June 20, 1939. H. M. OWENDOFF 2,162,744

AMPLIFIER

Filed Jan. 7, 1937

FIG. 1

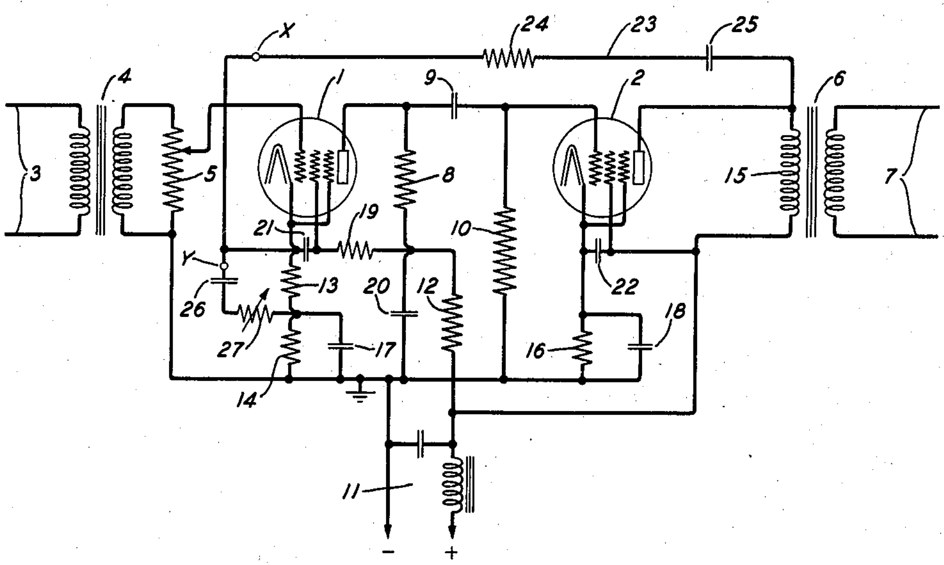
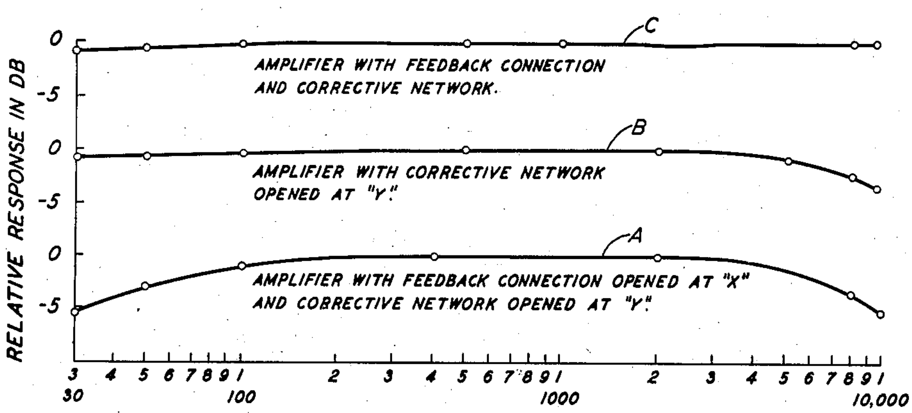


FIG. 2



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AMPLIFIER

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3 Claims. (Cl. 179—171)

This invention relates to wave amplifying systems.

An object of the invention is to control transmission properties of such systems, as for example transmission efficiency and distortion.

In one specific aspect, the invention is applied to an amplifier for speech or other audio frequency signal waves, having an output transformer that, because of its economical design, has its primary inductance so low as to tend to cause objectionable lowering of the transmission efficiency of the amplifier with frequency decrease in the lower portion of the signal frequency range, and its leakage inductance and secondary capacity so large as to tend to cause objectionable lowering of the transmission efficiency of the amplifier with frequency increase in the upper portion of the range.

A feature of the invention relates to opposing these tendencies by negative feedback in the amplifier of the voltage across the primary winding of the transformer. This voltage, and consequently the amount of the negative feedback, decreases with decrease in the primary impedance of the transformer. Thus, in the lower portion of the signal frequency range, compensation is effected for decrease of amplifier gain with frequency decrease, and in the upper portion of the range, compensation is effected for such decrease of amplifier gain with frequency increase as is due to primary capacity of the transformer. Then, in accordance with the invention, to compensate for the effect of the secondary capacity and the leakage inductance in lowering the amplifier gain with frequency increase in the upper portion of the range, further control of the amount of the negative feedback may be provided by suitable design of the feedback circuit. For example, when it is desired to accentuate the decrease of negative feedback with frequency increase in the upper portion of the range, the voltage to be fed back (that is, the voltage across the primary winding of the transformer) may be applied through a resistance to an impedance in the input circuit of the amplifier, this impedance being, for instance, a resistance shunted by a series-connected resistance and capacity so that the value of the impedance decreases with frequency increase in the upper portion of the range.

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

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

Fig. 2 shows curves facilitating explanation of the operation of the amplifier of Fig. 1.

The amplifier of Fig. 1 comprises two vacuum tubes 1 and 2 in cascade connection. It amplifies signal waves supplied to tube 1 from incoming line or circuit 3 through input transformer 4 and gain control potentiometer 5, and transmits the amplified waves through output transformer 6 to outgoing line or circuit 7. The signals may be, for example, audio frequency signals such as speech or music.

The tubes are coupled by an interstage coupling circuit comprising a coupling resistor 8, stopping condenser 9 and grid leak resistor 10.

Plate voltage for the tubes is supplied through filter 11. Plate current for tube 1 passes through resistors 12 and 8, tube 1, and resistors 13 and 14. Plate current for tube 2 passes through the primary winding 15 of transformer 6, tube 2, and resistor 16.

Resistors 14 and 16, by-passed by condensers 17 and 18, respectively, supply grid biasing potentials for tubes 1 and 2, respectively, and resistor 13 also supplies a grid biasing potential for tube 1.

The resistor 12, a resistor 19, and by-pass condensers 20, 21 and 22 supply steady potentials for biasing the screen grids of the tubes from the plate voltage supply source, as usual.

A feedback connection 23 including a resistor 24 and a stopping condenser 25 of negligibly low reactance connects the plate of tube 2 to the end of resistor 13 at the cathode of tube 1. Thus, since the cathode of tube 2 is connected to the other end of resistor 13 through the by-pass condensers 18 and 17, and since the lower end of winding 15 is connected to the cathode of tube 2 through by-pass condensers 22, the alternating current voltage across winding 15 is fed back across resistor 13 through the feedback connection. This feedback is negative feedback or gain-reducing feedback. Negative feedback is advantageous for example for reducing the modulation and noise in the amplifier, as pointed out in the paper by H. S. Black on Stabilized feed-back amplifiers, Electrical Engineering, January 1934, pages 114–120, and the voltage amplification for propagation once around the feedback loop may be of a large order of magnitude than unity, for obtaining large modulation reduction, as pointed out in that paper.

The feedback connection deriving the voltage to be fed back from across the winding 15 renders it feasible to employ an output transformer of highly economical design yet avoid having the low primary reactance that is entailed by the low cost produce objectionable variation of the transmission efficiency of the amplifier in the signal frequency band.

For example, the primary inductance of the transformer may be so small that, without the feedback, the inductance would cause objectionable lowering of the transmission efficiency of the amplifier with decrease of frequency in the lower portion of the signal frequency range, and the primary capacity of the transformer may be so large that, without the feedback, the capacity would cause objectionable lowering of the transmission efficiency of the amplifier with frequency increase in the upper portion of the band, for instance as indicated by curve A of Fig. 2, wherein each of the curves A, B and C may indicate the variation of the response of the amplifier with frequency under the condition noted at the curve.

The corrective network referred to in Fig. 2 is condenser 26 and resistance 27 connected in series across the resistance 13. When the circuit of this corrective network is open or the network is omitted from the amplifier, but the feedback connection is functioning, the variation of the amplifier gain with frequency may be, for instance, as indicated by curve B. The amount of the negative feedback varies with frequency in response to the change in the impedance of the winding 15 with frequency or in other words varies with frequency in accordance with the variation in the transmission efficiency of the amplifier with frequency, so as to reduce the latter variation.

For instance, at low frequencies where, with decreasing frequency, the inductive reactance of the transformer becomes so low that without the feedback connection the amplifier gain decrease would become too great, the lowering of the inductive reactance or the lowering of the impedance of winding 15 decreases the amount of negative feedback and so reduces the gain decrease, the gain variation with frequency then being, for example, as indicated in curve B.

Similarly, at high frequencies where, with increasing frequency, the primary capacitive reactance of the transformer tends to become so low that without the feedback connection the amplifier gain decrease would become too great, the lowering of the capacitive reactance or the lowering of the impedance of winding 15 decreases the amount of negative feedback and so reduces the gain decrease, the gain variation with frequency then being, for example, as indicated in curve B.

Curve C indicates a further improvement or correction at the high frequencies, to compensate for the effect of the secondary capacity and the leakage inductance of the transformer in lowering the amplifier gain with frequency increase in the upper portion of the signal frequency range, such increase in improvement being obtained by connecting in circuit the corrective network consisting of condenser 26 and resistor 27. This capacitive network decreases the negative feedback with increase of frequency in the upper portion of the signal frequency range, by causing the impedance of the circuit consisting of resistor 13 and the corrective network in parallel to decrease with the frequency increase and thus reduce the ratio of the voltage across this circuit to the voltage across the resistor 24, with the frequency increase.

When the frequency is high enough to render the shunting effect of the corrective network upon the resistance 13 appreciable and render the voltage across resistor 27 appreciable in comparison to the voltage across condenser 26, the corrective network decreases the amount of negative feedback with increase of frequency, for frequencies below those at which the reactance of condenser 26 is negligible compared to the impedance of resistor 27.

At these high frequencies, therefore, the gain of the amplifying portion of the circuit is made relatively great compared with the gain at other portions of the band, and this increased gain overcomes the relatively high loss in the output circuit coupling at high frequencies.

Even in the case in which the tube 2 is a screen grid tube or a pentode tube, supplying the space current of the tube through the winding 15 tends to lower the inductance of the transformer greatly, or greatly increase the cost of the transformer for a given value of inductance. It has been found that the feed-back circuit of Fig. 1 can readily reduce by a factor of ten, for example, the inductance required in the transformer in order to keep the gain variation of the amplifier within given limits.

What is claimed is:

1. A wave translating system comprising an audio frequency amplifier, an input circuit for supplying an audio frequency band of signal waves thereto, said amplifier having an output transformer whose primary inductance is sufficiently low to cause objectionable lowering of the transmission efficiency of said system with frequency decrease in the lower portion of said band and whose leakage inductance and secondary capacity are sufficiently large to cause objectionable lowering of the transmission efficiency of said system with increase of frequency in the upper portion of said band, an impedance in said input circuit, and a feedback path from said output transformer to said input circuit, said path comprising a resistor connected in series with said impedance across the primary winding of said transformer, said resistor feeding back across said impedance a voltage derived from the primary winding of said transformer in gain-reducing phase, said impedance comprising a resistance shunted by a capacitive impedance, said inductance of said transformer tending to cause said gain-reducing feedback to decrease with frequency in said lower portion of said band, and said capacitive impedance reducing the ratio of the voltage across the first-mentioned impedance to the voltage across said resistor with frequency increase in said upper portion of said band and thereby decreasing said gain-reducing feedback with frequency increase in said upper portion of said band, to compensate for said lowering of transmission efficiency caused by said leakage inductance and secondary capacity.

2. A wave translating system comprising an amplifier for a frequency band of signal waves, input and output circuits therefor, an impedance connected as a two-terminal impedance in said input circuit, said output circuit having reactance that tends to lower the amplifier gain with frequency increase in a portion of said band, and a feedback connection from said output circuit to said input circuit, said connection comprising a resistance connected in series with said impedance across said output circuit with one end of said resistance at the potential of one of said terminals for signal frequencies, said resistance deriving from said output circuit a voltage proportional to that across said output circuit and feeding said derived voltage back through said

resistance across said two terminals of said impedance in said input circuit in gain-reducing phase, and said impedance comprising capacitive reactance that reduces the ratio of the voltage across said impedance to the voltage across said resistance with frequency increase in said portion of said band, thereby reducing said gain-reducing feedback with said frequency increase and compensating for said tendency of said reactance of said output circuit to lower the amplifier gain.

3. A wave translating system comprising two electric space discharge devices each having an anode, a cathode and a grid, a source of waves to be translated by said system for connection to one of said devices, an output transformer for said system having its primary winding connected between the anode and the cathode of said other device, and circuits coupling said devices in a closed feedback loop having the voltage amplification for propagation once around the loop large compared to unity to reduce distortion introduced by the system below the distortion without feedback, said circuits comprising means connecting the anode of said one device to the grid of the other, an impedance connecting said cathodes, a connection from the grid of said one device through said source to a point on said impedance, and a feedback connection comprising a resistance extending from the terminal of said winding electrically nearest the anode of said other device to a point on said impedance electrically closer than said first point to the cathode of said one device, said feedback connection and the portion of said impedance between said second-mentioned point and the cathode of said other device being connected in series across said winding, and said impedance comprising a resistance between said points and, in shunt to the latter resistance, a capacity and a resistance in series.

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