No. 727,330. PATENTED MAY 5, 1903.

R. A. FESSENDEN.

SIGNALING BY ELECTROMAGNETIC WAVES.

APPLICATION FILED MAR. 21, 1903.

NO MODEL. 2 SHEETS—SHEET 1.

FIG.1.

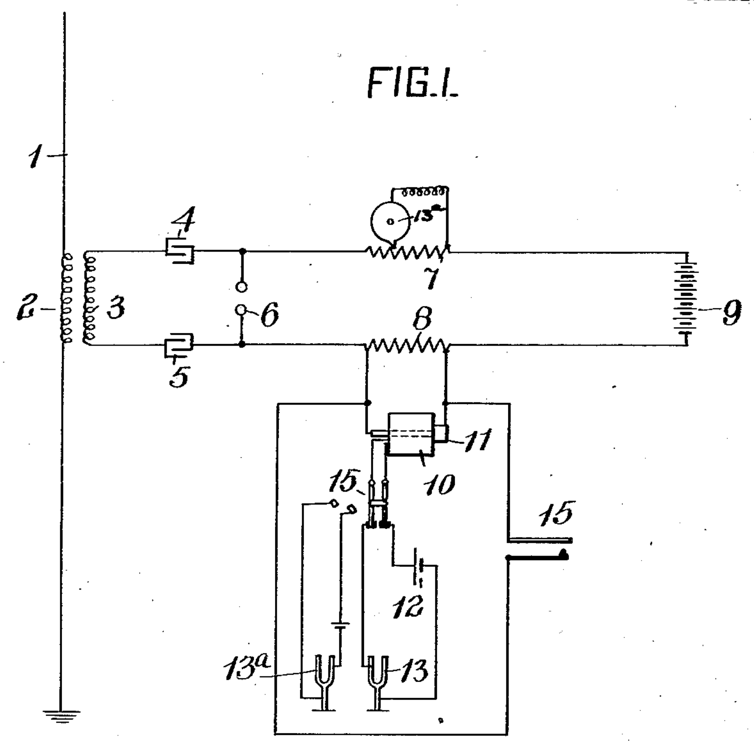

FIG.3.

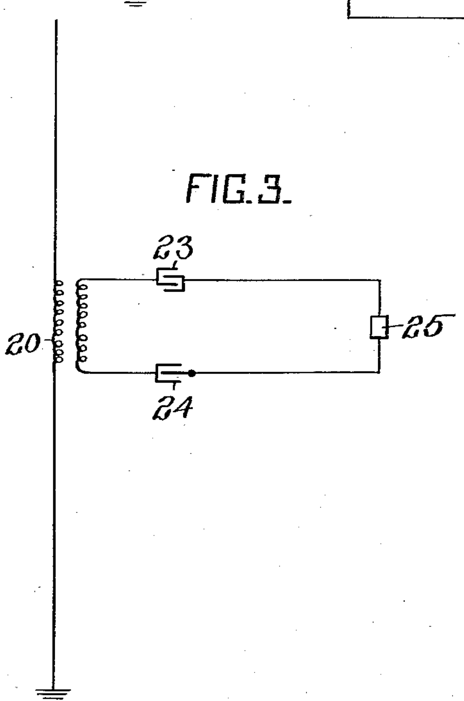

FIG.2.

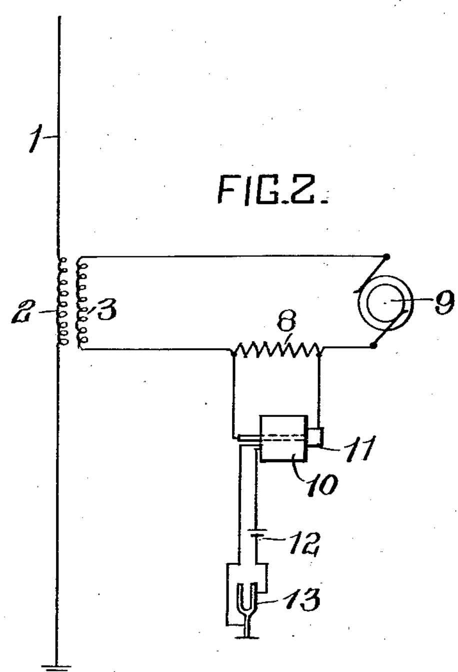

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FIG. 4.

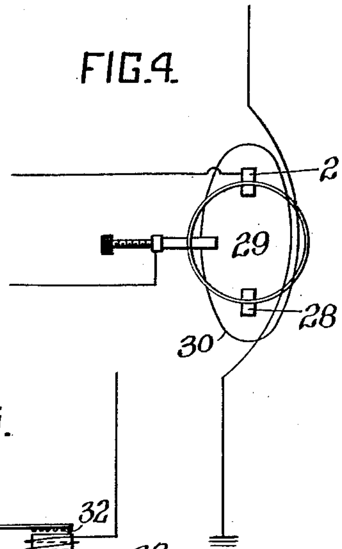


FIG. 5.

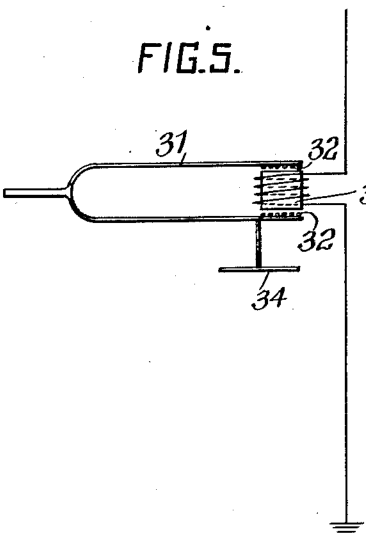


FIG. 6.

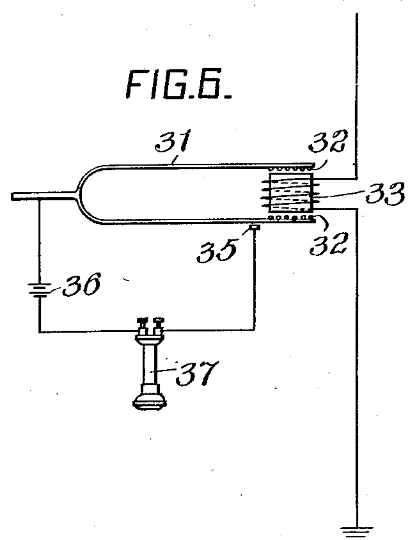
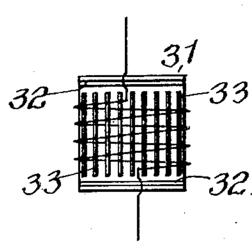


FIG. 7.



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UNITED STATES PATENT OFFICE.

REGINALD A. FESSENDEN, OF FORT MONROE, VIRGINIA.

SIGNALING BY ELECTROMAGNETIC WAVES.

SPECIFICATION forming part of Letters Patent No. 727,330, dated May 5, 1903.

Application filed March 21, 1903. Serial No. 148,863. (No model.)

To all whom it may concern:

Be it known that I, REGINALD A. FESSENDEN, a citizen of the United States, residing at Fort Monroe, in the county of Elizabeth City and State of Virginia, 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 methods of signaling by electromagnetic waves described in Letters Patent No. 706,742, granted to me August 12, 1902, and has for its object a selective method of signaling which consists in varying the character of the radiations from the sending-station at a rate independent of the natural periodicities of the system.

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 the apparatus employed at the sending-station. Fig. 2 illustrates a modification of the sending apparatus. Fig. 3 is a diagrammatic view illustrating a form of receiving apparatus. Fig. 4 illustrates a form of receiver. Fig. 5 illustrates a second form of the receiver. Fig. 6 illustrates a modification of the receiver shown in Fig. 5, and Fig. 7 is an end view of the receiver shown in Figs. 5 and 6.

In the practice of my invention the primary 2 of a transformer is arranged in series with the vertical conductor 1, which is grounded, as shown. The secondary 3 of the transformer is included in a circuit consisting of the condensers 4 and 5 and a gap 6, which is normally non-conducting—as, for example, an air-gap, a Wenhelt interrupter, or similar device. The local circuit, including the secondary of the transformer, the condensers, and the non-conducting gap, is preferably tuned to the periodicity of the sending-conductor 1. A generator 9, preferably of the continuous-current kind and preferably a storage battery, is arranged in series with the condenser and secondary of the transformer, and means, such as resistances 7 and 8, are included in the circuit of the generator, preferably, but not necessarily, in opposite legs of the circuit. The generator may be arranged to give any desired potential, a voltage of one thousand being the suitable one, though a voltage as low as fifty may be used, depending, among other things, upon the nature of the gap. Very high voltages may be suitably obtained, if desired, by using a continuous-current generator with revolving field and making the sections of the winding of the armature primaries of transformers whose secondaries are connected to a commutator and commutated by revolving brushes. In this way any desired amount of insulation can be obtained, and there is no need for heavy insulation on the generator itself, but merely on the transformers and the commutator where there is no difficulty in using it. The means 7 and 8 govern the rate at which the condensers 4 and 5 are charged, this function being described in United States Patent No. 706,742, above referred to.

A motor 10, carrying on its armature-shaft a commutator and regulated as to speed by the tuning-fork 13 in the circuit of the battery 12, as described in United States Patent No. 715,203, granted December 2, 1902, is employed for short-circuiting the retarding means or resistance 8, thereby varying the number of discharges per second at every revolution of the armature of the motor. A second tuning-fork 13^a and local battery 12^a may be employed for regulating the motor, though the same local battery may be used for both forks. When using the second tuning-fork and battery, they are adapted to be connected to the motor by means of a switch 14. These tuning-forks have different rates of vibration, and hence when one or the other is connected to the motor the latter will rotate at different rates per second, causing a corresponding change in the number of times per second that the discharge frequency is changed. As, for example, the circuits may be so arranged that the local circuit, including the secondary of the transformer, the condensers, and gap, has a natural period of two million per second, and the retarding means, as 7 and 8, may be so arranged that there will be two thousand discharges per second when the resistance 8 is in circuit and ten thousand discharges per second when it is short-circuited. Then the commutator 11, governed by the tuning-fork 13 or 13^a, may be so arranged as to effect a change in the rate of discharge (and hence a change in the amount of energy radiated) five hundred times per second. It will thus be seen that we have three different frequencies—first, the electrical wave frequency, which is determined by the local circuit 3, 4, 5, and 6; second, the discharge frequency, which is governed by the generator 9 and the retarding means 7 for a given value of the capacity; third, the independent frequency, which is determined by the tuning-fork controlling the motor.

In the operation of this method it is preferred to tune the receiving-station electrically to the wave frequency and to tune the receiver mechanically or electrically, or both, to the independent frequency. In the case illustrated the receiving-circuit would be tuned electrically to the wave frequency of two million and the receiver tuned mechanically or electrically, or both, to a frequency of five hundred.

The distinct feature of this method is that there is not only electrical tuning to the wave frequency, but also tuning either mechanically or electrically, or both, to another frequency which is independent of the discharge or group frequency.

It is not essential that the resistance 8 be employed, as it may be omitted, in which case the commutator 11 entirely interrupts the discharges the required number of times per second instead of varying the rate of discharge. In sending messages a key 15 is used, which on being depressed short-circuits the retarding means or resistance 8 (or, if this is omitted, closes the discharge-circuit) during the time the signal is being sent. The key 15 may also be arranged to operate in this reverse way—*i. e.*, to interrupt the discharges on being depressed.

The method described herein has the advantage over that described in Letters Patent No. 706,742 in that instead of employing a continuous-current generator an alternating-current generator having a freqnency of from ten thousand to one hundred thousand per second, as described in Letters Patent No. 706,737, granted to me August 12, 1902, may be used, in which case the energy radiated may be practically constant. In the method described in Letters Patent No. 706,742 a continuous voltage is used, or, if an alternating generator of the usual frequency is employed, the lower tuning is made to the frequency of the alternating generator; but when an independent frequency, as described herein, is used in connection with an alternating-current generator the radiation occurs at fixed intervals of time, though the amount of energy radiated during each commutation may be and with usual frequencies will be unequal, and hence sharp mechanical tuning can be had.

A particular advantage in the method described herein lies in the fact that a slight variation in the voltage or speed of the generator does not affect the low-frequency tuning or tuning to the lower frequency, which in this case is the independent frequency.

As shown in Fig. 1, a rotating commutator 11ᵃ, with a sending-key, may be employed to shunt any desired amount of the resistance. When it is desired to send two or more messages simultaneously, the amount of resistance 7 and of other resistances in the charging-circuit may be varied in substantially the same manner as shown in Fig. 10 of Patent No. 706,742, above referred to. To this end a suitable shunting device, as the rotating commutator 11ᵃ, with a sending-key, is so arranged as to be capable of shunting any desired amount of resistance 7 or other resistances if more than two messages are to be sent, and so impose an arbitrary frequency different from that imposed by commutator 11 and resistance 8 or other commutators and resistances when two or more messages are to be sent simultaneously to two or more stations tuned to different independent frequencies.

At the receiving-station the receiver proper, which may be of the constantly-receptive or automatically self-restoring wave-responsive type, may be arranged in series with the receiving-conductor; but it is preferred to arrange such receiver in the circuit of the secondary of a transformer having its primary 20 arranged in series with the vertical. In the circuit of the secondary 21 of the transformer are included capacities 23 and 24, preferably unequal, so as to permit sharp tuning. The circuit consisting of the secondary of the transformer and the capacities is preferably tuned electrically to the wave frequency of the sending end, and the receiver 25 is preferably tuned mechanically or electrically, or both, to the independent frequency. A suitable form of receiver is shown in Fig. 4 and consists of a thin silver ring pivotally mounted on two silver knife-edges 27 and 28 and resting on a knife-edge of carbon 29 and included with a coil 30, which is in series with the vertical conductor. One of the silver knife-edges, as 27, a portion of the ring, and the carbon knife-edge 29 are included in a local circuit having a battery and an indicating mechanism, as a telephone. This construction of receiver is fully shown and described in Letters Patent No. 706,736, granted to me August 12, 1902. Such a ring constructed of No. 40 silver wire has a natural elastic period of vibration of about fifteen per second.

A second form of receiver is shown in Fig. 5 and consists of a small tuning-fork 31, made of thin phosphor-bronze about fifteen one-thousandths of an inch thick and having armatures 32 secured to its extremities, preferably formed of layers of No. 40 soft-iron wire. Between the ends of the tuning-fork an electromagnet is arranged consisting of pieces of thin sheet-iron wound with a coil of wire whose terminals may be connected in series with the vertical or in series with the secondary of the transformer having its primary connected to the vertical. It is found in practice that it is sometimes beneficial when this form of receiver is used that it should be very nearly tuned electrically to the wave frequency of the sending-station, but not quite. On waves being received at the sending-station the electromagnet 33 is energized and attracts the prongs of the tuning-fork without change of direction so long as the radiation is being sent. When the motor 10 alters in the manner described the amount of energy sent out, either by changing the number of sparks per second or by entirely interrupting the discharges, the prongs resume their original position. Every time the independent frequency of the sending-station is made equal to the natural period of the tuning-fork 31 there will be constantly-increasing amplitude of vibration. To produce an indication, one of the prongs may be directly fastened to a telephone-diaphragm 34, as shown in Fig. 5, or a microphonic contact 35, a local battery 36, and an indicating mechanism 37, as a telephone, may be used, as shown in Fig. 6. The circuit including the microphonic contact and telephone may also be tuned electrically to the independent frequency, and this may be done also when there is no mechanical tuning. The method described herein has a number of advantages over that described in Patent No. 706,737, above referred to.

First, in the operation of the method described in the patent it is evident that the group frequency would depend upon the voltage of the generator if a dynamo were used, for the higher the voltage the greater the number of discharges per second, and that if an alternator is used, since its voltage is constantly varying, the group frequency will depend upon the periodicity of the alternator, since the groups available for mechanical tuning would have the same periodicity as the alternator. Consequently sharpness of tuning will depend upon the speed regulation of the generator in all cases where a dynamo is used. It is found in practice that mechanical tuning can be carried to an accuracy of at least one part in four hundred, and it has been carried to a much greater extent, though in general such extreme accuracy is not necessary. On the other hand, it has been found difficult to regulate the speed of a dynamo within one part in twenty or twenty-five. By this is meant not the average speed, but the extreme values of instantaneous speed upon which the tuning depends. In the method herein described this difficulty is entirely overcome, and instead of attempting the extremely-difficult problem of regulating a dynamo (giving, for example, several kilowatts output) to a constant speed of one-fourth of one per cent. the dynamo regulation becomes an almost negligible factor, and the only speed which must be regulated is that of a small motor consuming a few watts of energy and capable, therefore, of being governed accurately by a standard tuning-fork. The method of mechanical tuning is thus made practical for the use of a generator other than storage batteries, while before it was only with the greatest difficulty that accurate mechanical tuning could be attained.

In the method described in United States Patent No. 706,737 the number of discharges per second is limited, because the discharge frequency is the frequency to which the mechanical tuning is tuned. Consequently since it is difficult to tune to very high periodicities mechanically a very high number of discharges per second cannot be used. In the method described herein the number of discharges per second may be very high. For instance, if an ordinary air-gap with air or magnetic blast be used we may obtain fifty thousand or more sparks per second. Since, however, the independent frequency is independent of the discharge frequencies, we can thus combine the great radiating effect of high frequencies and yet obtain accurate mechanical tuning or accurate electrical tuning, or both, to the lower frequency, in this case to the independent frequency. Being thus rendered independent of the frequency of the alternator we can use a wide range of mechanical tuning with an ordinary alternator of commercial frequency. For example, if the periodicity of the alternator be sixty per second we can obtain mechanical tuning and of course electrical tuning over a range of frequency varying from ten per second up to five thousand and higher from the same alternator without changing its periodicity. It is not essential that the tuning to the independent frequency be mechanical or electrical alone, as both may be combined, though the use of either alone is preferred to the combination of the two, and in many cases electrical tuning to both wave frequency and electrical frequency may be used.

In the extreme case, where the discharge frequency becomes identical with that of the wave frequency—as, for example, with a high-frequency alternating generator, as shown in Fig. 2—the independent frequency may be varied in the same way as in the case described in Fig. 1—*i. e.*, by means of the tuning-fork. It is preferred to have the commutator 11 with a number of segments, so as to change the discharge gradually and preferably to have the change vary as a sine curve, as this renders the low-frequency tuning sharper.

By "cumulative receiver" is meant a receiver such as described in previous Letters Patent, in which the indication is proportional not to the maximum intensity of the current or voltage produced at the receiving-station, but to their integral or total effect. (See United States Patent No. 706,736, lines 12 to 13, page 3.) It is obvious that the motor or apparatus for producing the independent frequency may be placed in any of the other electrical circuits—as, for example, in the field of the dynamo of the auxiliary circuit 3 4 5 6 or in the vertical—with good results, but it is preferred to place it in the position shown.

When the commutator is placed in the vertical, it is preferred to use the form of commutator construction described above, in which the alternation is effected gradually and not abruptly, as by an interrupting form of commutator. This is on account of the fact that the voltages used in wireless telegraphy are so high that if the circuit be interrupted suddenly there will be difficulty from arcing between the contacts of the interrupter.

It has been proposed to arrange a vibrating interrupter between the spark-gap and the vertical conductor; but such arrangement is inoperative, and its use has not, so far as known, been attempted.

On account of the high potentials necessary for wireless work it would be practically impossible to operate such a vibrator so as to obtain a sufficient length of insulating-gap, especially with a vibrating form of make and break. In addition to the trouble from arcing the interruptions will be irregular, as the duration of the time of activity of the vertical will not depend solely on the period of the interrupter, but on the distance the vibrating contacts happen to be separated and the spark potential at that time. For example, if the induction-coil primary is broken at a time when the contacts are separated, say, a distance of half an inch the spark will jump and the vertical will be charged. If, however, the primary is not broken until the contacts have approached to within a quarter of an inch, the first change-spark will take place at a later point of time in the period of the vibration. Hence the times between successive charges and discharges will not be constant, and the tuning cannot be accurate. This difficulty cannot be overcome by working in an insulating liquid, as, though the insulation is better before contact, an arc will be drawn in retracting, and it will be but a short time before insulating power of the liquid is destroyed.

I claim herein as my invention—

1. In a system of signaling by electromagnetic waves, the method herein described, which consists in varying the character of radiation periodically at a rate independent of the natural periodicities of the system.

2. In a system of signaling by electromagnetic waves, the method herein described which consists in varying the character of the radiation periodically at a rate independent of both the wave and discharge frequencies.

3. In a system of signaling by electromagnetic waves, the method herein described which consists in emitting waves of a given periodicity by discharges of a given periodicity and periodically varying the character of the radiation at a periodicity different from the natural periodicities of the system.

4. In a system of signaling by electromagnetic waves, the method herein described which consists in emitting waves of a given periodicity by discharges of a given periodicity and periodically varying the character of the radiation at a periodicity different from both the wave frequency and the discharge frequency.

5. In a system of signaling by electromagnetic waves, the method herein described which consists in periodically varying the character of the radiation at a sending-station at a periodicity independent of the generating force.

6. In a system of signaling by electromagnetic waves, the method herein described which consists in periodically varying the character of the radiation at a periodicity independent of the voltage of the generator.

7. In a system of signaling the method herein described, which consists in emitting energy periodically, and periodically varying the character of the energy emitted at a periodicity independent of the periodicity of the emitted energy and of the periodicity of the generator.

8. In a system of signaling the method herein described, which consists in emitting energy periodically, periodically varying the character of the energy emitted at a periodicity independent of the periodicity of the emitted energy and of the periodicity of the generator, and operating by the energy received at the receiving-station a receiver tuned to the frequency of the emitted radiation and to the independent frequency.

9. In a system of signaling the method herein described, which consists in emitting energy periodically, periodically varying the character of the energy emitted at a periodicity independent of the periodicity of the emitted energy and of the periodicity of the generator, and operating by the energy received at the receiving-station a receiver tuned electrically to the frequency of the emitted radiation and mechanically to the independent frequency.

10. In a system of signaling the method herein described, which consists in emitting energy periodically, periodically varying the character of the energy emitted at a periodicity independent of the periodicity of the emitted energy and of the periodicity of the generator, and operating by the energy received at the receiving-station a receiver tuned electrically to the frequency of the emitted energy, and operating an indicating mechanism tuned to the independent frequency.

11. In a system of signaling by electromagnetic waves, the method herein described which consists in generating electrical waves of a high frequency, by means of electrical discharges of a lower frequency, and periodically changing the character of the radiation at a rate independent of the wave frequency and the discharge frequency.

12. In a system of signaling by electromagnetic waves, the method herein described which consists in generating electrical waves of a high frequency by means of electrical discharges, periodically changing the character of the radiation at a rate independent of the wave frequency and the discharge frequency, and operating by the energy so emitted a receiver at a receiving-station, tuned both to the wave frequency and to the independent frequency.

13. In a system of signaling by electromagnetic waves, the method herein described which consists in generating electrical waves of a high frequency by means of electrical discharges, periodically changing the character of the radiation at a rate independent of the wave frequency and the discharge frequency, and operating by the energy so emitted a receiver, at a receiving-station, tuned electrically to the wave frequency and mechanically to the independent frequency.

14. In a system of signaling the method herein described, which consists in emitting energy periodically from a sending-station and periodically varying the character of the energy emitted at a periodicity independent of the periodicity of the emitted energy and of the generator, and producing by the energy so emitted indications at a receiving-station by means of a cumulatively-acting receiver.

15. In a system of signaling by electromagnetic waves, the method herein described which consists in generating electrical waves of a high frequency by means of electrical discharges, periodically changing the character of the radiation at a rate independent of the wave frequency and the discharge frequency, and operating by the energy so emitted a receiver at a receiving-station, tuned electrically to the wave frequency and also electrically to the independent frequency.

16. In a system of signaling by electromagnetic waves, the method herein described, which consists in causing radiations, periodically varying the character of such radiation at a rate independent of the natural periodicities of the system and operating by the energy received at the receiving-station a receiver of the character substantially as described tuned to the frequency of the emitted radiation and to the independent frequency.

17. In a system of signaling by electromagnetic waves, the method herein described, which consists in the generation of radiation, varying the character of the radiation periodically at a rate independent of both wave and discharge frequencies and operating at the receiving-station a receiver of the character described tuned to the frequency of the emitted radiation and to the independent frequency.

18. In a system of signaling by electromagnetic waves the method herein described, which consists in emitting waves of a given periodicity by discharges of the given periodicity, periodically varying the character of the radiation at a periodicity different from the natural periodicities of the system and operating by the energy received at the receiving-station a receiver of the character described tuned to the frequency of the emitted radiation and to the independent frequency.

19. In a system of signaling by electromagnetic waves, the method herein described, which consists in emitting waves of a given periodicity by discharges of a given periodicity, periodically varying the character of the radiation at a periodicity different from both the wave frequency and the discharge frequency and operating a receiver of the character described tuned to the frequency of the emitted radiation and to the independent frequency.

In testimony whereof I have hereunto set my hand.

REGINALD A. FESSENDEN.

Witnesses:

T. L. SCLATER,

O. S. MARIE.