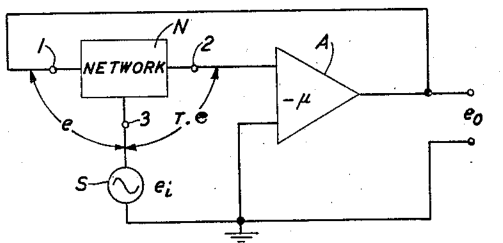
Jan. 11, 1949. J. W. RIEKE 2,459,046

NEGATIVE FEEDBACK AMPLIFIER

Filed Jan. 30, 1946

FIG. 1



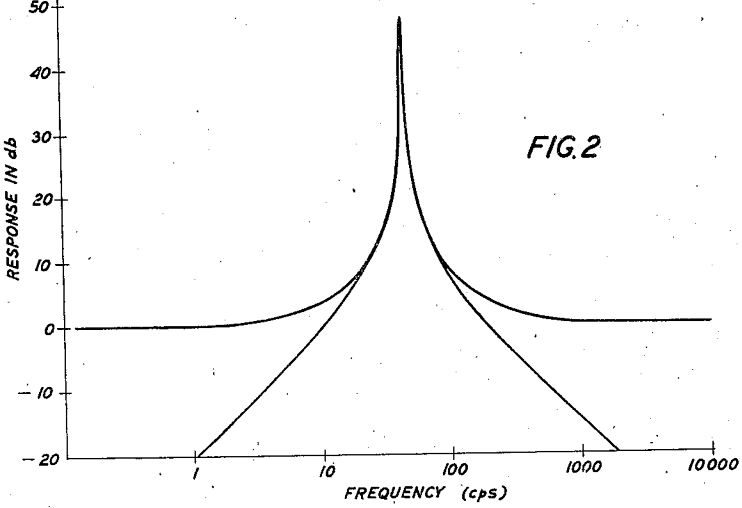
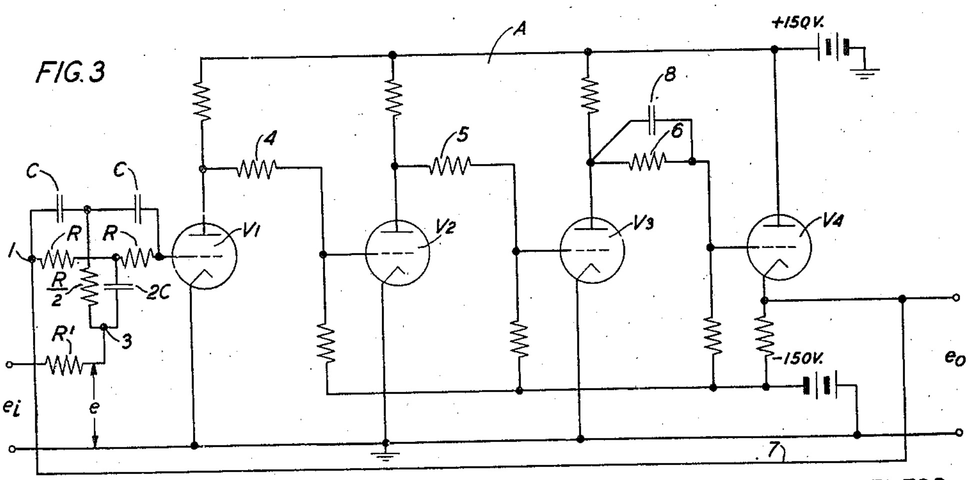


FIG. 3



INVENTOR
J. W. RIEKE

BY B. C. Seger

ATTORNEY

Patented Jan. 11, 1949

2,459,046

UNITED STATES PATENT OFFICE

2,459,046

NEGATIVE FEEDBACK AMPLIFIER

John W. Rieke, Astoria, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application January 30, 1946, Serial No. 644,271

8 Claims. (Cl. 179—171)

1

This invention relates to wave amplifying systems.

An object of the invention is to improve their frequency selectivity by negative feedback.

Three-terminal resistance-capacitance null networks one terminal of which may be grounded, for instance a parallel T-network, have been used in the return path of negative feedback amplifiers to produce sharply tuned transmission characteristics, for example as described in Patent 2,173,426 to H. H. Scott or in his paper entitled "A new type of selective circuit and some applications," Proceedings of the Institute of Radio Engineers, February 1938, page 226. The sharpness of the resulting transmission, Q, is determined by the amount of amplifier gain available. A Q factor of several hundred may be obtained in this manner.

In accordance with the present invention, the network terminal which heretofore has been grounded is, instead, used as the signal input terminal. Thus, the tree-terminal network has one terminal connected to the amplifier output circuit, a second connected to the amplifier input circuit, and the third connected through the signal source to a common point of the amplifier input and output circuits. This connection of the signal source between the third terminal of the network and the common point of the amplifier input and output circuits improves the transmission characteristic of the feedback amplifier as explained hereinafter. An additional terminal is available for signal input which mixes the input signal with the feedback signal without requiring the usual mixing elements and which provides ideal input and network terminating impedances.

It is an object of the invention to facilitate obtaining desirable values of input and network terminating impedances in the circuit of an amplifier having a three-terminal feedback network for controlling the amplifier transmission.

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

Fig. 1 is a block diagram, and Fig. 3 a circuit diagram, of an amplifier embodying a form of the invention; and

Fig. 2 shows transmission characteristics indicating improvement obtained by the invention.

In Fig. 1 an amplifier A with a gain equal to $-\mu$ is connected between the output and input terminals 1 and 2 of a three-terminal null network N whose transmission, T, is a function of

2

frequency. A source S of signal or input voltage e_i is connected from the third terminal or common input-output terminal 3 of the network to ground or the common input-output terminal of amplifier A. Then the amplifier output voltage is

$$e_0 = -e_i \frac{\mu(1-T)}{1+\mu T}$$

Thus, when $T=1$ there is no forward gain or, in other words, the gain of the feedback amplifier is zero. The usual R-C null networks have transmission values of unity when the frequency approaches zero or infinity and values near zero when the frequency approaches null frequency. Such a network, when used as network N in Fig. 1, makes the gain of the feedback amplifier equal $-\mu$ at null frequency and tend toward zero at higher and lower frequencies; whereas, when used in the conventional manner it makes the gain equal

$$\frac{\mu}{1+\mu T}$$

which does not tend toward zero at high and low frequencies, but approaches

$$\frac{\mu}{1+\mu}$$

as a limit. The difference between the characteristics is shown by Fig. 2, from which the increase in sharpness of tuning or selectivity is apparent. In this case, a double T R-C null network is used with an amplifier having 48 decibels gain.

In the practical case the amplifier gain for this example is much higher than 48 decibels, the amplifier being, for instance, a multistage amplifier as shown in Fig. 3, and the excess gain is useful for stabilizing the circuit variations. The gain of the feedback amplifier at the network null frequency is made equal to 48 decibels by inserting in series with the middle terminal 3 of the network N a resistance R′ which makes the loss of the feedback path or β-circuit at the null frequency equal to 48 decibels instead of infinite loss. This result can also be achieved by a deliberate network unbalance. The amplifier A shown by way of example in Fig. 3 is a four-stage amplifier, the last stage being a cathode follower stage, and comprises vacuum tubes V1, V2, V3 and V4 with resistance 4 connecting the plate of tube V1 to the grid of tube V2, resistance 5 connecting the plate of tube V2 to the grid of tube V3, and resistance 6 connecting the plate of tube V3 to the grid of tube V4. Conductor 7 connects the cathode of tube V4 to terminal 1 of the three-terminal null network N, terminal 2 of the network being connected to the grid of tube V1. Terminal 3 of the network is connected through resistance R′ and the signal input source e_i to a terminal, shown grounded, common to the amplifier input and output circuits. Condenser 8 across resistance 6 assists in maintaining the total phase shift through the amplifier and feedback network less than 360 degrees at the frequencies where the amplifier gain falls off to zero (decibles), thus suppressing the singing tendency of the amplifier.

In Fig. 3 the elements of network N are proportioned as indicated on the drawing. Referring to this figure,

$$\frac{e_0}{e}=-\frac{\mu K}{1+K+\mu}\cdot\frac{1}{1+j\frac{K(1+\mu)}{4(K+1+\mu)}\left(\frac{f}{f_0}-\frac{f_0}{f}\right)}$$

where μ is the amplifier gain,

$$K=\frac{R}{R'}$$

and

$$f_0=\frac{\frac{1}{2\pi RC}}{\sqrt{1+\frac{4R'}{R}}}=\frac{1}{2\pi RC\sqrt{1+\frac{4R'}{R}}}$$

The Q of the response characteristic is given by:

$$Q=\frac{K(1+\mu)}{4(K+1+\mu)}$$

If $\mu>>K$,

$$Q=\frac{K}{4}\quad\text{and}\quad\frac{e_0}{e}=4Q\frac{1}{1+jQ\left(\frac{f}{f_0}-\frac{f_0}{f}\right)}$$

The connection of the present invention, applying the signal to the network terminal that heretofore normally has been grounded, provides greater circuit flexibility and thereby achieves the improved characteristic pointed out above and an economy of gain and circuit elements.

When using feedback through a network to control the transmission characteristic of an amplifier, the output signal must be returned through the network to the input. The signal to be amplified must be mixed linearly with the feedback signal at the input. This is frequently done by the use of transformers whose windings may be inserted in series with the feedback signal lead at the input; by the use of mixing networks; or by the use of a vacuum tube to mix the two signals. In certain cases the input signal or feedback signal circuits will permit the injection of one or the other of these signals into the cathode of the input stage. In that case both grid and cathode are available as input terminals and the two signals are linearly mixed. In other cases, as in the present case, it is desirable that the feedback network face a very high impedance at its output terminals and that its input impedance be fairly high. By using the third terminal of the network in this case for the signal input terminal these impedance conditions are met without the use of transformers, mixing networks or additional vacuum tubes. The advantages of the connection can be realized with any three-terminal network that yields a desirable transmission characteristic.

What is claimed is:

1. A frequency selective wave translating system comprising a wave source, an amplifier, a negative feedback path from the amplifier output circuit to the amplifier input circuit, and a three-terminal resistance-capacitance network included in said path with one terminal connected to a point of the amplifier output circuit, a second terminal connected to a point of the amplifier input circuit, the third terminal connected through said source to a common point of the amplifier output and input circuits of potential different from the potentials of the two first-mentioned points, and the attenuation of said network for transmission therethrough from said first and third terminals to said second and third terminals having a peak value at a prescribed frequency with lower values at lower and higher frequencies.

2. An electric system having, in combination, a source of energy, an amplifier having an input circuit and an output circuit and means comprising a three-terminal network having a common input and output terminal and said source for degeneratively coupling the amplifier output circuit to the amplifier input circuit with said common terminal connected through said source to a common point of the amplifier input and output circuits, said network having substantially minimum transmission at a predetermined frequency and the system as a whole having parameters such as to provide substantially maximum transmission at the predetermined frequency in order to render the system as a whole selective to the predetermined frequency and such that at frequencies substantially removed from the predetermined frequency a sufficiently large fraction of the output voltage is fed back degeneratively to the input circuit of the amplifier so as to cancel substantially the entire gain of the amplifier.

3. An electric system including a three-terminal network, said system selectively transmitting a frequency predetermined by the characteristics of the component circuit elements of the network and one of the three terminals of the network being a common input and output terminal of the network, said system comprising, in combination, a source of energy, an amplifier having an input circuit and an output circuit, and means comprising said network and said source for degeneratively coupling the amplifier output circuit to the amplifier input circuit with said one terminal of said network connected through said source to a common point of said amplifier input and output circuits, said network including means for rendering said degenerative coupling substantially ineffective at said predetermined frequency.

4. An electric system selective to a predetermined frequency and comprising, in combination, a source of energy, an amplifier having an input circuit and an output circuit, and means for degeneratively coupling the output circuit to the input circuit including said source and a three-terminal network having one terminal connected through said source to a common point of said input and output circuits and the other two terminals respectively connected to said input and output circuits at points of potentials different from the potential of said common point, said network including means for rendering the degenerative coupling substantially zero at said predetermined frequency, and the system as a whole having parameters such as to provide substantially maximum transmission at the said predetermined frequency in order to render the system as a whole selective to said predetermined frequency.

5. An electric system comprising, in combina-

tion, a source of energy, an amplifier having an input circuit and an output circuit, and means comprising said source and a parallel-T network of impedances for degeneratively coupling the amplifier output circuit to the amplifier input circuit with a common input and output terminal of said network connected through said source to a common point of the amplifier input and output circuits.

6. An electric system selectively transmitting a prescribed frequency and comprising, in combination, a source of energy, an amplifier having an input circuit and an output circuit, and means comprising said source and a parallel-T network of impedances for degeneratively coupling the amplifier output circuit to the amplifier input circuit with a common input and output terminal of said network connected through said source to a common point of said amplifier input and output circuits, said network having substantially zero transmission at said prescribed frequency as determined by the characteristics of its component elements.

7. A frequency selective wave translating system comprising a wave source, an amplifier, a negative feedback path from the amplifier output circuit to the amplifier input circuit, and a three-terminal resistance-capacitance network included in said path with one terminal connected to a point of the amplifier output circuit, a second terminal connected to a point of the amplifier input circuit, the third terminal connected through said source to a common point of the amplifier output and input circuits of potential different from the potentials of the two first-mentioned points, and the transmission of said network from said first and third terminals to said second and third terminals substantially zero at a prescribed frequency and substantially unity at frequencies approaching zero and infinity.

8. A frequency selective wave translating system comprising a wave source, an amplifier, a negative feedback path from the amplifier output circuit to the amplifier input circuit, and a three-terminal network included in said path with one terminal an input terminal of said network connected to a point of the amplifier output circuit, a second terminal, an output terminal of said network connected to a point of the amplifier input circuit and the third terminal an input and output terminal of said network connected through said source to a common point of the amplifier output and input circuits of potential different from the potentials of the two first-mentioned points, said network comprising resistances and capacitances so related that transmission through said network from said first and third terminals to said second and third terminals is substantially balanced out at a prescribed frequency but increases with frequency change in either sense from said prescribed frequency.

JOHN W. RIEKE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,173,426	Scott	Sept. 19, 1939
2,245,365	Riddle, Jr.	June 10, 1941
2,365,575	Maxwell	Dec. 19, 1944
2,372,419	Ford et al.	Mar. 27, 1945