias resistor 26. This resistor is connected in the cathode lead of tube V, so the space current of the tube flowing through the resistor supplies grid biasing potential for the tube. Condenser 27 serves to by-pass, around resistor 26, signal waves in the upper portion of the signal frequency range, but preferably has sufficient reactance in the lower portion of the signal frequency range to cause resistor 26 to produce enough negative feedback to prevent the gain of the preliminary amplifier from increasing unduly with frequency decrease in that range. A tendency toward such gain increase may result from the fact that the preliminary amplifier has a feedback path comprising resistor 28 and stopping condenser 29 for producing negative feedback in the preliminary amplifier. This negative feedback is advantageous for reducing distortion and stabilizing gain as pointed out in the paper by H. S. Black on Stabilized feedback amplifiers, Electrical Engineering, January 1934, pages 114–120. However, at frequencies in the lower portion of the signal frequency range, the reactance of the stopping condenser 29 may be sufficient to reduce this negative feedback to such an extent as to tend to cause the gain of the preliminary amplifier to rise unduly with frequency decrease. This tendency is overcome by the supplementary negative feedback obtained at low frequencies by giving the condenser 27 sufficient reactance at those frequencies.

The tubes 3 and 3′ are coupled to the tubes 4 and 4′ by an interstage coupling circuit comprising coupling resistors 31 and 31′, stopping condensers 32 and 32′ and grid leak resistors 33 and 33′.

The tubes 4 and 4′ are coupled to the tubes 5 and 5′ by an interstage coupling circuit comprising coupling resistors 34 and 34′, stopping condensers 35 and 35′ and grid leak resistors 36 and 36′.

Plate voltage for the tubes is supplied from source 37 and rectifier 38 through filter 39 and a voltage divider comprising resistors 41, 42 and 43, which may respectively have resistances of 2,000 ohms, 10,000 ohms, and 45,000 ohms, for example. Resistor 43 is by-passed by a condenser 44; and resistors 42 and 43 are by-passed by a condenser 45.

Plate current for tubes 5 and 5′ passes through conductor 46, primary windings of transformer 2, tubes 5 and 5′ and resistor 47, to ground G.

Plate current for tubes 4 and 4′ passes through conductor 48, resistance 49, resistors 34 and 34′, tubes 4 and 4′ and resistors 50 and 50′, to ground G.

Plate current for tubes 3 and 3′ passes through conductor 48, resistor 51, resistor 52, resistors 31 and 31′, tubes 3 and 3′ and resistor 53, to ground G. A path, comprising resistors 54 and 55 in serial relation, is connected between the junction of resistors 31 and 31′ and ground G, and shunts the circuits including resistors 31 and 31′, tubes 3 and 3′ and resistance 53.

Circuits for supplying screen voltage for tubes 5 and 5′ extend from the voltage divider through conductor 56, tubes 5 and 5′ and resistor 47, to ground G. The tubes 5 and 5′ may be, for example, beam power tubes or power pentodes of any usual type. When the voltage impressed on the control grids of such tubes exceeds the overload level of the tubes, their plate current (and their screen current, also) normally tends to increase. However, in the system shown, the value of resistance **42** is so chosen that, should the signal voltage impressed on the control grids of tubes **5** and **5'** exceed the overload level of these tubes, the resulting additional screen current flowing through resistance **42** will so reduce the screen voltage that the plate current will not increase. Preventing the plate current of the power tubes from increasing beyond the normal value under load, prevents an unnecessary strain on the rectifier system **38** which should be as small as practicable for portable application. It is desirable that the value of resistance **42** be as small as is consistent with the above requirement in order that the output power of the tubes will not be materially reduced while holding the screen voltage within the limits recommended by the tube manufacturer.

Circuits for supplying screen voltage for tubes **4** and **4'** extend from the voltage divider through conductor **48**, resistor **51**, resistor **60**, tubes **4** and **4'** and resistors **50** and **50'**, to ground G.

Circuits for supplying screen voltage for tubes **3** and **3'** extend from the voltage divider through conductor **48**, resistor **51**, resistor **52**, resistor **54**, tubes **3** and **3'** and resistor **53**, to ground G.

Condensers **61**, **62**, **63**, **64**, **65**, **66** and **67** are by-pass condensers.

Alternating plate current of tubes **3** and **3'** passes from the cathodes of those tubes through condensers **66** and **62** in series, to resistances **31** and **31'**.

Resistor **53** supplies grid biasing potential to tubes **3** and **3'**.

Alternating plate current of tubes **5** and **5'** passes from the cathodes of those tubes through condenser **67**, and thence through by-pass condenser **68** of filter **39**, to transformer **2**.

Resistor **47** supplies grid biasing potential to tubes **5** and **5'**.

Alternating plate current of tubes **4** and **4'** passes from the cathodes of these tubes through resistances **50** and **50'** and condenser **65**, to resistances **34** and **34'**. Resistances **50** and **50'** thus produce local negative feedback in these tubes.

However, the principal feedback in the amplifier is negative feedback around the last two stages, produced by feedback connections **70** and **70'**, respectively, from the plates of tubes **5** and **5'**, respectively, to the cathodes of tubes **4** and **4'**, respectively. This negative feedback is advantageous, for example, for reducing modulation and noise in the amplifier, as pointed out in the above mentioned paper by H. S. Black, and the voltage amplification for propagation once around the feedback loop may be a larger order of magnitude than unity, for obtaining large modulation reduction, as pointed out in that paper.

The feedback connections **70** and **70'** may include resistors **71** and **71'**, respectively, as shown, but are conductive and include no stopping condensers.

Grid biasing voltage for tube **4** is supplied partly from passage of the plate and screen direct currents of tube **4** through resistor **50**, partly from passage through resistor **50** of direct current flowing from filter **39** to resistor **50** via transformer **2** and resistor **71**, and partly from passage through resistor **50** of direct current flowing from the voltage divider to resistor **50** via conductor **48**, resistor **51**, resistor **60** and resistor **72**. By obtaining grid biasing voltage from three separate branches of the circuit it is possible to control, by the choice of the resistance values of resistors **50**, **60**, **71** and **72**, the amount of local negative feedback of tube **4**, the amount of negative feedback common to tubes **4** and **5**, and the magnitude of the grid biasing potential of tube **4**. The amount of local feedback is determined by the value of resistor **50**. The amount of feedback common to tubes **4** and **5** is controlled by the value of resistor **71** when the value of resistor **50** has been previously determined. Resistors **60** and **72** are then chosen to bring the total current flowing through resistor **50** to a value which will produce the desired grid biasing potential drop.

Similarly, grid biasing potential for tube **4'** is supplied partly from passage of the plate and screen direct currents of tube **4'** through resistor **50'**, partly from passage through **50'** of direct current flowing from filter **39** to resistor **50'** via transformer **2** and resistor **71'**, and partly from passage through **50'** of direct current flowing from the voltage divider to resistor **50'** via conductor **48**, resistor **51**, resistor **60** and resistor **72'**. The amount of local feedback is determined by the value of resistor **50'**. The amount of feedback common to tubes **4'** and **5'** is determined by the value of resistor **71'** and resistor **50'**. The final adjustment of grid biasing potential of tube **4'** is made by the choice of the resistance value of resistors **60** and **72'**.

The resistors shown may have the following resistance values, by way of example:

Resistor	Ohms
34	250,000
49	20,000
50	800
51	7,000
52	6,000
54	20,000
55	7,000
60	30,000
71	250,000
72	40,000

In the modification shown in Fig. 2, a resistor **80** by-passed by a condenser **81** is inserted between resistors **50** and **50'** and ground G, a high resistance **82** is inserted between resistors **33** and **33'** and ground G, and a by-pass condenser **83** is added in order to maintain a connection of negligible reactance between the junction of resistors **33** and **33'** and the junction of resistors **50** and **50'**. With this modification, the direct currents passing through resistors **50** and **50'** pass also through resistor **80**, and the grid bias for tubes **4** and **4'** is augmented by the voltage across resistor **80**. The resistor **82** and condenser **83** form a grid filter for this voltage.

What is claimed is:

1. A two-stage, impedance coupled, electric space discharge tube amplifier, a source of space current therefor, a resistance connected between the cathode of the first tube and the negative terminal of said source, a conductive connection from a point of positive potential on the source of space current to the plate of the first tube, a conductive connection from a point of positive potential on the source of space current to a point between said resistance and the cathode of the first tube, and an alternating current and direct current circuit connecting said resistance in shunt relation to the anode-cathode space path of said second tube with respect to the source of space current.

2. An amplifier comprising electric space discharge devices, means connecting said devices in cascade relation, an input circuit and an output circuit for said cascade connected devices, a space current supply source for said devices, a resistance in said input circuit, means for feeding alternating current and direct current from said output circuit through said resistance, and a conductive connection between said source and said input circuit for supplying direct current from said source to said input circuit.

3. In a negative feedback vacuum tube amplifier having a source of space current for the amplifier and a grid biasing resistance in the grid-cathode circuit of a tube of the amplifier, means for producing two negative biasing voltages for the grid of said tube, said means comprising a feedback path for producing negative feedback in the amplifier and transmitting direct current from said source through said resistance and a second direct current connection between said source and the input circuit of said tube.

4. A vacuum tube amplifier and means for producing a negative grid biasing potential for a tube of said amplifier comprising an alternating current and direct current path from the output circuit to the input circuit of the amplifier for producing negative feedback therein, a source of space current for said amplifier, a resistance in the grid-cathode circuit of said tube, a conductive connection from a point of positive potential on said source to a point on the grid-cathode circuit of said tube between said resistance and the cathode of said tube, and means including said path and said connection for transmitting two direct currents from said space current source in the same direction through said resistance, one through said path and the other through said connection.

5. A wave translating circuit comprising two electric space discharge tube amplifying devices impedance-coupled in cascade relation, a source of direct current, means connecting said source to the anode and the cathode of each of said devices for supplying space current to each device, an impedance serially included in the grid-cathode circuit of the first device, an alternating current and direct current circuit including said impedance in shunt relation to the anode-cathode circuit of the second device, the connections being such that the anode of the second device is connected to the point on said impedance that is nearest to the cathode of the first device, and a direct current circuit connecting at least a portion of said direct current source across at least a portion of said impedance.

6. In obtaining a negative grid biasing potential for a tube of a multistage amplifier having a negative feedback circuit from the amplifier output circuit to the amplifier input circuit including a resistance in the grid-cathode circuit of the tube, the method which comprises transmitting a direct current through the feedback circuit from the amplifier output circuit in a given direction through the resistance, and transmitting in the same direction through the resistance a direct current exclusive of the space current of the tube.

7. In a push-pull two-stage impedance coupled amplifier circuit, each of said stages having two electric space discharge tubes in push-pull relation, a common source of space current for all of said tubes, an impedance included in the grid-cathode circuit of the first tube on one side of the push-pull circuit, an alternating current and direct current circuit connecting the anode of the last tube on said one side of the push-pull circuit to the point on said impedance that is nearest to the cathode of said first tube on said one side of the push-pull circuit and including said impedance in shunt relation to at least a portion of the anode-cathode circuit of said last tube on said one side of the push-pull circuit, a second impedance included in the grid-cathode circuit of the first tube on the other side of the push-pull circuit, and an alternating current and direct current circuit connecting the anode of the last tube on said other side of the push-pull circuit to the point on said second impedance that is nearest to the cathode of said first tube on said other side of the push-pull circuit and including said second impedance in shunt relation to at least a portion of the anode-cathode circuit of the last tube on said other side of the push-pull circuit.

8. A two-stage, push-pull, negative feedback amplifier circuit, comprising a source of space current and on each side of the push-pull circuit one vacuum tube impedance-coupled to another, an alternating current and direct current impedance in the grid-cathode circuit of said one tube, an alternating current impedance in the anode-cathode circuit of said other tube, and an alternating current and direct current circuit connecting the first-mentioned impedance across said alternating current impedance of the anode-cathode circuit of said other tube and in shunt relation to said source of space current with respect to the anode-cathode space path of said other tube, said alternating current and direct current circuit being such that the anode of said other tube is conductively connected to the end of said first impedance closest to the cathode of said one tube.

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