

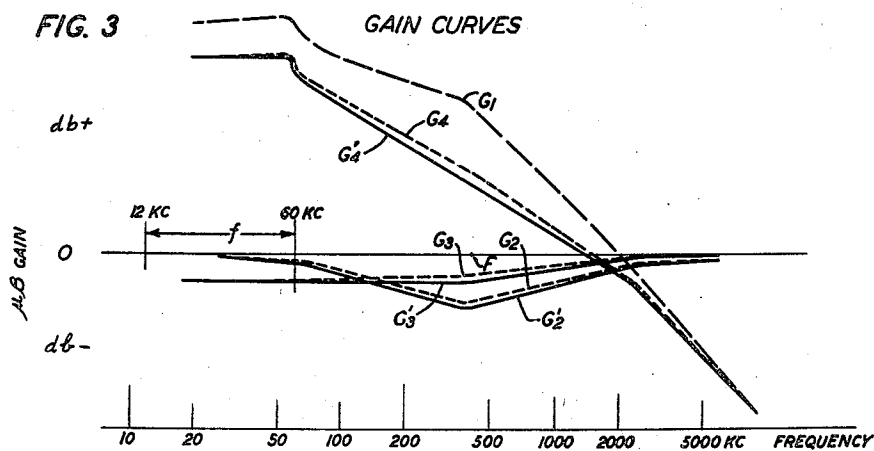
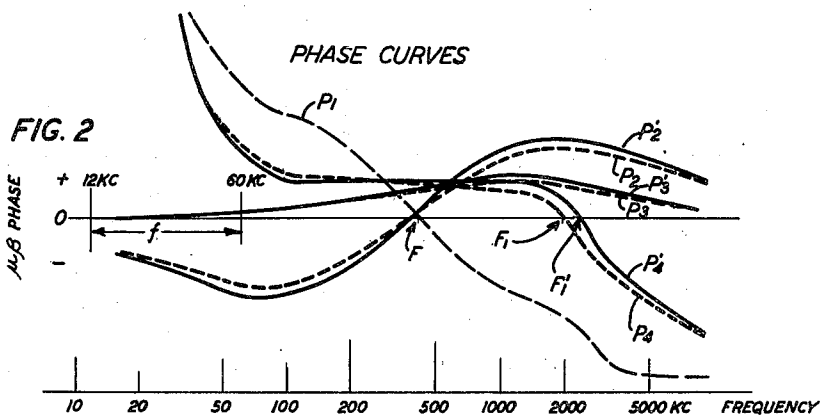
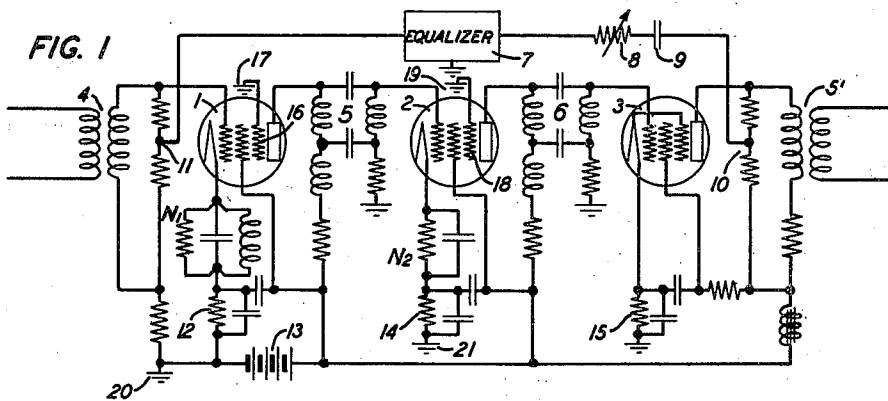
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FEEDBACK AMPLIFIER CIRCUIT

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FEEDBACK AMPLIFIER CIRCUIT

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The present invention relates to the amplification of electrical waves for signaling or other purposes and more especially to electrical wave amplifiers employing a gain reducing feedback for improving the amplification, for example by reducing modulation in the amplifier.

An object of the invention is to facilitate control of gain and phase characteristics to improve the operation of an amplifier provided with a gain reducing feedback.

In an amplifier provided with a gain reducing feedback designed for the amplification of waves of a band of frequencies, the permissible gain within the useful band is ordinarily limited by the singing tendency of the amplifier at some frequency outside the band, for example at some very high frequency. Various expedients have been resorted to in the art for suitably modifying and controlling the phase and gain characteristics in the region in which the amplifier has a tendency to sing so as to maintain the amplifier stable against singing without an undue sacrifice of gain in the utilized range. One means that has been used for this purpose comprises a cathode network, that is, an impedance connected in series in the cathode return for producing local negative feedback for the stage in question to influence the gain and phase relations at the particular frequency at which the amplifier has a tendency to sing without such network.

In a specific application of the present invention applicant has found that an appreciable improvement in the singing margin can be obtained in the case of an amplifier using a pentode tube stage by changing the wiring of the tube elements so that the inherent capacity existing between the suppressor grid and the anode has less tendency to shunt the high frequency circuits away from the cathode network.

The nature of the invention and its particular features and objects will be more clearly understood from the following detailed description of an illustrative embodiment as shown in the accompanying drawing.

In the drawing, Fig. 1 is a schematic circuit diagram of an amplifier embodying the invention; and

Figs. 2 and 3 show typical curves illustrating the effects obtained with the invention.

Referring to Fig. 1, tubes 1, 2 and 3 are connected to amplify waves incoming through transformer 4 and to impress the amplified waves on an outgoing circuit through transformer 5'. Suitable interstage networks 5 and 6 are shown,

these being impedance coupling networks including series capacities and shunt inductances or resistances. The showing of the interstage networks 5 and 6 is to be taken as illustrative rather than limiting. A negative feedback connection comprising equalizer 7, regulator 8 and condenser 9 is included between an output bridge 10 and an input bridge 11. The purpose of this feedback connection is to feed back some portion of the output waves in reverse phase to the input side of the amplifier so as to reduce the gain of the amplifier and improve its performance from the standpoint of modulation and linearity. The equalizer 7 has an attenuation characteristic variable over the utilized frequency band for controlling the relative gain reduction throughout the utilized band in some desired manner, for example, to equalize for the variable attenuation experienced by the waves in traversing the line with which the amplifier is associated.

The tubes 1, 2 and 3 are pentode tubes. Plate voltage is supplied from source 13. Resistances 12, 14 and 15 shunted by suitable condensers provide negative grid bias in the respective stages. Network N₁ is included in the cathode lead of tube 1 common to the grid and plate circuits for that tube for a purpose disclosed and claimed in D. D. Robertson Patent 1,994,486, March 19, 1935 to which reference may be made for a fuller disclosure of this feature. As there described, network N₁ reduces the gain and improves the phase margin at a particular high frequency region in which the amplifier has a tendency to develop oscillations or singing. A network N₂ of somewhat similar configuration is included in the cathode lead of tube 2 common to the grid and plate circuits of that tube, operating in a manner similar to that of N₁, and produces a further improvement in the singing margin of the amplifier.

The amplifier as a whole, so far as the foregoing description goes, is similar to that disclosed in Fig. 1 of the Robertson patent and is suitable for use as a mid-line or terminal repeater in a broad band transmission system, such as a carrier wave signaling system operating over a frequency range of the order of 10 to 60 kilocycles.

As explained in the Robertson patent such an amplifier may develop a singing tendency at some frequency outside the utilized range, for example at some high frequency, such as 400 kilocycles. Without the provision of circuit means to counteract this tendency the amplifier might have to be operated with less feedback than is required for the waves in the signal frequency band. The provision of suitably designed cath-

ode networks, such as N_1 , or both N_1 and N_2 , as generally described in the Robertson patent, enables an amplifier to be operated with greater feedback and greater improvement in modulation and stability in the utilized range by favorably affecting both the gain and phase characteristics in the neighborhood of the potential singing point.

Applicant has found that a further increase in the singing margin of an amplifier can be obtained by the simple expedient of connecting the suppressor grid of either or both stages 1 or 2 directly to ground instead of directly to the cathode as was done, for example, in Robertson. The reason for this improvement appears to be that with the connection of the suppressor grid to ground the inherent capacity existing between the suppressor grid and the anode appears in series relation rather than in shunt relation to the network circuit N_1 or N_2 with respect to the internal plate generator of the tube. The capacity current due to this inherent capacity instead of flowing to the cathode without traversing the cathode network as formerly is now caused to return to the cathode through the cathode network.

The manner of connection for accomplishing this is to connect suppressor grids 16 and 18 directly to grounds shown at 17 and 19, these grounds being in reality the same grounds as shown at 20 and 21. This can conveniently be done by using a six-prong pentode in place of the usual five-prong pentode and bringing the suppressor grid connection out through the sixth prong directly to ground.

The improved effect of this manner of connecting the suppressor grid is illustrated in Figs. 2 and 3 which show curves similar to the portions of the curves in the Robertson patent in the vicinity of the potential singing point.

Referring to Fig. 2, the utilized signal band is shown at f and the curve P_1 shows the high frequency portion of the $\mu\beta$ phase shift of the amplifier without either of the networks N_1 , N_2 . It crosses the zero axis in the neighborhood of 400 kilocycles, which is marked as a potential singing point F since under the conditions assumed the amplifier has positive $\mu\beta$ gain at this frequency as will be seen in Fig. 3 (G_1). As pointed out by Robertson the frequency at which the phase shift becomes zero can be raised to some value F_1 shown as about 2 megacycles by inclusion of networks N_1 and N_2 whose insertion phase shift characteristics are shown at P_2 and P_3 respectively, the resultant for the amplifier being P_4 . By using the direct ground connections 17 and 19 for the screen grids (six-prong tubes) the phase curves P_2 and P_3 are shifted to P_2' and P_3' giving a resultant phase characteristic for the amplifier of P_4' which has a zero value in the vicinity of 2.5 megacycles, F_1' .

Referring to Fig. 3, the high frequency portion of the $\mu\beta$ gain characteristics of the amplifier without either network N_1 , N_2 is shown by G_1 , which is seen to have a relatively large positive value at the frequency of F and which does not fall to zero until about the frequency 2.1 megacycles is reached, this being very close to the point F_1 of Fig. 2. Use of networks N_1 and N_2 in the manner disclosed by Robertson, with their gain (loss) characteristics G_2 and G_3 , respectively, lowers the gain characteristic of the total amplifier to G_4 and gives an improvement in singing margin represented by the shift of the zero gain value from the frequency of F_1 to a

frequency about half a megacycle lower. Use of the direct ground connections 17, 19 for the screen grids (six-prong tubes) modifies curves G_2 and G_3 to an extent roughly indicated by G_2' and G_3' and gives a resultant $\mu\beta$ gain characteristic for the amplifier of G_4' which is seen to reach zero value at about a tenth of a megacycle lower than the curve G_4 for the case of conventional five-prong pentodes.

Comparison of curves P_4 and G_4 with curves P_4' and G_4' indicates a material improvement in singing margin, the phase and gain characteristics being both modified in a favorable direction. This additional margin of stability against singing becomes important especially in the design of broad band amplifiers in which the difficulty of obtaining the required phase characteristic is increased by the necessity for large feedback in the useful band.

What is claimed is:

1. In an amplifier, a pentode tube, a gain reducing feedback comprising an impedance connected in series in the cathode return for providing in the amplifier a desired loss and phase margin against singing, and means for increasing the margin against singing comprising a circuit connecting the suppressor grid externally of said tube to a point in said network remote from the cathode connection.

2. In an amplifier, a plurality of stages in tandem each including a pentode tube, a gain reducing feedback around a plurality of said tubes, a local gain reducing feedback for one of said pentode tubes comprising an impedance common to the alternating current grid and plate circuits and in series in the cathode return branch, and means for improving the high frequency gain and phase characteristics of said amplifier comprising a circuit connecting the suppressor grid of said stage to a point in said impedance network remote from the cathode terminal.

3. In an amplifier circuit for amplifying waves of a range of frequencies, said amplifier having a tendency to sing at some particular frequency, a pentode tube in one stage of said circuit, an impedance in the common portion of the grid and plate circuits of said pentode for reducing said singing tendency and a connection from the suppressor grid to the cathode including said impedance in series for further reducing said singing tendency.

4. In an amplifying circuit, a stage comprising a discharge tube having a cathode, an anode, a control grid, a screen grid and a suppressor grid, circuits connecting said control grid, anode and suppressor grid each to said cathode, said circuits having a common portion adjacent the cathode, said amplifying circuit having a tendency to sing when operated above a certain value of gain, and means to reduce such singing tendency comprising an impedance included in said common portion of said circuits.

5. In an amplifier circuit for amplifying waves of a band of frequencies, said amplifier having a tendency to sing at some particular frequency outside said band, a pentode tube in one stage of said circuit having its cathode connected to ground through an impedance network common to the anode circuit and control grid circuit of said tube whereby a negative feedback is produced tending to modify the gain and phase characteristics of the amplifier at its potential singing frequency and reduce the singing tendency, and means for still further modifying said gain and phase characteristics in the direction to reduce

singing tendency comprising a connection of low impedance from the suppressor grid to ground.

6. The combination with a broad band amplifier comprising in one stage a pentode tube, said amplifier having a negative feedback path from its output to its input for feeding back waves in such phase as to reduce the gain in the useful frequency band, and an impedance between the cathode and ground and common to the cathode-

anode and grid-cathode circuits of said pentode tube for preventing singing at a frequency above the band at which a singing tendency exists, of means for further opposing such singing tendency comprising a circuit connection for directly grounding the suppressor grid of said pentode tube.

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