No. 706,736. Patented Aug. 12, 1902.

R. A. FESSENDEN.

APPARATUS FOR WIRELESS TELEGRAPHY.

(Application filed May 17, 1900. Renewed Nov. 29, 1901.)

(No Model.) 3 Sheets—Sheet 1.

FIG. 1.

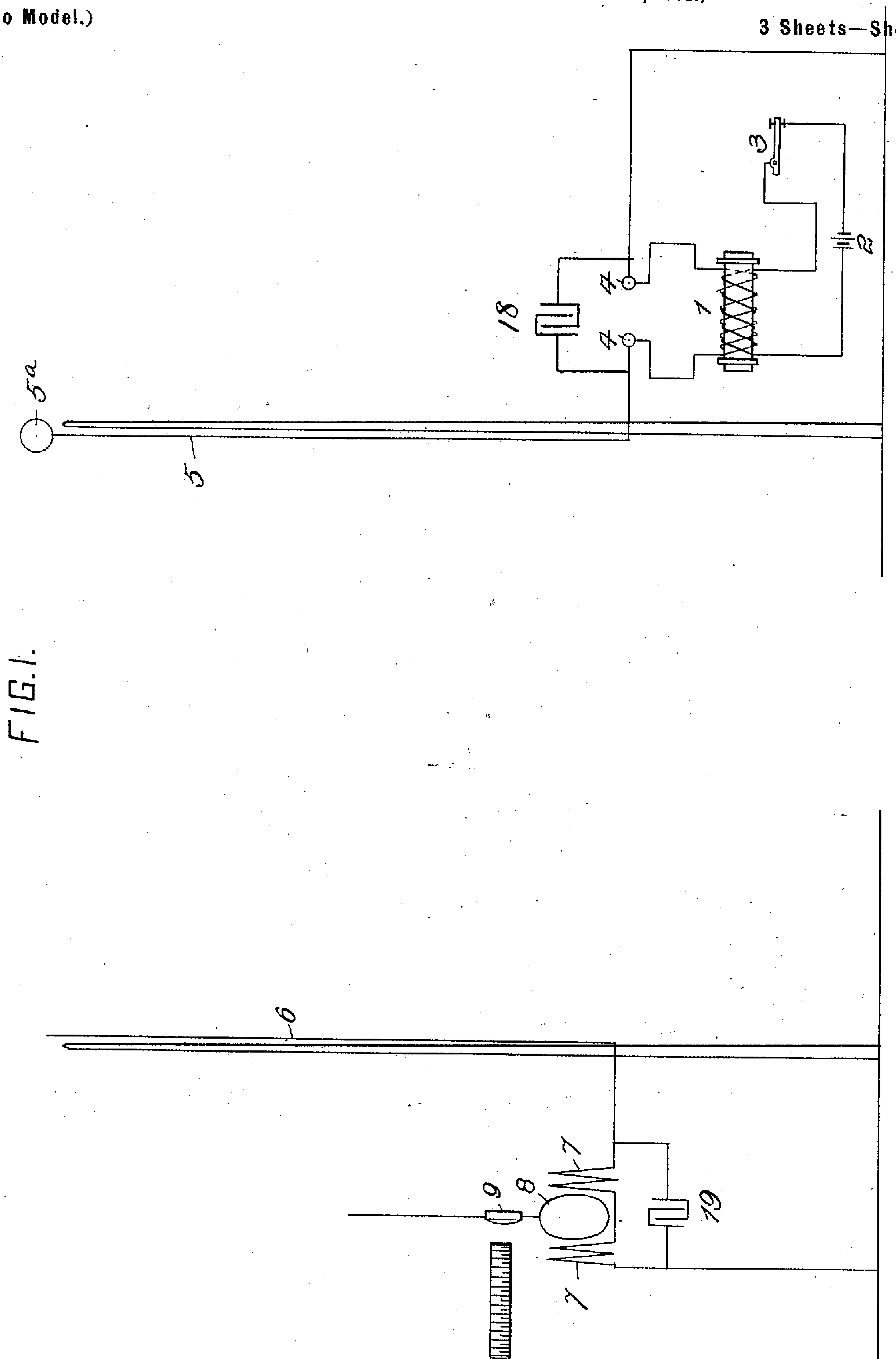

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FIG. 2.

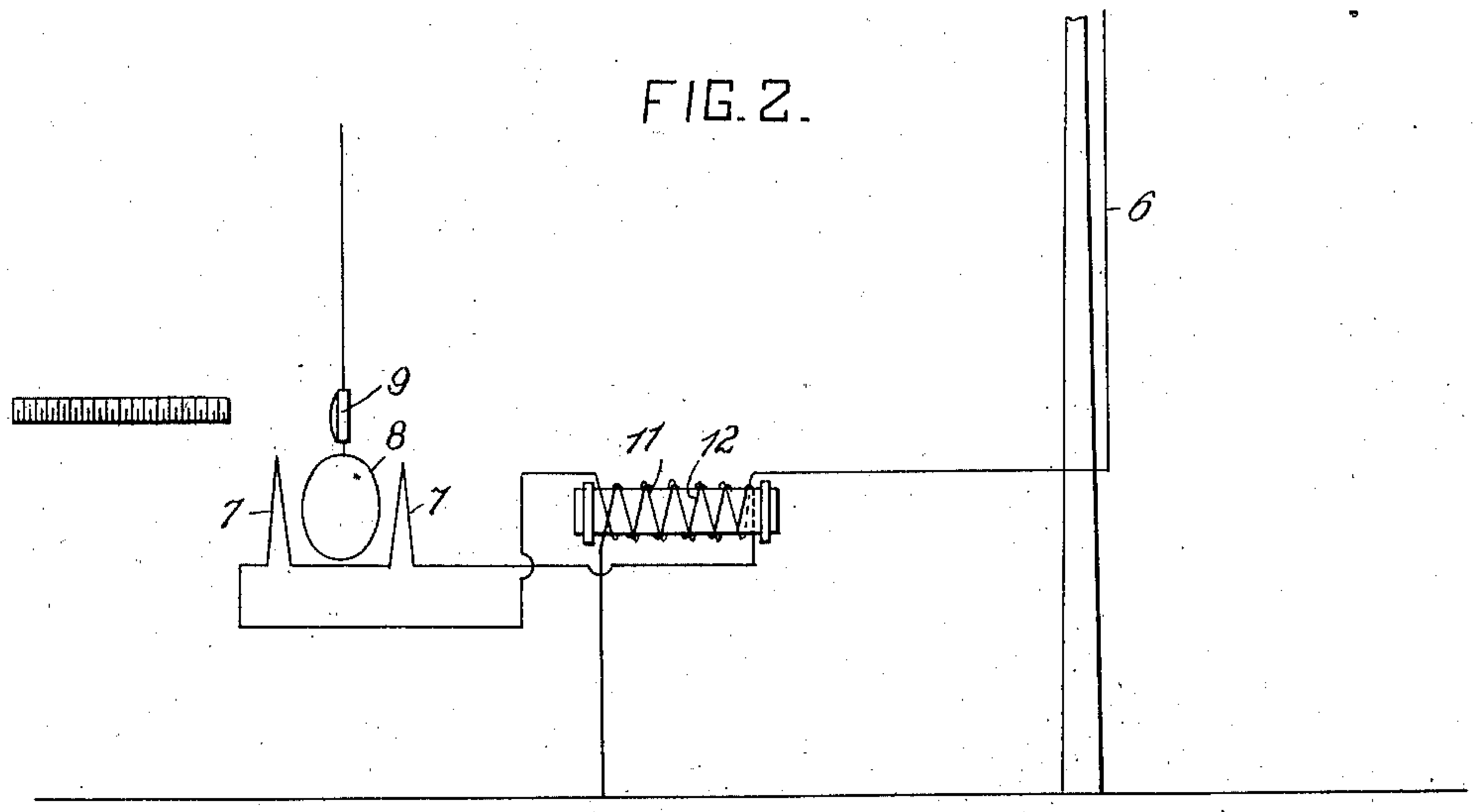

FIG. 5.

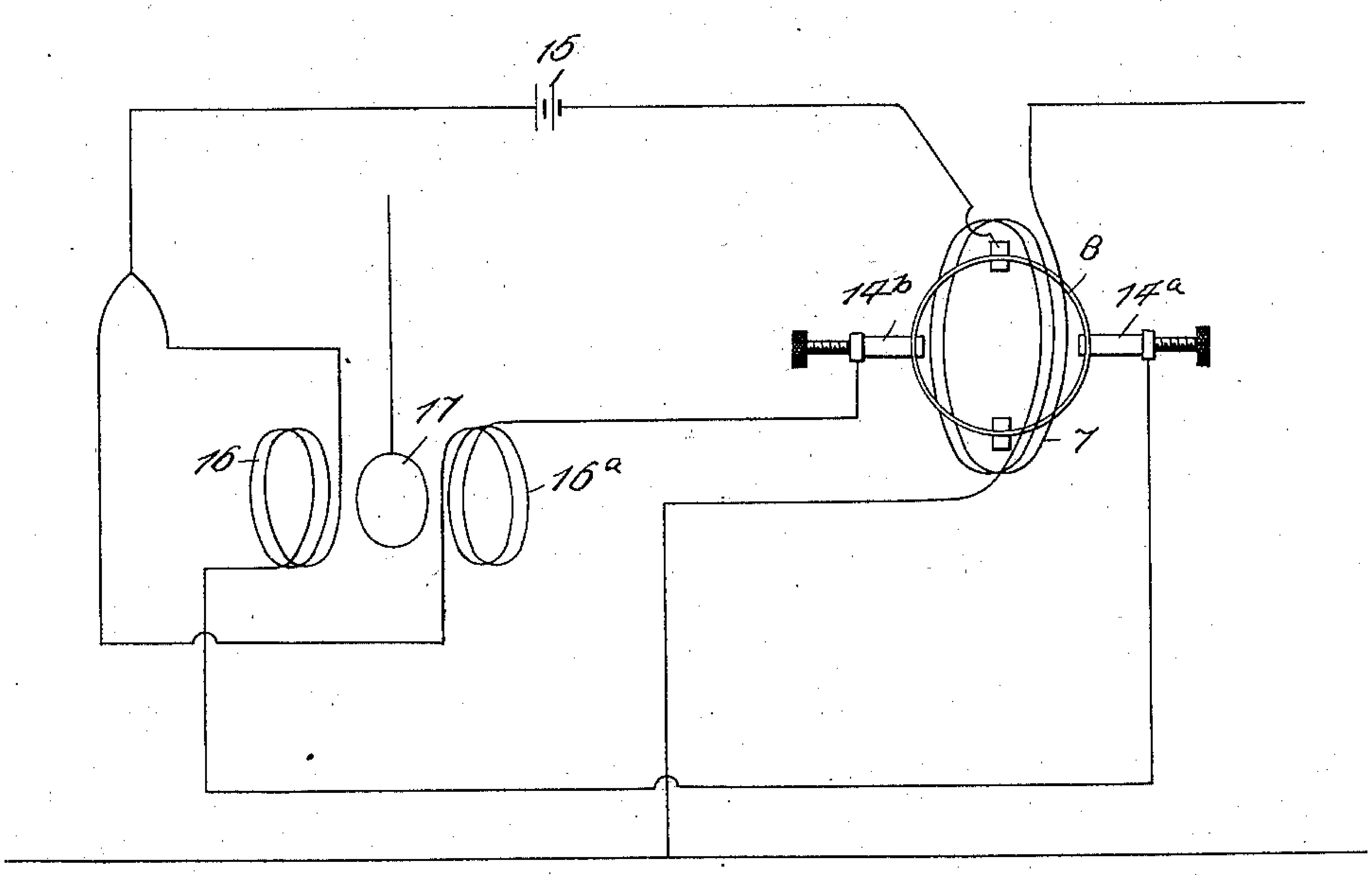

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FIG. 3.

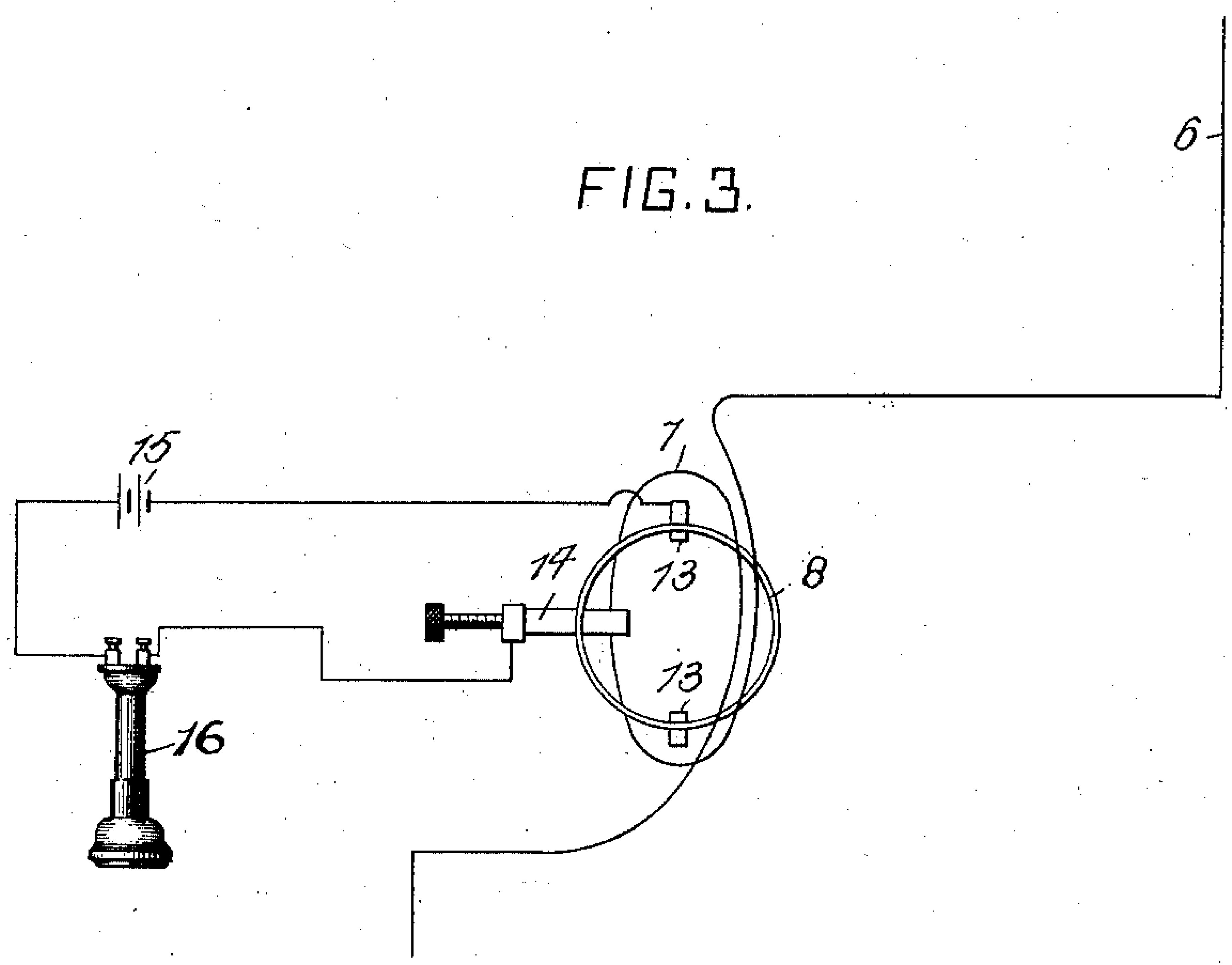
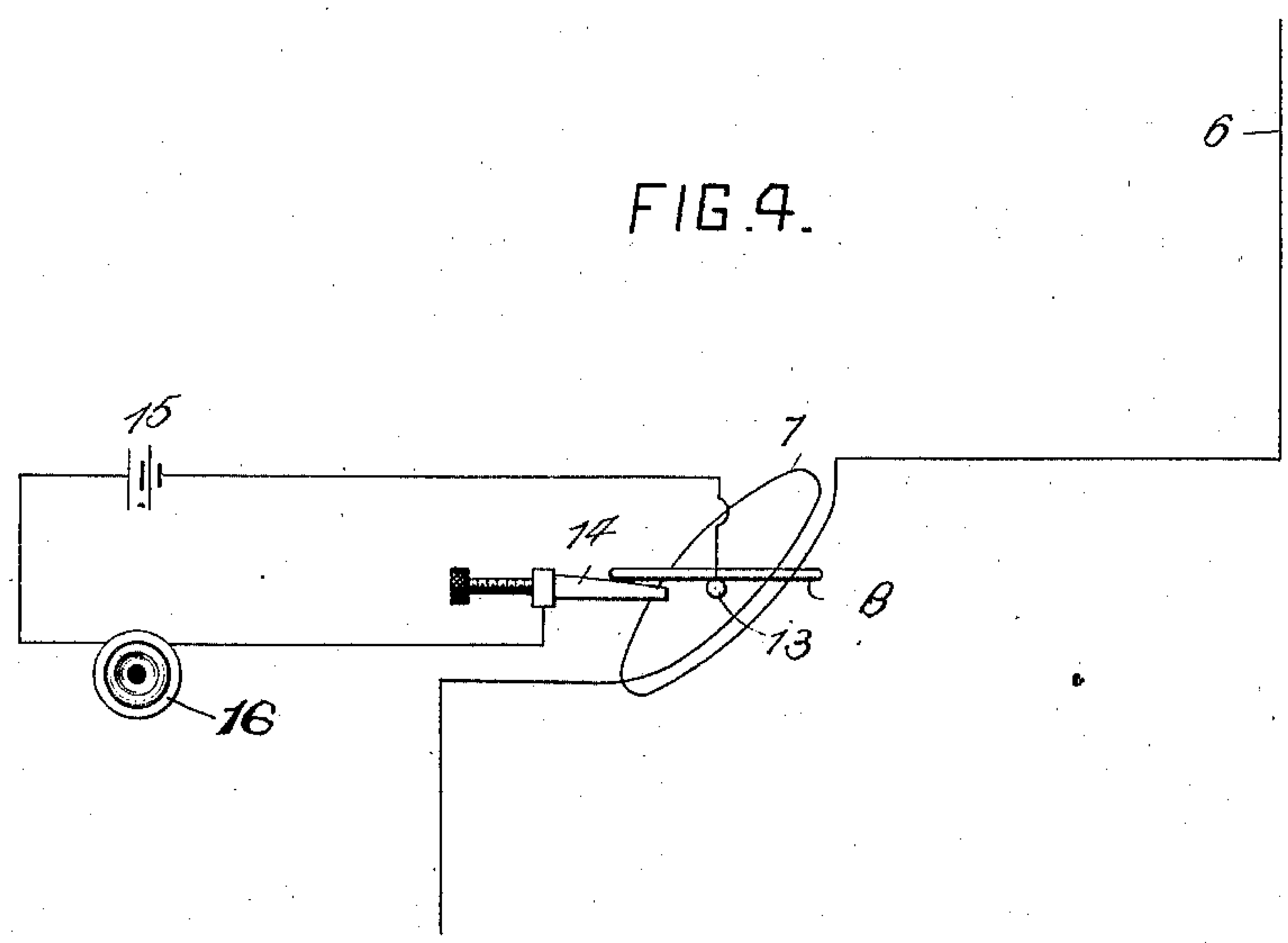


FIG. 4.



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UNITED STATES PATENT OFFICE.

REGINALD A. FESSENDEN, OF ALLEGHENY, PENNSYLVANIA.

APPARATUS FOR WIRELESS TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 706,736, dated August 12, 1902.

Original application filed December 15, 1899, Serial No. 740,429. Divided and this application filed May 17, 1900. Renewed November 29, 1901. Serial No. 84,097. (No model.)

To all whom it may concern:

Be it known that I, REGINALD A. FESSENDEN, a citizen of the United States, residing at Allegheny, in the county of Allegheny and State of Pennsylvania, have invented or discovered certain new and useful Improvements in Apparatus for Wireless Telegraphy, of which improvements the following is a specification.

The invention described herein relates to certain improvements in apparatus for the electrical transmission of signals from one station to another without the use of conductors connecting such stations, such apparatus being more especially designed for the carrying out of method described and claimed in application, Serial No. 740,429, filed December 15, 1899.

In the methods heretofore employed the electromagnetic waves generated at the receiving-station produce voltages in the receiving-circuit. These voltages or currents being impressed upon a suitable material normally non-conductive render the same conductive, and thereby permit the passage of a current through a circuit in which said material, usually termed a "coherer," is included. After the passage of the voltages produced by each series of electromagnetic waves generated at the sending-station the coherer must be operated in some way to restore it to normal or non-conductive condition.

The object of the present invention is to provide for the generation by currents produced by electromagnetic waves of induced currents in a second element or circuit and by the reaction of the current in this second element or circuit on the field formed or produced by the currents in the receiving-conductor to produce motion which is directly or indirectly observable.

In general terms the invention consists in apparatus whereby the energy of electric currents produced by electromagnetic waves may be transformed into the energy of motion and the energy of such motion employed for producing intelligible signals.

The invention is hereinafter more fully described and claimed.

In the accompanying drawings, forming a part of this specification, Figure 1 is a diagrammatic view showing the arrangements employed at the sending and receiving stations. Figs. 2 and 3 are diagrammatic views illustrating a modification of the receiving apparatus. Fig. 4 is a side elevation of the apparatus shown in Fig. 3, and Fig. 5 is a further modification of the receiving apparatus.

The apparatus employed at the sending-station may be similar to that now in use for the generation of electromagnetic waves, and consists of an induction-coil 1, having its primary coil in circuit with a generator 2, said circuit having a make-and-break mechanism 3 included therein. One of the discharging knobs or terminals 4 is connected with the radiating portion of the sending-conductor 5, while the other knob or terminal is grounded.

The terms "sending-conductor" and "receiving-conductor" are employed herein as indicating all of the circuits from top to ground, if grounded, or, if not grounded, from one extreme end to the other extreme end, including all apparatus in series with the circuits, while the term "radiating portion" indicates all of sending-conductor from top or extreme end of same to point of junction with the apparatus for effecting the oscillatory charging and discharging thereof, such as sparking terminals, transformer-coils, armature-windings, &c. By "electromagnetic waves" as used herein is meant waves of a wave length long in comparison with the wave length of what are commonly called "heat-waves" or "radiant heat." By "grounded conductor" is meant a conductor grounded either directly or through a capacity, an inductance, or a resistance, so that the current in the conductor flows from the conductor to ground, and vice versa, when electromagnetic waves are generated. The terms "tuned" and "resonant" are used herein as one including the other. By the term "current-operated wave-responsive device" as used herein and by me generally is meant wave-responsive devices having all their contacts good contacts and operated by currents produced by electromagnetic waves. They are hence to be distinguished from wave-responsive devices depending for operation upon varying contact resistance.

At the receiving-station the receiving-conductor is conveniently formed by a wire or wires 6, projecting up vertically or at an inclination to a suitable height, which are also grounded. A coil or coils 7 are arranged in the circuit of the conductor 6, and an element or coil of wire 8, forming a closed circuit, is supported with a freedom of movement in such relation to the coil or coils 7 that the current produced by the electromagnetic waves will induce a current in the element 8. The element 8 is suspended, preferably, in such manner that a plane at right angles to its axis will form an angle of approximately forty-five degrees (45°) with a plane at right angles to the axis of the coil or coils 7, so that the reaction of the current induced in said element, with the field produced by the coil or coils 7, will cause the element 8 to move with reference to the coils 7. This motion of the element may be observable by means of a mirror 9, attached thereto, reflecting a beam of light on a scale, or said element may form a part of the circuit of a recording-siphon, &c. As shown in Fig. 2, the coil 7 may be connected to the secondary coil 11 of a transformer, whose primary coil 12 is connected in series with the receiving-conductor.

A desirable means for transforming the electromagnetic waves into recordable motion is shown in Figs. 3 and 4. The element 8 is balanced on supporting-rods or knife-edges 13, one of which is formed of a good electrical conductor, as silver, the element 8 being preferably formed by a silver ring. A carbon block 14 is so arranged that a portion of the ring between the supporting-rods will normally rest lightly thereon. This microphonic contact, the conducting pivotal support, and the portion of the ring between them form parts of an electric circuit, which also includes a generator 15 and a recording instrument 16, as a telegraphic sounder or the receiver of a telephone. When a current is produced, as above described, in the coil 7, the element or ring 8 will be caused to press on the carbon block, thereby increasing its conductivity. When using a telephone-receiver as a recording instrument, the generator 15 is preferably of a character capable of producing an alternating current, as such current causes a constant vibration of the diaphragm, the vibrations increasing in intensity with an increased flow of current in the circuit. This increase in intensity of action with increased flow of current is characteristic of this form of receiver and also of the form shown in Fig. 1. In this it is sharply differentiated from such devices as the coherer, which either give a strong indication or do not give any. This characteristic is advantageous in that if the signal sent—say a dot—be too weak to give an action of the full intensity it may still in most cases be read and not missed entirely, which is of value in sending code-messages.

In the construction shown in Fig. 5 the circuit of the generator 15 is divided, one branch including a coil 16 and connected to a microphonic contact 14^a, while the other branch of the circuit includes a reversely-wound coil 16^a and is connected to a microphonic contact 14^b. These contacts are arranged on opposite sides of the ring 8 and are so adjusted that the ring will normally rest equal on both blocks, so that an equal current will flow through both of the coils 16 16^a, thereby maintaining a magnetic disk 17 suspended between the coils in equilibrium with relation to the coils. Adjustable resistances may be placed in the circuits of the coils, thereby avoiding the necessity of delicate adjustments of the carbon blocks. When the coils and the ring or element 8 are energized, the pressure of the latter on one contact is increased and that on the other decreased, thereby correspondingly changing the resistances in the two branches. The increased flow of current through one coil and decreased flow through the other coil, due to the change in resistances, will produce a greater movement of the magnetic disk 17 than if only a single coil were used. The movement of the disk 17 can be rendered observable in many ways known in the electric signaling art—as, for example, by securing a mirror thereon.

The closed circuit or element 8 is preferably made of a light good conducting material, such as aluminium or silver, so that it will quickly respond to changes in the current produced in the receiving-conductor by electromagnetic waves. The ring or element 8 should have relatively low resistance and high self-induction, so that the current in the ring instead of being maximum at the instant when the current in the field-coil is maximum is practically forty-five degrees different in phase from the current in the field-coil. To accomplish this, the ring or element 8 may consist of more than one turn or coil of wire; but one turn is preferable. It is also preferred that the field should consist of a coil formed by a single turn of wire 7, as shown in Figs. 2, 3, and 4, thereby reducing the resistance-drop in the receiving apparatus, and hence increasing its ability to resonate. By "resistance" is meant not only pure ohmic resistance, but also its well-known equivalent in alternating-current work—*i. e.*, losses produced by eddy-currents and hysteresis.

It will be understood that in the forms shown in Figs. 3, 4, and 5 the coils 7, which for convenience may be termed the "field-coils," may be connected in series with the receiving-conductor, as shown in Fig. 1, or may be connected to the secondary coils of a transformer, the primary coil of which is connected in series with the receiving-conductor.

As shown in Fig. 1, a condenser 19 may be connected in shunt with the field coil or coils 7 for the purpose of obtaining as large a current as possible in the field-coil 7, as this increase in current will give a great torque to the ring 8. The local circuit thus formed is a closed circuit and is to be differentiated from the open local circuits employed in connection with the coherer. An alternating-current circuit may be closed through a resistance, an inductance, or a capacity, and since even the insulated ends of a circuit will always have some capacity relative to each other it follows that all alternating-current circuits are theoretically closed. What is meant, therefore, by a "closed alternating-current circuit" is a circuit in which the current is relatively large for a small impressed voltage in the circuit—*i. e.*, the circuit is one of low virtual resistance as compared with a coherer. By an "unclosed" or "open" circuit is meant one in which the current is relatively small or negligible for a small impressed voltage—*i. e.*, one whose virtual resistance is high. Where a current-actuated wave-responsive device is employed, a closed circuit should also be employed to obtain a large effective current to actuate said device. Where a voltage-actuated device, such as a coherer, is employed and a large effective difference of potential is required, an open circuit, as defined above, should be used. This is especially important, because while a resonant rise of voltage may be obtained in an open circuit a large resonant rise of current is possible only in a closed circuit of low ohmic resistance used in connection with a source of maintained radiation. It will be evident that according to this definition of closed and unclosed tuned circuits in many cases the sending or receiving conductor would come under the head of a "closed tuned circuit," especially when having large capacity and low inductance; but where reference is made herein to a "closed tuned circuit" a sending or receiving conductor is not meant. When no condenser is employed, this large current must flow in the vertical wire and there would be a great loss of energy on account of the resistance of the receiving-conductor 6, and, further, without the condenser a large amount of energy will be required to give the statical charge to the receiving-conductor. Hence on account of the small energy furnished by the waves a large current cannot be obtained in field coil or coils 7 without the condenser. By employing a condenser of the proper size relative to the received waves, so as to form a local circuit tuned to the periodicity of the electromagnetic waves, the current in receiving-conductor 6 may be made to have a value equal to difference between the current in the field coil or coils and the current in the condenser. Either of these currents may therefore be large and either or both may be used to produce motion, while the current in the receiving-conductor 6 may be kept so small that there is practically no loss of energy on account of its resistance or of the statical charging of the receiving-conductor and all the energy may be used in producing motion. Without the condenser the current in the field coil or coils 7 will be practically a quarter-phase behind the voltage on account of the self-inductive lag in the field-coil. If the condenser were substituted for the field-coil, there would be a current in it nearly a quarter-phase in advance of the voltage due to the capacity lead. When both the field-coil and the condenser are introduced, one in shunt with the other, there will be a current in the field coil or coils lagging ninety degrees (90°) and in the condenser a current leading ninety degrees, (90°.) The sum of the two currents, one hundred and eighty degrees apart in phase, is equal to the difference between their values. Hence if there is a current in the field coil or coils of one ampere and in the condenser a current of nine-tenths ($\frac{9}{10}$) of an ampere the current in the receiving-conductor 6 will be one-tenth ($\frac{1}{10}$) of an ampere. By employing a similarly-tuned local circuit in resonance to the periodicity used at the sending-station, said circuit consisting of a capacity in the form of a condenser and an inductance formed by the connecting-wires placed in shunt across the spark-gap, an increased effect is also obtained on account of the oscillations being prolonged.

It is preferred to place a shunt-circuit containing a condenser across the terminals of the induction-coil at the sending-station for the purpose of maintaining sustained radiation. This shunt-circuit must be tuned to the receiving-conductor; otherwise the oscillations produced by it will have no action upon the wave-responsive device at the receiving-station. This shunt-circuit by virtue of its capacity stores up an additional amount of energy, and when a spark passes across the gap, since the sending-conductor can radiate energy at a given rate, it must continue to radiate for a longer time in order to dissipate this additional stored-up energy.

It is characteristic of the method shown that the receiving mechanisms are actuated by currents produced by electromagnetic waves and not by voltages, as in the case of the coherer. Hence when the receiving mechanisms described herein are used in connection with a secondary circuit said circuit is controlled by the currents generated by electromagnetic waves and not by voltages. It is also characteristic that when a secondary circuit is used in connection with the type of wave-responsive device shown in Figs. 3, 4, and 5 that a portion of the secondary circuit is traversed and controlled by currents produced by electromagnetic waves. It is further characteristic of my improved system that the indications produced by the receiving mechanism herein described are dependent upon the total amount of energy emitted to form a signal, and is not, as in the case of the coherer, dependent upon the maximum of the voltage. It is also characteristic of the combination of closed tuned circuits with current-operated wave-responsive devices that the effect on the wave-responsive device is cumulative—*i. e.*, dependent on the total or integral activity of the circuit and not on the maximum activity or voltage. On account of the fact that the period of electromagnetic waves, such as are commonly used in the art, is much less than that of practically producible and observable mechanical movements a single electromagnetic wave will have produced its impulses before the receiver herein described will have made an appreciable motion or have been appreciably affected. Consequently if a source of sustained radiation be used at the sending end each wave will produce its individual effect, and the effect will be conserved, as in the case of the ballistic galvanometer the effects of all the waves will be added together and cumulative to produce an indication. Since in the arrangement herein described the receiver is constantly receptive—*i. e.*, is always capable of being affected by the waves—and not, as in the case of the coherer, rendered incapable of response to the waves for a portion of the time, the speed of signaling will be increased.

I claim herein as my invention—

1. In a plant for the transmission of signals by electromagnetic waves, the combination of means located at the sending-station for the generation of electromagnetic waves, a receiving-conductor at the other station, means for directly translating the energy of the currents produced in the receiving-conductor by the electromagnetic waves into energy of motion and means for observing or recording such motion, substantially as set forth.

2. In a plant for the transmission of signals by electromagnetic waves, the combination of means located at the sending-station for the generation of electromagnetic waves, a receiving-conductor at the other station, a field coil or coils adapted to be energized by the currents produced in the receiving-conductor and a ring forming a closed circuit movably supported with its plane normally at an angle less than a right angle to the field, the ring having relatively low resistance and high self-induction so that a current induced therein will impart a twisting movement to the ring and means for recording or observing the movements of the ring, substantially as set forth.

3. As a means for transforming the energy of electromagnetic waves into the energy of motion, the combination of a receiving-conductor in which currents may be produced by electromagnetic waves, a field coil or coils adapted to be energized by the current produced in the receiving-conductor, a condenser connected in shunt with said field, and a ring forming a closed circuit movably supported in such relation to the field that a current will be induced therein, substantially as set forth.

4. In a plant for the electrical transmission of signals without the use of wires, the combination of means for the generation of electromagnetic waves, said means including a capacity of relatively large radiating-surface, and means for directly translating the energy of the currents produced in a receiving-conductor by electromagnetic waves into the energy of motion, substantially as set forth.

5. As a means for transforming the energy of electromagnetic waves into the energy of motion, the combination of a receiving-conductor in which currents may be produced by electromagnetic waves, a field formed by a single turn of wire adapted to be energized by the currents produced in the receiving-conductor, and a ring forming a closed circuit movably supported in operative relation to the coil, the ring having relatively low resistance and high self-induction, substantially as set forth.

6. In a system of transmission of energy by means of electromagnetic waves, a receiving system including in combination a receiving-conductor and a wave-responsive device, the portion of the receiving system containing said wave-responsive device constituting a closed circuit tuned to the frequency of the transmitter, substantially as set forth.

7. In a system of transmission of energy by electromagnetic waves, a receiving system including in combination a receiving-conductor, a wave-responsive device, which is also an inductance and a condenser in shunt thereto, said inductance and capacity being adjusted to make the portion of the receiving system in which they are placed resonant to the frequency of the transmitter, substantially as set forth.

8. In a system of transmission of energy by electromagnetic waves, a receiving system including in combination a receiving-conductor and a wave-responsive device, the portion of the system containing said wave-responsive device having two conducting-paths in shunt relation, one having inductance and the other having capacity, said inductance and capacity being adjusted to each other and to the frequency of the transmitter to cause one hundred and eighty degrees difference in phases of the currents in the two conducting-paths, substantially as set forth.

9. In a receiving system for transmission of energy by electromagnetic waves, a closed circuit tuned to the frequency of the transmitted impulses and a current-operated wave-responsive device, substantially as set forth.

10. In a system of transmission of energy by electromagnetic waves, a transmitter system including a tuned circuit, said system being adjusted to radiate trains of electromagnetic waves in which a single frequency is predominant, in combination with a receiver system including a closed circuit tuned to said predominant frequency, substantially as set forth.

11. In a system of transmission of energy by electromagnetic waves, a transmitter sys-

tem including a closed tuned circuit, said system being adapted to radiate trains of electromagnetic waves in which a single frequency is predominant, and a receiver system including a closed circuit tuned to said predominant frequency, substantially as set forth.

12. In a system of transmission of energy by electromagnetic waves, the combination of a generator, a grounded sending-conductor, a receiving-conductor, means for translating the energy of currents produced at the receiving-station by electromagnetic waves radiated from the sending-conductor into the energy of motion and means for observing or recording such motion, substantially as set forth.

13. In a system of transmission of signals by electromagnetic waves, the combination of means for generating and radiating electromagnetic waves at the sending-station, a receiving-circuit at the receiving-station tuned to the sending-circuit, and a low-resistance means for producing signals by currents produced by electromagnetic waves radiated from the sending-conductor, substantially as set forth.

14. In a system of transmission of signals by electromagnetic waves, the combination of means for generating and radiating electromagnetic waves at a sending-station, a receiving-circuit at the receiving-station tuned to the sending-circuit, and a current-actuated wave-responsive device included in said receiving-circuit, substantially as set forth.

15. In a receiver system for signaling by electromagnetic waves, a low-resistance receiving mechanism in series with a transformer, the primary of the transformer being in the circuit of the receiving-conductor, substantially as set forth.

16. A system of signaling by electromagnetic waves, having in combination a receiving-conductor and a differentially-wound indicating mechanism controlled by currents produced in the receiving-conductor by electromagnetic waves, substantially as set forth.

17. A system of signaling by electromagnetic waves, having in combination a receiving-conductor and a differentially-wound indicating mechanism dependent for its operation on currents produced by electromagnetic waves, substantially as set forth.

18. A system for signaling by electromagnetic waves, having in combination therewith a differentially-wound mechanism dependent for its operation on currents produced by electromagnetic waves, substantially as set forth.

19. In a system of signaling by electromagnetic waves the combination of a receiving-conductor, a secondary circuit and a current-actuated wave-responsive device controlling the secondary circuit, substantially as set forth.

20. In a system of signaling by electromagnetic waves the combination of a receiving-conductor, a secondary circuit and a self-restoring current-actuated wave-responsive device controlling the secondary circuit, substantially as set forth.

21. A system for signaling by electromagnetic waves having in combination therewith a current-actuated wave-responsive device operative in a closed circuit, tuned to the frequency of the electromagnetic waves to which it is desired to respond, substantially as set forth.

22. In a plant for the transmission of electrical energy without the use of wires, the combination of means located at the sending-station for the generation of electromagnetic waves, a receiving-conductor at the other station, and means having a low resistance for directly translating the energy of the currents produced in the receiving-conductor by the electromagnetic waves into the energy of motion, substantially as set forth.

23. In a plant for the transmission of electrical energy without the use of wires, the combination of means located at the sending-station for the generation of electromagnetic waves, and a low-resistance receiving mechanism at the other station operative by the currents generated by the electromagnetic waves, substantially as set forth.

24. In a plant for the transmission of electrical energy without the use of wires, the combination of means located at the sending-station for the generation of electromagnetic waves, including a grounded sending-conductor, a receiving-conductor and a low-resistance receiving mechanism in circuit with the receiving-conductor, substantially as set forth.

25. In a plant for the transmission of electrical energy without the use of wires, the combination at the receiving-station of two local or secondary circuits, a receiving mechanism having a movable member, a wave-operated means adapted to increase the resistance in one local circuit and to decrease the resistance in the other local circuit, the currents thus modified tending to produce motion of the movable member in the same direction, substantially as set forth.

26. In a system of signaling by electromagnetic waves, the combination at the sending-station of a generator, a sending-conductor, a spark-gap, and a condenser connected across the spark-gap so that the condenser and its connecting-wires form a local and parallel circuit in resonance to the sending-conductor, substantially as set forth.

27. In a system of signaling by electromagnetic waves, the combination at the sending-station of a generator, a grounded conductor, a spark-gap, and a condenser connected across the spark-gap so that the condenser and its connecting-wires form a local and parallel circuit in resonance to the sending-conductor.

28. In a receiving system for transmission

of energy by electromagnetic waves, a closed circuit of low resistance tuned to the frequency of the transmitted impulses and a current-actuated wave-responsive device, substantially as set forth.

29. In a system of signaling by electromagnetic waves, the combination at the receiving-station of a closed tuned circuit and a current-operated wave-responsive device adapted to give indications proportioned to the total activity of the receiving-circuit, substantially as set forth.

30. In a system of wireless transmission of energy by electromotive waves, an apparatus for utilizing the energy of said waves, said apparatus including in combination a conductor constructed and arranged to cause the energy of each wave to develop electric-current flow, means for rendering said current-flow persistent and for coördinating the currents developed by successive waves to cause them to act cumulatively upon each other to produce an increased or reinforced resultant current-flow, and means operated by said resultant current-flow to produce a sensible effect or indication, substantially as set forth.

31. A system of signaling by electromotive waves, having at the receiving-station a current-operated constantly-receptive wave-responsive device.

32. A system of signaling by electromotive waves, having at the receiving-station a current-operated, self-restoring, constantly-receptive wave-responsive device.

33. A system of signaling by electromotive waves, having at the receiving-station a current-operated, constantly-receptive, wave-responsive device, in conbination with a closed tuned circuit.

34. A system of signaling by electromotive waves, having in combination a current-operated, constantly-receptive wave-responsive device at the receiving-station and a source of persistent radiation at the sending-station.

35. A system of signaling by electromotive waves, having in combination a closed tuned circuit, a current-operated, constantly-receptive, wave-responsive device at the receiving-station and a source of persistent radiation at the sending-station.

In testimony whereof I have hereunto set my hand.

REGINALD A. FESSENDEN.

Witnesses:

WM. MCK. BURROUGHS,
ALFRED H. THIESSEN.