Feb. 26, 1924. 1,484,967

J. C. SCHELLENG

AMPLIFYING SYSTEM

Filed Dec. 24, 1920

Fig. 1.

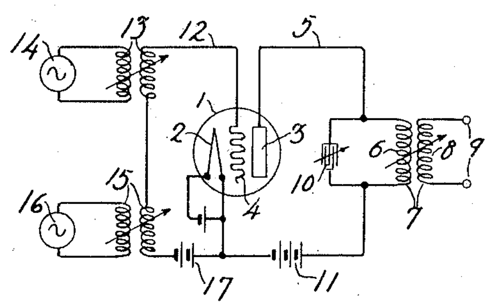


Fig. 2.

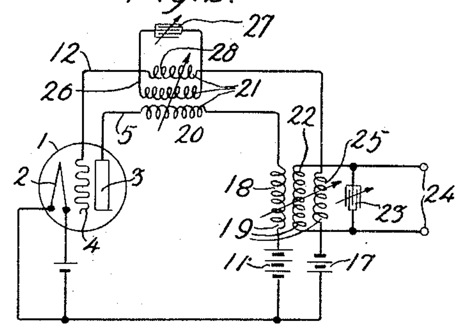
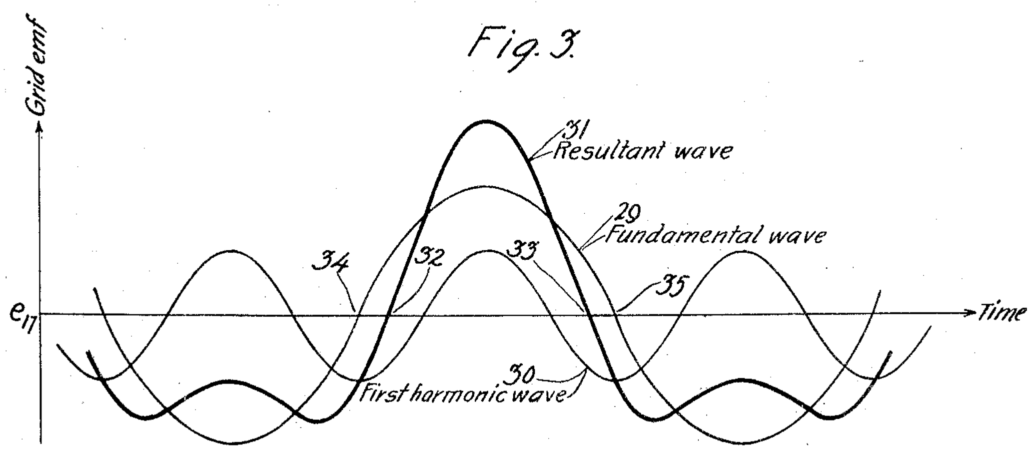


Fig. 3.



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Patented Feb. 26, 1924. 1,484,967

UNITED STATES PATENT OFFICE.

JOHN C. SCHELLENG, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY. INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

AMPLIFYING SYSTEM.

Application filed December 24, 1920. Serial No. 432,905.

To all whom it may concern:

Be it known that I, John C. Schelleng, a citizen of the United States, residing at East Orange, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in an Amplifying System, of which the following is a full, clear, concise, and exact description.

This invention relates to electric wave amplifying systems, and more particularly to systems of amplifying or generating waves in which the magnitude of the amplified or generated waves is determined by variations in the internal impedance, or resistance of the amplifying device.

One object of the invention is to amplify or generate electrical oscillations at high efficiency.

Another object is to reduce energy losses occurring in the amplifying system due to amplified energy flowing therethrough.

Another object is to utilize a single three-electrode thermionic tube, with the minimum number of connected elements, to amplify or generate waves of a desired frequency with a minimum loss of energy in the tube.

One of the requirements for a high efficiency vacuum tube amplifier is that the greater portion of the space current should flow in a time $2t$ such that $\cos \frac{2\pi t}{T}$ does not differ greatly from unity, where T represents the period of the wave to be produced in the output circuit, or in other words, this space current should flow in a time which is very small as compared to the time of one cycle of the output wave.

According to the present invention, a system is provided in which the space current will flow in accordance with the above described relation, this result being accomplished by combining with the fundamental wave, a first harmonic wave, in such phase relation that the maximum positive potential of the given wave coincides in phase with a maximum positive potential of the first harmonic wave. The amplitude of the first harmonic wave is preferably less than that of the fundamental wave, and may be chosen to have approximately one-quarter the amplitude of the fundamental wave. The resultant wave of potential produced by this combination has a much sharper peak than a single sine wave of fundamental frequency having an equivalent effective value. It has been found that by applying this resultant wave to the control circuit of a thermionic amplifier, waves in amplified form are produced in the output circuit of the amplifier much more efficiently than if a sine wave of the frequency to be amplified and of equivalent effective value to that of the resultant wave previously mentioned, were alone applied to the control circuit.

Other objects and features of the invention will be apparent from the more detailed description.

Referring to the drawings: Fig. 1 is a diagram of an amplifier circuit utilizing the principle of this invention;

Fig. 2 illustrates the application of the invention to a regenerative amplifier, or oscillator;

Fig. 3 is a diagram showing the form of waves impressed upon the control circuit of the amplifier, or oscillator.

In Fig. 1, the thermionic tube 1 contains a cathode 2, anode 3, and the control electrode or grid 4. Between the cathode 2 and the anode 3 is connected the anode circuit 5 which includes in series therewith primary winding 6 of the variable coupling transformer 7, the secondary winding 8 of which constitutes a portion of a work circuit connected to the output terminals 9. In shunt to the winding 6 is the variable capacity 10 by means of which the circuit including the capacity 10 and the winding 6 is tuned substantially to resonance with the frequency of the waves to be amplified, whereby waves of said frequency are selected from the other waves appearing in the anode circuit 5. Battery 11 supplies space current to the tube 1. The tube 1 may be looked upon as being a relay of the variable impedance type, that is, a relay which operates by varying the impedance of its output circuit in response to variations in the electric energy impressed upon its input circuit.

Between the cathode 2 and the grid 4 is connected the control circuit 12, which includes in series therewith; the variable inductive coupling 13 with the source 14 of given waves to be amplified, the variable inductive coupling 15 with the source 16 of first harmonic waves of the source 14, and battery 17 to maintain the grid 4 normally polarized negatively.

In Fig. 2, the circuit is arranged to generate sustained oscillations and differs only slightly from the arrangement in Fig. 1, the principal difference being that waves corresponding to those supplied by the sources 14, 16 in Fig. 1, are derived from the anode circuit 5 of the amplifier. In series with the anode circuit 5, Fig. 2, is a source of space current 11; primary winding 18 of the variable coupling transformer 19; and the primary winding 20 of the variable coupling transformer 21. Coupled to the primary winding 18 is the secondary winding 22, shunted by the condenser 23 for the purpose of tuning to the frequency of the waves to be amplified. Output terminals 24 are connected to the terminals of the winding 22. A secondary winding 25 coupled to the winding 22 has induced therein waves of frequency corresponding to the frequency of the waves to be amplified. Coupled to the primary winding 20 is the secondary winding 26 in series with condenser 27 by means of which the circuit including the winding 26 and the condenser 27 is tuned to a harmonic frequency of the waves to be amplified, preferably the first harmonic frequency. Coupled to the winding 26 is the secondary winding 28 in which are induced the harmonic waves corresponding to the current in winding 26. It is thus seen that the winding 22 corresponds to the source of waves 14 in Fig. 1, while the winding 26 corresponds to the source of waves 16 in Fig. 1.

Referring to Fig. 3, E. M. F. waves impressed upon the grid circuit 12 are plotted as ordinates, while time is plotted as abscissæ. Curve 29 represents the wave of given or fundamental frequency; curve 30 represents the wave having the first harmonic frequency of the fundamental wave 29, and having a maximum positive potential occurring at substantially the same instant as the maximum positive potential of the fundamental wave 29; while wave 31 represents the resultant wave produced by the addition of waves 29 and 30 in the grid circuit 12. The first harmonic wave 30 has a relatively smaller amplitude than the fundamental wave 29 and is preferably chosen to have an amplitude of the order of magnitude of one-quarter that of the fundamental. This amplitude relation may be adjusted by the couplings 13, 15 in Fig. 1, and the couplings 19, 21 in Fig. 2. The phase relation between the waves 29 and 30 may be adjusted by any of the well-known expedients, as by varying the self and mutual inductance, and the capacity in the sources 14 and 16, which sources may be in the output circuit of a single generator of harmonics.

In the same manner as a resultant control wave may be built up from a fundamental wave combined with a first harmonic wave, to provide a wave having a sharper positive peak than the fundamental wave, it is possible to combine more than one harmonic wave with the fundamental wave, to produce the desired peak of positive potential.

It will be seen that the wave 31 between the points 32 and 33 is much steeper, or in other words, forms a sharper peak than the sine wave 29 of fundamental frequency between the corresponding points 34 and 35. By virtue of the shape of wave 31 impressed upon the grid 4, the space current between electrodes 2 and 3 will be made to vary in a similar manner for a portion of the cycle, whereby a sharper impact is produced upon the circuit 6, 10, Fig. 1, or the circuit 22, 23, Fig. 2, than could be produced by the sine wave 29, thus resulting in a larger impact excitation of waves of the fundamental frequency than could be produced if the sine wave 29 were alone impressed upon the grid 4. In Fig. 2, at the same time that waves of fundamental frequency are excited in the circuit 22, 23, first harmonic waves are excited in circuit 26, 27.

The rate of change of E. M. F. in passing from a negative to a maximum positive ordinate, and vice versa, as shown in Fig. 3, is greater for the wave 31 than for the wave 29. This results in a much more rapid change from maximum to minimum resistance and from minimum to maximum resistance in the tube 1 than would take place if the wave 29 were alone impressed upon the grid 4, and consequently the amount of energy which can flow during the intervals when the tube 1 has a resistance intermediate between a maximum and minimum value, is much more limited when the tube 1 has a resistance intermediate between a maximum and minimum value than when the wave 29 is alone impressed upon the grid 4. By limiting the amount of energy which can pass through the tube 1, during the specified intervals, the loss of energy within the tube is correspondingly limited because of the fact that the loss equals the integrated product of the space current squared by the resistance of the tube by the time of flow. Inasmuch as the factor of time in this product is relatively small during the intervals when the product of the current squared by the resistance is large, the loss in the tube during these intervals will be relatively small.

At other times, the resistance of the tube is either near a maximum or a minimum value. During the interval when the wave 31 is near its maximum negative value, the resistance of the tube is a maximum, and the current is accordingly so small that the integrated product of the current squared by the resistance of the tube by the time of flow, is very small. During the interval when the wave 31 is near its maximum positive value, the resistance of the tube is a minimum, and is so small that the product just mentioned is very small.

It is thus seen that at all times the energy loss in the tube is relatively small as compared with the loss which would occur if the wave 29 were alone applied to the grid 4. In view of the fact that the loss in using the control wave 31 is less than when using the wave 29 alone, there is a corresponding increase in the electrical efficiency of the amplifying circuit.

The method and means for generating or amplifying waves as herein described is of broad application, and it is not intended that the invention should be limited to the specific combinations shown in Figs. 1 and 2. The invention is covered generically in the appended claims.

What is claimed is:

1. The method of electric wave amplification which consists in combining with the given wave to be amplified, a wave of higher frequency in such phase relation that the positive peaks of said given wave occur at substantially the same time as positive peaks of said high frequency wave, and subjecting the combined waves to an amplifying process.

2. The method of electric wave amplification which consists in combining with the given wave to be amplified, a double frequency wave in such phase relation that the positive peaks of said given wave occur at substantially the same time as positive peaks of said double frequency wave, and subjecting the combined waves to an amplifying process.

3. The method of regenerative amplification of electric waves which comprises amplifying said waves and selecting from the amplified output waves a combined wave consisting of a fundamental wave and a wave of higher frequency in such phase relation that the positive peaks of said fundamental wave occur at substantially the same time as positive peaks of said higher frequency wave.

4. The method of regenerative amplificacation of electric waves which comprises amplifying said waves and selecting from the amplified output waves a combined wave consisting of a fundamental wave and a double frequency wave in such phase relation that the positive peaks of said fundamental wave occur at substantially the same time as positive peaks of said double frequency wave.

5. The method of electric wave amplification which comprises combining with the given wave to be amplified, a dissimilar wave and varying in accordance with said combined waves, the resistance controlling the flow of amplified waves; said combined waves being so related that the rate of change of resistance from the maximum to the minimum value, and vice versa, over a greater portion of the resistance range, exceeds the rate of change obtained by varying the resistance in accordance with said given wave alone.

6. The method of electric wave amplification which comprises combining with the given wave to be amplified, a wave the maximum amplitude of which is approximately one-quarter the maximum amplitude of said given wave and subjecting the combined waves to an amplifying process.

7. The method of electric wave amplification which comprises combining with the given wave to be amplified, a wave of higher frequency having a maximum amplitude of the order of magnitude of one-quarter the maximum amplitude of said given wave, and subjecting the combined waves to an amplifying process.

8. The method of electric wave amplification which comprises combining with the given wave to be amplified, a double frequency wave of smaller maximum amplitude than said given wave, and subjecting the combined waves to an amplifying process.

9. The method of electric wave amplification which comprises combining with the given wave to be amplified, a wave of higher frequency and of smaller maximum amplitude than said given wave, said waves being in such phase relation that the positive peaks of said given wave occur at substantially the same time as positive peaks of said higher frequency waves, and subjecting the combined waves to an amplifying process.

10. The method of electric wave amplification which comprises combining with the given wave to be amplified, a double frequency wave having a maximum amplitude of the order of magnitude of one-quarter the maximum amplitude of said given wave, said waves being in such phase relation that the positive peaks of said given wave occur at substantially the same time as alternate positive peaks of said first harmonic wave, and subjecting the combined waves to an amplifying process.

11. In combination, a relay of the variable impedance type, a source of waves of fundamental frequency coupled thereto to be repeated, and means coupled to said relay to transmit thereto a positive peak of a wave of frequency harmonic to said fundamental frequency at substantially the same time as each positive peak of said fundamental wave transmitted thereto.

12. In combination, an amplifier of the space current type, a source of waves of fundamental frequency coupled thereto to be amplified, and means coupled to said amplifier to transmit thereto a wave of frequency harmonic to said fundamental frequency and having a maximum amplitude approximately one-quarter that of said fun-

damental wave in the phase relation in which each positive peak of said fundamental wave occurs at substantially the same time as a positive peak in said harmonic wave.

13. In combination, a relay of the variable impedance type having an input circuit and an output circuit, a source of waves of fundamental frequency coupled to said input circuit, and another source of waves of frequency harmonic to said fundamental frequency coupled to said input circuit in the phase relation to transmit thereto a positive wave peak at substantially the same time as each positive peak of said fundamental wave in said input circuit.

14. In combination, a space current device having an anode, a cathode, and a control element, an input circuit associated with said control element and an output circuit associated with said anode, means to polarize said control element, a source of waves of fundamental frequency coupled to said input circuit, and means for transmitting to said input circuit a wave of frequency harmonic to said fundamental frequency in the phase relation in which a positive peak of said harmonic wave in said input circuit occurs at substantially the same time as each positive peak of said fundamental wave in said input circuit.

15. In combination, a space current device having an anode, a cathode and a control element, an input circuit associated with said control element and an output circuit associated with said anode, means associated with said input circuit to apply a negative polarizing potential to said control element, a source of waves of fundamental frequency coupled to said input circuit, and means for transmitting to said input circuit a wave of frequency harmonic to said fundamental frequency in the phase relation in which a positive peak of said harmonic wave in said input circuit occurs at substantially the same time as each positive peak of said fundamental wave in said input circuit.

16. In combination, a relay of the variable impedance type having an input circuit and an output circuit, a source of waves of fundamental frequency coupled to said input circuit, a source of waves of frequency harmonic to said fundamental frequency coupled to said input circuit in the phase relation to transmit thereto a positive wave peak at substantially the same time as each positive peak of said fundamental wave in said input circuit, and a work circuit associated with said output circuit selectively receptive to waves of said fundamental frequency.

17. In combination, a relay of the variable impedance type having an input circuit and an output circuit, a source of waves of fundamental frequency coupled to said input circuit, a source of waves of frequency harmonic to said fundamental frequency coupled to said input circuit in the phase relation to transmit thereto a positive wave peak at substantially the same time as each positive peak of said fundamental wave in said input circuit, means associated with said output circuit to select therefrom a wave of fundamental frequency, and a work circuit coupled to said frequency selecting means.

18. In combination, a relay of the variable impedance type having an input circuit and an output circuit, a source of waves of fundamental frequency coupled to said input circuit, a source of waves of frequency harmonic to said fundamental frequency coupled to said input circuit in the phase relation to transmit thereto a positive wave peak at substantially the same time as each positive peak of said fundamental wave in said input circuit, and means resonant to a wave of said fundamental frequency to receive said wave from said output circuit.

19. A high efficiency relay system comprising a relay of the variable impedance type having an input circuit and an output circuit, means for transmitting to said input circuit a wave of fundamental frequency and a wave of frequency harmonic to said fundamental frequency in the phase relation in which each positive peak of said fundamental wave occurs at substantially the same time as a positive peak in said harmonic wave and in the direction to produce maxima of current in said output circuit in response to said positive peaks.

20. In combination, a relay of the variable impedance type having an input circuit and an output circuit, a fundamental frequency wave source coupled to said input circuit, and means coupled to said input circuit to transmit thereto a wave of double frequency having a maximum amplitude of approximately one-quarter the maximum amplitude of said fundamental wave.

21. In a relay of the variable impedance type having an input circuit and an output circuit, the method of relaying electric currents at high efficiency which comprises combining with a given wave to be amplified, a double frequency wave of smaller maximum amplitude than said given wave, each positive peak of said given wave occurring at substantially the same time as a peak in said double frequency wave, and impressing said coincident peaks on said input circuit in the direction to produce space current maxima in said output circuit.

In witness whereof, I hereunto subscribe my name this 21st day of December, A. D. 1920.

JOHN C. SCHELLENG.