Jan. 16, 1923. 1,442,781.

H. W. NICHOLS.

REAMPLIFYING SYSTEM.

FILED JULY 7, 1921.

Fig. 1.

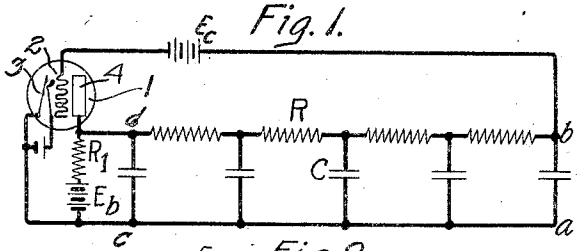


Fig. 2.

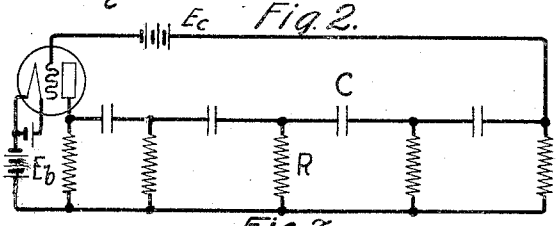


Fig. 3.

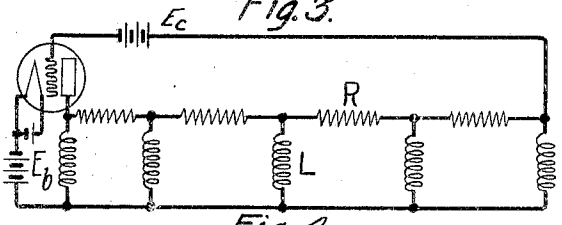


Fig. 4.

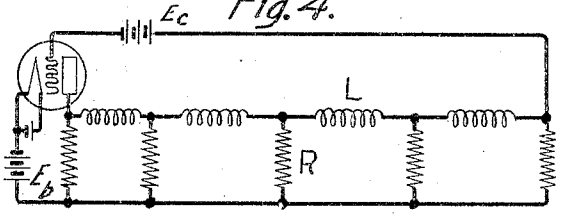


Fig. 5.

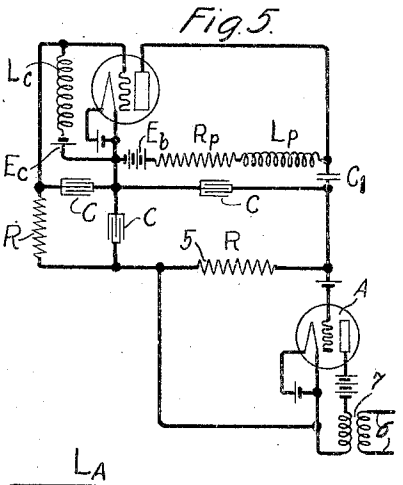


Fig. 6.

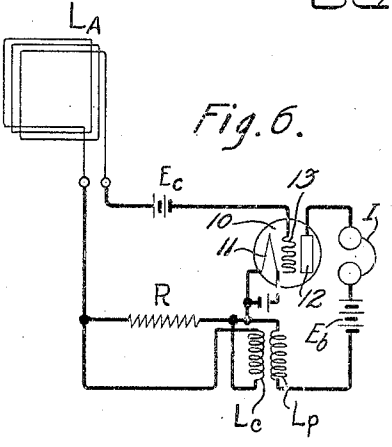


Fig. 7

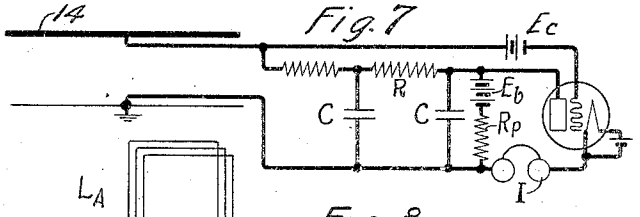
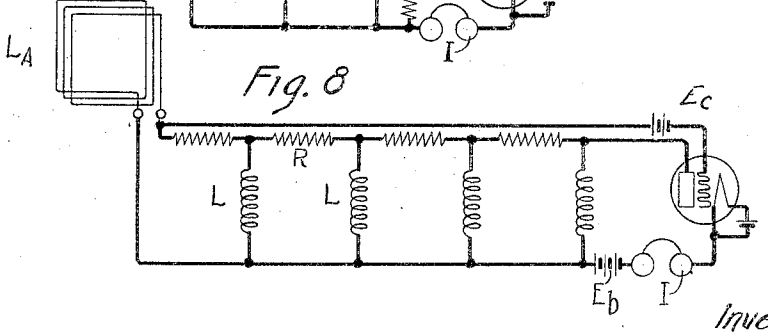


Fig. 8



Inventor:
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by C. C. Sprague Atty.

Patented Jan. 16, 1923. 1,442,781

UNITED STATES PATENT OFFICE.

HAROLD W. NICHOLS, OF MAPLEWOOD, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

REAMPLIFYING SYSTEM.

Application filed July 7, 1921. Serial No. 482,912.

To all whom it may concern:

Be it known that I, HAROLD W. NICHOLS, a citizen of the United States, residing at Maplewood, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Reamplifying Systems, of which the following is a full, clear, concise, and exact description.

This invention relates to reamplifying systems.

One object of the invention is to provide an arrangement which will selectively amplify electrical waves of a given frequency, or range of frequencies, without amplifying disturbing energy or other waves of considerably different frequency.

A feature of the invention is a reamplifying arrangement which is substantially independent in its frequency selection of one kind of reactance.

Another feature of the invention is a thermionic oscillator in which the frequency of the oscillations produced is determined by constants of the thermionic device and an associated network and is substantially independent of one kind of reactance.

An additional feature of the invention consists in using one element of the feed-back circuit of an amplifier to serve also as a radio receiving antenna.

A further feature of the invention is a radio receiving system, the selectivity of which is substantially independent of one kind of reactance and hence avoids, to a large degree, the tendency of the ordinary tuned circuit to set up natural oscillations when disturbed by interfering energy.

A still further feature of the invention is a filter through which energy is transmitted and thereafter reimpressed upon the same filter in phase with the energy originally applied.

According to the present invention, a three-element electric discharge device or other equivalent amplifier is provided with a feed-back circuit connecting its output circuit to its input circuit. This feed-back circuit consists of a network having effective reactance of substantially one kind only, and the amplifier may be operated to produce continuous oscillations of a frequency determined by its own characteristics and those of the network, or it may be operated at such a degree of amplification as to reamplify impressed waves without maintaining continuous oscillations. A reactance element of the feed-back network may serve also as an antenna and the amplifying circuit may in that case, serve for the reception of radio signal waves.

The novel features which are considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawing in which Figs. 1 to 4 inclusive illustrate different arrangements of reamplifying circuits; Fig. 5, an application of the circuit of Fig. 1 to production and transmission of alternating current; Fig. 6, a radio receiving system including a reamplifying arrangement substantially free from reactance of one kind and Figs. 7 and 8, modified forms of radio receiving systems.

Referring to Fig. 1, a thermionic three-element amplifier 1, preferably highly evacuated, is shown associated with a network consisting of a plurality of meshes or sections, each having a series resistance R and a shunt capacity element C, and substantially free from inductance. The amplifier is provided with an impedance control element or grid 2, a hot filament cathode 3, and an anode or plate electrode 4. The space current for the amplifier is supplied by a source E_b in series with a very large resistance R_1. In the circuit of this figure and in those of each of the following figures a source E_c may be used to maintain the grid at the most desirable potential with respect to the cathode.

The input terminals of the amplifier, namely, those leading to the cathode and grid are connected to points *a*, *b*, the terminals of the end capacity element C of the network. The output terminals of the amplifier, namely, those leading to the cathode and plate, are connected to points *c*, *d*, the terminals of the end capacity element C at the opposite end of the network from terminal points *a* and *b*. A varying E. M. F.

applied to terminals *a* and *b* will accordingly be impressed upon the input circuit of the amplifier to produce an amplified E. M. F. across the output terminals *c* and *d*. The network in transferring amplified energy from points *c* and *d* to points *a* and *b*, operates both to shift its phase and to attenuate it. Each section of the network shifts the phase of the transmitted wave by a certain amount. If the phase shift throughout the entire network, that is, from points *c* and *d* to points *a* and *b*, is substantially 180 degrees or 180 degrees plus 360 degrees or a multiple of 360 degrees, the amplified energy transmitted from terminals *c*, *d* to terminals *a*, *b*, will be in phase agreement with the applied E. M. F., thus giving rise to re-amplification. If the total attenuation which the network causes, is less than the amplification which occurs in consequence of the operation of amplifier 1, the amplified energy which reaches terminals *a*, *b*, will, after attenuation in the network, be greater than the energy initially impressed at these terminals, and if the amplified energy is in phase agreement with the impressed energy, the amplifier and network may act as an oscillator.

The sections of the network may be made alike, in which case the network is termed "iterative," or they may be unlike. In the case of the iterative network, the phase shift and attenuation are the same for each mesh and it is accordingly possible to readily calculate the phase shift and attenuation produced by the network as a whole or conversely to determine the constants of the network which will produce a definite phase shift and attenuation at a given frequency. The method of calculation for iterative networks is similar to that by which the constants are determined for reactive iterative networks as set forth in United States patents to G. A. Campbell, Nos. 1,227,113 and 1,227,114 patented May 22, 1917. The frequency of the oscillations and the amplifying power necessary to produce them may be calculated in the manner outlined in the article entitled "The audion as a circuit element" Physical Review, N. S. volume 13, No. 6, June, 1919. Note particularly pages 412 to 414 inclusive.

Fig. 2 discloses an arrangement similar to that of Fig. 1, but including a network having shunt resistances R and series capacity elements C and substantially free from inductance. In this arrangement no separate space current path is necessary for the source E_b. Fig. 3 illustrates an amplifying arrangement having a network with series resistances R and shunt inductance elements L and substantially free from capacity reactance. Fig. 4 illustrates the converse arrangement of Fig. 3 with series inductances L and shunt resistances R.

It is theoretically possible to design oscillators of each of the four types described with but two meshes in the feed-back network. In general, it will be found desirable to use a greater number of meshes. For the arrangement of Figs. 1 and 3, the frequency of the oscillations produced or for which the device will act as a reamplifying arrangement, if not adjusted to the oscillating condition, decreases with an increasing number of sections in the network. The higher frequency oscillations will therefore be obtained with but two sections, and the lower frequencies with larger numbers of sections. The frequency of the oscillations produced is a function of both the characteristics of the network and of the voltage amplifying factor of the amplifier. For the circuit arrangements of Figs. 1 and 3, increasing the amplifying factor, increases the frequency and decreasing the amplifying factor, decreases the frequency, the circuit being otherwise unvaried. The arrangements of Figs 2 and 4 produce their lowest frequency oscillations with two meshes in the feed-back network. As the number of meshes is increased, the frequency of the oscillations produced by these arrangements increases. With a given network, the oscillators of these two figures produce increasing frequency oscillations as the voltage amplifying power of their amplifiers is decreased and vice versa.

Fig. 5 illustrates an oscillator of the type of Fig. 1 in which the feed-back circuit comprises two meshes. A thermionic amplifier A of the well-known highly evacuated three-element electric discharge type has its input circuit connected directly across the terminals of a series resistance 5 in the feed-back network and serves to supply amplified oscillations to a work circuit 6 coupled to the output circuit of the amplifier by a transformer 7. Space current is supplied to the discharge device of the oscillator by source E_b through a path including extremely high impedance elements L_p and R_p. This path therefore plays no essential part in the determination of the oscillation frequencies. The grid of the oscillator is polarized by a source E_c in series with a very large inductance L_c. In a given example, the internal space current path resistance of the oscillator tube between the cathode and anode was approximately 35,000 ohms. The voltage amplifying factor of the tube was 31. The voltage of source E_b, 750 volts; of source E_c, 5 volts. The inductance of L_c was such as to make its impedance at 1,100 cycles approximately a megohm and that of L_p, 100 henries. The capacity of condenser C_1 was 5 mf. and each of the elements C were of 4,000 mmf. capacity. The resistance R_p was 64,000 ohms and each of the series resistances R

of the network were of 70,000 ohms magnitude. The calculated frequency of the oscillator from the formula

$$f=\frac{1}{2\pi CR}\sqrt{\frac{3(1+R)}{R_0}}$$

which may be readily deduced for this particular network by the methods of the Physical Review article, previously cited, is about 1,100 cycles. In this formula, f represents the frequency of the oscillations in cycles per second; C, the capacity of each shunt condenser of the network; R_0, the internal space current resistance of the oscillator tube, and R, the series resistance of each of the elements of the network. The frequency of the oscillations produced by this arrangement was measured and found to agree very closely with that calculated.

Fig. 6 illustrates a reamplifying circuit adapted to serve as a radio receiver. A thermionic amplifier 10 is provided with a cathode 11, anode 12 and impedance control element 13. Its input circuit includes an inductance L_c coupled to an inductance L_p in the plate circuit, a resistance R in shunt to L_c, and an inductance L_A which serves as a loop receiving antenna. The plate circuit includes, in addition to inductance L_p and the space current source E_b, a receiver or other signal translating element I. The circuit is arranged to be substantially free of capacity reactance, and the arrangement operates to reamplify waves or produce oscillations, the frequency of which is determined by the resistance and inductance of the network and the internal space current resistance of the tube. Any casual capacities of this arrangement are of such an order that they have negligible effect in determining the frequency of the oscillations generated. The oscillator circuit may be set at the critical point of oscillation to serve as a reamplifier and demodulator for waves of the desired frequency received by antenna L_A, or it may be set to oscillate at the frequency of the desired waves in the manner of the system of the U. S. patent to Kendall No. 1330471, patented Feb. 10, 1920. Finally, the oscillator may, if desired, be arranged to oscillate at a frequency different from that of received oscillations so that the receiving system may operate according to the well known heterodyne method. Whichever of these three operations occurs, the received oscillations will be demodulated to yield intelligible signals in the receiver I.

Figs. 7 and 8 disclose reamplifying arrangements arranged to function in the same general manner as that of Fig. 6. The circuit of Fig. 7 is analogous to that of Fig. 1, but has fewer meshes and has its end capacity element formed by a capacity antenna 14. This arrangement reamplifies or oscillates at a frequency substantially independent of fortuitous inductances. The circuit of Fig. 8 is analogous to that of Fig. 3 and has its end inductance L_A in the form of a loop antenna. This circuit like that of the reamplifying arrangement of Fig. 6 is substantially independent in its selectivity of any fortuitous capacities that may exist.

It is to be understood that various features of the invention are capable of application in other relations and are therefore not to be limited to any of the particular arrangements or uses suggested in the foregoing disclosure, but only by the scope of the appended claims.

What is claimed is:

1. A network comprising a plurality of meshes, means for impressing oscillations upon one portion of said network, means for feeding back a part of the energy of the impressed oscillations transmitted through said network to impress this energy upon the same portion of the network in phase with the oscillations originally impressed thereon.

2. A network comprising a plurality of meshes and including an antenna, means for impressing oscillations upon one portion of said network, means for feeding back a part of the energy of the oscillations transmitted through said network and for reimpressing the energy fed back upon the same portion of the network in phase with the oscillations originally impressed thereon.

3. An amplifier having an input circuit and an output circuit, and a network connected to each of said circuits to feed back amplified energy from said output circuit to said input circuit, said network serving to determine the phase of the energy fed back and being substantially free from one kind of reactance.

4. An amplifier having input and output circuits and means substantially free from reactance of one kind for feeding back amplified energy from said output circuit to said input circuit, said means comprising an iterative network of similar sections.

5. An oscillator comprising an amplifier having an input circuit, an output circuit, and means for feeding back amplified energy from said output circuit to said input circuit, said means consisting of an iterative network including reactance of one kind only.

6. An amplifier having input and output circuits and connecting means to feed back amplified energy from said output circuit to said input circuit comprising a network having substantially only one kind of reactance, one of the reactance elements of said network consisting of a receiving element for radiant energy.

7. An amplifier having an input circuit and an output circuit, a network connected to each of said circuits to feed back amplified energy from said output circuit to said input

circuit, said network serving to determine the phase of the energy fed back and being substantially free from one kind of reactance, and an antenna substantially free from that same kind of reactance, said antenna being connected to said input circuit.

8. An amplifier having input and output circuits, and connecting means to feed back amplified energy from said output circuit to said input circuit comprising a network having substantially only one kind of reactance, one of the reactance elements of said net work consisting of a wave energy receiving element.

9. An amplifier having an input circuit, an output circuit, and means for feeding back amplified energy from said output circuit to said input circuit, said means consisting of an iterative network, each section of which comprises a resistance element and a reactive element consisting of reactance of one kind only, one of the elements of said network consisting of a receiving element for external energy.

10. An amplifier having input and output circuits, and connecting means to feed back amplified energy from said output circuit to said input circuit comprising an iterative network having substantially capacitative reactance only.

11. An amplifier having input and output circuits, and connecting means to feed back amplified energy from said output circuit to said input circuit comprising a network having substantially capacitative reactance only, one of said capacitative reactance elements consisting of a wave energy receiving element.

In witness whereof, I hereunto subscribe my name this 1st day of July A. D., 1921.

HAROLD W. NICHOLS.