Oct. 9, 1928. 1,687,220

S. S. MACKEOWN

ELECTRIC WAVE PRODUCER

Filed Oct. 16, 1923

Fig. 1.

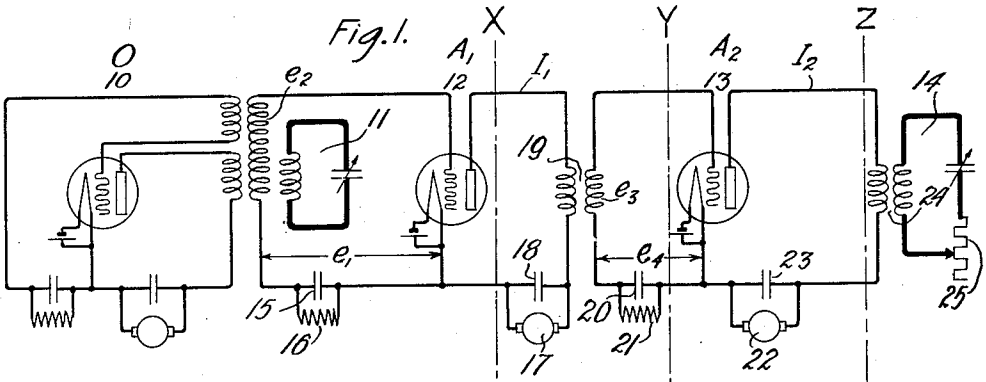


Fig. 2.

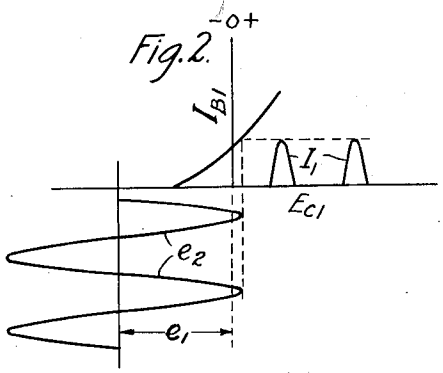


Fig. 4.

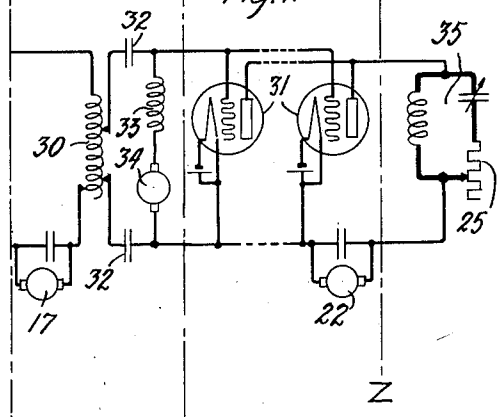


Fig. 3.

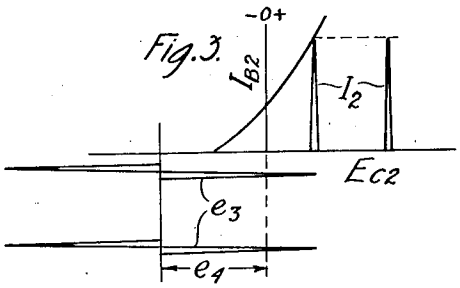
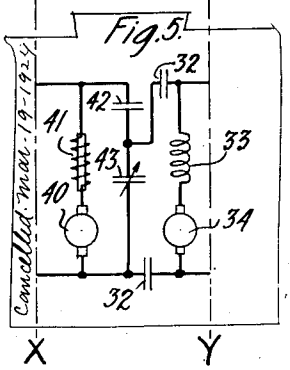


Fig. 5.



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UNITED STATES PATENT OFFICE.

SAMUEL S. MACKEOWN, OF ITHACA, NEW YORK, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

ELECTRIC-WAVE PRODUCER.

Application filed October 16, 1923. Serial No. 668,797.

This invention relates to methods and means for producing electric waves.

One object of the invention is to produce electric waves at high efficiency.

Another object of the invention is to operate amplifiers of the variable impedance type at the highest possible efficiency.

It is known that for the most efficient production of waves by a variable impedance device in a direct current circuit, for example, by an amplifier of the space current type, it is essential that the space current through the amplifier tube vary from a minimum to a maximum value and vice versa in a very sudden or impulsive manner.

It is old to apply sine wave variations of potential to the normally negatively polarized grid in an amplifier in order to impulsively excite the amplifier to obtain amplification of an impressed wave at high efficiency. The highest efficiency obtainable by such a method of operation is limited in any practical case by the fact that the constant negative potential and the sine wave potential applied to the grid of the amplifier become prohibitively high as the efficiency is increased.

In accordance with the present invention, an amplifier is excited by very steep control impulses transmitted from a relay which converts sine waves into the control impulses. The rate of change of potential in the control impulses is much greater than in a sine wave of the same amplitude and periodicity and causes the amplifier to operate at a much higher efficiency than is obtainable by sine wave excitation of the amplifier.

Further details regarding the nature, objects and method of operation of the invention are set forth in the following specification with reference to the drawing.

In the drawing, Fig. 1 is a circuit diagram showing one modification of the invention employing transformer couplings between different portions of the circuit each transformer comprising two windings insulated from each other. Figs. 2 and 3 are graphs showing how the impulse excitation takes place. Fig. 4 is a circuit diagram showing an auto-transformer coupling between two vacuum tube devices in tandem and a conductive connection between the last vacuum tube in tandem and the resonant output circuit.

In Fig. 1, the oscillator 10 of the vacuum tube or other well known type, produces oscillations of low power and of substantially constant frequency in the resonant frequency determining circuit 11. Relay 12 and amplifier 13 in tandem transmit waves from the oscillator 10 to the resonant output circuit 14 tuned by inductance and capacity to the frequency of oscillator 10. Resonant circuit 14 may be the oscillatory radiating circuit of an antenna for transmitting radio waves or may be any well known form of energy absorbing work circuit. Relay 12 may or may not amplify but for convenience of description will be called an amplifier. Amplifiers 12 and 13 are of the variable impedance type, each being provided with an electron emitting cathode, an electron receiving anode and a grid electrode for controlling space current between the anode and cathode.

The condenser 15 and leak resistance 16 cooperate to maintain the grid of amplifier 12 at such a high negative potential with respect to the cathode that space current from the source 17 cannot flow except during brief intervals when the positive peaks of waves from source 10 are applied to the grid of amplifier 12. The space current source 17 may be a direct current generator, as shown, or any other well known source of direct current such as a battery or the like. Condenser 18 shunts source 17 to provide a path of low impedance for impulses passing through the output circuit of amplifier 12, and tends to reduce fluctuations in the voltage of source 17. The output circuit of amplifier 12 is inductively coupled to the input circuit of amplifier 13 by means of transformer 19, having primary and secondary windings insulated from each other. Condenser 20 and leak resistance 21 in the input circuit of amplifier 13 cooperate to maintain the grid of the amplifier at such a high negative potential with respect to the cathode that space current from generator or battery 22 cannot flow except during the brief intervals when positive impulses are applied to the grid. Condenser 23, shunting the space current source 22, provides a path of low impedance for impulses passing through the output circuit of the amplifier and tends to reduce fluctuations in the voltage of source 22. The output circuit of amplifier 13 is coupled to resonant circuit 14 by means of transformer 24 having primary and secondary windings insulated from each other.

The operation of the circuit of Fig. 1 is indicated in Figs. 2 and 3 in which the ordinates I_{B_1} and I_{B_2}, respectively, represent space current and the abscissæ E_{C_1} and E_{C_2} respectively, represent potentials of the grid with respect to the cathode. In Fig. 2, e_1 represents the normal polarizing potential across condenser 15. It will be seen that this potential is so large that space current is normally reduced to zero. The wave e_2 impressed from oscillator 10 upon the grid of amplifier 12 is of sufficient value to cause space current impulses I_1 to be periodically transmitted through the output circuit of the amplifier. These impulses, it will be noted, are in synchronism with the wave e_2 and are produced by positive peaks of wave e_2.

Impulses of space current I_1 in passing through the primary winding of transformer 19 produce waves e_3, Fig. 3, in the secondary winding of the transformer in the grid circuit of amplifier 13. The negative polarizing potential e_4 across condenser 20 is applied to the grid of amplifier 13 to prevent the transmission of space current through the amplifier during intervals between the positive peaks of waves e_3. It will be noted that wave e_3 is much steeper than wave e_2 impressed upon amplifier 12. The impedance of amplifier 13 accordingly undergoes very rapid variation from a substantially infinite value to approximately minimum value and vice versa as the control waves e_3 are applied to the grid of the tube to periodically cause space current impulses I_2 to be transmitted through the primary winding of transformer 24. These space current impulses I_2 appearing at regular intervals synchronously with the positive peaks of waves e_3, contain a wave component having the same frequency as wave e_2 and of greatly amplified value. This wave component is selected by resonant circuit 14 which functions to provide a relatively high impedance in the output circuit of amplifier 13 for waves of the frequency of oscillator 10 and of relatively low impedance to waves of higher frequencies. Resistance 25 represents the resistance corresponding to the load and may be the energy dissipating part of an antenna or other work circuit.

Waves of the frequency of oscillator 10 are produced in amplified form at very high efficiency by the operation of amplifiers 12 and 13. The amplified waves of the frequency of oscillator 10 are stored up in resonant circuit 14 whereas waves of higher frequencies in passing through the output circuit of amplifier 13 are subjected to very slight impedance and consequently involve very small losses at these high frequencies, it being noted that the impedance of amplifier 13 is very small whenever space current passes therethrough.

In Fig. 4, the circuit between vertical lines XX, YY may be substituted between the lines XX, YY, Fig. 1. Similarly the portion of Fig. 4 between lines YY, ZZ may be substituted between these lines in Fig. 1, and the portion of Fig. 4 to the right of line ZZ may be substituted to the right of line ZZ, Fig. 1.

Inductance coil 30, Fig. 4, in the output circuit of amplifier 12, see Fig 1, is provided with two variable taps at its remote ends. These taps lead to amplifier tubes 31 arranged in parallel in well known manner. A greater number of amplifier tubes may be connected in parallel between the tubes 31 at the points indicated by the broken lines. Blocking condensers 32 prevent the transmission of direct current from the circuits of amplifier 12 to the circuits of amplifier 31 or vice versa and also prevent generator 34, to be described, from being short circuited. High frequency choke coil 33 furnishes a direct current path between the grids and cathodes of amplifier 31. The grids of amplifier 31 are maintained polarized at a high negative potential e_4, see Fig. 3, with respect to the cathodes by means of direct current generator 34 or its equivalent. Resonant circuit 35 corresponding in function to resonant circuit 14, Fig. 1, is conductively connected with its inductance and capacity in parallel between the anodes and cathodes of amplifier 31. The function of generator 34 is similar to that of circuit 15, 16 described in connection with Fig. 1.

In certain tests of the circuit of Fig. 4, substituted in the circuit of Fig. 1, electric waves have been produced at an anode circuit efficiency for the amplifier 31 of approximately 93%, that is 93% of the direct current energy taken from source 22 was converted into alternating current of the frequency of source 10 and transmitted into oscillatory circuit 35 for radiation or other purposes.

The following data applies to the above mentioned tests:

Auxiliary amplifier (amplifier 12)
- Anode voltage (source 17) = 400 volts
- Anode current (I_1) = 60 milliamperes
- Inductance in anode circuit (coil 30) = 6.5 millihenrys

Power amplifier (amplifier 31)
- Inductance in grid circuit (coil 30) = 1.75 millihenrys
- Anode voltage (22) = 3615 volts
- Anode current (I_2) = 525 milliamperes
- Antenna resistance (resistance 25) = 36 ohms
- Antenna current = 7.00 amperes
- Power input to power amplifier from direct current source 22 = 1900 watts
- Power output in antenna (35) = 1760 watts
- Anode circuit efficiency = 93%

It will be appreciated that this anode circuit efficiency approaches the theoretical maximum limit of 100% and is, so far as is known, higher than has been obtained by any other known form of high frequency wave producing circuit of the prior art.

Various modifications of the specific circuits disclosed will be obvious to one skilled in the art without departing from the invention herein disclosed. The features of the invention which are considered novel are set forth in the appended claims.

What is claimed is:

1. The method of amplifying a wave which comprises amplifying the peaks of one polarity only of the wave to be amplified and amplifying the peaks of one polarity only of the resulting wave.

2. The method of operating amplifiers of the space current type which comprises generating a sine wave, amplifying peaks of one polarity only of said wave to produce a source of impulses having a more rapid rate of change from maximum to minimum and vice versa than said sine wave and amplifying peaks of one polarity only of said impulses, whereby said sine wave is reproduced in amplified form at high efficiency.

3. Means for amplifying waves including a plurality of amplifiers of the space current type in tandem, and means associated with each of said amplifiers and normally adjusted to prevent the flow of space current therethrough, whereby waves may be repeated at high efficiency.

4. Means for producing waves at high efficiency including a plurality of amplifiers of the space current type in tandem, means associated with each said amplifier and normally adjusted to prevent the flow of space current therethrough, and a source of waves coupled to the first amplifier in tandem to transmit waves therethrough, whereby amplified waves are produced at high efficiency in the last amplifier in tandem.

5. Means for producing waves at high efficiency including a source of waves of low power, a plurality of amplifiers of the space current type connected in tandem, means associated with said amplifiers and normally adjusted to prevent the flow of space current therethrough, an output circuit for the last amplifier in tandem tuned to the frequency of waves from said source, means for coupling said source to the first amplifier in tandem, whereby high power waves of the frequency of waves from said source are reproduced at high efficiency in said tuned output circuit.

6. Means for producing waves at high efficiency including a plurality of relays of the variable impedance type in tandem, means adjusted to render said relays normally substantially infinite in impedance, a source of waves of low power, means to couple said source to the first relay in tandem, whereby the impedance of said relays is periodically varied from substantially infinite to a minimum value and vice versa in synchronism with waves from said source, and an output circuit for the last relay in tandem tuned to the frequency of waves from said source.

7. Means for producing waves at high efficiency including a plurality of relays of the variable impedance type in tandem, means rendering said relays normally substantially infinite in impedance, a source of waves of low power, means to couple said source to the first relay in tandem whereby the impedance of said relays is periodically varied from substantially infinite to a minimum value and vice versa in synchronism with waves from said source, and a resonant circuit tuned to the frequency of waves from said source conductively connected to the output of the last relay in tandem.

8. Means for producing waves at high efficiency including a plurality of amplifiers of the variable impedance type in tandem, an output circuit for the last amplifier in tandem tuned to the frequency of waves to be produced, means adjusted to render said amplifiers normally substantially infinite in impedance, and means for impressing energy upon the first amplifier in tandem to cause said amplifiers to periodically and impulsively vary from substantially infinite to minimum impedance and vice versa at the same frequency as the waves to be produced, whereby high power waves of said frequency are produced at high efficiency in said tuned output circuit.

9. Means for producing waves at high efficiency including a plurality of amplifiers of the space current type connected in tandem, means comprising a grid leak resistance and a condenser in shunt thereto associated with said amplifiers and adjusted to normally prevent the flow of space current therethrough, inductive couplings between said amplifiers, a source of waves of low power coupled to said first amplifier in tandem, and a resonant circuit in the output of the last amplifier in tandem, said circuit being tuned to the frequency of waves from said source, whereby amplified waves of said frequency are reproduced in said resonant circuit at high efficiency.

10. Means for producing waves at high efficiency, including a source of waves of low power, an auxiliary amplifier of the variable impedance type having an input and an output circuit, means associated with said input circuit adjusted to render said amplifier substantially infinite in impedance and to allow the positive peaks only of waves from said source to render said amplifier substantially minimum in impedance, a power amplifier having an input circuit coupled to the output circuit of said auxiliary amplifier, said input circuit including means for rendering the power amplifier normally substantially infinite in impedance and allowing the positive peaks of waves impressed upon the input circuit of said amplifier to periodically render said amplifier substantially minimum in impedance, an output circuit for said power am-

plifier of high impedance to waves of the frequency of said source and of low impedance to waves of higher frequency, whereby waves of the frequency of said source are reproduced in said output circuit at high efficiency.

11. The method which comprises repeating the peaks of one polarity only of a wave to be repeated, repeating the peaks of one polarity only of the resulting wave, and utilizing the peaks so repeated to the exclusion of the peaks of the other polarity.

In witness whereof, I hereunto subscribe my name this 26th day of September A. D., 1923.

S. S. MACKEOWN.