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ELECTRIC WAVE AMPLIFIER

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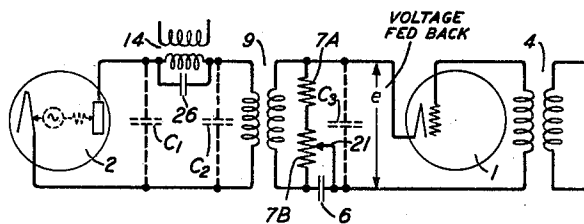


FIG. 2

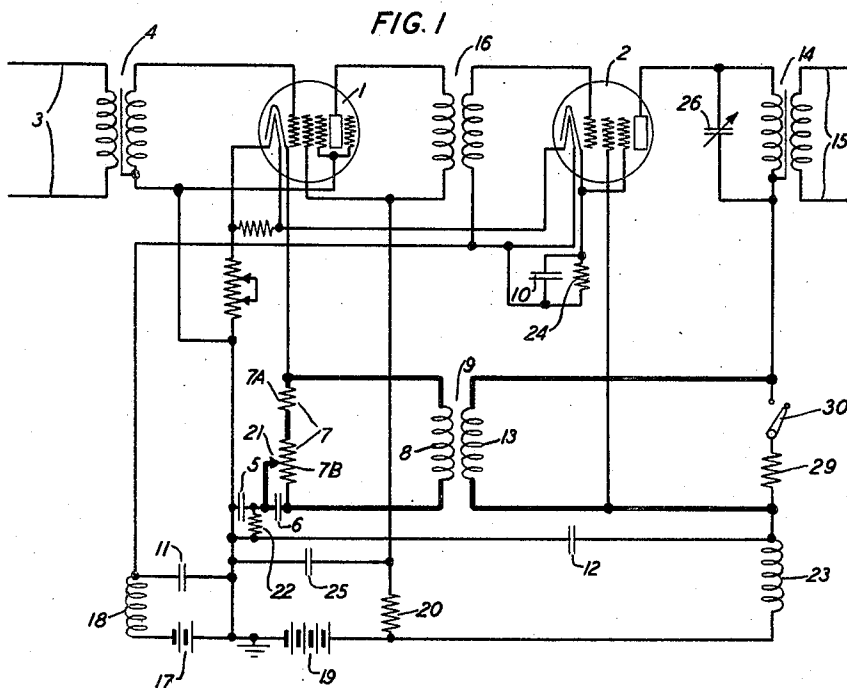
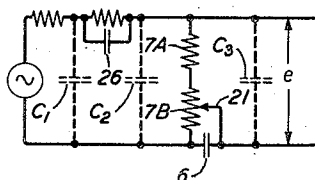


FIG. 1

FIG. 3



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ELECTRIC WAVE AMPLIFIER

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6 Claims. (Cl. 179—171)

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 and gain introduced by the systems, to facilitate application of feedback in the systems and provide adequate margin against singing, and to facilitate application of proper biasing potentials to grids of vacuum tubes in the systems.

In one specific aspect the invention is applied to a two-stage vacuum tube amplifier, introducing an even number of phase reversals in transmission from the grid of the first tube to the plate-cathode path in the last tube and having a feedback path that introduces a phase reversal in transmission therethrough so that the feedback is negative feedback or gain-reducing feedback.

In accordance with the invention, a feedback transformer may be connected in the feedback path, with its primary winding in serial relation to the primary winding of the amplifier output transformer and its secondary winding in serial relation to the secondary winding of the amplifier input transformer. The feedback transformer and the output transformer can have their primary windings connected between the positive pole of the space current source for the amplifier and the plate of the last tube, and the feedback transformer can prevent the feedback path from providing a short circuit or shunt circuit, around the space path in the last tube and the primary winding of the output transformer for direct current from the space current source.

Preferably the feedback transformer does not introduce a phase reversal in the feedback path, but such reversal is obtained by connecting the cathode of the second tube to the end of the secondary winding of the feedback transformer remote from the cathode of the first tube, for alternating current, or in other words connecting that winding between the cathodes, (so that when the alternating potential of the plate of the last tube is negative with respect to the cathode of the last tube, the fed back voltage tends to make the grid of the first tube positive with respect to the cathode of the first tube). A gain control resistor may be connected across this winding and its effective value may be varied to vary the amount of the negative feedback through the feedback path and thereby adjust the amplifier gain. This variation may be accomplished by a contact movable along the resistor and connected through a by-pass condenser to the end of the

resistor remote from the cathode of the first tube. As explained hereinafter, the short-circuiting, with respect to alternating current of the portion of the resistor not required for a given feedback adjustment, by means of the by-pass condenser, is advantageous in that it reduces phase shift in the feedback path and reduces change of the phase shift with change of the gain adjustment.

The movable contact may be conductively connected to the negative pole of the space current source for the first tube and the grid of the first tube, through a grid bias resistor shunted with a by-pass condenser if desired, so that, in addition to any negative biasing potential received by the grid due to the voltage drop created across the latter resistor by the space current, a negative biasing potential will be received by the grid due to voltage drop created between the cathode of the first tube and the movable contact by the flow of the space current between those points through the gain control resistor.

The insertion of the condenser in the alternating current short-circuiting connection from the adjustable contact to the end of the gain control resistor has the advantage of making direct current (the space current of the first tube) pass through the movable contact, which results in a quieter and more stable circuit under some circumstances, for the general reasons indicated in C. N. Nebel Patent No. 2,022,972, December 3, 1935. The circuit of the present invention attains this advantage with a single movable contact, instead of serially connected movable contacts as disclosed in the Nebel patent. The reduction in the number of the serially connected movable contacts not only reduces the number of contacts that might prove troublesome, but avoids possibility of the voltage of the space current supply source encountering high impedance at both contacts simultaneously and therefore having to divide its corrective effect between the two contacts.

While the insertion of the condenser (in the alternating current short-circuiting connection from the adjustable contact to the end of the gain control resistor) makes the movement of the contact vary the biasing potential that this resistor provides for the grid of the first tube, the connection of the secondary winding of the feedback transformer across the gain control resistor reduces the maximum value of this variation to one-fourth the value it would have without such connection of the transformer winding; because the direct current resistance of the winding is

negligible and so for direct current the winding effectively connects in parallel the two portions of the gain control resistor lying at either side of the movable contact. Considering the grid biasing effects of both the gain control resistor and the grid bias resistor, the amount by which the transformer winding reduces the variation of the total direct current resistance effective in biasing the grid, or reduces the total variation of grid bias due to movement of the adjustable contact, depends on the ratio of fixed to variable resistance. Thus if the fixed resistor be omitted (i. e., be of zero value), then the resistance effective in biasing the grid is all variable, and the maximum value with the transformer winding present is one-fourth of the total resistance of the variable resistor or one-fourth as great as it would be were the transformer winding absent.

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

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

Figs. 2 and 3 are simplified diagrams for facilitating explanation of operation of the circuit.

The amplifier comprises two heater type suppressor grid pentode vacuum tubes 1 and 2 in cascade connection. It amplifies signaling waves supplied to tube 1 from incoming line or circuit 3 through input transformer 4, by-pass condenser 5, by-pass condenser 6, and gain control resistor 7 and secondary winding 8 of feedback transformer 9, and transmits the amplified waves through by-pass condenser 10, by-pass condenser 11, by-pass condenser 12, primary winding 13 of transformer 9, and an output transformer 14, to outgoing line or circuit 15. The signaling waves may be, for example, modulated or unmodulated carrier waves.

The tubes are coupled by an interstage coupling circuit comprising a coupling transformer 16.

The heater current for the tubes is supplied by battery 17, through choke coil 18.

Plate and screen currents for tube 1 are supplied from battery 19 through resistor 20, and pass from the cathode through gain control resistor 7 and winding 8 to gain adjusting contact 21 movable along resistor 7, and thence through grid bias resistor 22 to the negative pole of the battery. Thus, negative grid biasing voltage for tube 1 is supplied by fall of potential in resistors 7 and 22 due to passage therethrough of space current of the tube.

Plate and screen currents for tube 2 are supplied from battery 19 and also battery 17 in series therewith, through choke coil 23 and winding 13, and pass from the cathode through grid bias resistor 24 for the tube and thence through choke coil 18 to the negative pole of battery 17.

The amplifier is provided with stabilizing feedback circuits in accordance with the principles described by H. S. Black in his Patent 2,102,671, December 21, 1937, and in his article entitled "Stabilized feed-back amplifiers," Bell System Technical Journal, January 1934. Alternating plate current of tube 1 passes through a circuit extending from the cathode through two branch circuits, one comprising resistance 7 and contact 21 and the other comprising winding 8 and condenser 6, and then extending on through by-pass condensers 5 and 25 and the primary winding of transformer 16 to the plate. Local negative feedback in the tube is thus produced by the fall of

potential in these branch circuits due to passage of this current therethrough.

However, the principal feedback in the amplifier is negative feedback around the two stages, produced by transformer 9 feeding into resistor 7. This negative feedback is advantageous for example for reducing modulation and noise in the amplifier, and stabilizing the gain of the amplifier and flattening its gain-frequency characteristic, as pointed out in the above-mentioned article and patent of H. S. Black, and the voltage amplification for propagation once around the feedback loop may be of a larger order of magnitude than unity, for example, for obtaining large modulation reduction, as pointed out therein.

In a particular amplifier the resistor 7 consisted of two sections, 7A and 7B, and the values of resistances 7A, 7B and 22 were, respectively, 100 ohms, 500 ohms and 600 ohms. As the portion of resistor 7 shunted by condenser 6 is increased by adjustment of contact 21, the current flowing in winding 8 as a result of the voltage induced in winding 8 from winding 13 remains substantially constant, and the overall negative feedback and the amplifier gain are decreased; and the local negative feedback around tube 1 is also decreased; and since the direct current resistance of winding 8 is negligible, the grid biasing voltage supplied by resistance 7 increases until it reaches a maximum when the contact is at the electrical mid-point of resistance 7. The reason why the secondary current of transformer 9 remains substantially constant is as follows: A driving voltage in series with the plate impedance of tube 2 sends current through the primary winding of transformer 9, and the plate impedance of tube 2 is very high compared to the impedance looking into transformer 9, regardless of the setting of the variable resistor. Therefore, it is substantially a constant current circuit, and varying the resistance varies the voltage across the resistance but not the current through the resistance.

For the signaling currents, the condenser 6 short-circuits a portion of the potentiometer formed by the feedback resistor and the movable contact; and this short-circuiting action reduces the phase shift in the feedback path for the overall feedback, and reduces the variation of this phase shift with movement of contact 21. The reduction of phase shift increases the phase margin of the amplifier or margin against singing around the overall feedback loop. To make clear the manner in which the short-circuiting effect of the condenser reduces the phase shift, reference may be made to Figs. 2 and 3. Fig. 2 is a simplified circuit of the feedback path, the capacities C_1 , C_2 and C_3 representing unavoidable capacities of elements, and Fig. 3 shows the feedback path in still further simplified form. Referring to Fig. 3, when the slider 21 is at the bottom of resistor 7B (the condition of maximum feedback), capacities C_2 and C_3 are directly in parallel. They then cannot, together, introduce more than 90 degrees phase shift. With the condenser 6 in circuit, this remains true regardless of the position of the slider, and, in general, phase conditions are more favorable at minimum feedback than at maximum feedback. Considering now, the case in which the short-circuiting connection including condenser 6 is omitted, the portion of resistor 7B below the slider constitutes a series arm in the feedback path, tending to separate the capacities C_2 and C_3 so that each can intro-

duce a maximum of 90 degrees phase shift. For this case, phase conditions may be, (as in the particular amplifier referred to above), less favorable at minimum feedback than at maximum feedback.

The particular amplifier referred to above is designed to work between a 125 ohm balanced circuit and a 10 ohm balanced circuit with a gain of 19 to 34 decibels according to the adjustment of the gain control contact. Its frequency range is 300 kilocycles to 550 kilocycles. Its output impedance exceeds 36 ohms throughout the frequency band of the amplifier. This relatively high output impedance is desired because the amplifier has its output circuit connected across the load circuit is parallel with the output circuit of a similar amplifier which is for emergency use. Only one amplifier at a time has input. Each therefore has output impedance high compared to the load impedance, so the one not in operation will not constitute a shunt on the circuit of such low impedance as would be wasteful of the power of the amplified waves. The interstage transformer of this particular amplifier is a 1 to 1 ratio coil with air core and is tuned by stray and tube capacities to the middle of the band. Its feedback transformer is likewise a 1 to 1 ratio coil with air core, and it is tuned by stray capacities and the capacity to ground of the shield and primary side of the output transformer to the middle of the band.

The suppressor grid of tube 1 is connected to ground rather than to the cathode because in the latter case changing the gain by means of the gain control resistor, which at the same time changes the amount of local feedback around tube 1, would change the effective output capacity of the tube and thereby shift the peak frequency of the interstage circuit. The shield of the output transformer is connected to the lower end of the primary (or high impedance) winding for a similar reason. In the latter case changes in overall feedback would change the effective capacity from different parts of the primary winding to ground and thus shift the tuning of the output transformer. A variable condenser connected across this winding may, if desired, be adjusted to compensate for changes in the tuning due to changes in reduction of the capacity between the windings and case, as well as in the plate-to-ground capacity of tube 2, caused by changes in feedback. The condenser can be adjusted to adjust resonance frequency for the output transformer to the middle of the band or to other desired frequencies.

The resonance frequency of the input transformer is affected by feedback, since the feedback changes the effective capacity across the coil. Only the capacity from grid to cathode is reduced by feedback. However, that capacity may be considerable because of stray capacity between plate and grid. Capacity from grid to ground is not affected by feedback.

In the particular amplifier mentioned above, the gain without feedback varies between limits of 47.5 decibels and 71.5 decibels in the frequency range from 300 kilocycles to 550 kilocycles, the gain-frequency characteristic being quite peaked. However, with the maximum negative feedback, the gain varied only between limits of 18.5 decibels and 19 decibels in this frequency range, and with the minimum negative feedback permitted by adjustment of the gain control contact the gain varied only between limits of 33.5 decibels and 35 decibels. At the

middle of the band the gain was 19 decibels with the maximum negative feedback and 34 decibels with the minimum negative feedback.

If desired, a resistance 29 may be shunted across winding 13, by switch 30. The values of resistances 29, 7A and 7B are chosen to give the amount of feedback desired and the amount of feedback variation desired. It is desirable to make the impedance of the feedback path as low as practicable, to reduce effect of stray capacities.

What is claimed is:

1. A wave translating system comprising a source of waves to be amplified, a load circuit for utilizing said waves, a vacuum tube amplifying device having input and output circuits connected to said source and said load circuit respectively for amplifying said waves and delivering them to said load circuit, input, output and feedback transformers for said device, means connecting said input and output transformers in said input and output circuits respectively, an impedance having a resistive component connected in a cathode-grid circuit and a cathode-anode circuit of said device for providing a grid biasing voltage for said device resulting from flow of direct space current of said device through said impedance, and a feedback path for producing negative feedback of said waves in said device by primary to secondary transmission through said feedback transformer, said feedback transformer having its primary winding connecting points of said output circuit of substantially different potential for said waves, with said primary winding in serial relation to the primary winding of said output transformer, and said feedback transformer having its secondary winding in parallel relation to said impedance with respect to the secondary winding of said input transformer.

2. A wave translating system comprising an amplifying device including an electric space discharge tube having an anode, a cathode and a grid and a path for producing negative feedback in said device, said path comprising a transformer and a resistance connected across the secondary winding of said transformer, a contact adjustable for connection to different points of said resistor, a connection including a by-pass condenser between said contact and one end of said resistor, a conductor connected to said cathode, a conductor connected to the negative pole of the space current source for said tube, a circuit connecting one of said conductors to said adjustable contact, a circuit connecting the other of said conductors to the other end of said resistor, and a conductive connection from said pole to said grid.

3. An amplifier for signaling waves and a load circuit connected to said amplifier for utilizing the amplified waves, said amplifier comprising two cascaded vacuum tubes having between their cathodes an alternating current and direct current impedance, an output circuit for the second tube feeding said load circuit, a second impedance, means for producing negative feedback of the signaling waves from said output circuit of the second tube to the grid-cathode circuit of the first tube, said means comprising circuits connecting said first-mentioned impedance in the grid-cathode circuit of the first tube and with regard to said signaling waves and also to unidirectional space current of the second tube conductively connecting said second impedance in serial relation to said load circuit with respect to the internal plate-cathode circuit of the sec-

ond tube with said impedance linking points in said output circuit of substantially different potential for said waves, and said means comprising also circuits for deriving from said second impedance alternating voltage to the exclusion of unidirectional voltage and applying the derived voltage to said first-mentioned impedance, and means for biasing the grid of the first tube with voltage across a portion of said first-mentioned impedance, said last-mentioned means comprising connections for passing space current of the first tube through a portion of said first-mentioned impedance.

4. A wave amplifying device including an electric space discharge tube having an anode, a cathode and a discharge control grid, a source of space current for said tube, a condenser and a resistance in serial relation in the grid-cathode circuit of said tube and also in serial relation between said cathode and the negative pole of said source, a phase reversing feedback circuit for producing gain-reducing feedback in said device, said feedback circuit comprising a transformer having a primary winding in serial relation to the output circuit of said device and a secondary winding feeding waves to said resistance, and a conductive connection across said condenser and a portion of said resistance, said connection having one end adjustable along said resistor for varying said portion.

5. An amplifier for amplifying waves received from an incoming circuit and transmitting the amplified waves to an outgoing circuit, said amplifier comprising a vacuum tube for receiving said waves from an incoming circuit, a second vacuum tube, an interstage coupling transformer for coupling said tubes in tandem relation, an output transformer having a primary winding in the plate circuit of said second tube and a secondary winding for connection to said outgoing circuit, a source of space current for said tubes, a circuit extending from the cathode of the first tube to the negative pole of said source and including in serial relation a resistance, a condenser and a branched circuit comprising a grid biasing resistance and a by-pass condenser therefor, said first-mentioned condenser having one terminal connected to the end of said first-men-

tioned resistance that is electrically remote from said cathode, a contact connected to the other terminal of said condenser and adjustable along that resistance, a conductive connection from said pole through said incoming circuit to the grid of said first tube, means producing negative feedback of said waves in said amplifier, said means comprising a feedback transformer having a primary winding in serial relation to said primary winding of said output transformer with respect to the plate-cathode space path in said second tube and a secondary winding feeding said signal waves to said first-mentioned resistance, and means for supplying space current for said second tube from said space current source through primary winding of said feedback transformer.

6. An amplifier for signaling waves having an output transformer with a primary winding and a secondary winding, said amplifier comprising two cascaded vacuum tubes having between their cathodes an alternating current and direct current impedance, an output circuit for the second tube feeding said transformer, a second impedance, means for producing negative feedback of the signaling waves from said output circuit of the second tube to the grid-cathode circuit of the first tube, said means comprising circuits connecting said first-mentioned impedance in the grid-cathode circuit of the first tube and with regard to said signaling waves connecting said second impedance in serial relation to said primary winding with respect to the internal plate-cathode circuit of the second tube with said second impedance linking points in said output circuit of substantially different potential for said waves, and said means comprising also circuits for deriving from said second impedance alternating voltage to the exclusion of unidirectional voltage and applying the derived voltage to said first-mentioned impedance, and means for biasing the grid of the first tube with voltage across a portion of said first-mentioned impedance, said last-mentioned means comprising connections for passing space current of the first tube through a portion of said first-mentioned impedance.

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