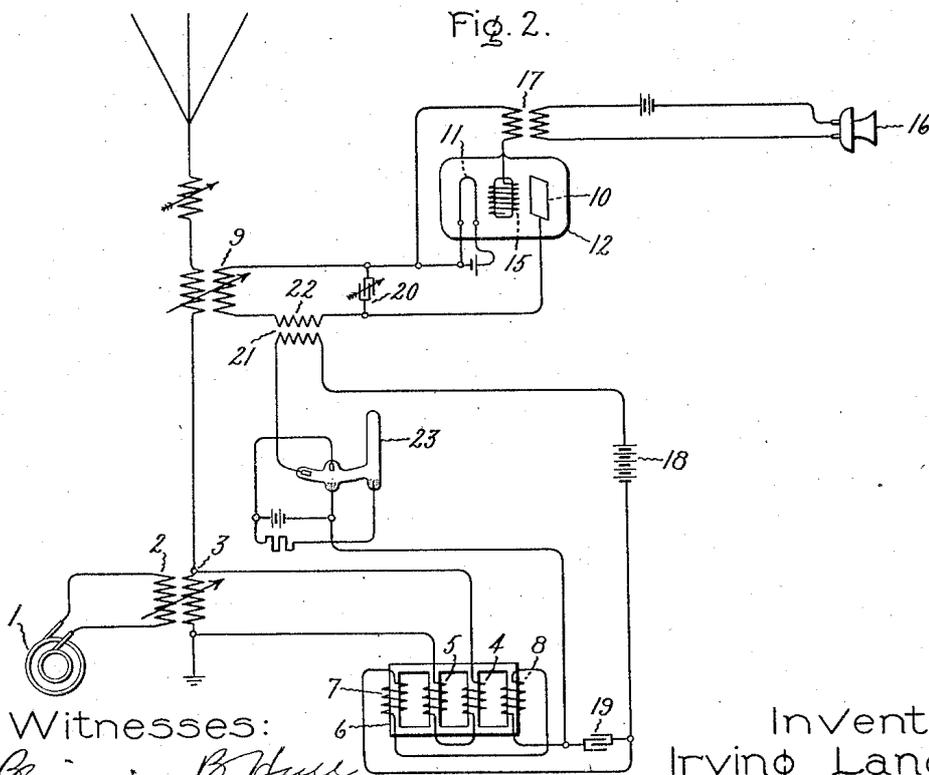
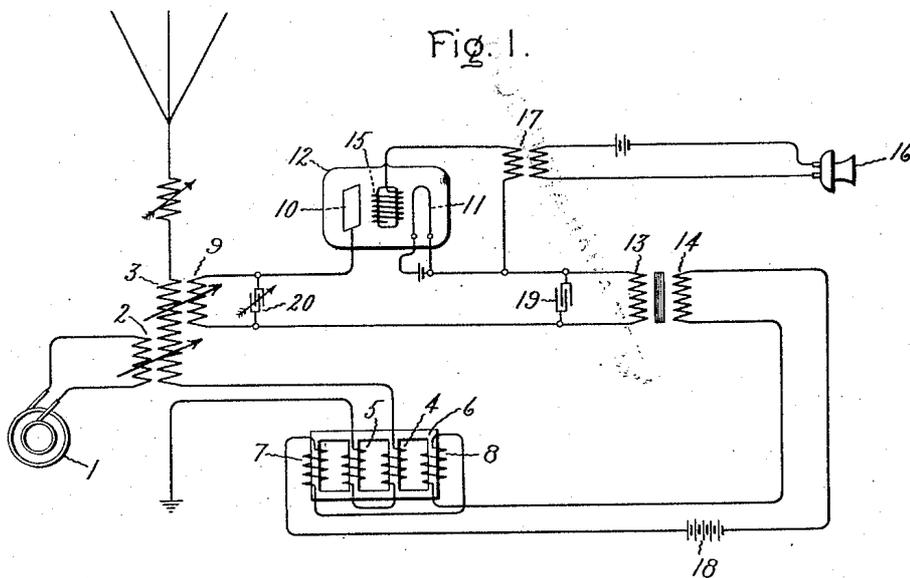


I. LANGMUIR,  
 METHOD OF AND MEANS FOR CONTROLLING ELECTRICAL ENERGY.  
 APPLICATION FILED NOV. 20, 1914.

1,301,279.

Patented Apr. 22, 1919.



Witnesses:  
*Benjamin B. Hull*  
*Helen O'ford*

Inventor:  
 Irving Langmuir,  
 by *Arthur S. Davis*  
 His Attorney.

# UNITED STATES PATENT OFFICE.

IRVING LANGMUIR, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

METHOD OF AND MEANS FOR CONTROLLING ELECTRICAL ENERGY.

1,301,279.

Specification of Letters Patent.

Patented Apr. 22, 1919.

Application filed November 20, 1914. Serial No. 873,115.

*To all whom it may concern:*

Be it known that I, IRVING LANGMUIR, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Methods of and Means for Controlling Electrical Energy, of which the following is a specification.

My present invention relates to a method of and means for controlling electrical energy, and more especially electrical energy in the form of high frequency alternating currents.

The object of my invention is to provide a system for controlling the flow of a high frequency alternating current in an electric circuit in such a way that large variations in the amplitude of the current may be produced by means of a variable controlling current of comparatively small magnitude flowing in a second circuit. A further object of my invention is to produce variable controlling current in the second circuit by means of energy derived from the source of energy which supplies the first circuit.

In carrying my invention into effect I subject a high frequency current derived from the source supplying the first circuit to the action of various modifying means in such a way as to produce a pulsating unidirectional current of the desired character to serve as a controlling current.

While in the description which follows I have illustrated the application of my invention to wireless telephony it is by no means limited to that use but is adapted to the transmission of other forms of signals by means of radiant energy or for the transmission of electric currents through wires.

The novel features which I believe to be characteristic of my invention are pointed out with particularity in the appended claims. The invention itself, however, with further objects and advantages will be best understood by reference to the following description taken in connection with the accompanying drawing in which Figure 1 is a simple diagrammatic representation of apparatus and circuit connections which may be employed in carrying my invention into effect, and Fig. 2 shows a modification thereof.

As indicated in Fig. 1 the source of high frequency alternating current 1 is inductively connected by means of the coil 2 to the coil 3 which is in series with the an-

tenna. The amount of current flowing in the antenna is controlled by varying the inductance of the antenna circuit by variations in a controlling current flowing in a second circuit. As here indicated two reactance coils 4 and 5 wound around the magnetic core 6 are included in the antenna circuit. Wound upon the same core are two coils 7 and 8 through which a controlling current is caused to flow. The coils 7 and 8 are connected in opposition to each other, hence the magnetizing action of the current flowing in coil 7 upon coil 5 is opposite in effect to that of the current flowing in coil 8 upon coil 4. Furthermore, as coils 7 and 8 are connected in opposition the voltage induced in coil 7 by the high frequency current is opposite to that induced in coil 8. The respective coils are so designed that the voltage induced in coil 7 is equal to that induced in coil 8 and therefore the resultant effect of these voltages in the controlling circuit is zero. The combined inductance of coils 4 and 5 will vary as a function of the magnetization of the core 6, this change in inductance being due to the varying magnetic reluctance at varying magnetic densities. Since the coils 7 and 8 are connected in opposition the combined impedance of coils 4 and 5 in the antenna circuit will be uniform for the two alternations of a complete cycle of the current. It will thus be evident that the current flowing in the antenna can be controlled by varying the amount of current supplied to the coils 7 and 8. While the form of inductive device here described is the preferred form I do not wish to be limited to this specific arrangement as variations may be made therein without departing from the scope of my invention.

The greater the amount of energy which it is desired to radiate the greater will be the magnetizing force which must be supplied to the coils 7 and 8 to give the desired control. If the controlling current applied to coils 7 and 8 is the current flowing in an ordinary telephone transmitter the amplitude of the current flowing in the antenna may be varied in accordance with the variations in the amplitude of the telephone current. Inasmuch, however, as the energy variations which may be produced by an ordinary telephone transmitter supplied by a constant source of potential is comparatively small, it is not possible to produce in this way sufficiently large variations in the mag-

netizing force to control large enough amounts of energy to transmit sound waves over great distances. One of the objects of my invention is to produce a controlling current in the coils 7 and 8, the energy variations of which will be much greater than it is possible to produce by means of a telephone transmitter supplied by a constant potential source.

In the organization here illustrated the energy from which the controlling current is produced is diverted from the antenna circuit by means of the coil 9 which is coupled with the antenna. While I have here indicated an inductive coupling, other forms of coupling may equally well be employed. The terminals of coil 9 are connected to the anode 10 and cathode 11 of an electron discharge relay 12, and included in the circuit is the primary 13 of a transformer 14. With a device of this character it is well known that if a variable potential is applied to the grid 15 of the relay a variable current will flow through the circuit. To provide this variable potential the local circuit of the telephone transmitter 16 is inductively connected to the grid circuit of the electron discharge relay through the transformer 17. With this arrangement there will flow through the circuit comprising the coils 9 and 13 and the relay 12, a current which will vary in accordance with the variations in the telephone current. The current thus obtained will preferably be of high potential and small amplitude and this current may be stepped down in voltage by the transformer 14 and caused to flow through the magnetizing coils 7 and 8. Since the current in the secondary of the transformer 17 is an alternating current it will be necessary with this arrangement to provide an initial unidirectional magnetization of the core 6, and this may be done by means of a direct current source of energy 18 included in the controlling circuit, the potential of which must always be greater than that obtained from the secondary of transformer 14. The current flowing in the controlling circuit may be considered as a pulsating current superimposed on a constant direct current. The constant direct current will produce a constant magnetization while the pulsating current will produce a magnetization in the same direction which is proportional to the amplitude of the pulsations. The current derived from the secondary of the transformer 14 will be an alternating current of the frequency of the sound waves which act on the telephone transmitter. This current will vary in accordance with the variations in the telephone current and consequently will vary the inductance of the coils 4 and 5 thereby varying the amount of current flowing in the antenna. The current flowing in the circuit comprising coils 9 and 13 and the electron discharge relay 12 may be considered as consisting of a high frequency pulsating current produced by the rectification of every alternate half cycle, having superimposed thereon a low frequency pulsating current corresponding to the telephone current. Inasmuch as the coil 13 may offer a high impedance to the high frequency component of this current, it may be found desirable to shunt this coil by a condenser 19 of such capacity as to allow the high frequency component to pass therethrough without allowing an appreciable amount of the low frequency component to pass. A variable condenser 20 may also be employed for tuning the circuit which comprises this condenser and coil 9 to the same frequency as the source 1 in order to obtain high potentials for the operation of relay 12. The amount of current in the circuit may also be adjusted by varying the coupling between the coil 9 and the antenna.

In the operation of this system it will be seen that the energy diverted from the antenna in the coil 9 will vary in accordance with variations in the current flowing in the antenna. As the current through the relay 12 increases the current in the controlling coils will increase and there will be a corresponding increase in the antenna current. This will produce an increase in the amount of energy diverted from the antenna and will thus produce a further increase in the controlling current of the coils 7 and 8. By utilizing this reinforcing action a comparatively small variation in the telephone current may produce a large enough energy variation in the control circuit to control large amounts of energy in the antenna. This reinforcing action may in some cases become so great as to lead to instability in the operation of the system. If such is the case it will become necessary to reduce the amplitude of the variations in the energy diverted from the antenna. With the arrangement here shown, the coils 2, 3 and 9 all being coupled together, the desired effect may be produced by forming a closer coupling between coils 2 and 9, and decreasing the coupling between the coils 3 and 9, thus diverting a larger proportion of the energy used for the controlling current directly from the generator itself and a smaller portion from the antenna. It will of course be apparent that all of the energy for the controlling current may be taken directly from the generator, in which case if the potential of the generator remains constant no reinforcing action will be present. On the other hand a portion of the energy may be taken directly from the generator and the remainder from the antenna.

In the arrangement shown in Fig. 2 I have indicated the reactive coils 4 and 5 as

connected in shunt to the secondary of the transformer 2. In this case as in the one already described energy is diverted from the antenna by means of the coil 9. The variable current produced in the circuit which comprises the coil 9 and the electron discharge relay 12 may be stepped down to low voltage in the coil 21 which is inductively related to coil 22 in the relay circuit and the low voltage, high frequency current thus obtained is rectified by the mercury rectifier 23 and caused to pass through the magnetizing coils 7 and 8. In this arrangement the battery 18 in the controlling circuit is connected so as to oppose the unidirectional potential obtained by means of the coil 21 and the rectifier 23. As the current flowing through the coils 9 and 22 increases, the magnetization of the core 6 produced by the battery 18 will decrease. This will cause a decrease in the current flowing through coils 4 and 5 and an increase in the potential across coil 3 and in the antenna current. As the antenna current increases the amount of energy diverted from the antenna by the coil 9 will increase as in the first illustration.

While I have here indicated the coils 4 and 5 as being connected in shunt across coil 3, it will be apparent that they may equally well be connected in shunt to any two points in the antenna circuit between which there is a large enough difference of potential. It will also be apparent that instead of connecting them directly to the antenna they may be coupled therewith in other ways. Since the results which may be obtained in this way are similar to those which are secured with the series connection, I consider the two as equivalent and when I speak of the antenna circuit as including reactance, I mean to imply either the series or shunt connection.

While I have illustrated only two embodiments of my invention it will be apparent that by varying the methods of connecting the various parts thereof and by varying the particular type of apparatus employed many modifications may be made without departing from the scope of the appended claims. Certain broad aspects of the apparatus and methods herein disclosed relating to the use of an electron discharge relay for diverting energy from an antenna and for supplying the controlling current to a variable inductance of the type herein described, are not of my invention, but are the invention of Ernst F. W. Alexanderson and are defined by the claims of his application, Serial No. 873,110, filed November 20, 1914.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. The combination in a system for transmitting wireless signals of an antenna circuit supplied by a source of high frequency current, a reactance included in said antenna

circuit, a second circuit including a magnetizing winding so related to said reactance that the impedance of the antenna circuit may be varied by varying the current in said magnetizing winding and means for diverting from the antenna circuit to said magnetizing winding an amount of energy sufficient to produce the desired variation in the current in said magnetizing winding.

2. The combination in a system for transmitting wireless signals of an antenna circuit supplied by a source of high frequency current, a reactance included in said antenna circuit, a second circuit including a magnetizing winding so related to said reactance that the impedance of the antenna circuit may be varied by varying the current in said magnetizing winding, and means for diverting from the antenna circuit to said magnetizing winding an amount of energy sufficient to produce the desired variation in the current in said magnetizing winding and which varies in accordance with variations in the antenna current.

3. The method of controlling the flow of high frequency alternating current in an electric circuit which consists in diverting a portion of the energy from the circuit, utilizing energy thus diverted to produce a magnetizing field, producing a pulsating current independently of the energy thus diverted, varying the magnetizing field in accordance with the variations in said pulsating current and subjecting the current in the circuit to the action of said magnetizing field.

4. The method of controlling the flow of high frequency alternating current in an electric circuit which consists in diverting from the circuit an amount of energy which varies in proportion to the amplitude of the current in said circuit, utilizing energy thus diverted to produce a varying magnetizing field and utilizing said varying magnetizing field to vary the inductive reactance of the circuit.

5. The method of controlling the flow of high frequency alternating current in an electric circuit which consists in diverting from the circuit an amount of energy which varies in accordance with variations in the amplitude of the current in said circuit, producing a pulsating current independently of the energy thus diverted, utilizing energy thus diverted to produce a magnetizing field, which varies in accordance with the variations in said pulsating current and subjecting the current in the circuit to the action of said magnetizing field.

6. The method of controlling the flow of high frequency alternating current in an electric circuit which consists in producing a pulsating current independently of the energy in said circuit, diverting from the circuit an amount of energy which varies in

accordance with variations in the amplitude of the current in said circuit and which also varies in accordance with variations in the amplitude of said pulsating current, utilizing energy thus diverted to produce a varying magnetizing field, and subjecting the current in the circuit to the action of said varying magnetizing field.

7. The combination in a wireless signaling system of an antenna circuit supplied by a source of high frequency current, a reactance coil in said antenna circuit, a second circuit including a magnetizing winding so related to said reactance coil that the impedance of the antenna circuit may be varied by varying the current in said magnetizing winding, means for diverting a portion of the energy from the antenna circuit, a third circuit having means therein for producing a pulsating current independently of the energy thus diverted, means for varying the amount of energy diverted from the antenna circuit in accordance with variations in the pulsating current flowing in said third circuit, and means for supplying energy thus diverted to the magnetizing coils.

8. The combination in a system for transmitting wireless signals of an antenna circuit supplied by a source of high frequency alternating current, a reactance included in said antenna circuit, a second circuit including a magnetizing winding so related to said reactance that the impedance of the antenna circuit may be varied by varying the current in said magnetizing winding, means for diverting from the antenna circuit an amount of energy which varies in accordance with the variations in the amplitude of the current in said circuit, and means for supplying energy thus diverted to the magnetizing coils.

9. The combination with an electric circuit supplied by a source of high frequency alternating current, of means for diverting a portion of the energy from said circuit, means for utilizing energy thus diverted to produce a varying magnetizing field, and means for utilizing said magnetizing field to vary the inductive reactance of the circuit.

10. The combination with an electric circuit supplied by a source of high frequency alternating current, of means for diverting a portion of the energy from said circuit, means for utilizing energy thus diverted to produce a magnetizing field which varies in accordance with variations in a pulsating current flowing in another circuit and means for utilizing said magnetizing field for varying the inductive reactance of the first circuit.

11. The combination with an electric circuit supplied by a source of high frequency alternating current, of means for diverting from said circuit an amount of energy which varies in accordance with variations in the

amplitude of the current in said circuit, means for utilizing energy thus diverted to produce a varying magnetizing field, and means for utilizing said varying magnetizing field for varying the inductive reactance of the circuit.

12. The combination with an electric circuit supplied by a source of high frequency alternating current, of means for diverting from the circuit an amount of energy which varies in accordance with variations in the amplitude of the current in said circuit, means for utilizing energy thus diverted to produce a magnetizing field which varies in accordance with the variations in a pulsating current flowing in another circuit, and means for utilizing said magnetizing field for varying the inductive reactance of the first circuit.

13. The combination with an electric circuit supplied by a source of high frequency alternating current, of means for diverting from said circuit an amount of energy which varies in accordance with the variations in the amplitude of the current in said circuit, means for further varying the amount of energy thus diverted in accordance with the variations in an independently produced pulsating current flowing in another circuit, means for utilizing energy thus diverted to produce a varying magnetizing field, and means for subjecting the current in the first circuit to the action of said varying magnetizing field.

14. The method of controlling the flow of high frequency alternating current in an electric circuit which consists in producing a low frequency pulsating current independently of the energy in said circuit, producing by means of energy derived from the high frequency alternating current in the circuit a magnetizing field which varies in accordance with the variations in said low frequency current and subjecting the current in the circuit to the action of said magnetizing field.

15. The combination with an electric circuit supplied by a source of high frequency alternating current of a second circuit having means therein for producing independently of the energy in said first circuit a low frequency pulsating current, means for producing by energy derived from said first circuit a magnetizing field which varies in accordance with the variations in the low frequency current in said second circuit, and means for subjecting the current in the first circuit to the action of said magnetizing field.

16. The combination in a wireless signaling system of an antenna circuit supplied by a source of high frequency alternating current for transmitting wireless signals through space, means for diverting a portion of the energy from said antenna circuit,

means for utilizing energy thus diverted to produce a varying magnetizing field, and means for subjecting the current in the antenna circuit to the action of said magnetizing field.

17. The combination in a wireless signaling system of an antenna circuit supplied by a source of high frequency alternating current for transmitting wireless signals through space, a second circuit having means therein for producing a pulsating current, means for diverting a portion of the energy from said antenna circuit, means for utilizing energy thus diverted to produce a magnetizing field which varies in accordance with the pulsating current flowing in said second circuit and means for subjecting the current in the antenna circuit to the action of said magnetizing field.

18. The combination in a wireless signaling system, of an antenna circuit supplied by a source of high frequency alternating current for transmitting wireless signals through space, means for diverting from said antenna circuit an amount of energy which varies in accordance with variations in the amplitude of the current in said circuit, means for utilizing energy thus diverted to produce a varying magnetizing field, and means for subjecting the current in the antenna circuit to the action of said varying magnetizing field.

19. The combination in a wireless signaling system of an antenna circuit supplied by a source of high frequency alternating current for transmitting wireless signals through space, a second circuit having means therein for producing a pulsating current, means for diverting from the antenna circuit an amount of energy which varies in accordance with the variation in the amplitude of the current in said antenna circuit, means for utilizing energy thus diverted to produce a magnetizing field which varies in accordance with the variations in a pulsating current flowing in said second circuit, and means for subjecting the current in the antenna circuit to the action of said magnetizing field.

20. The combination in a wireless signaling system of an antenna circuit supplied by a source of high frequency alternating current for transmitting wireless signals, means for diverting from said antenna circuit an amount of energy which varies in accordance with the variations in the amplitude of the current in said circuit, means for further varying the amount of energy thus diverted in accordance with the variations in a pulsating current flowing in another cir-

cuit, means for utilizing energy thus diverted to produce a varying magnetic field and means for subjecting the current in the antenna circuit to the action of said varying magnetic field.

21. The method of controlling the flow of high frequency alternating current in an electric circuit which consists in producing by means of energy diverted from said circuit a magnetizing field which varies in accordance with variations in a low frequency pulsating current flowing in another circuit, and utilizing said magnetizing field to vary the inductive reactance of the first circuit.

22. The method of transmitting wireless signals through space which consists in impressing a radio frequency current upon an antenna, diverting from the antenna a portion of the energy thus supplied, utilizing the energy thus diverted to produce a varying magnetizing field and utilizing the magnetizing field thus produced to vary the current in the antenna.

23. The method of wireless signaling which consists in impressing a radio frequency current upon an antenna, diverting from the antenna a portion of the energy thus supplied utilizing the energy thus diverted to produce a varying magnetizing field and utilizing the magnetizing field thus produced to vary the inductive reactance of the antenna circuit.

24. The method of transmitting wireless signals through space which consists in impressing a radio frequency current upon an antenna, diverting from the antenna a portion of the energy thus supplied, utilizing the energy thus diverted to produce a magnetizing field which varies at an audio frequency, and utilizing the magnetizing field thus produced to vary the current in the antenna.

25. The method of wireless signaling which consists in impressing a radio frequency current upon an antenna, diverting from the antenna a portion of the energy thus supplied, utilizing the energy thus diverted to produce a magnetizing field which varies at an audio frequency, and utilizing the magnetizing field thus produced to vary the inductive reactance of the antenna circuit.

In witness whereof, I have hereunto set my hand this 18th day of November, 1914.

IRVING LANGMUIR.

Witnesses:

ERNST F. W. ALEXANDERSON,  
BENJAMIN B. HULL.