No. 706,745. Patented Aug. 12, 1902.

R. A. FESSENDEN.

SIGNALING BY ELECTROMAGNETIC WAVES.

(Application filed July 1, 1902.)

(No Model.) 2 Sheets—Sheet 1.

FIG. 1.

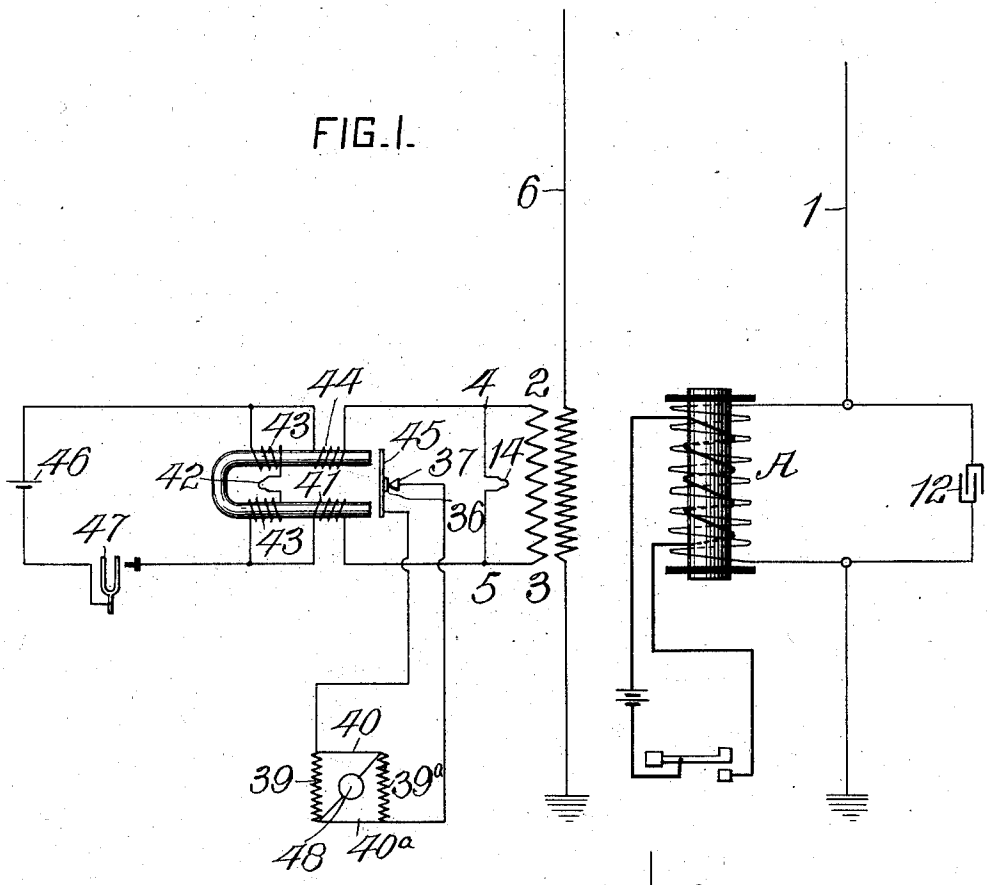

FIG. 2.

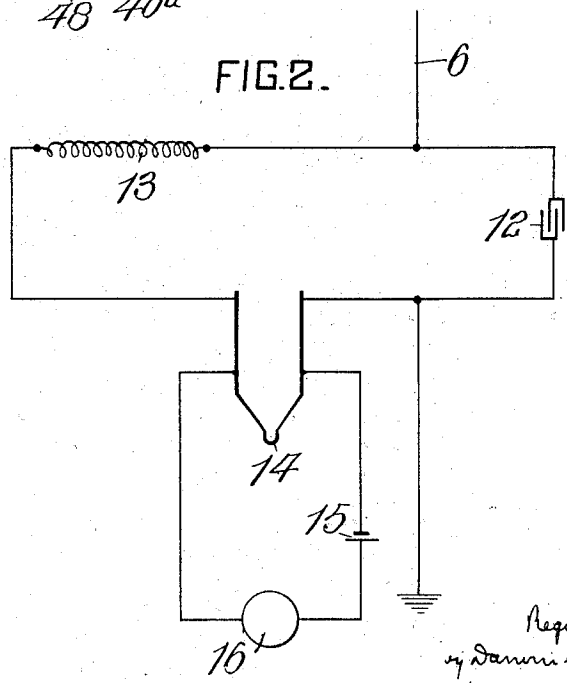

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FIG. 3.

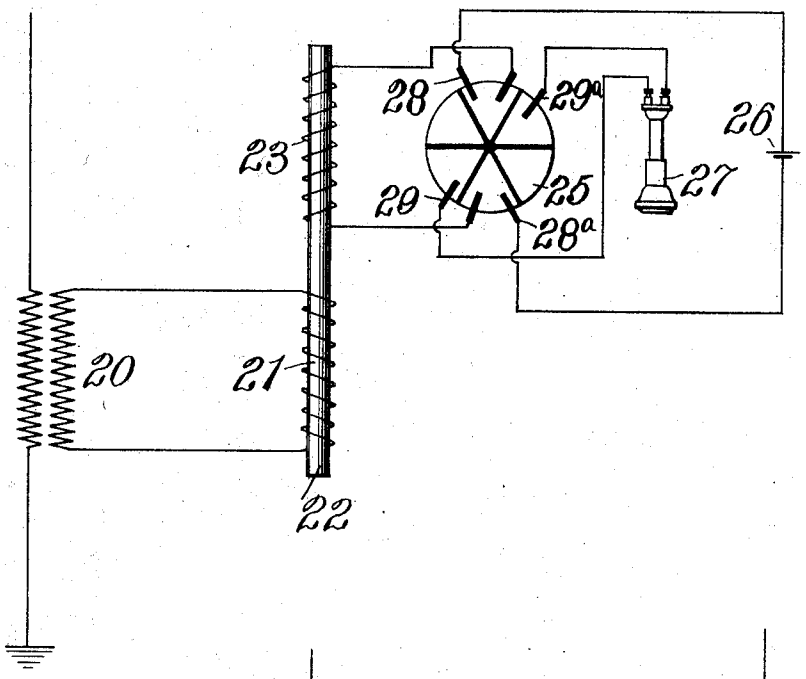


FIG. 4.

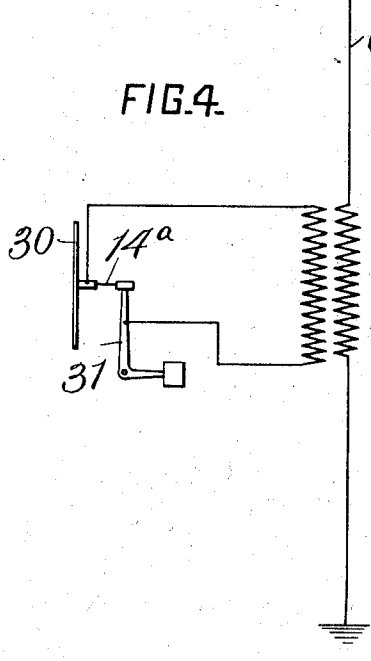
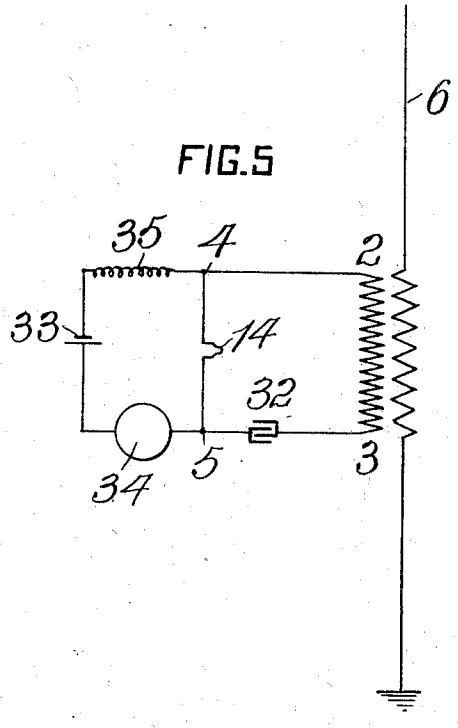


FIG. 5.



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UNITED STATES PATENT OFFICE.

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SIGNALING BY ELECTROMAGNETIC WAVES.

SPECIFICATION forming part of Letters Patent No. 706,745, dated August 12, 1902.

Application filed July 1, 1902. Serial No. 113,969. (No model.)

To all whom it may concern:

Be it known that I, REGINALD A. FESSENDEN, a citizen of the United States, residing at Manteo, in the county of Dare and State of North Carolina, have invented or discovered certain new and useful Improvements in Signaling by Electromagnetic Waves, of which improvements the following is a specification.

The invention described herein relates to certain improvements in receiving-circuits for signaling by electromagnetic waves, and has for its object the protection of current-operated receivers from external electrical disturbances and the obtaining from a given amount of electromagnetic waves energy of such a ratio of voltage to current as may be best adapted for the operation of such current-actuated wave-responsive devices.

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 illustrating an arrangement of circuits and apparatus at the sending and receiving stations embodying my improvement, and Figs. 2, 3, 4, and 5 illustrate modified forms of currents and apparatus at the receiving-station.

The form of apparatus shown in Fig. 1 consists at the sending-station of a radiating conductor 1, connected to one terminal of the sparking gap, the opposite terminal being grounded, a generator A, of any suitable form or construction, and a local tuned circuit containing a capacity 12 in parallel with the sending-conductor for the purpose of prolonging the radiation. This construction is substantially similar to that shown and described in application Serial No. 110,460, filed June 6, 1902.

At the receiving end I employ a current-operated wave-responsive device 14—*e. g.*, a receiver, as described in application Serial No. 113,968, filed July 1, 1902—in a closed tuned circuit 2 3 4 5, energized by the receiving-conductor 6, containing the primary 7 of a transformer. The circuit 2 3 4 5, which is here a secondary circuit, is tuned to the frequency of the electromagnetic waves and is preferably of low resistance and has a larger ratio of inductance to capacity than that of the receiving-conductor for the purpose of protecting the receiver from foreign electrical disturbances.

Any suitable form of indicating mechanism, such as a telephone or galvanometer, may be employed. A differentially-wound indicating mechanism, such as the differentially-wound telephone 41, is desirable for many purposes and has one circuit connected across the receiver 14. A resistance 42, preferably formed by a loop similar to the receiver 14, is arranged in one of the circuits of the differential instrument, the receiver 14 being in the other circuit, so that the circuits are balanced. Coils 43 and 44 are oppositely wound, and the two circuits being balanced there is normally no appreciable effect on the diaphragm 45. The source of voltage 46 and tuning-fork 47 are used to produce intermittent currents in the differential circuits, and, as mentioned above, there is normally no effect. When an electromagnetic wave causes a current to pass through the loop 14, thereby raising its resistance, the current in circuits containing the coils 44 of the differential instrument is weakened, and the circuits being out of balance an indication is produced by the instrument.

When it is not desired to use an intermittent current—as, for example, when the receiving mechanism is tuned mechanically to a given note for selective purposes—the circuit including the generator is made continuous, as by wedging the prongs of the tuning-fork or in any other suitable manner.

When a train of waves is radiated from the sending-station and received by the receiving-conductor, it causes currents to flow through the receiver 14, heating it up, thereby changing its resistance. The resistance of the differential circuit containing the receiver is therefore increased, the current therein reduced, and sound produced by the telephone. The transformer is here shown as a step-down transformer, as this form has advantages when used in connection with current-operated receivers of very low resistance; but step-up transformers may be used.

A second form of closed tuned circuit is shown in Fig. 2, where the condenser 12, inductance 13, and receiver 14 form a closed tuned circuit, which is here arranged so that the ratio of inductance to capacity therein is

larger than that ratio in the receiving-conductor. A variation of resistance in the receiver 14, caused by currents produced by electromagnetic waves, affects the current in the local circuit 14 15 16 and produces an indication in the galvanometer 16.

A third arrangement of circuits is shown in Fig. 3, where a secondary closed tuned circuit 20 21 has a portion of its length wrapped around a core 22, consisting of fine iron wire, preferably insulated by a single silk covering. No. 40 B. & S. gage of wire is a suitable size. A second coil 23 on the core has its terminals formed by two brushes bearing on a six-part commutator 25 in such a way that as the commutator rotates this second coil 23 is alternately connected to a battery 26 and telephone 27, which are connected, respectively, to brushes 28 28^a and 29 29^a, bearing on the commutator. When the coil 23 is connected to battery 26, the core 22 is magnetized and will retain a certain amount of magnetism when the battery is disconnected. If in this condition electromagnetic waves generate a rapidly-alternating current in the coil 21, a portion of this remnant magnetism will be shaken out, thus releasing an amount of energy much larger than that furnished by the electromagnetic waves. This change of magnetism in the core will produce a current in the coil 23, which being now connected to the telephone 27 will produce a sound therein.

A fourth arrangement of receiving-circuits is shown in Fig. 4, where the secondary closed tuned circuit has a receiver 14^a, such as described in application No. 110,460, but straight instead of bent to loop form, having one end fastened to the telephone-diaphragm 30 and the other end connected to the bent lever 31, which maintains a constant tension on the receiver and diaphragm. On the receiver being heated by currents produced by electromagnetic waves it expands, and sound is produced by the movement of the diaphragm.

It is characteristic of the arrangements shown in Figs. 1, 2, and 4 that the wave-responsive device is maintained in a constantly-receptive position—*i. e.*, it is not, as in the case of the coherer while being tapped or the magnetic receiver while being magnetized, rendered incapable of response to the waves for a portion of the time. The speed of signaling will be greater when the arrangement of receiver and circuit is such that the receiver is constantly receptive.

A fifth arrangement of receiving-circuits is shown in Fig. 5, where the secondary closed tuned circuit 2 3 4 5 contains a condenser 32 and receiver 14. A local closed circuit, including a battery 33, choke-coil 35, receiver 14, and an indicating mechanism 34, has its resistance altered when currents produced by electromagnetic waves pass through the receiver 14 and change its resistance, thereby producing an indication. In this arrangement of circuits the condenser 32 serves the double purpose of tuning the closed secondary circuit and of preventing the current from battery 33 from flowing continuously through the coil 2 3.

As a means of amplifying the indications I prefer to use a local microphonic circuit, as shown in Fig. 1, where a small carbon block 36 is attached to the diaphragm of the differential telephone 41 and a carbon point 37 bears lightly thereon. A local battery generates a current which passes continuously through the microphonic contact and a bridge consisting of the arms 39 39^a and 40 40^a and a siphon-recorder 48. The arms of the bridge are balanced as regards ohmic resistance. Hence for all steady or slowly-varying currents no portion of the current passes through the siphon-recorder. The arms 39 39^a have, however, very high self-induction and the arms 40 40^a very low self-induction, and both are of low resistance. On any sudden change of current, such as will be produced by the motion of the diaphragm on the receipt of a signal, the suddenly-varying current cannot flow through the arms 39 39^a, but will flow through the arms 40 40^a and the siphon-recorder 42, thereby producing an amplified indication. 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 send-

ing or receiving conductor is not meant. It is characteristic of these closed tuned circuits that they have a peculiar advantage when used in connection with the form of receiver described in application Serial No. 113,968 in that such circuits act to prevent the burning out of the receivers by electrical disturbances produced by lightning discharges. They also permit of the employment of more sensitive current-actuated wave-responsive devices. They also permit of step-down transformers being used instead of step-up, thus enabling practically all of the energy of the waves to be utilized and giving sufficient inductance with small length of wire.

It is especially characteristic of my invention—*i. e.*, the use of closed tuned circuits in connection with current-actuated wave-responsive devices as distinguished from open tuned circuits and voltage-actuated wave-responsive devices—that in my construction the voltages in the receiving-circuit are kept small, and hence practically all the energy received from the electromagnetic waves is employed affecting the receiver, and hence indications can be produced by an amount of energy which is an extremely small fraction of that necessary when open tuned circuits and voltage-actuated wave-responsive devices are employed. Thus since the capacity of a coherer is small a small amount of energy is sufficient to raise it by itself to a breakdown voltage; but in operation it is connected to a circuit having several hundred times the capacity, and as this circuit must be raised to practically the same potential as the coherer the efficiency of working is low—as, for example, with closed tuned circuits and a receiver, as described in application No. 113,968, messages at the rate of thirty words per minute were sent and received over a distance of fifty miles, (*i. e.*, from Cape Hatteras to Roanoke Island,) using a spark one thirty-second ($\frac{1}{32}$) of an inch long at the sending end. When a coherer and an open tuned circuit were used under the same circumstances, the spark length had to be increased to five and one-half inches before any messages could be received. The energies in the two cases were approximately in the ratio of one to forty thousand.

By the term "current-operated wave-responsive devices" 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.

I claim herein as my invention—

1. In a system of signaling by electromagnetic waves, the combination at the receiving-station of a current-operated wave-responsive device and a closed circuit, said closed circuit having a ratio of inductance to capacity larger than the ratio of inductance to capacity in the receiving-conductor, substantially as set forth.

2. In a system of signaling by electromagnetic waves, the combination at the receiving-station of a current-operated wave-responsive device, a closed circuit, said closed circuit having a ratio of inductance to capacity larger than the ratio of inductance to capacity in the receiving-conductor, and a source of persistent radiation at the sending-station, substantially as set forth.

3. In a system of signaling by electromagnetic waves, the combination of a current-operated wave-responsive device in series with a closed circuit, said closed circuit having a ratio of inductance to capacity greater than the ratio of inductance to capacity of the receiving-conductor, substantially as set forth.

4. In a system of signaling by electromagnetic waves, the combination of a current-operated wave-responsive device in series with a closed circuit, said closed circuit having a ratio of inductance to capacity greater than the ratio of inductance to capacity of the receiving-conductor, and a source of persistent radiation at the sending-station, substantially as set forth.

5. In a system of signaling by electromagnetic waves, the combination of a current-operated wave-responsive device in series with a closed tuned circuit, said circuit having a ratio of inductance to capacity greater than the ratio of inductance to capacity of the receiving-conductor, and a source of persistent radiation at the sending-station, substantially as set forth.

6. In a system of signaling by electromagnetic waves, the combination at the receiving-station of a current-operated wave-responsive device and a closed tuned circuit, said closed tuned circuit having a ratio of inductance to capacity larger than the ratio of inductance to capacity in the receiving-conductor, substantially as set forth.

7. In a system of signaling by electromagnetic waves, the combination at the receiving-station of a current-operated wave-responsive device, a closed tuned circuit, said closed tuned circuit having a ratio of inductance to capacity larger than the ratio of inductance to capacity in the receiving-conductor, and a source of persistent radiation at the sending-station, substantially as set forth.

8. In a system of signaling by electromagnetic waves, the combination of a current-operated wave-responsive device in series with a closed tuned circuit, said closed circuit having a ratio of inductance to capacity greater than the ratio of inductance to capacity of the receiving-conductor, substantially as set forth.

9. In a system of signaling by electromagnetic waves, the combination at the receiv-

ing-station, of a current-operated wave-responsive device, and a closed secondary circuit, substantially as set forth.

10. In a system of signaling by electromagnetic waves, the combination of a current-operated wave-responsive device and a closed tuned secondary circuit, substantially as set forth.

11. In a system of signaling by electromagnetic waves, the combination at the receiving-station, of a current-operated wave-responsive device, a closed secondary circuit and a source of persistent radiation at the sending-station, substantially as set forth.

12. In a system of signaling by electromagnetic waves, the combination at the receiving-station, of a current-operated wave-responsive device, a closed tuned secondary circuit and a source of persistent radiation at the sending-station, substantially as set forth.

13. In a system of signaling by electromagnetic waves, the combination at the receiving-station, of a current-operated wave-responsive device and a step-down closed tuned secondary circuit, substantially as set forth.

14. In a system of signaling by electromagnetic waves, the combination at the receiving-station, of a closed tuned secondary circuit, a current-operated wave-responsive device in series with said circuit and a source of persistent radiation at the sending-station, substantially as set forth.

15. In a system of signaling by electromagnetic waves, the combination of a step-down closed tuned secondary circuit and a current-operated wave-responsive device in series with said circuit, substantially as set forth.

16. In a system of signaling by electromagnetic waves, a current-operated wave-responsive device, in combination with a microphonic circuit controlled thereby, and an indicating mechanism controlled by the microphonic circuit and adapted to be inoperative for steady or slowly-varying currents and responsive to rapid variations of currents, substantially as set forth.

17. In a system of signaling by electromagnetic waves, the combination of a receiving-circuit and a receiver having small heat capacity and adapted to be energized by currents produced by electromagnetic waves in the receiving-circuit, substantially as set forth.

18. In a system of signaling by electromagnetic waves, the combination of a receiver rapidly responsive as regards temperature to variations in currents produced by electromagnetic waves and an indicating mechanism controlled by changes in temperature due to variations in currents in said receiver, substantially as set forth.

19. In a system of signaling by electromagnetic waves, the combination of a receiving-conductor, a receiver rapidly responsive as regards temperature to variations in electric currents and adapted to be energized by currents produced by electromagnetic waves in the receiving-conductor, a circuit controlled by said receiver and an indicating mechanism controlled by said circuit, substantially as set forth.

20. In a system of signaling by electromagnetic waves, the combination of a grounded sending-conductor, a receiving-conductor, a receiver rapidly responsive as regards temperature to variations in electric currents and adapted to be energized by currents produced by electromagnetic waves in the receiving-conductor, a circuit controlled by said receiver and an indicating mechanism controlled by said circuit, substantially as set forth.

21. A system of signaling by electromagnetic waves, having in combination a receiver responsive as regards temperature to variations in currents produced by electromagnetic waves, and a differentially-wound indicating mechanism controlled by currents produced in the receiving-conductor by electromagnetic waves, substantially as set forth.

22. In a system of signaling by electromagnetic waves, the combination of a receiving-conductor, a receiver responsive as regards temperature to variations in currents produced in said conductor by electromagnetic waves, a circuit controlled by said receiver and a differentially-wound mechanism controlled by said circuit, substantially as set forth.

23. In a system for signaling, &c., by electromagnetic waves, the combination of a receiver responsive as regards temperature to variations in currents produced by electromagnetic waves and a differentially-wound indicating mechanism dependent for its operation on currents produced by electromagnetic waves in the receiving-conductor, substantially as set forth.

24. A system for signaling, &c., by electromagnetic waves, having in combination a receiver rapidly responsive as regards temperature to variations in currents produced by electromagnetic waves, and a differentially-wound mechanism controlled by said receiver, substantially as set forth.

25. In a system for wireless transmission of energy by electromagnetic waves, an apparatus for utilizing the energy of said waves, said apparatus including in combination a conductor adapted to receive the energy of said waves and to conserve the same in the form of electric-current flow, means for transforming said current energy into energy of a different order or class, said means being adapted to conserve and accumulate such transformed energy, and a sensitive receiver cumulatively responsive to said transformed energy, substantially as set forth.

26. In a system for wireless transmission of energy by electromagnetic waves, an apparatus for utilizing the energy of said waves, said apparatus including in combination a conductor adapted to receive the energy of said waves and to conserve the same in the form

of electric-current flow, means for transforming said current energy into energy of heat, said means being adapted to conserve and accumulate such transformed energy, and a sensitive receiver cumulatively responsive to said transformed energy, substantially as set forth.

27. A system of signaling by electromagnetic waves, having in combination at the receiving-station a closed tuned secondary circuit and a constantly-receptive current-operated, wave-responsive device, substantially as set forth.

28. A system of signaling by electromagnetic waves, having in combination at the receiving-station a closed tuned secondary circuit and a constantly-receptive, self-restoring, current-operated, wave-responsive device, substantially as set forth.

29. A system of signaling by electromagnetic waves, having at the receiving-station a closed tuned secondary circuit and a constantly-receptive, current-operated, wave-responsive device, in combination with a source of persistent radiation at the sending-station, substantially as set forth.

30. A system of signaling by electromagnetic waves, having in combination at the receiving-station, a closed tuned secondary circuit and a constantly-receptive rapidly-responsive, wave-responsive device, and a source of persistent radiation at the sending-station, substantially as set forth.

In testimony whereof I have hereunto set my hand.

REGINALD A. FESSENDEN.

Witnesses:

DARWIN S. WOLCOTT,

JOHN L. FLETCHER.