

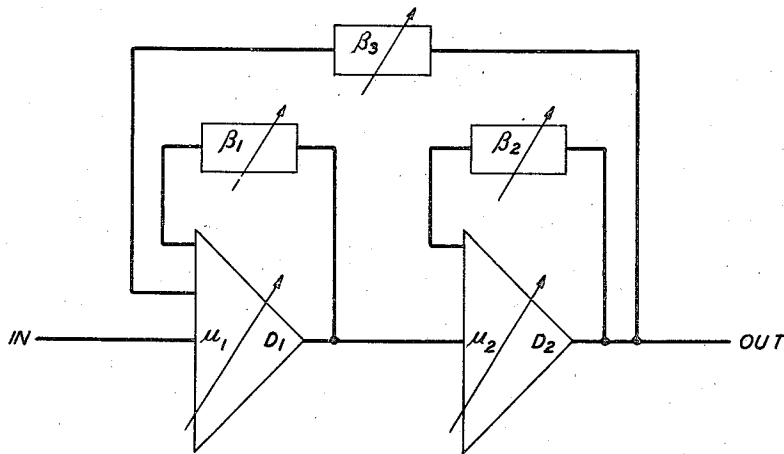
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Q. E. GREENWOOD

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FEEDBACK AMPLIFIER

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INVENTOR
Q. E. GREENWOOD
BY
B. L. Heger
ATTORNEY

UNITED STATES PATENT OFFICE

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FEEDBACK AMPLIFIER

Quentin E. Greenwood, Flushing, N. Y., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

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1 Claim. (Cl. 179-171)

This invention relates to feedback amplifiers. An object of the invention is to reduce modulation produced by an amplifier, especially modulation components in the amplifier output originating in different stages or cascaded amplifying portions of the amplifier.

In accordance with the invention as applied, for instance, to a two-stage amplifier, the modulation is reduced to a low value by means of multiple feedback paths, the reduction being accomplished, for example, as described hereinafter, by so adjusting the feedback circuits that the distortion voltages arising in the first and second stages partially cancel each other at the repeater output.

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

The two-stage amplifier is shown schematically in the single figure of the drawing. Each stage may contain one or more tubes, and the tubes may be cascaded in the stage. Feedbacks through the β_1 and β_2 paths are adjusted to give the low modulation condition while the β_3 feedback can be used to give the amplifier a frequency characteristic and the proper stability, and to further reduce the modulation.

Referring to the drawing, the expression for the output distortion voltage D_0 is found to be

$$D_0 = \frac{D_2(1 - \mu_1\beta_1 + \mu_2\frac{D_1}{D_2})}{1 - \mu_2\beta_2 + (\mu_1\beta_1)(\mu_2\beta_2) - \mu_1\beta_1 - \mu_1\mu_2\beta_3} = \frac{D_2[1 - \mu_1\beta_1 + \mu_2\frac{D_1}{D_2}]}{(1 - \mu_1\beta_1)(1 - \mu_2\beta_2) - \mu_1\mu_2\beta_3} \quad (1)$$

where μ_1 and μ_2 are the voltage gains of the first and second stages, β_1 , β_2 , β_3 are the losses in the feedback paths expressed as a voltage ratio. D_1 is the distortion voltage without feedback at the first stage output for a specified input level. Similarly D_2 is the distortion voltage without feedback at the amplifier output due to the non-linear elements in the second stage for a specified fundamental input level.

From the above expression, it may be seen that the distortion voltage D_0 approaches zero when

$$\mu_1\beta_1 = 1 + \mu_2\frac{D_1}{D_2} \quad (2)$$

The values of D_1 and D_2 are determined by the fundamental voltage applied at the input grids of

the first and second stages, respectively. These fundamental voltages differ by the factor

$$\frac{(1 - \mu_2\beta_2)}{\mu_1}$$

thus the ratio

$$\frac{D_1}{D_2}$$

can be expressed

$$\frac{D_1}{D_2} = \frac{f_1(e_1)}{f_2(e_2)} = \frac{f_1(e_2 \times \frac{(1 - \mu_2\beta_2)}{\mu_1})}{f_2(e_2)} \quad (3)$$

where e_1 and e_2 are the amplitudes of the fundamental voltages at the first and second stage inputs. Substituting this into Equation 2, the condition for zero output distortion becomes,

$$\mu_1\beta_1 = 1 + \mu_2 \frac{f_1(e_2 \times \frac{(1 - \mu_2\beta_2)}{\mu_1})}{f_2(e_2)} \quad (4)$$

Since $f_1(0) = 0$, this equation is satisfied if the feedback factor or loop propagation $\mu_2\beta_2 = 1$ and the feedback factor $\mu_1\beta_1 = 1$.

Other values may also be assigned $\mu_1\beta_1$ and $\mu_2\beta_2$ which approximately satisfy Equation 4. For example, in most vacuum tubes the distortion voltages D_1 and D_2 contain second order terms which are large compared with the third, fourth, etc. order terms. The magnitudes of these second order terms are approximately proportional to the square of the input grid level, hence the value of

$$\frac{D_1}{D_2}$$

may be written

$$\frac{D_1}{D_2} = \frac{A_1 e_1^2}{A_2 e_2^2} = \frac{A_1}{A_2} \times \left[\frac{1 - \mu_2\beta_2}{\mu_1} \right]^2$$

where A_1 and A_2 are circuit constants. Substituting in Equation 2, the condition for minimum second order distortion becomes

$$\mu_1\beta_1 = 1 + \mu_2 \left[\frac{1 - \mu_2\beta_2}{\mu_1} \right]^2 \times \frac{A_1}{A_2} \quad (5)$$

Similarly, for a circuit in which the third order terms are relatively large, the condition for minimum distortion would be

$$\mu_1\beta_1 = 1 + \mu_2 \left[\frac{1 - \mu_2\beta_2}{\mu_1} \right]^3 \times \frac{A_{11}}{A_{12}} \quad (6)$$

since the third order terms are approximately proportional to the input level cubed.

Suitable values for $\mu_1\beta_1$ and $\mu_2\beta_2$ can be chosen to satisfy Equation 5 or 6 when μ_1 , μ_2 , and β_1 (or β_2) are known. Some examples will be given based on values of μ_1 , μ_2 , β_1 and β_2 which are constant in the band. It will be assumed that each stage consists of a single tube and that $A_1 = (+)KA_2$, K being a positive constant. This assumption means that for the two tubes, the distortion products of a given order are of the same sign but not necessarily the same magnitude (a condition ordinarily satisfied by common types of practical tubes). Then, in Equation 5, taking $\mu_1 = \mu_2 = -10$ and $\mu_2\beta_2 = -5$, we get

$$\mu_1\beta_1 = 1 - 1.6 \frac{A_1}{A_2}$$

which approximates $-.6$ when $A_1 = A_2$. Again, in Equation 5, taking $\mu_1 = \mu_2 = -10$ and $\mu_2\beta_2 = -5$, we get

$$\mu_1\beta_1 = 1 - 3.6 \frac{A_1}{A_2}$$

which approximates -2.6 when $A_1 = A_2$. Again, in Equation 5, taking $\mu_1 = \mu_2 = -10$ and $\mu_2\beta_2 = -2$ we get

$$\mu_1\beta_1 = 1 - .9 \left(\frac{A_1}{A_2} \right)$$

which approximates 0.1 when $A_1 = A_2$. Now, in Equation 5, assuming that $\mu_1 = -10$, but that (for example by using in the second stage a phase reversing transformer or two tubes in tandem) μ_2 is made equal to $+10$, and taking $\mu_2\beta_2 = -7$, we get

$$\mu_1\beta_1 = 1 + 6.4 \left(\frac{A_1}{A_2} \right) \doteq 7.4$$

Whether high or low values are chosen may depend upon the particular circuit under consideration. Small parasitic feedbacks may make it undesirable to make $\mu_1\beta_1$ and $\mu_2\beta_2$ small.

When Equation 4 is satisfied by making $\mu_1\beta_1$ and $\mu_2\beta_2$ equal to unity, the feedback at the distortion frequencies is effectively very large. For other values of $\mu_1\beta_1$ and $\mu_2\beta_2$ which satisfy Equations 5 or 6, the distortion voltages from the first and second stages partially cancel at the am-

plifier output. In either case the modulation is reduced to a low value.

The gain of the amplifier is given by

$$\text{Gain} = \frac{\mu_1\mu_2}{(1 - \mu_1\beta_1)(1 - \mu_2\beta_2) - \mu_1\mu_2\beta_3}$$

Since the $\mu_1\mu_2\beta_3$ term in the denominator does not appear in Equations 4, 5 and 6, it can have any desired value that is compatible with stability of the amplifier. It can therefore be used to determine the amplifier gain, to further reduce the modulation and to give the proper stability to the amplifier. The amplifier will be stable if the polar plots of the following quantities for frequencies from zero to infinity do not encircle or pass through the point $1, <0$.

$$\mu_1\beta_1 + \frac{\mu_1\mu_2\beta_3}{1 - \mu_2\beta_2}$$

$$\mu_2\beta_2 + \frac{\mu_1\mu_2\beta_3}{1 - \mu_1\beta_1}$$

$$\frac{\mu_1\mu_2\beta_3}{(1 - \mu_1\beta_1)(1 - \mu_2\beta_2)}$$

The first and second expressions are the total feedback factors for the first and second stages; the third is the feedback factor at points in the circuit not included in the β_1 and β_2 loops.

What is claimed is:

An amplifier having individual feedback paths of propagations β_1 and β_2 respectively around first and second cascaded amplifying portions forming therewith two feedback loops of loop propagations $\mu_1\beta_1$ and $\mu_2\beta_2$, respectively, and an over-all negative feedback path around both portions forming therewith a third feedback loop, $\mu_1\beta_1$ and $\mu_2\beta_2$ differing from unity, $\mu_1\beta_1$ minus unity being equal to μ_2 times the ratio of the magnitude of a given order of distortion components generated by the first and second amplifying portions at their respective outputs without feedback, and said portions and paths having propagations adapted to maintain the amplifier stable.

QUENTIN E. GREENWOOD.