

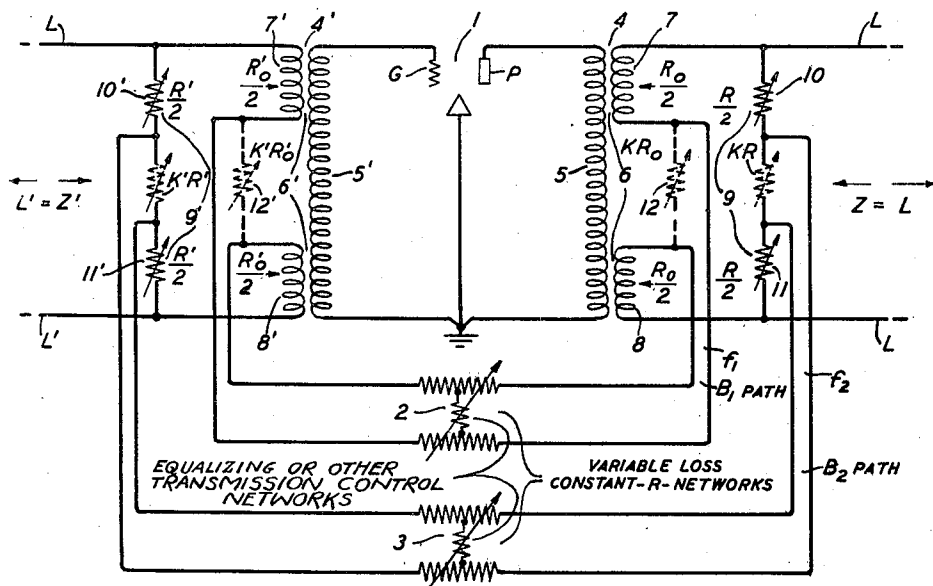
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H. S. BLACK

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ELECTRIC WAVE AMPLIFYING SYSTEM

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INVENTOR
H. S. BLACK
BY *H. A. Burgess*
ATTORNEY

UNITED STATES PATENT OFFICE

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ELECTRIC WAVE AMPLIFYING SYSTEM

Harold S. Black, Elmhurst, N. Y., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

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9 Claims. (Cl. 179-171)

This invention relates to wave amplifying systems.

Objects of the invention are to control gain, feedback and impedances and relations of gain, feedback and impedances in such systems.

It is also an object of the invention to so effect such control that the amplifying systems can be connected to circuits that are unbalanced with respect to ground.

In one specific aspect the invention is an amplifier having two feedback circuits, each including amplifier input and output transformers and each symmetrical or balanced with respect to the two sides of the attached incoming and outgoing circuits, and each, by its feedback, affecting the gain in the same sense as the other, but feedback through one tending to increase the amplifier input or output impedance, or both, and feedback through the other opposing such tendency. For example, the feedback through one feedback circuit may be series-series negative feedback tending to raise the amplifier input and output impedances, and the feedback through the other may be shunt-shunt negative feedback opposing that tendency.

By adjustment of the two feedback circuits or paths, any desired impedance and gain adjustment can be obtained. Moreover, since changes in amplification of the amplifying element affect the series and shunt feedbacks in the same sense, the effects of such changes on amplifier impedance are opposite, tending to neutralize each other so that the amplifier impedance is more stable than with either feedback alone. With sufficient feedback through each path, the amplifier impedance asymptotically approaches an appreciable finite constant value independent of variations in the magnitude of the feedback, this constant value being adjustable at will by adjustment of the relative amounts of series and shunt feedback.

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

The single figure of the drawing is a schematic circuit diagram of an amplifier circuit embodying a form of the invention.

The amplifier shown may be, for example, a stabilized feedback amplifier of the general type in which a portion of the output wave is fed back in gain-reducing phase and in amount sufficient to reduce distortion below the distortion level without feedback. Such feedback is disclosed, for example, in my copending application 606,871 filed April 22, 1932, for Wave translation system,

which issued as Patent No. 2,102,671, and in my article on Stabilized feedback amplifiers published in Electrical Engineering, January 1934, pages 114 to 120.

The amplifying path or element 1 of the amplifier is shown as of the vacuum tube type and may have a single stage or any desired number of tandem connected stages, G and P designating the grid of the first tube and the plate of the last tube. The amplifier comprises, in addition to the amplifying path, two feedback paths or circuits f_1 and f_2 shown as respectively including transmission control networks 2 and 3 of generalized impedances.

The amplifying path or element 1 may be referred to as the μ -circuit, and the feedback circuits or paths f_1 and f_2 may be referred to as the β -circuits or β -paths β_1 and β_2 respectively, the significance of μ and β being as indicated in the application and article just mentioned. The networks 2 and 3 may be referred to as the β -circuit networks. They may be, for example, constant-resistance networks of the type disclosed for instance in Zobel Patent 1,603,305, October 19, 1926, or Stevenson Patent 1,606,817, November 16, 1926.

The amplifier has an output transformer 4 with a primary winding 5 and with a secondary winding 6 connected to outgoing line or circuit L of impedance L. The impedance of the secondary winding, without feedback, is R_o . This secondary winding 6 has two sections 7 and 8, shown as of the same number of turns, serially connected by an impedance 12, shown as of value KR_o , which may be constituted, for example, by the impedance of network 2. K is a constant. Across line L is a resistance 9 in two sections 10 and 11, each shown as of impedance

$$\frac{R}{2},$$

serially connected by an impedance KR which may be, for example, the impedance of network 3.

The amplifier has an input transformer 4' with a secondary winding 5' and a primary winding 6' of impedance R_o' connected to incoming line or circuit L' of impedance L'. The primary winding 6' has two sections 7' and 8', shown as of the same number of turns, serially connected by an impedance 12', shown as of value $K'R_o'$ which may be constituted, for example, by the impedance of network 2. K' is a constant. Across line

L' is a resistance 9' in two sections 10' and 11', each shown as of impedance

$$\frac{R'}{2},$$

- 5 serially connected by an impedance K'R' which may be, for example, the impedance of network 3. If desired, when KR₀ and K'R₀' are equal, network 2 can be omitted and KR₀ and K'R₀' be
10 combined into a single resistor KR₀. Similarly, if desired when KR and K'R' are equal network 3 can be omitted and KR and K'R' be combined into a single resistor R. If KR₀ and K'R₀' are
15 not equal and network 2 be omitted, then KR₀ and K'R₀' can be combined into a single resistor whose value is equal to

$$\frac{KR_0 \cdot K'R'_0}{KR_0 + K'R'_0}.$$

- 20 It is seen that the path f₁ is in serial relation to the line L' with respect to the amplifier input and is in serial relation to the line L with respect to the amplifier output. Thus the feedback through path f₁ is a series feedback at the input
25 side of the amplifier and a series feedback at the output side of the amplifier. Therefore, the feedback through path f₁ will be referred to as a series-series feedback, and path f₁ will be referred to as a series-series feedback path or circuit.

- 30 It is seen that the path f₂ is in shunt relation to the line L' with respect to the amplifier input and is in shunt relation to the line L with respect to the amplifier output. Thus the feedback through path f₂ is a shunt feedback at the input
35 side of the amplifier and a shunt feedback at the output side of the amplifier. Therefore, the feedback through path f₂ will be referred to as a shunt-shunt feedback, and path f₂ will be referred to as a shunt-shunt feedback path or circuit.

- 40 The feedback through path f₁ may be, for example, negative feedback with $\mu\beta_1 \gg 1$ and the feedback through path f₂ may be, for example, negative feedback with $\mu\beta_2 \gg 1$. The feedbacks are applied to the amplifier through the input
45 and output coils or transformers. This procedure includes the coils within the μ -circuit of the feedback loops, thus reducing their distortion by feedback. As a result they will, in general, be cheaper to build and be able to provide much higher
50 gains when desired. Also, since the primary winding of transformer 4' ordinarily will be of low impedance compared to the secondary winding and the secondary winding of transformer 4 ordinarily will be its low impedance winding, the
55 design of the feedback circuits is simplified because any β -circuit networks such as 2 and 3 are in low impedance circuits and stray tube and coil capacity troubles are minimized.

- The impedances R₀, KR₀, KR and R, and similarly the impedances R₀', K'R₀', K'R' and R', may be resistances, for example. Lowering the value of KR₀ tends to lower the loss that this series impedance introduces in transmission between the amplifier and the line L, but tends to
60 reduce the amount of feedback through path f₁; and similarly, lowering the value of K'R₀' tends to lower the loss in transmission from line L' to the amplifier, but tends to reduce the amount of feedback through f₁. On the other hand, increasing the value of R tends to reduce the loss that this shunt impedance introduces in transmission between the amplifier and line L, but tends to reduce the amount of feedback through path f₂; and similarly, increasing R' tends to lower
70 the loss in transmission from line L' to the

amplifier, but tends to reduce the feedback through f₂.

Furthermore, increasing the loss of network 2 decreases the feedback through path f₁ and similarly increasing the loss of network 3 decreases the feedback through path f₂.

In this amplifier circuit line L is not conjugate to the amplifier input impedance Z', nor is the amplifier output impedance Z conjugate to the line L'. Thus a change in the value of L is reflected as a change in Z' and a change in L' produces a change in Z. A decrease in the value of L causes Z' to increase and an increase in the value of L causes Z' to decrease; likewise a decrease in the value of L' causes Z to increase, and an increase in the value of L' causes Z to decrease. However, the effect upon Z' of an increase or decrease in L can be offset by a readjustment of networks 2 and 3 so that no change is observed at Z'; and, similarly, the effect upon Z of an increase or decrease in L' can be offset by a readjustment of networks 2 and 3 so that no change in Z occurs. Thus regardless of the terminating impedances L and L' the amplifier impedances Z and Z' can be adjusted by varying the loss and impedance values of the networks 2 and 3 so that any desired values of Z and Z' can be obtained.

As the magnitude of feedback increases, the input and output impedances Z' and Z will approach

$$Z' = \frac{M'R'[(L+R)(K'+1)+K'R']}{L(M'+K')+M'(K'R'+R)}$$

and

$$Z = \frac{MR[(L'+R')(K+1)+KR]}{L'(M+K)+M(KR+R')}$$

where

$$M' = \frac{\text{resistance } 12'}{\text{resistance } (10' + 11')}$$

and

$$M = \frac{\text{resistance } 12}{\text{resistance } (10 + 11)}.$$

These impedance expressions are valid when networks 2 and 3 have equal losses of any finite value. When the losses of networks 2 and 3 are not equal the values of Z and Z' will be simultaneously lowered by increasing the loss of 2 or decreasing the loss of 3. Similarly the values of Z and Z' will be simultaneously raised by decreasing the loss of 2 or increasing the loss of 3.

Further, the feedbacks through paths f₁ and f₂ tend to make the amplifier input impedance Z' and amplifier output impedance Z independent of the value of either R₀ or R₀'. To illustrate, with large amounts of feedback through paths f₁ and f₂, the feedbacks make the output impedance practically independent of the value of the impedance between the plate P and the cathode structure in the last tube as viewed through transformer 4.

Under these conditions the amplifier output impedance Z is practically independent of the value of R₀ and entirely independent of the impedance L of the line or load into which the amplifier works. On the other hand, variations of the impedance KR₀, KR or R do affect the impedance Z, as shown by the formula given above for the value that Z approaches with large amounts of feedbacks.

Similarly, with large amounts of feedbacks through paths f₁ and f₂, the feedbacks make the amplifier input impedance Z' practically independent of the value of the impedance R₀'. On the other hand, variations of K'R₀', K'R' and R' do affect the amplifier input impedance Z' as

shown by the formula given above for the value of Z' approached with large amounts of feedbacks.

The value of the amplifier input impedance Z' is not dependent upon the value of the impedance L' from which the amplifier works.

As shown by the formulae just mentioned for Z and Z' , the value of Z can be varied, for example by varying KR , without affecting the value of Z' , and, similarly, the value of Z' can be varied, for example by varying $K'R'$, without affecting the value of Z .

With this amplifier circuit, two points are available for control of gain, amplifier impedance and other factors influenced by feedback. For example, networks 2 and 3 may be adjustable resistance pads for controlling gain, or may be variable loss, constant resistance transmission equalizing networks having their attenuation-frequency characteristics simulate the attenuation-frequency characteristic of the circuit in which the amplifier is connected. As indicated above, by having the networks 2 and 3 constant- R networks their loss can be varied, to vary the amplifier gain, without varying the amplifier input or output impedance. On the other hand, as also indicated above, the feedback paths f_1 and f_2 afford means for obtaining a wide range of amplifier impedances, for example by varying KR_0 , KR or R to change the output impedance Z or varying $K'R_0$, $K'R'$ or R' to change the input impedance Z' , without changing the amplifier gain. Since shunt negative feedback reduces the amplifier impedances and series negative feedback raises them, but the gain is reduced as either type of feedback increases, by proper adjustment of the shunt feedback and the series feedback practically any desired gain and amplifier impedances can be obtained with these feedbacks, regardless of the values of the gain and impedances without feedback.

The control of the amplifier input impedance by the feedbacks may be used, for instance, to lower the input impedance and match it to the impedance of the attached incoming circuit for increasing signal to resistance noise ratio in the general manner described in my copending application Serial No. 663,317, filed March 29, 1933, for Wave translation system.

The control of the amplifier output impedance by the feedbacks may be used, for example, to raise or lower the amplifier output impedance without materially changing the impedance into which the output tube works, so that in the general manner described in the copending application Serial No. 663,317, the output tube, though its impedance may differ from its optimum load impedance, can be worked into an impedance having substantially that optimum value and at the same time the amplifier output impedance can be matched to the impedance of the outgoing line, without undue transmission loss.

It is emphasized that the amplifier can be used in either a balanced or unbalanced system, as regards balance-to-ground. Either or both of the lines L and L' can be balanced or unbalanced with respect to ground.

What is claimed is:

1. An amplifier having a plurality of feedback circuits producing a substantial amount of resultant feedback from its output circuit to its input circuit, a wave transmission circuit connected to said amplifier, the feedback through certain of said feedback circuits tending to produce increase in the amplifier impedance that faces said

transmission circuit, and the feedback through the others so opposing said tendency that, with a substantial amount of resultant feedback, said amplifier impedance asymptotically approaches an appreciable and finite constant value independent of variations in the resultant feedback.

2. An amplifier having series-series and shunt-shunt feedback paths, with the feedback through said paths sufficient in magnitude and of such relative values as to cause the amplifier input and output impedances asymptotically to approach an appreciable and finite fixed value independent of variations in resultant feedback.

3. A wave amplifying system and a circuit coupled thereto, said system having two feedback paths, each balanced with respect to the two sides of said circuit and each by its feedback affecting the amplifying gain of said system in the same sense as the other, but one tending to increase and the other to decrease the impedance of said system that faces said circuit.

4. An amplifier having an amplifying element and having a transformer, and a wave transmission circuit, said transformer having one winding connected to said amplifying element and another winding connected to said transmission circuit, and said amplifier having two feedback paths each connected to said other winding for feeding waves from the output side of said amplifier to the input side of said amplifier through said transformer, each of said feedback paths being symmetrical with respect to the two sides of said circuit and each by its feedback affecting the amplifier gain in the same sense as the other, but one increasing and the other decreasing the amplifier impedance that faces said transmission circuit.

5. An amplifier having its amplifying element unsymmetrical with respect to ground and having input and output transformers, and a wave transmission circuit connected to one of said transformers, said amplifier having two feedback paths from the output side of the output transformer to the input side of the input transformer, each of said paths being symmetrical with respect to the two sides of said circuit and each by its feedback affecting the amplifier gain in the same sense as the other, but one increasing and the other decreasing the amplifier impedance that faces said transmission circuit.

6. An amplifier having input and output transformers and incoming and outgoing circuits respectively connected to the input side of said input transformer and the output side of said output transformer, said amplifier having two feedback paths each producing negative feedback from the output side of said output transformer to the input side of said input transformer, each of said paths being symmetrical with respect to the two sides of said circuit and each, by its feedback, affecting the amplifier gain in the same sense as the other, but one tending to increase and the other to decrease each of the amplifier impedances that face said transmission circuits.

7. An amplifier having series-series and shunt-shunt feedback paths, and a variable loss network of the constant-resistance type in one of said paths.

8. An amplifier having series-series and shunt-shunt feedback paths, and variable loss networks of the constant-resistance type, one in each of said paths.

9. An amplifier having input and output circuits and having input and output impedances, a wave source attached to said input impedance,

a load circuit attached to said output impedance, and two feedback impedances, one of said feedback impedances and the load circuit being in serial relation with respect to the amplifier output circuit, and the amplifier input circuit and said one impedance being in serial relation with

respect to the source, and the source in parallel with the amplifier input impedance and said one feedback impedance in series, being connected across the other feedback impedance and the load circuit in parallel.

HAROLD S. BLACK.