No. 767,979. PATENTED AUG. 16, 1904.

J. S. STONE.

SPACE TELEGRAPHY.

APPLICATION FILED NOV. 24, 1903. RENEWED JUNE 20, 1904.

NO MODEL.

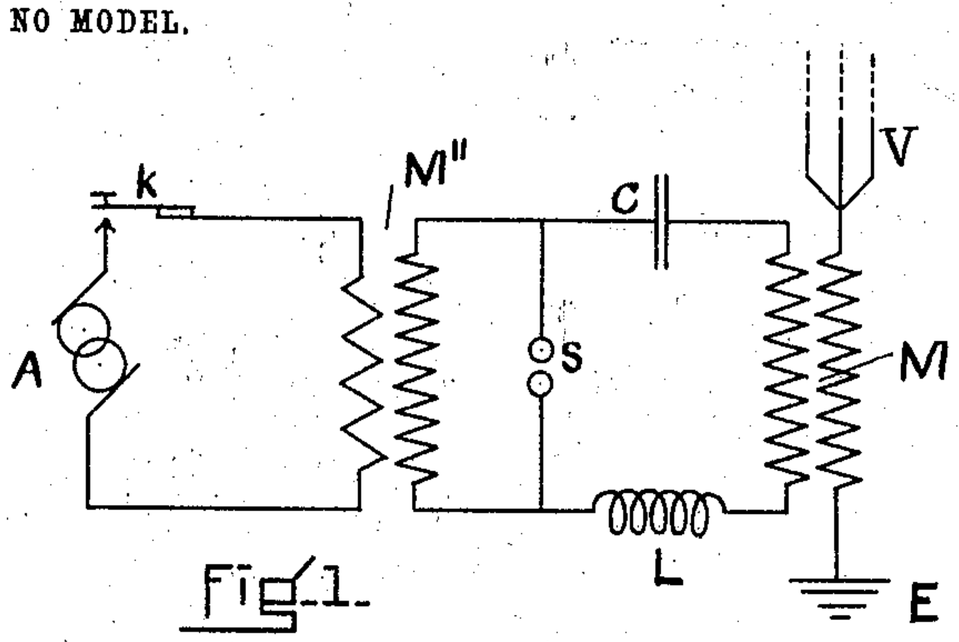

Fig. 1.

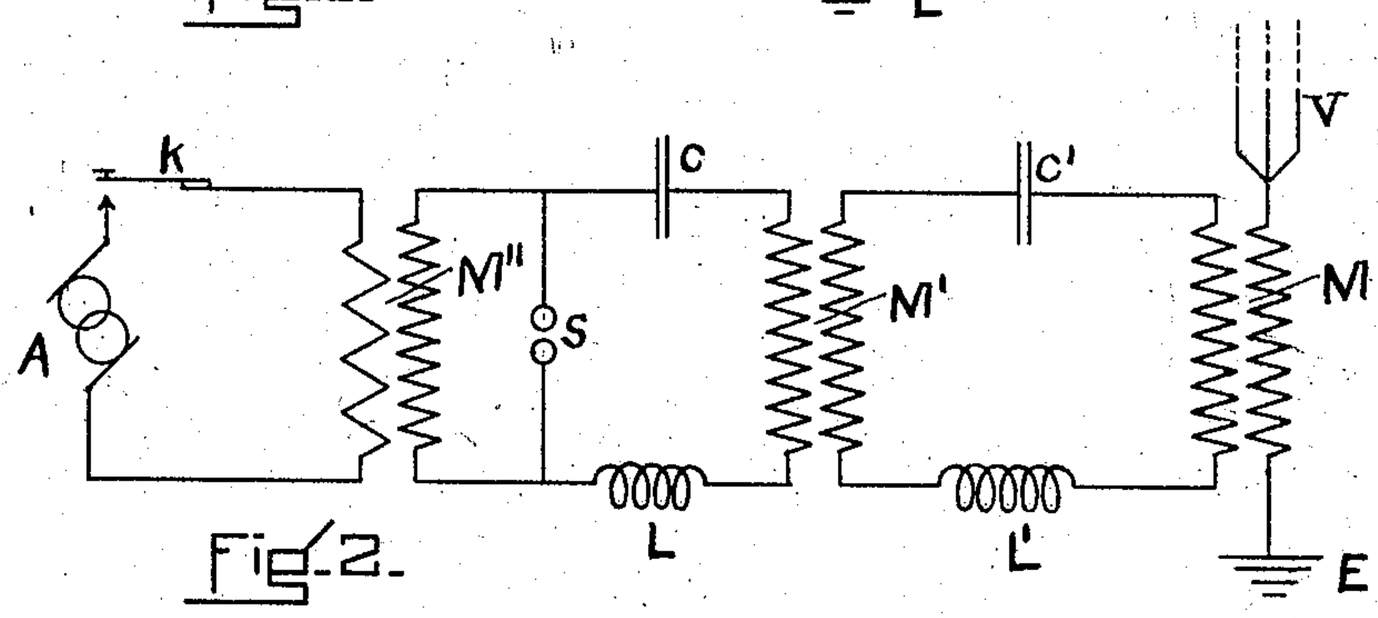

Fig. 2.

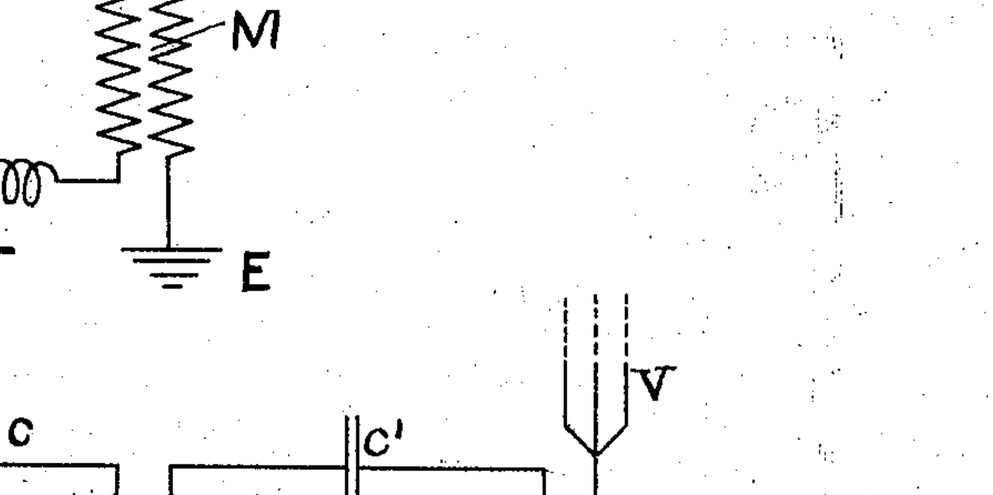

Fig. 3.

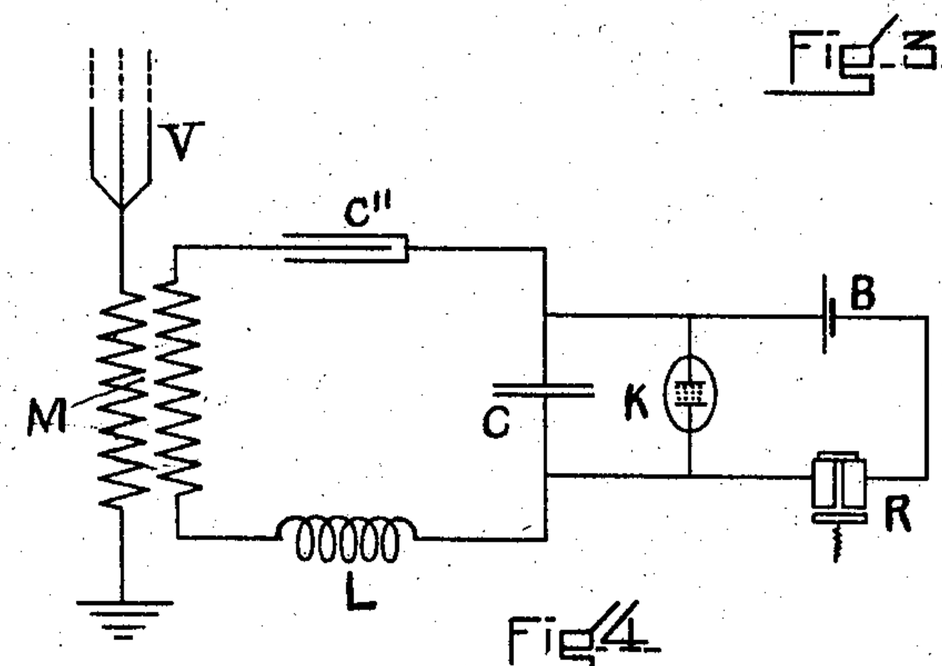

Fig. 4.

WITNESSES.

G. Adelaide Higgins.

Ellen B. Tomlinson

INVENTOR.

Jesse S. Stone.

No. 767,979. Patented August 16, 1904.

UNITED STATES PATENT OFFICE.

JOHN STONE STONE, OF CAMBRIDGE, MASSACHUSETTS, ASSIGNOR TO WILLIAM W. SWAN, TRUSTEE, OF BROOKLINE, MASSACHUSETTS.

SPACE TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 767,979, dated August 16, 1904.

Application filed November 24, 1903. Renewed June 20, 1904. Serial No. 213,324. (No model.)

To all whom it may concern:

Be it known that I, JOHN STONE STONE, a citizen of the United States, and a resident of Cambridge, in the county of Middlesex and State of Massachusetts, have invented a certain new and useful Improvement in Space Telegraphy, of which the following is a specification.

My invention relates to the art of transmitting intelligence from one station to another by means of electromagnetic waves without the use of wires to guide the waves to their destination; and it relates more particularly to the system of such transmission in which the electromagnetic waves are developed by producing electric vibrations or oscillations in an elevated conductor, preferably vertically elevated, whereby the electric force of the radiated waves becomes normal to the surface of the earth and the magnetic force thereof becomes parallel to said surface. Such waves I have termed "free or unguided electromagnetic waves" to distinguish them from waves guided to their destination by wires, although the earth or water over which they pass exerts a guiding influence.

In my Letters Patent Nos. 714,756 and 714,831, dated December 2, 1902, I have described such systems of transmission in which a sonorous or persistently-oscillating circuit is associated with an elevated conductor at a transmitting-station as a means for developing in said conductor forced simple harmonic electric oscillations of a definite frequency, whereby simple harmonic electromagnetic waves are transmitted by said conductor; and I have also described a closed resonant circuit attuned to said frequency and associated with an elevated conductor at a receiving-station for selectively absorbing the energy of the simple harmonic electromagnetic waves generated by the transmitting-conductor. In said Letters Patent the characteristics of the elevated conductors are not specified, because the sonorous circuit therein described is adapted adapted to be associated with any form of elevated conductor, which would then radiate simple electromagnetic waves independently of the electrical and geometric constants of said elevated conductor, and the receiving system is adapted to selectively receive the energy of the waves to which the resonant receiving circuit or circuits are attuned irrespective of the electrical or the geometric constants of any elevated receiving-conductor with which said resonant receiving circuit or circuits may be associated.

Although I have successfully employed an elevated conductor consisting of a single wire, I have found that an elevated-conductor system consisting of a plurality of separated wires or conductors or a sheet of metal is more efficient than one consisting of a single wire, such as commonly employed.

An elevated-conductor system consisting of a plurality of separated parallel wires or conductors employed as a transmitting-conductor system has long been known, and therefore is not claimed broadly, but only in combination with a system in which forced substantially simple harmonic electrical oscillations are developed in such elevated-conductor system by means of a sonorous circuit associated therewith in contradistinction to the systems most commonly used to-day in which electrical oscillations are created in the elevated conductor by causing an oscillatory electric discharge to take place at a spark-gap in the elevated conductor itself.

A system employing an elevated transmitting-conductor system consisting of a plurality of separated parallel wires, the lower ends of all of which are connected to the same pole of an oscillator, such as the Righi oscillator, (*i. e.*, to one terminal of a spark-gap,) the other pole of which (*i. e.*, the other terminal of the spark-gap) is connected to earth, has been described by Dr. Angelo Della Riccia on page 352 of a publication entitled the "*Rivista di Artiglieria e Genio*," published at Rome, June, 1898, and on page 353 of said publication has been set forth the theory of such elevated-conductor system—namely, that in such conductor system the capacity is increased and the self-induction decreased.

According to Della Riccia the multiple-wire radiating system described in said publication was used by Marconi at an early date, and

such a system, consisting of four vertical wires, each 48.6 meters long, connected together at top and bottom, but kept apart throughout their length by being suspended from the arms of a wooden cross each four meters long, was afterward patented abroad by said Marconi, and reference may therefore be had to his Belgian Patent, No. 152,810, October 25, 1900, published December 15, 1900. A similar multiple-conductor radiating system consisting of several separated parallel conductors all connected at their lower extremities to an oscillator has been described in a publication entitled "*Bulletin de l'Association des Ingénieurs Électriciens sortis de l'Institute Électrotechnique Montefiore*," pages 200–202, published at Liege, June, 1898. A system employing such system of parallel wires, as a receiving-conductor connected in series with a coherer, has been described in the French patent to Dr. Ferdinand Braun, No. 286,623, dated May 8, 1899, and published August 17, 1899. In United States Letters Patent No. 706,737, dated August 12, 1900, a similar conductor is described, and certain advantages alleged to result from its use have been set forth therein, while a more detailed exposition of the theory of such conductor than is contained in said patent is to be found on pages 1003 and 1004 of the *Electrical World and Engineer*, Vol. 37, published at New York, June 29, 1901. In this paper it is explained that inasmuch as the equation for the logarithmic decrement of electrical oscillations contains the term $\frac{R}{L}$ said decrement may be decreased—*i. e.*, the oscillations may be prolonged or rendered more persistent—by increasing L, the inductance, or by decreasing R, the resistance, or both, but that it is preferable to decrease resistance, so as not to change the period of oscillation. In Patent No. 706,737 it is explained that the object of using a transmitting-conductor consisting of a metallic cylinder, which is alleged to be the equivalent of several conductors in parallel, is to obtain electrical oscillations of such low frequency—for example, one hundred thousand periods per second—that mechanical movements may be produced by the direct interaction of currents produced by such waves and a magnetic field, to increase the energy of the system by increasing the capacity of the elevated conductor, to make the elevated conductor a persistent oscillator, so that "resonance effects" may be obtained, and, finally, to produce simple harmonic electromagnetic signal-waves. Such uses of an elevated conductor herein described form no part of this invention, as will be hereinafter explained.

In the drawings which accompany and form part of this specification, Figures 1, 2, and 3 are diagrammatic illustrations of three forms of transmitting apparatus, and Fig. 4 is a diagrammatic illustration of a receiving system.

In the figures of the drawings, A represents a source of periodically-varying electromotive force, which may be an alternating-current generator. M M′ M″ are transformers. L L′ are inductances. C C′ C″ are condensers. S is a spark-gap. *k* is a key. K is an electroreceptive device or wave-detector. B is a battery. R is a relay or signal-indicating device. V is an elevated conductor, consisting of a plurality of wires or conductors which may or may not be parallel, the lower ends of all of which are connected to the same terminal of one of the windings of transformer M. At the transmitting-station this conductor is connected to the secondary winding of said transformer, and at the receiving-station it is connected to the primary thereof. In lieu of the elevated conductor above described I may employ a conductor consisting of a sheet of metal.

For details of apparatus and the operation thereof reference may be had to my Letters Patent hereinbefore referred to, it being sufficient in this specification to say that the circuit C S L M and the circuit or circuits interposed between said circuit and the elevated conductor are sonorous or persistently-oscillating circuits each attuned to the same definite frequency, that the transformers M M′ M″ are preferably step-up transformers arranged to transform in the same direction, and that instead of a single resonant circuit, such as shown in Fig. 4, a group of resonant circuits may be interposed between the receiving-conductor and the electroreceptive or electric translating device, as described in my prior patents, and that such group of resonant circuits when employed are to be connected inductively in series by step-up transformers arranged to transform in the same direction. The elevated-conductor system V M E may have its fundamental equal to the period of the circuits associated therewith, as described in my prior patents.

In Fig. 3 the multiple-conductor radiating system is shown as applied to the transmitting system described in my Patent No. 714,832, December 2, 1902, in which the auxiliary inductance-coil L may be suppressed, its function being performed by the primary of transformer M when the ratio of the square of the mutual inductance between the sonorous circuit and the elevated conductor to the product of the inductances of the two associated circuits is small compared to unity.

By adjusting the electromagnetic constants of the sonorous circuit S C M L and of all resonant circuits interposed between said circuit and the elevated conductor, if such resonant circuits are used as shown in Fig. 2, the frequency of the electrical oscillations developed in said circuit or circuits is determined,

and since these electrical oscillations are forced upon the elevated conductor V, as explained in my prior patents, the frequency of the electrical oscillations in the elevated conductor, and consequently the frequency of the electromagnetic waves radiated therefrom, is also determined by the electromagnetic constants of said sonorous circuit independently of the fundamental period or the geometric constants of said elevated conductor. By sufficiently increasing the capacity of condenser C and the inductance of the sonorous circuit or by simply increasing the capacity of said condenser as low a frequency as may be desired may be obtained. I therefore do not employ the elevated conductor herein described for determining the frequency of the radiated waves or for producing electromagnetic waves of a low frequency.

The potential energy stored in a system is proportional to the electrostatic capacity of the system and to the square of the potential to which said system is charged. By increasing the capacity of the elevated conductor the potential energy of said conductor may be increased; but the capacity of the system does not increase proportionately to the number of conductors employed. In fact, it increases very slowly as the number of conductors is increased when the conductors are close together, while with a spark-gap included in series with the elevated conductor the potential to which the system may be charged is limited to that potential difference just sufficient to produce a spark at the gap, as I have pointed out in my Letters Patent No. 714,832, December 2, 1902. It will therefore be seen that the energy of a system employing a plurality of radiating-conductors or a metallic cylinder, the lower end of the radiating system so formed being connected in series with a spark-gap, is subject to the limitations above set forth and cannot be very greatly increased.

In the system herein described the capacity of the condenser C may be increased at will by merely increasing the surface of the condenser—for example, by merely increasing the number of condenser-plates—and this increase of capacity, as is well known, is directly proportional to such increase of condenser-surface. The capacity of the condenser C therefore can be made many times greater than the capacity of any system of elevated conductors of practicable construction.

While the potential to which condenser C may be charged is limited to the difference of potential just sufficient to produce a spark at the gap S, the potential of the electrical oscillations impressed upon the elevated conductor may be increased at will by means of the step-up transformer M or the step-up transformers M M′, or any number of them. It will therefore be seen that I do not employ a radiation system such as described herein, because it possesses greater capacity than a single conductor and may thus be charged with a greater amount of potential energy.

The sonorous circuit S C M L is a persistently-oscillating circuit because of its capacity and inductance and because of the relation of its resistance thereto, and whereas a radiating-conductor consisting of a cylinder or a large number of wires connected directly to a spark-gap is practically aperiodic I have experimentally determined that the sonorous circuit hereinbefore mentioned may easily be designed so as to be an extremely-persistent oscillator.

The reason why an elevated-conductor system consisting of a plurality of separated conductors is practically aperiodic is because of its relatively small inductance and relatively large radiating power. Even if the factor R/L were applicable to determine the rate of decay of electrical oscillations in an elevated-conductor system of any type it is obvious that in the system herein described, where a plurality of separated conductors are connected together in parallel, the inductance, as well as the resistance, of the system is decreased, so that the value of the factor R/L is not materially altered. However, the factor R/L does not enter into the determination of the persistency of oscillation of a linear oscillator, as is the case with a closed oscillator, from which there is but small loss of energy by radiation. The inductance of the elevated-conductor system herein described is much smaller than that of a single wire, the resistance is also smaller, and the capacity is larger; but this does not in any way make it a more persistent oscillator than a single wire, since it is an even better radiator than the single wire and will therefore be more rapidly damped through loss of its energy than would be the case with a single wire. The mere fact that the resistance of the elevated-conductor system is lower than that of a single wire can have little or inappreciable effect, since the energy dissipated in an oscillator owing to the resistance of the wire is negligible compared to that dissipated by radiation.

It has been alleged that a radiating system consisting of a large number of wires is by virtue of its supposed uniformly-distributed capacity and inductance adapted to develop simple harmonic electromagnetic waves, whereas mathematical analysis indicates the contrary. As fully set forth in my prior patents, the electromagnetic waves radiated by the system herein described independently of the geometric or electrical constants of the elevated conductor are simple harmonic waves. I therefore do not use the elevated-conductor system herein described to produce persistent trains of electromagnetic waves or to produce resonant effects at a receiving-sta-

tion, nor do I use such conductor to produce simple harmonic electromagnetic waves, as all these results are effected by the system described in my prior patents hereinbefore referred to when a single-wire elevated conductor is employed as a radiating system.

When a single-wire elevated conductor is employed as a radiating system and is for this purpose associated with a sonorous circuit, only a limited amount of the energy of said sonorous circuit can be conveyed to and radiated by the elevated conductor per unit of time; but by employing an elevated-conductor system consisting of two or more wires or conductors or a sheet of metal a proportionately-greater amount of the electrical energy developed in the sonorous circuit may be radiated by said elevated-conductor system per unit of time. The reason for this is that there are practical limitations to the potential to which the elevated conductor may be raised, and for a given potential of the elevated conductor the potential energy of the field, and consequently the radiation, is proportional to the capacity of the elevated conductor. Thus in a given time more energy may be radiated by a conductor consisting of a plurality of wires or of a sheet of metal than by a conductor consisting of a single wire, other things being equal. In other words, it requires a greater time to radiate a given amount of energy by a single conductor than by the multiple-wire radiating system herein described. To express the same idea differently, the magnitude of electrical movement in the elevated conductor or the amplitude of the current-flow therein per unit of time is increased—*i. e.*, more energy is taken from the associated sonorous circuit during such time.

Throughout the specification and claims wherever I have used the term "forced electric oscillations" I desire to be understood as meaning electrical oscillations whose periodicity is dependent only upon the period of an impressed force, and the term is used in the same sense in which it has long been used in physics, and particularly in the following works: *Electric Waves*, being a translation into English by Professor Jones of the papers published by Dr. Hertz in *Wiedemann's Annalen; Theory of Electricity and Magnetism*, by Webster; *Electromagnetic Theory*, by Oliver Heaviside; *Theory of Sound*, by Lord Rayleigh; *Calculus for Engineers*, by Perry.

As I have before pointed out, the period of such forced oscillations may or may not coincide with the period of the fundamental or upper harmonics of the system executing these vibrations, although the amplitude of the vibrations will be greater when such accordance in period is affected.

I claim—

1. In a system of space telegraphy, a radiating-conductor comprising a plurality of separated conductors and means associated with said radiating-conductor for developing therein forced electrical oscillations of a definite frequency.

2. In a system of space telegraphy, a radiating-conductor comprising a plurality of separated conductors and a sonorous circuit for developing therein forced electrical oscillations.

3. In a system of space telegraphy, a radiating system consisting of a plurality of separated conductors serially connected with the secondary of a transformer and means including the primary of said transformer for developing forced electrical oscillations in said radiating system.

4. In a system for developing free or unguided simple harmonic electromagnetic signal-waves of a definite frequency, a radiating conductor comprising a plurality of separated conductors and means for developing therein forced simple harmonic electrical oscillations of corresponding frequency.

5. In a system of space telegraphy, a sonorous circuit adapted to develop simple harmonic electrical oscillations of a definite frequency and a radiating system, comprising a plurality of separated conductors associated therewith, said radiating system being attuned as to its fundamental to said definite frequency.

6. In a system of space telegraphy, a receiving system consisting of a plurality of separated conductors and a closed resonant circuit associated therewith and attuned to the frequency of the waves the energy of which is to be received.

7. In a system of space telegraphy, a source of electrical energy, a radiating system comprising a plurality of separated conductors and attuned as to its fundamental to the frequency of the waves to be transmitted, and a group of resonant circuits, interposed between said source of electrical energy and said radiating system, the said circuits being connected inductively in series by means of transformers arranged to transform in the same direction and to impress the energy of said source of electrical energy upon the radiating system at increased potential.

8. In a system of space telegraphy, a source of electrical energy, a radiating system comprising a plurality of separated conductors and attuned as to its fundamental to the frequency of the waves to be transmitted, and a group of resonant circuits interposed between said source of electrical energy and said radiating system.

9. In a system of space telegraphy, a source of electrical energy, a radiating system comprising a plurality of separated conductors, and a group of resonant circuits interposed between said source of electrical energy and said radiating system, the said circuits being connected inductively in series by means of transformers arranged to transform in the

same direction and to impress the energy of said source of electrical energy upon the radiating system at increased potential.

10. In a system of space telegraphy, a source of electrical energy, a radiating system comprising a plurality of separated conductors, and a group of resonant circuits interposed between said source of electrical energy and said radiating system.

11. In a system of space telegraphy, a source of electrical energy, a radiating system comprising a plurality of separated conductors and attuned as to its fundamental to the frequency of the waves to be transmitted, and a resonant circuit interposed between said source of electrical energy and said radiating system and associated with said radiating system by means of a step-up transformer.

12. In a system of space telegraphy, a source of electrical energy, a radiating system comprising a plurality of separated conductors and attuned as to its fundamental to the frequency of the waves to be transmitted, and a resonant circuit interposed between said source of electrical energy and said radiating system.

13. In a system of space telegraphy, a source of electrical energy, a radiating system comprising a plurality of separated conductors, and a resonant circuit interposed between said source of electrical energy and said radiating system and associated with said radiating system by means of a step-up transformer.

14. In a system of space telegraphy, a source of electrical energy, a radiating system comprising a plurality of separated conductors and a resonant circuit interposed between said source of electrical energy and said radiating system.

In testimony whereof I have hereunto subscribed my name this 23d day of November, 1903.

JOHN STONE STONE.

Witnesses:
G. A. HIGGINS,
E. B. TOMLINSON.