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2,337,423

NEGATIVE FEEDBACK AMPLIFIER

Filed Oct. 1, 1942

FIG. 1

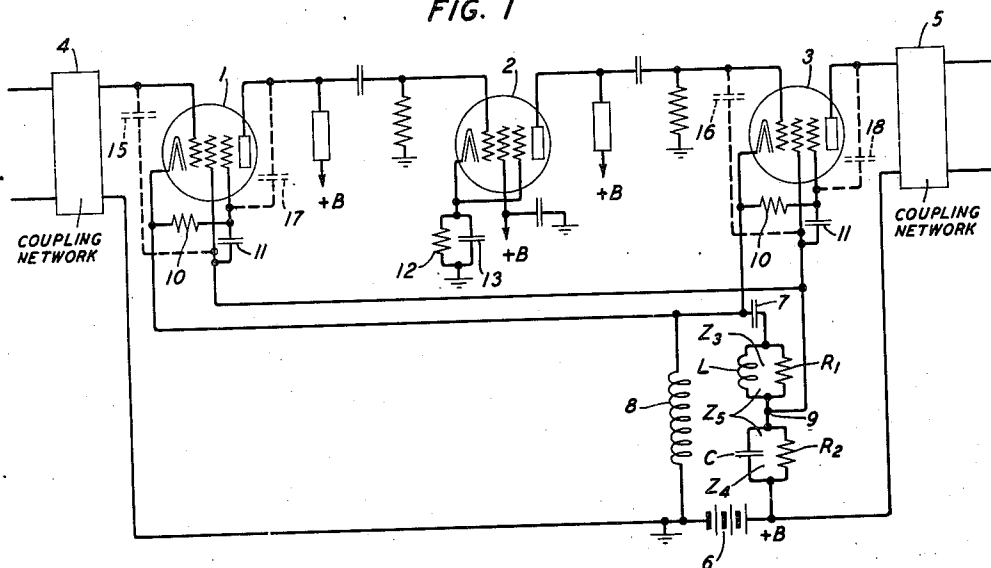


FIG. 2

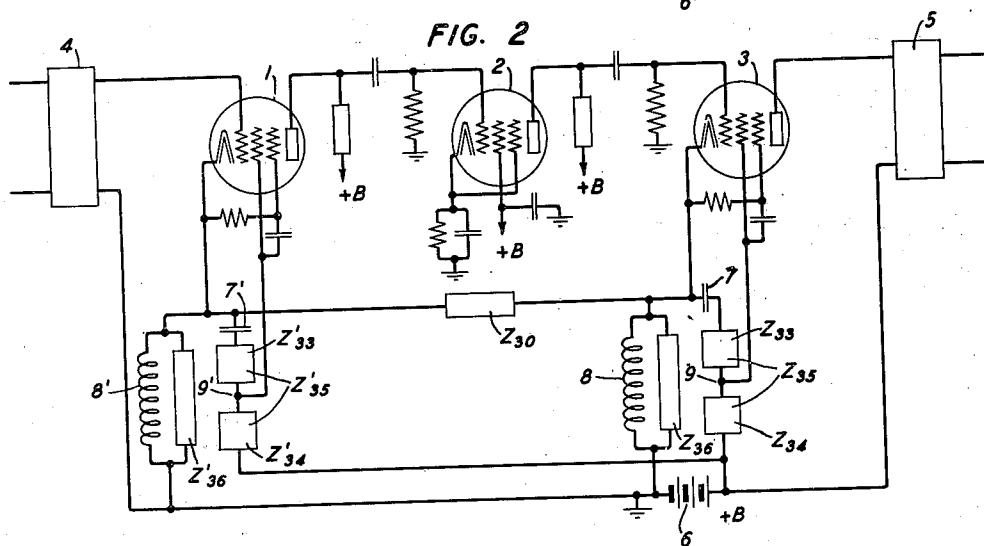


FIG. 1A

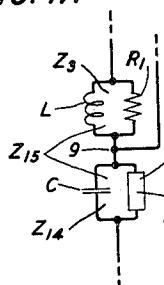
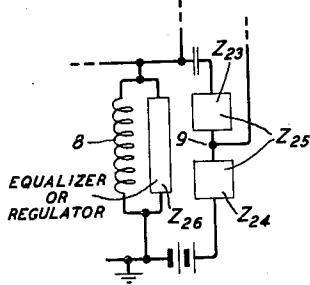


FIG. 1B



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NEGATIVE FEED-BACK AMPLIFIER

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3 Claims. (Cl. 179-171)

This invention relates to feedback systems, as for example, wide band vacuum tube amplifiers with negative feedback.

Objects of the invention are to control transmission properties of such systems, as for example, to increase the amount of feedback obtainable without undue modulation or noise effects.

It is also an object of the invention to facilitate application of feedback in such systems.

In one specific aspect the invention is a broad band three-stage cathode feedback amplifier having the cathodes of the first and third tubes removed from ground by the feedback impedance or beta circuit structure, for example, as in J. M. West Patent 2,227,048, December 31, 1940, or H. W. Bode Patent 2,315,040, March 30, 1943, with frequency selective means connecting the screen grids and suppressor grids of those tubes to their respective cathodes in the transmission band of the amplifier but to ground in the asymptotic frequency region above the transmission band. The asymptotic frequency region refers to the region in which parasitic impedances of the apparatus elements of the amplifier are the dominant impedances in determining the feedback in that region (as discussed in H. W. Bode Patent 2,123,178, July 12, 1938).

It has been found desirable from the standpoint of noise and modulation performance of the amplifier to have these screen and suppressor grids at the potentials of their cathodes in the transmission band. For example, it has been found that with the suppressor grid of one of these tubes grounded in the transmission band the suppressor-cathode impedance may be so small and non-linear that its appearance across the beta circuit causes the tube to be a principal source of modulation, and that noise and modulation effects introduced by the amplifier are appreciably greater when the potential of the screen grid of the first of these tubes in the transmission band is ground potential than when it is the cathode potential. Moreover, connection of the screen grid of the third stage to its cathode in the transmission band is desirable, as otherwise the suppression of modulation due to feedback is essentially nullified, due to flow of the screen grid current through the beta circuit structure in the band.

However, above the transmission band the frequency selective means transfers connection of the screen and suppressor grids to ground, as just indicated. The transfer is desired in order to increase the feedback obtainable in the trans-

mission band; for it has been found that, in the manner indicated hereinafter, the transfer improves the distribution of parasitic tube capacities from the standpoint of increasing the transmission efficiency of the feedback path in the asymptotic frequency region and thereby gives a material increase in the feedback in that region, an increase that (in accordance with the teaching of the Bode Patent 2,123,178 (mentioned above) increases the feedback obtainable in the transmission band.

It is an object of the invention to achieve large feedback in a cathode feedback amplifier with low modulation and noise effects.

It is also an object of the invention to reduce noise effects or modulation due to voltage between the cathode and the screen grid or the suppressor grid of a tube of a cathode feedback amplifier in the transmission band of the amplifier without necessitating decrease of the maximum permissible feedback in the transmission band.

It is also an object of the invention to improve distribution of parasitic capacities due to auxiliary grids in a cathode feedback amplifier without deleteriously affecting modulation or noise effects in the amplifier.

It is also an object of the invention to reduce undesired feedback to auxiliary grids of cathode feedback amplifiers in the transmission band without necessitating decrease of the maximum permissible feedback in the band.

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

Fig. 1 is a schematic circuit diagram of an amplifier embodying the specific aspect of the invention mentioned above;

Figs. 1A and 1B show modifications of the beta circuit structure of Figs. 1; and

Fig. 2 shows a modified form of amplifier.

The amplifier of Fig. 1 may be of the general type shown in Fig. 9 of the West patent mentioned above, designed, for example, to give a gain of several times ten decibels over a frequency range from 60 to 6,000 kilocycles with a feedback of several times ten decibels over that transmission band.

The cascade of suppressor grid pentode tubes 1, 2 and 3 has an input coupling network 4 and an output coupling network 5. Each of these networks may be, for example, a transformer network of the type disclosed in Fig. 8 of the West patent mentioned above or Fig. 24 or 25 of H. W. Bode Patent 2,242,878, May 20, 1941.

The feedback coupling impedance network or beta circuit structure Z_5 comprises networks Z_3 and Z_4 in series. Network Z_3 comprises inductance L and resistance R_1 in parallel. Network Z_4 comprises condenser C and resistance R_2 in parallel. Network Z_5 is connected to ground through the B battery or source 6 and to the cathodes of tubes 1 and 3 through a stopping condenser 7 of low reactance. The voltage drop in coil 8 due to the plate and screen grid direct currents of tubes 1 and 3 provides grid bias for tubes 1 and 3. This coil has high inductance, so that it will avoid unduly shunting the feedback impedance Z_5 as regards alternating current, and so that it will provide discrimination against flow of screen grid currents of tubes 1 and 3 through the feedback impedance Z_4 in the transmission band of the amplifier (where, as pointed out below, Z_4 may provide the feedback coupling and Z_3 may be very small) and thereby prevent unwanted feedbacks due to such current flow.

Resistance 12 biases the control grid of tube 2, and condenser 13 is a by-pass.

The heater circuits (not shown) for the vacuum tubes of the amplifier may be, for example, of the type disclosed in my Patent 2,260,493, including a network for isolating the heaters of the first and third tubes from ground to keep as much as possible of the heater-cathode capacity of those stages from appearing between cathode and ground or, in other words, across the feedback coupling impedance or beta circuit.

The parasitic capacity between the screen grid and the control grid in tube 1 is indicated at 15, and the corresponding capacity of tube 3 is indicated at 16. The parasitic capacity between the plate and the suppressor grid in tube 1 is indicated at 17, and the corresponding capacity of tube 3 is indicated at 18.

The screen grids of tubes 1 and 3 are connected to the junction 9 of networks Z_3 and Z_4 . The suppressor grids of these tubes are connected to their cathodes through high resistances 10 and are connected to point 9 through by-pass condensers 11 of low reactance. The feedback network Z_5 serves as the frequency-selective network for transferring connection of these screen and suppressor grids from their cathodes to ground above the transmission band of the amplifier.

For example, over a frequency range including the transmission band of the amplifier, the impedance of network Z_3 may be substantially that of coil L which may be substantially zero (i. e., negligibly small compared to the control grid-screen grid reactance of each of the end tubes 1 and 3 and compared to the plate-suppressor grid reactance of each of these tubes), the impedance of network Z_4 over that range being substantially that of resistance R_2 , which may provide the feedback over that range; and over a higher frequency range, including the asymptotic frequency region, the impedance of network Z_4 may be at least as low as that of condenser C , which may be substantially zero, and the impedance of network Z_3 may provide the feedback over that range. Over the transition region between the two frequency ranges the impedance of feedback network Z_5 may be made a constant resistance (i. e., the feedback coupling impedance may be made independent of frequency over the transition region), by making $R_1=R_2$ and $L/C=R_1R_2$. With regard to the frequency at which the impedance-frequency curves of impedances Z_3 and Z_4 cross or intersect, i. e., the frequency at which $Z_3=Z_4$, which may be called

the cross-over frequency, it is not always necessary, in order to obtain improvement in accordance with the invention that this frequency be above the transmission band of the amplifier, or that the grid transfer to the cathodes be completed above the transmission band. For example, considerable improvement can be obtained with the cross-over frequency at the top of the band (i. e., with the transfer only half completed at the top of the band), or even with the cross-over frequency substantially below the top of the band.

Provision by coil 8 against flow of screen grid currents through Z_4 in the transmission band avoids necessity for high impedance for this purpose between the screen grids and ground, such, for example, as impedance 60 in Fig. 9 of the West Patent 2,227,048, which might undesirably shunt the beta circuit. With the screen grids at a relatively high impedance point, not only would there be increased tendency to unwanted feedback through the screen grid circuit, but transferring the connection of the screen grids to ground would become physically relatively difficult.

Transferring the screen and suppressor grids from their cathodes in the transmission band to ground in the asymptotic frequency region causes some of the grid-cathode capacity and plate-cathode capacity of the tubes to become capacity to ground, thus substantially decreasing the grid-cathode capacity and the plate-cathode capacity and substantially increasing the grid-ground capacity and the plate-ground capacity. For example, for tube 1 the parasitic capacity 15 between control grid and screen grid is capacity from control grid to cathode with the screen grid at the cathode potential, but becomes substantially a capacity from control grid to ground with the screen grid at ground potential, since the direct capacity between screen grid and cathode is relatively small; and for tube 3 the parasitic capacity 18 between plate and suppressor grid is capacity from plate to cathode with the suppressor grid at the cathode potential, but becomes substantially a capacity from plate to ground with the suppressor grid at ground potential.

It will be apparent from the West Patent 2,227,048 that by this redistribution of parasitic capacities the circuit is rendered more effective in transmitting the output voltage of tube 3 to the feedback coupling impedance Z_5 and transmitting this voltage appearing across Z_5 to the grid and cathode of tube 1. In other words, the redistribution of parasitic tube capacities among the several elements of the asymptotic amplifier increases the transmission efficiency of the feedback path in the asymptotic frequency region, largely by reducing the principal loss components of the feedback in that region. These components are the so-called output and input potentiometer losses, that is, the losses represented by the so-called output and input potentiometer terms. As brought out in discussion of a normal series feedback amplifier in H. W. Bode Patent 2,242,878, May 20, 1941, these terms represent or are a measure of the transmission from the plate of the output tube to the beta circuit structure and from the beta circuit structure to the input grid of the input tube. Thus, in the cathode feedback amplifier, the input potentiometer term is the ratio of the grid-cathode impedance to the sum of the grid-cathode impedance plus the grid-ground impedance; and the output potentiometer term is the ratio of the plate-cathode

impedance to the sum of the plate-cathode impedance and the plate-ground impedance.

The increase of the transmission efficiency of the feedback path in the asymptotic frequency region increases the feedback in that region and consequently, in accordance with the teaching of the Bode Patent 2,123,178, increases the maximum feedback that can be achieved in the transmission band.

The redistribution of the parasitic tube capacities also facilitates obtaining the appropriate ratios that, as shown in the Bode Patent 2,242,878, must, if a satisfactory asymptotic frequency characteristic is to be obtained for $\mu\beta$ exist between the grid-cathode capacity of the input tube and the capacity across the high impedance side of the input coupling network 4 and between the plate-cathode capacity of the output tube and the capacity across the high impedance side of the output coupling network 5.

Especially when the grid transfer to the cathodes is completed above the transmission band, as indicated by Fig. 1A the resistance R_2 may be replaced by an impedance network Z_{12} which may be a transmission equalizing network to compensate for frequency variation of line attenuation below the frequency at which the transfer is completed, or by an impedance network including a thermistor controlled by a pilot channel operated transmission regulator as in R. R. Blair Patent 2,178,333, October 31, 1939; or, as indicated in Fig. 1B such an equalizing network or gain regulating network may be included in an additional beta circuit arm Z_{26} which may be connected across a network Z_{25} of the same type as the network Z_5 of Fig. 1 and may include a stopping condenser (not shown) for direct current, if desired. In Fig. 1A, networks Z_{14} and Z_{15} correspond respectively to networks Z_4 and Z_5 of Fig. 1. In Fig. 1B, networks Z_{23} , Z_{24} and Z_{25} may be respectively of the same types as the networks Z_3 , Z_4 and Z_5 of Fig. 1, which they respectively replace, and network Z_{24} may be of sufficiently high impedance to provide adequate discrimination against flow of screen grid currents through Z_{26} .

Fig. 2 shows a modification of the amplifier of Fig. 1 comprising a more complex beta circuit structure. The design parameters provided by the more complex beta circuit structure afford greater flexibility in design, which is useful especially in designing for maximum feedback. The beta circuit structure is shown as a π network having a series arm Z_{30} and shunt arms Z_{36} and Z'_{36} with separate networks Z_{35} and Z'_{35} for transferring the grids of the first and third tubes (from their respective cathodes in the transmission band to ground in the asymptotic frequency region as described in connection with the preceding figures). Networks Z_{33} , Z_{34} , Z_{35} and Z_{36} , respectively, correspond to and may be of the same types as networks Z_{23} , Z_{24} , Z_{25} and Z_{26} of Fig. 1B; the same is the case for networks Z'_{33} , Z'_{34} , Z'_{35} and Z'_{36} ; and the resistances of coils 8 and 8' may serve for biasing the control grids of tubes 1 and 3, networks Z_{30} , Z_{36} and Z'_{36} , including series stopping condensers (not shown), if desired. By making the impedance of arm Z_{30} approach zero

the amplifier of Fig. 2 can be reduced to one having the beta circuit a single shunt arm.

What is claimed is:

1. An electric wave amplifier comprising an odd number of amplifying stages, each of said stages including cathode, control grid and anode electrodes and one of the end stages including also an auxiliary electrode, a negative feedback circuit embracing all of the stages and comprising a feedback coupling means providing cathode-to-ground wave impedance that is substantially greater in the end stages than in an intermediate stage, said means comprising an impedance having two portions in series between the cathode of said one end stage and ground, and means connecting said auxiliary electrode to the junction of said portions, the one of said portions nearer ground substantially exceeding the other over the major part of the transmission frequency band of the amplifier, and the other of said portions substantially exceeding said one portion in the asymptotic frequency region of the amplifier above the transmission band.
2. An amplifier comprising cascaded vacuum tubes, each having cathode, control grid and anode electrodes and one of the end tubes including also an auxiliary electrode, input and output coupling networks for said amplifier, a voltage-voltage negative feedback circuit comprising said networks and a feedback coupling impedance having two portions in series across said feedback circuit between the cathode of said one end tube and ground, and means connecting said auxiliary electrode to the junction of said two portions, the magnitudes of said portions varying with frequency in opposite senses for the two portions about a frequency at least as high as a frequency in the upper part of the transmission frequency band of the amplifier.
3. A three-stage amplifier comprising end stages and an intermediate stage each having an anode, a cathode and a control grid, one of said end stages having also a screen grid, a negative feedback circuit embracing said three stages and comprising a feedback coupling means providing cathode-to-ground wave impedance that is substantially greater in said end stages than in said intermediate stage, said means comprising an impedance having two portions in series between the cathode of said one end stage and ground, means connecting said screen grid to the junction of said portions, the one of said portions nearer ground substantially exceeding the other over the major part of the transmission frequency band of the amplifier and the other of said portions substantially exceeding said one portion in the asymptotic frequency region of the amplifier above said band, a direct current source for biasing said screen grid, an inductance connected across said feedback coupling means and having high impedance compared to that means in said band, and a circuit connecting the cathode of said one end tube and said screen grid and including said inductance, said source and said one portion in series.

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