

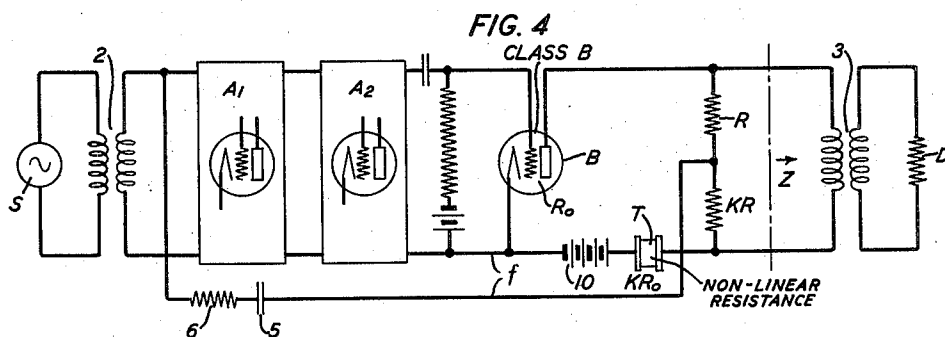
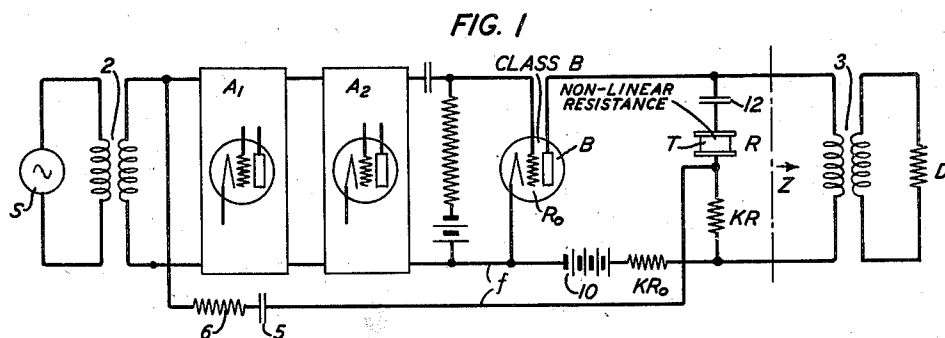
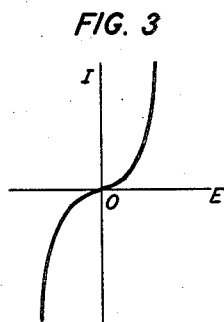
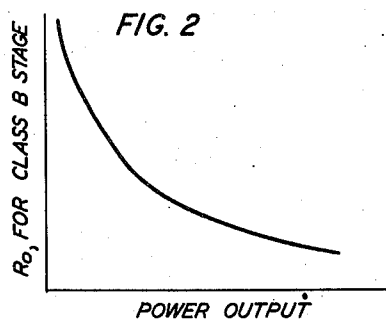
Dec. 28, 1937.

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2,103,490

WAVE TRANSLATING CIRCUITS

Filed April 1, 1936



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2,103,490

WAVE TRANSLATING CIRCUITS

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Application April 1, 1936, Serial No. 72,146

8 Claims. (Cl. 179-171)

This invention relates to wave translation and especially to retroaction or feedback in wave translating systems as, for example, in systems involving vacuum tubes or electric wave amplifying devices.

An object of the invention is to control transmission properties of such systems as, for example, to control modulation, impedance relations and plate power efficiency in such systems.

It is especially an object of the invention to control feedback in such systems.

The invention also aims to facilitate application of feedback in such systems.

It is also an object of the invention to control the phase of waves fed back in such systems.

A further object is to reduce singing tendency in such systems as, for example, to so control the phase of waves fed back as to reduce singing tendency in amplifiers that feed back a portion of the output waves in gain-reducing phase and in amount sufficient to reduce distortion below the distortion level without feedback.

In one specific aspect, the invention is embodied in such an amplifier with an output bridge network that, in known fashion, has the plate-cathode impedance R_o in the tube (or tubes) of the final stage in a ratio arm of the bridge and has the load circuit and the feedback path in opposite diagonals of the bridge to render the load circuit and the feedback path conjugate and consequently prevent the load impedance from affecting the feedback action.

In some cases, the impedance R_o might vary widely, tending to unbalance the bridge and destroy the desired conjugacy. For example, if it were attempted to use an output bridge in a class B output stage (i. e., an output stage operated in accordance with so-called class B operation, in which the grid potential is such that the plate current without feedback would be interrupted for the order of half the period of the waves being amplified), a balance ordinarily would be obtained at only one input since the tube impedance R_o would change greatly with grid swing. Hence, the load impedance would affect the phase shift characteristic of the feedback loop and increase the difficulty of insuring against singing.

To remedy this defect in accordance with the invention, a suitable non-linear impedance element may be used to provide a variable impedance in one arm of the bridge which may be used to balance the tube approximately.

This may be done, for example, as indicated in detail hereinafter, by using the variable alternating current swing of the output voltage of the

tube to vary the impedance of the non-linear impedance element or by so using the variable alternating current swing and, at the same time, using the variable space current to vary the operating point of the non-linear impedance element (i. e., to variably bias it).

As indicated above, in the operation of feedback amplifiers, especially with class B output stages, loop gain (i. e., the decibel gain for a single trip around the feedback loop) and loop phase shift (i. e., the phase shift experienced by waves in passing once around the feedback loop) present important limitations.

Objects of the invention are to control such loop phase shift and gain.

The invention also aims to so control such loop phase shift and gain as to reduce singing tendency or increase the distortion suppression obtainable.

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

Figs. 1 and 4 are circuit diagrams of two forms of the invention which are specifically mentioned above; and

Figs. 2 and 3 show curves for facilitating explanation of the invention.

Fig. 1 shows a feedback amplifier of the type referred to above. The amplifier is shown by way of example as a three-stage amplifier. The first and second stages A_1 and A_2 may be class A stages, and the third stage may be a class B stage with the vacuum tube B having its plate-cathode space path resistance R_o vary widely with grid swing, as indicated by the curve of Fig. 2 between R_o and power output of the tube.

The stages of the amplifier may have resistance-capacity coupling, for example. A source S supplies waves, for example, speech waves, to the input of stage A_1 through input transformer 2. The amplified waves are transmitted from tube B to the load or receiving circuit which may comprise an output transformer 3 and a receiving device D of any suitable character as, for example, a loud-speaker for reproducing sound waves. The load impedance is designated Z, as indicated in the drawing.

The impedance R_o is one ratio arm of an output bridge network. The other ratio arms are resistances KR_o , KR and R . The load impedance Z is in one of the bridge diagonals. The other diagonal includes a feedback path f , which may include a stopping condenser 5 and a resistance 6 for controlling the amount of the feedback.

A space current supply source 10 supplies space current for tube B through resistance KR_o and the

primary winding of the transformer 3. A stop-ping condenser 12 prevents flow of direct current from source 10 through resistance R.

Since the resistance R_0 is the plate resistance of a class B stage, the magnitude of R_0 varies widely with grid swing as indicated in Fig. 2, and consequently tends to unbalance the bridge and thus destroy the desired conjugacy of the load and the feedback path. However, the resistance R may be a non-linear resistance suitable for compensating for this unbalancing tendency.

For example, the resistance R may be that of a resistance device T of the type composed of finely divided conducting or semi-conducting crystalline particles or particles of crystalline substances held in random contact within a binder or matrix of non-conducting or insulating material to form a solid element or aggregate with a suitable non-rectilinear current-voltage characteristic or non-linear conductivity or resistance, the term non-linear signifying that the voltage-current ratio or the resistance is not independent of the magnitudes of voltage and current.

One example of a suitable material of this type is a mixture of silicon carbide and carbon with clay as a binder, made as specified in United States Patent 1,822,742, issued September 8, 1931, to K. B. McEachron. A well-known material of this kind has the commercial name "Thyrite". The device T has symmetrical non-linear conductivity as illustrated in Fig. 3 which shows a curve representing current through the device as a function of voltage across the device. The current is designated I and the voltage E. The curve shows the current increasing much more rapidly than in proportion to the voltage. The resistance of the device for any current or voltage, being given by

$$\frac{E}{I}$$

is, of course, also symmetrically non-linear. The general form of the resistance-current characteristic is shown in Fig. 2 of the above-mentioned patent to McEachron, for example. The device T or any equivalent device with the property of suitably changing its impedance upon change of applied voltage may be used as indicated herein for carrying out the principles of the present invention.

As the grid swing in the tube B increases from a normal or chosen magnitude and consequently tends to increase the voltage across T, the current through T will increase and the resistance of T will decrease. As will be apparent for example from the disclosure in the above-mentioned McEachron patent, composition and dimensions of the non-linear resistance material can be selected to make the current-resistance characteristic of T such that the decrease of resistance of T compensates for the bridge unbalancing tendency of decrease of R_0 and maintains the bridge approximately balanced. Similarly, increase of R_0 will be accompanied by increase of the resistance of T to maintain approximate bridge balance. Thus, in the bridge network the ratio arm containing T approximately balances the arm containing R_0 , notwithstanding the wide variation of R_0 with grid swing.

In Fig. 4 the resistance KR_0 , instead of the resistance R, is shown as the compensating non-linear resistance T. It is shown as in serial relation with R_0 and source 10 with respect to direct current, so that its impedance is controlled not only by the alternating current or voltage

output of tube B but also by the direct current that flows through R_0 or the direct current voltage applied to T. Thus, with increase of the grid swing in tube B from a normal or chosen value and consequent increase of the alternating voltage across T (or alternating current through T), and the direct current biasing voltage across T (or direct current through T), the resistance of T will decrease because of the increase of biasing voltage or direct current as well as because of the increase of alternating voltage or current; and, as will be apparent from the disclosure in the above-mentioned McEachron patent, the current-resistance characteristic of T can be chosen accordingly to compensate for the bridge unbalancing effect of change in R_0 and maintain the bridge approximately balanced. In other words, in the bridge network the ratio arm T approximately balances the arm containing R_0 and, as was the case in the amplifier of Fig. 1, the desired conjugacy of load and feedback path is approximately maintained despite wide variation of R_0 with grid swing. As indicated above, this conjugacy prevents the load impedance Z from affecting the phase characteristic of the feedback loop and thus facilitates control of singing tendency, and is especially desirable in amplifiers whose loop gains in the utilized frequency range are high (for example, several times ten decibels) for obtaining large distortion reduction by feedback.

What is claimed is:

1. A wave translating system comprising, in combination, an amplifying device having a space discharge path and operating in accordance with so-called class B operation in which the steady grid potential is such that the plate current without feedback would be interrupted for the order of half the period of the waves being amplified, a feedback path for feeding back a portion of the output waves in gain-reducing phase and in amount sufficient to reduce the distortion below the distortion level without feedback, an outgoing circuit, and an output bridge for rendering said outgoing circuit and said feedback path conjugate, said bridge having said space discharge path in a ratio arm and having a non-linear impedance device in a second ratio arm, the impedance of said space discharge path varying widely upon wide change of grid swing, and the impedance of said non-linear impedance device correspondingly varying to compensate for variation of the impedance of said space discharge path and balance said bridge.

2. An amplifier comprising an amplifying element whose output impedance varies with variation of the magnitude of the waves to be amplified by said amplifying element, a feedback path for producing negative feedback in the amplifier for reducing modulation in the amplifier, an outgoing circuit for the amplifier, and an amplifier output bridge having said feedback path and said outgoing circuit in its diagonals, respectively, and having the output impedance of said amplifying element in a ratio arm of the bridge, and an impedance device having a non-linear voltage-current characteristic in another ratio arm of the bridge for balancing the variable output impedance of said amplifying element and rendering the bridge diagonals conjugate.

3. An electric space discharge device having an output stage including an electric space discharge tube with anode, cathode and grid elements, a source of input waves therefor, means for causing extinction of the anode-cathode space cur-

rent of said tube during an appreciable portion of the negative swing of waves from said source, a feedback path for producing feedback in said device of waves that reduce the magnitude of its output waves below their magnitude without feedback, an outgoing circuit for said device, a bridge network for rendering said outgoing circuit and said feedback path conjugate at balance of said bridge network, said bridge network having the anode-cathode space path of said tube in a ratio arm of the bridge network, and a non-linearly conductive device in another ratio arm of the bridge network to compensate for unbalancing effect upon said bridge network of change in impedance of said anode-cathode space path with change of grid potential swing in said tube.

4. A wave translating device having a space discharge path subject to change of its alternating current impedance, a feedback path and an output circuit, and means cooperating with said space discharge path, said feedback path and said output circuit to form therewith a network having balancing arms for rendering said feedback path and said output circuit conjugate, said network having said space discharge path in one of said balancing arms and having in another of said balancing arms a non-linear impedance device responsive to current change in said space discharge path to compensate for unbalancing effect of said impedance change of said space discharge path upon said network.

5. A wave translating device having a space discharge path, a feedback path and an output circuit, and means cooperating with said space discharge path, said feedback path and said output circuit to form therewith a bridge network, said bridge network having said feedback path and said output circuit in branches of said bridge network that are conjugate at balance of the bridge network, and having said space discharge path in a ratio arm of the bridge network, and having in another ratio arm of the bridge network a resistance device with a non-linear current-resistance characteristic responsive to current change in said space discharge path to compensate for unbalancing effect of impedance change of said space discharge path upon said bridge network.

6. A space discharge device having a space discharge path of variable alternating current impedance, a space current supply source, an output circuit, a feedback path, means cooperating with said space discharge path, said feedback

path and said output circuit to form therewith a bridge network for rendering said feedback path and said output circuit conjugate, said bridge network having said variable impedance space discharge path in a ratio arm of the network and having in an adjacent ratio arm a non-linear impedance device of correspondingly variable impedance for balancing the impedance of said space discharge path.

7. A space discharge device having a space discharge path, a space current supply source, an output circuit, a feedback path, means cooperating with said space discharge path, said feedback path and said output circuit to form therewith a bridge network for rendering said feedback path and said output circuit conjugate, said space discharge path being in a ratio arm of said bridge network and having its alternating current impedance vary with change of swing of the voltage delivered to said output circuit, said bridge network having in an adjacent ratio arm, a symmetrically non-linearly conductive solid impedance element whose impedance varies with said change of swing to compensate for the bridge unbalancing tendency of said variation of the impedance of said space discharge path, and a stopping condenser in serial relation with said impedance device and said space discharge path with respect to said source.

8. A space discharge device having a space discharge path, a space current supply source, an output circuit, a feedback path, means cooperating with said space discharge path, said feedback path and said output circuit to form therewith a bridge network for rendering said feedback path and said output circuit conjugate, said bridge network having said space discharge path in a ratio arm of the network and having in an adjacent ratio arm a non-linear impedance device, said impedance device being in serial relation with said source and said space discharge path with respect to direct current and comprising crystalline particles held in random contact by an insulating binder, said space discharge path having its alternating current impedance vary with change of swing of the alternating current therethrough, and said impedance device having its alternating current impedance controlled by said swing and by the direct space current from said source to compensate for the bridge unbalancing tendency of said variation of the impedance of said space discharge path.

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