March 17, 1931. G. C. SOUTHWORTH 1,796,486

AMPLIFIER FOR SHORT ELECTRIC WAVES

Filed May 1, 1926

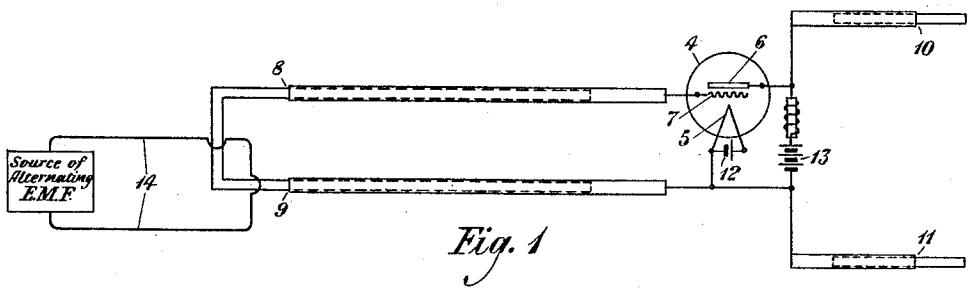


Fig. 1

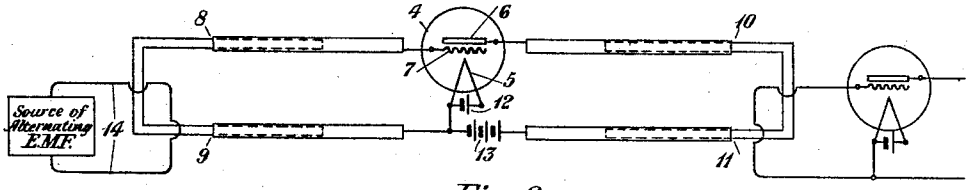


Fig. 2

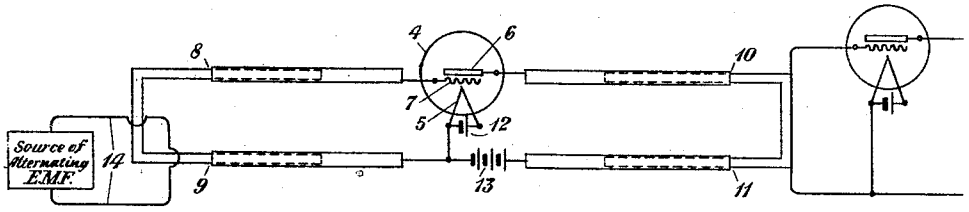


Fig. 3

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UNITED STATES PATENT OFFICE

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AMPLIFIER FOR SHORT ELECTRIC WAVES

Application filed May 1, 1926. Serial No. 106,132.

This invention relates to means for amplifying short electric waves, and more particularly to means suitable for amplifying alternating voltages and currents of frequencies higher than those now generally used in radio communication.

It is desirable that the frequency range available for communication purposes be materially extended. This is so especially because of the approaching need for a greater number of radio speech channels in view of the threatened congestion in the communication spectrum.

With the technique universally employed in the commercial field at the present time, engineers are confronted, in their efforts to produce very high frequencies for communication purposes—that is, to produce "ultra-radio" frequencies for use in radio communication, with the requirement of inductances and capacities so small as to be impracticable. At frequencies as low as three megacycles per second (3 mc.), corresponding to a wave length of one hundred meters (100 m.), such small coils and condensers are required that stray inductances imposed by connecting wires and extraneous capacities between pieces of apparatus often present difficulties which are considerable. When a frequency of approximately 30 mc., corresponding to a wave length of approximately 10 m., is reached, the coils and the condensers required are miniatures of the apparatus used in commercial radio practice, their inductances and capacities being but little greater than those of the necessary connecting wires.

It is the object of applicant's invention to provide means suitable to commercial use for producing alternating voltages and currents of "ultra-radio" frequencies and of such amplitude as to be useful in the practice of radio communication.

Applicant accomplishes his purpose by employing a three-electrode vacuum tube amplifier and applying methods new in the amplification of alternating voltages and currents to the solution of the problems of impressing the high frequency alternating voltages on the grid and of relaying the amplified waves.

In the vacuum tube amplifiers now in general use for amplifying alternating voltages and currents of "radio" frequencies, that is, frequencies lower than perhaps 30 mc., the grid and the filament of the tube are connected in a circuit, usually known as the "input circuit", having localized inductance furnished by a coil and localized capacity furnished by a condenser, the grid and the filament being connected to the terminals of the condenser. Electromagnetic energy is applied to the circuit, and a resonant condition of the circuit is set up, in which condition the energy is periodically transformed from the magnetic to the electric state. This resonant condition is obtained by the adjustment of the localized capacity or the localized inductance or both. At the time when the energy is wholly electric, or substantially so, the condenser is charged, and a relatively high voltage is impressed between the grid and the filament, this voltage controlling the electron stream from the filament to the plate. The natural period of oscillation of the circuit depends upon the time required for the energy to change from the magnetic to the electric state in the coil and condenser.

Instead of adopting the methods discussed above, applicant makes use of a "wave circuit", defined below, in which electromagnetic energy in the form of a wave travels in the space between two conductors and is reflected from the ends of a "rectangle". The term "wave circuit", as used by applicant, designates an extended circuit in which conductors are used to guide electric waves, or, in other words, a circuit the physical dimensions of which are appreciable in comparison with the length of the waves. Such a circuit may also be considered as a circuit having distributed inductance and capacity, as distinguished from localized inductance and capacity. In the wave circuit, the natural period of oscillation depends on the length of the conductors as compared with the wave length, or, in other words, as compared with the frequency of the alternations. Various distinctions between the "radio frequency amplifier" and applicant's "ultra-radio frequency amplifier" will

be more fully pointed out after a description has been given of one desirable embodiment of this invention.

The invention will be clearly understood from the following description of a desirable embodiment thereof. This description is to be read with reference to the accompanying drawing. Figure 1 of the drawing shows diagrammatically applicant's circuit so arranged that high frequency alternating voltages are amplified, and a considerable portion of the energy is radiated. Fig. 2 shows diagrammatically an arrangement of the circuit for amplifying the currents and communicating the output of the amplifier to the succeeding circuit—of a radio receiving system, for instance. Fig. 3 shows an arrangement similar to that of Fig. 2, but involving a different method of coupling between the amplifier and the succeeding circuit.

In each of the three circuits shown, there is the three-electrode vacuum tube 4, with filament 5, plate 6, and grid 7. The input or grid-filament circuit is completed by the parallel guiding conductors 8 and 9, which may be closed at the end, as shown, or open. The input circuit is thus substantially a rectangle having at its right end the grid-filament capacity. The output or plate-filament circuit is completed by the guiding conductors 10 and 11. The battery 12 furnishes the filament current, and the battery 13 provides the plate voltage.

The alternating electromotive force is communicated to the input circuit, in the arrangements shown in the drawing, from the circuit 14, which includes a source of electromotive force. It is to be understood that no limitation is placed on the scope of the invention by the specific showing here made, since it will be clear to those skilled in the art that the waves to be amplified may be set up in the input circuit by any one of a number of well known methods, the choice of the one most suitable being determined by the particular use to be made of the amplifier.

When a relatively small alternating electromotive force is applied to the input circuit, an electromagnetic wave will flow along the conductors 8 and 9, or, viewed somewhat differently, will travel in the space between these conductors, with a velocity approaching that of light. This wave will be reflected at the end 5—7 of the "rectangle", traveling back at the same rate of speed to the other end, where it will be again reflected, and so on. Resonance is produced by the adjustment of the length of the conductors 8 and 9 relative to the frequency of the applied electromotive force. Any wave circuit will be satisfactory which comprises conductors of suitable conductance and is so constructed or arranged that it may be readily adjusted as to form and dimensions. The conductors shown in the drawing are cylindrical and of substantial diameter and are in two telescoping sections, whereby length adjustment is readily made. The required length of the wave circuit relative to the frequency of the applied electromotive force will be generally discussed hereinafter.

When the energy is applied or reflected at the left end of the input circuit (with reference to the drawing) it is mainly magnetic. At an intermediate point between this end of the circuit and the vacuum tube end, it is both magnetic and electric. When the energy reaches the tube end of the circuit, it is mainly electric, and it will be readily understood by those skilled in the art that a relatively large voltage will be impressed between the grid and the filament. As in the case of the vacuum tube amplifier used for lower frequencies, the voltage impressed on the grid acts on the electron stream between the filament and the plate, changing the plate current in the output circuit.

The output or plate circuit of the tube 4 is designed, like the input circuit, to guide the electric waves, set up in this case by the changes in the voltage between the plate and the filament, due to the grid voltage change. This output circuit comprises the guiding conductors 10 and 11, terminating at the left end in the plate and the filament, respectively, and is formed in accordance with the disposition to be made of the output energy of the amplifier. If it is desired to radiate the energy directly into the ether, the guiding conductors 10 and 11 are widely separated and may be either open, as shown in Fig. 1, or closed. If, however, it is desired to communicate the energy output to another circuit, for instance the circuit including a succeeding amplifier tube or a detector tube in a receiving set, the guiding conductors are placed relatively close together, and are, for example, coupled to the succeeding circuit directly, as shown in Fig. 2, or by the indirect inductive method of Fig. 3. The conductors 10 and 11 are preferably constructed and adjusted as are the input circuit conductors 8 and 9.

In order to produce the condition of resonance in a simple wave circuit is it approximately accurate to say that in the case of conductors closed or open at both ends, the length of the conductors must be equal to one-half the length of the waves, and in the case of conductors closed at one end and open at the other, the length of the conductors must be equal to one-fourth the length of the waves. If, however, a wave circuit closed at both ends is terminated in a capacity, the length of the conductors which is required for resonance will be, in most cases, slightly greater. This condition exists in the circuits shown in Figs. 2 and 3 of the drawing, since the wave circuits are terminated in either the grid-filament capacity or the plate-filament ca-

pacity of the tube. Again, if a wave circuit is closed at one end and terminated in a capacity, the length of the conductors will be slightly less than in the simple case, in most instances. If the tube capacity terminating the wave circuit is so large that the requirements for resonance, as stated above, would lead to a rectangle too short to be practicable for coupling, the rectangle should be lengthened by one-half the wave length or any multiple thereof. In other words, the guiding conductors will now be so adjusted, in the case of conductors closed at both ends, as to make the length of the wave circuit approximately one-half the wave length or equal to the wave length, or to one and one-half times the wave length, or to twice the wave length, etc. Likewise, in the case of conductors open at only one end, the length of the conductors will be adjusted to make the wave circuit length approximately one-fourth of the wave length or equal to three-fourths of the wave length, or to one and one-fourth times the wave length, or to one and three-fourths times the wave length, etc. It is to be remembered that the tube capacity renders necessary circuit lengths somewhat different from those indicated above.

It will help to clarify the description of applicant's amplifier to note the following distinctions between the "radio frequency amplifier" and the "ultra-radio frequency amplifier" embodying the invention. In the case of the former, the impressed grid voltages are derived from energy oscillating from the magnetic state to the electric state in a coil and a condenser. The natural period of oscillation is determined by the time required for the energy to change from the magnetic to the electric state in these elements, which, in turn, depends on their inductance and capacity. The oscillations take place in a space very small in comparison with the length of the waves to be produced. In applicant's amplifier, the energy is in the form of an electro-magnetic wave guided along the conductors. In the input circuit, when the energy reaches the grid, it is electric and provides the necessary voltage for operating the tube. The natural period of oscillation is determined by the time required for a wave to travel the length of the "rectangle" and be reflected back. The oscillations take place in a space appreciable when compared with the wave length.

While applicant's invention has been described in a specific embodiment for the purpose of illustration, it is to be understood that it is capable of embodiment in other and different forms without a departure from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A system for amplifying electric waves, comprising a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode and having only distributed capacity and distributed inductance, and an output circuit including said cathode and said anode and having only distributed capacity and distributed inductance.

2. An amplifier of electric waves, comprising a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode and having only distributed capacity and distributed inductance, an output circuit including said cathode and said anode and having only distributed capacity and distributed inductance, means for impressing electric waves on said input circuit, and means for communicating electric energy from said output circuit.

3. A system for amplifying electric waves, comprising a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode and having only distributed capacity and distributed inductance, and an output circuit including said cathode and said anode and having only distributed capacity and distributed inductance, said input circuit and said output circuit being adjustable as to form and dimensions.

4. An amplifier of electric waves, comprising a vacuum tube having an anode, a cathode, and a controlling electrode; an input circuit including said cathode and said controlling electrode, and an output circuit including said cathode and said anode, said circuits having only distributed capacity and distributed inductance and being adjustable as to form and dimensions; means for impressing electric waves on said input circuit; and means for communicating electric energy from said output circuit.

5. In a system for amplifying electric waves, including a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode and having only distributed capacity and distributed inductance.

6. In a system for amplifying electric waves, including a vacuum tube having an anode, a cathode, and a controlling electrode, an output circuit including said cathode and said anode and having only distributed capacity and distributed inductance.

7. In a system for amplifying electric waves, including a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode and having only distributed capacity and distributed inductance, said circuit being adjustable as to form and dimensions.

8. In a system for amplifying electric waves, including a vacuum tube having an

anode, a cathode, and a controlling electrode, an output circuit including said cathode and said anode and having only distributed capacity and distributed inductance, said circuit being adjustable as to form and dimensions.

9. In a system for amplifying electric waves, a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode and having only distributed capacity and distributed inductance, and an energy supplying circuit associated with said input circuit, said energy supplying circuit being associated with said vacuum tube only through said input circuit.

10. A system for amplifying electric waves, comprising a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode and having only distributed capacity and distributed inductance, an output circuit including said cathode and said anode and having only distributed capacity and distributed inductance, and an energy supplying circuit associated with said input circuit, said energy supplying circuit being associated with said vacuum tube only through said input circuit.

11. An amplifier of electric waves, comprising a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode, an output circuit including said cathode and said anode, means for impressing electric waves on said input circuit, and means for communicating electric energy from said output circuit, said input and said output circuits each having only distributed capacity and distributed inductance in addition to any inductance or capacity which may be involved in the coupling between said circuits and the impressing means and the communicating means respectively.

12. An amplifier of electric waves, comprising a vacuum tube having an anode, a cathode, and a controlling electrode; an input circuit including said cathode and said controlling electrode; an output circuit including said cathode and said anode; means for impressing electric waves on said input circuit; and means for communicating electric energy from said output circuit; said input and said output circuits being adjustable as to form and dimensions and having each only distributed capacity and distributed inductance in addition to any inductance or capacity which may be involved in the coupling between said circuits and the impressing means and the communicating means respectively.

13. In a system for transmitting electric waves, comprising a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode and having only distributed capacity and distributed inductance, and an output circuit including said cathode and said anode and having only distributed capacity and distributed inductance.

14. In a system for transmitting electric waves including a vacuum tube having an anode, a cathode, and a controlling electrode, an input circuit including said cathode and said controlling electrode and having only distributed capacity and distributed inductance.

15. In a system for transmitting electric waves, including a vacuum tube having an anode, a cathode, and a controlling electrode, an output circuit including said cathode and said anode and having only distributed capacity and distributed inductance.

In testimony whereof, I have signed my name to this specification this 29th day of April, 1926.

GEORGE C. SOUTHWORTH.