No. 767,977. PATENTED AUG. 16, 1904.

J. S. STONE.
SPACE TELEGRAPHY.

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

NO MODEL.

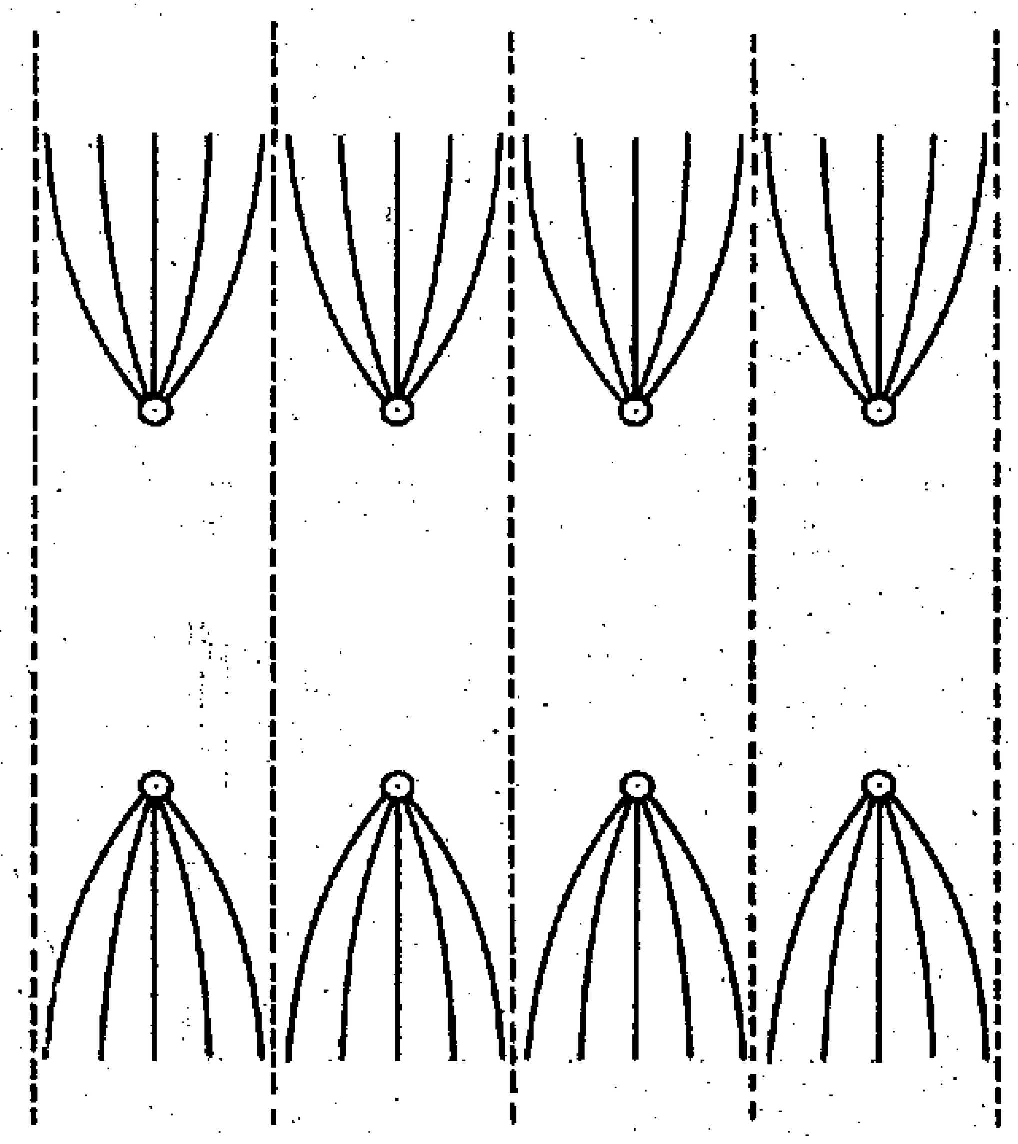

Fig. 1.

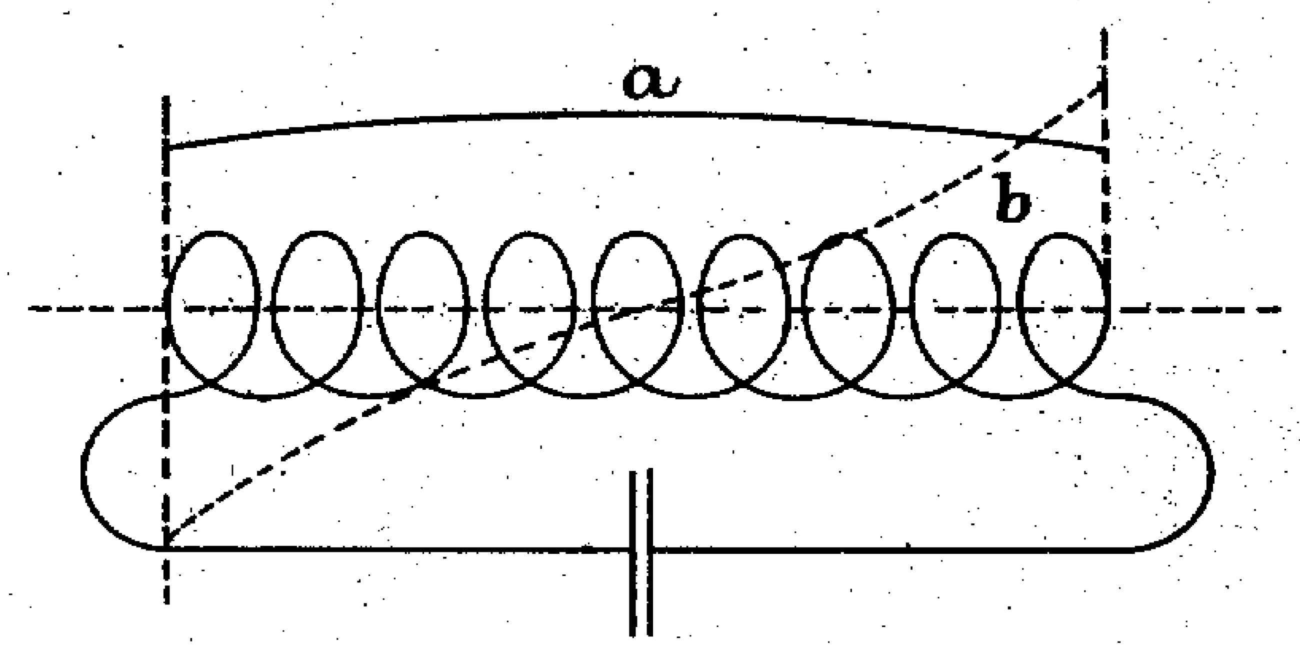

Fig. 2.

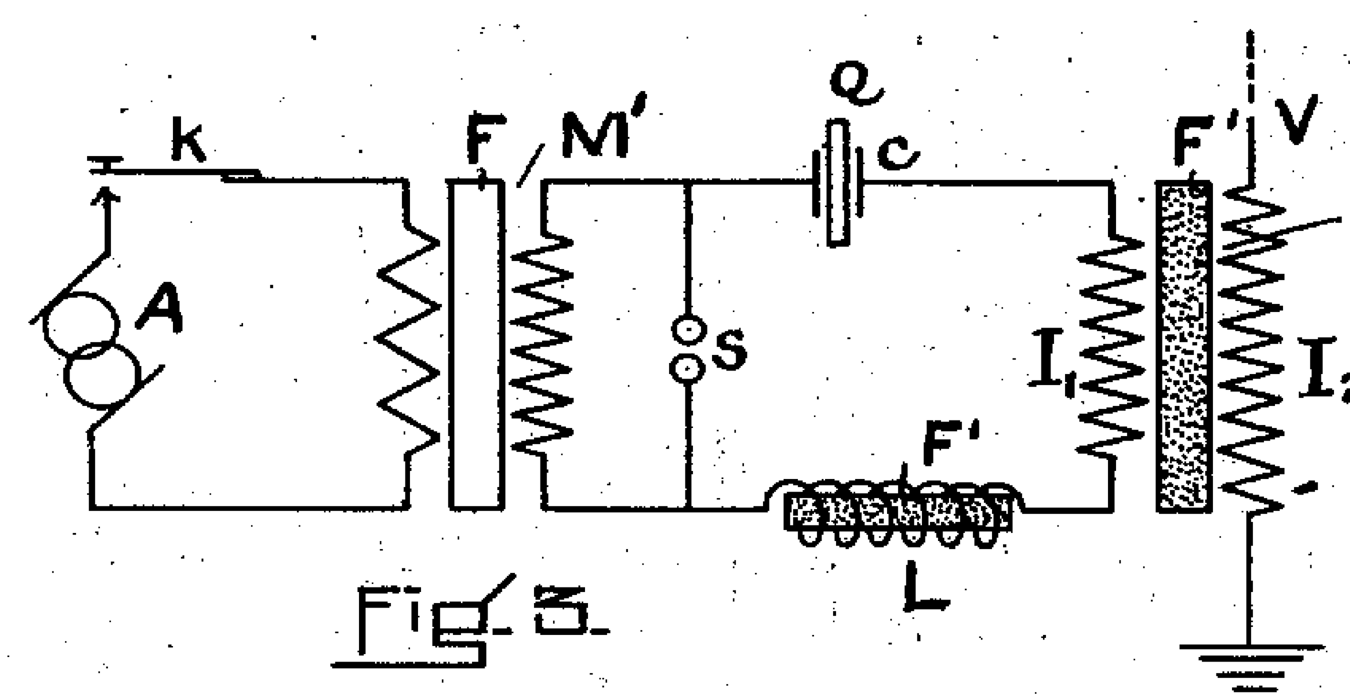

Fig. 3.

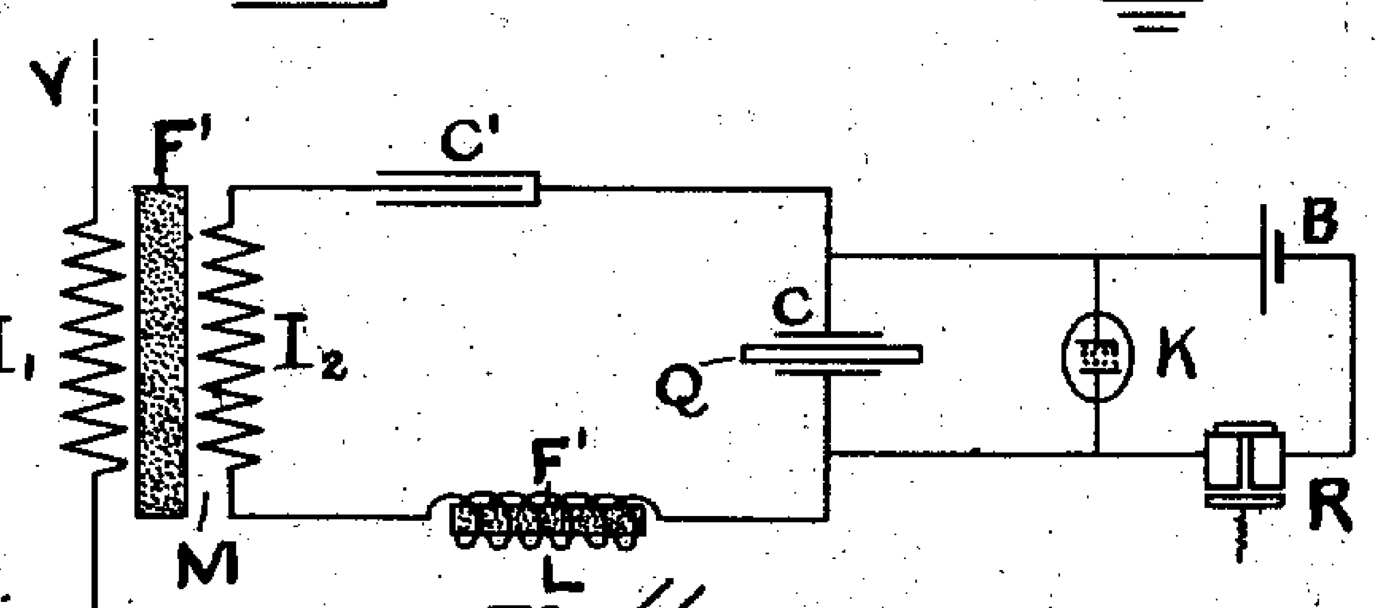

Fig. 4.

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No. 767,977. Patented August 16, 1904.

UNITED STATES PATENT OFFICE.

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SPACE TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 767,977, dated August 16, 1904.

Application filed November 24, 1903. Renewed June 20, 1904. Serial No. 213,322. (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 electromagnetic waves are developed by producing electric vibrations in an elevated conductor, preferably vertically elevated. In my Letters Patent No. 714,756, dated December 2, 1902, I have described such system of telegraphy by electromagnetic waves in which electrical vibrations of definite frequency and substantially simple harmonic in form—*i. e.*, as nearly simple harmonic in form as it is possible to produce them—are developed in a sonorous or persistently-oscillating circuit and impressed on an elevated conductor, whereby electromagnetic waves of corresponding frequency and form are radiated. In said Letters Patent I have explained that the condenser included in the sonorous circuit so associated with the elevated conductor and the tuning-condensers in all resonant circuits employed in either the transmitting or receiving systems should be devoid of dielectric hysteresis and that all coils, whether they form the windings of transformers or sources of auxiliary inductance, should be devoid of magnetic hysteresis in order that the electrical oscillations developed in the sonorous circuit may be as nearly simple harmonic as possible and in order that the resonant circuits at the receiving-stations may respond strongly to oscillations of one frequency and practically to the exclusion of oscillations of other frequencies.

In my Letters Patent No. 714,832, dated December 2, 1902, I have stated that although a condenser devoid of dielectric hysteresis may best be constructed by employing air as a dielectric some other dielectric, either solid or liquid, sufficiently free from dielectric hysteresis may be found, and I have therein stated that the cores of the coils employed may be made of finely-divided soft iron embedded in a dielectric matrix for the purpose of increasing the magnetization in the coils, although the magnetic hysteresis of such coils may be most completely minimized by excluding paramagnetic material from their construction.

The object of this invention is the realization of a system of space telegraphy similar to that described in my Letters Patent No. 714,756, in which the magnetization of the coils is increased by providing said coils with a core consisting of finely-divided soft iron embedded in a dielectric matrix and in which the capacity of the condensers of given cubical contents is greatly increased or the cubical contents for a given capacity greatly reduced by providing said condensers with solid dielectrics consisting of a material substantially free from dielectric hysteresis and of greater specific inductive capacity than air.

In my Letters Patent Nos. 717,511, 717,512, dated December 30, 1902, and Nos. 714,832, 714,833, dated December 2, 1902, and in Letters Patent No. 726,368, granted April 28, 1903, upon an application filed by me April 4, 1894, I have described a manner in which iron or other paramagnetic material may be employed with advantage to enhance the energy stored in a magnetic field. In the present application I have reference particularly to the use of finely-comminuted paramagnetic material embedded in a dielectric matrix used as a means of enhancing the inductance of a coil without introducing the effects of variable permeability and hysteresis losses.

I am aware of publications by Oliver Heaviside as follows: *Electrical Papers*, Vol. II, pages 111, 113, and 158, in which it is stated that cores made of finely-divided iron in a matrix of beeswax may be used to augment the inductance of coils without producing appreciable aberration of the permeability of the coil and without dissipating appreciable energy in hysteresis losses. I first received the suggestion which resulted in my use of such a material from the above-cited publications of Oliver Heaviside, and having found the material to possess the properties he ascribed to it I now disclose a highly-useful application of it in the art of wireless telegraphy.

The advantages to be gained by the use of finely-divided paramagnetic material in a dielectric or highly-insulating material may best be realized by having reference to my United States Letters Patent Nos. 714,756, 714,832, and 737,170, wherein is set forth the necessity of excluding magnetic hysteresis from coils forming part of a resonant circuit and wherein is also set forth the advantages of increasing the value of the selectance function $\sqrt{\frac{L}{C R^2}}$.

As pointed out in the above-cited patents, the kinetic energy of the coil supplying the inductance of a resonant circuit must be large compared to its potential energy when supporting a current of the frequency to which the circuit is attuned. The construction of a coil which will enhance the energy stored in the magnetic field will, *cæteris paribus*, evidently enhance the value of $\frac{L}{R}$, and provided such construction does not proportionally increase C it is of evident advantage in coils for use in a resonant circuit; but in single-layer coils, such as described in my Letters Patent No. 714,756, the electric force is substantially normal to the coil, as shown in Fig. 1 of the present specification, except at a potential node. In such coils, provided the kinetic energy is large compared to the potential energy for a particular frequency for currents of that frequency, the length of the coil is a fraction of half a wave length of the potential or current along the coil. Careful consideration of the theory of wave propagation along single-layer coils will show that in an infinite coil of this type the propagation of the wave is in general similar to that in an infinite linear conductor of uniformly-distributed inductance, capacity, and resistance, where the inductance per unit of length of the coil takes the place of the inductance per unit of length of the uniform conductor, the capacity per unit of length of the coil takes the place of the capacity per unit of length of the uniform conductor, and the resistance per unit of length of the coil takes the place of the resistance per unit of length of the uniform conductor. The theory of such propagation is so well known that no exposition of it is here necessary. Suffice it to say that in half a wave length the kinetic energy is equal to the potential energy. This phenomenon places a definite limitation upon the length of the coil which may be employed in a given resonant circuit, and were it not for the fact that in general in such coils the capacity per unit of length of the wire is diminished below that of a linear conductor in about the same proportion or ratio as the inductance is increased above that of a linear conductor by winding the wire in a single-layer coil there would be no advantage in winding the wire in the form of a coil. However, as the capacity per unit of length of the wire in a single-layer coil in general does diminish in about the same ratio as the inductance per unit of length is increased when the wire is wound in an infinite coil it follows that for a given frequency the length of wire per wave length in such a coil is approximately equal to that in a linear circuit of such wire or 3×10^{10} centimeters per second divided by the vibrations per second. In view of the foregoing it follows that except in the immediate vicinity of current-nodes the inductance per unit of length of the conductor is increased by being wound in the form of a coil, and except in the immediate vicinity of a potential node the capacity per unit of length of a wire is proportionately diminished by being wound in the form of a coil. In the case of a single-layer coil and condenser forming a resonant circuit excited by forced vibrations corresponding in frequency to the frequency to which the circuit is attuned the potential difference of the coil may be very great compared to the impressed electromotive force; but provided the kinetic energy is small compared to the potential energy in the coil the current throughout the coil is not substantially different, as shown diagrammatically in Fig. 2, where the full-line curve *a* indicates the current and the dotted-line curve *b* indicates the potential at phase $\frac{\pi}{2}$ and π, respectively. Careful consideration will show that the introduction of a dielectric core in the coil will tend to increase the potential energy of the current flowing in the coil, but that if the increase in the kinetic energy effected by the introduction of this core be greater than this increase in potential energy the length of wire in the coil may, *cæteris paribus*, be decreased and the selectance $\sqrt{\frac{L}{C R^2}}$ correspondingly improved. The increase in capacity here mentioned is insignificant compared to the increase in inductance when a core of finely-comminuted iron embedded in a matrix of paraffin or beeswax and rosin is introduced in such a coil. Such a core is preferably constructed by melting a mixture of beeswax and rosin in a suitable cylindrical mold, pouring fine soft-iron filings in the mixture, and then allowing the mixture to harden after careful stirring.

Condensers as usually constructed consist of conducting-surfaces separated by solid dielectrics, such dielectrics being chosen with respect to their dielectric strengths and their specific inductive capacities. It has long been recognized that such solid dielectrics possess an electrical property which corresponds to the mechanical property of imperfect elasticity. This property of solid dielectrics in condensers produces the phenomenon known as dielectric hysteresis, by which a portion of the electrical energy of every charge stored in the condenser is absorbed and converted into heat. It may also result in the distortion of the wave form of an alternating current traversing such condenser and generally produces marked diminution in the phenomenon of resonance when such condensers are used to tune resonant circuits, as first determined by Dr. Louis A. Duncan in a series of experiments, some of the results of which were set forth in a paper presented at a general meeting of the American Institute of Electrical Engineers June 6, 1892, and published in Vol. IX of the transactions of that society. It has also long been known that if air or any elementary gas be substituted for the solid dielectric in the condenser, these gases having practically perfect mechanical elasticity, the resulting condenser does not possess dielectric hysteresis, does not cause a dissipation of any appreciable portion of the electric energy of a charge stored in the condenser, does not distort an alternating current traversing the condenser, and does not diminish the phenomena of resonance when it is used to tune a resonant circuit. However, air and other gases have small dielectric strengths and small specific inductive capacities as compared to the dielectric strengths and specific inductive capacities of the solid materials usually employed as dielectrics in condensers. Therefore an air-condenser capable of storing a given amount of energy is in general vastly greater in cubical contents than the corresponding condenser with a solid dielectric.

Dr. Louis Duncan has discovered that glass made by fusing quartz which possesses almost perfect mechanical elasticity is devoid of dielectric hysteresis. Moreover, since the dielectric strength of fused quartz-glass is excessively high and its specific inductive capacity much greater than that of air, it follows that by the use of this material as a dielectric in a condenser the amount of electric energy which may be stored in such a condenser per unit of cubical contents is much greater than that which may be stored in condensers having any known gaseous dielectric. Finally, owing to the perfect electrical elasticity of fused quartz-glass these condensers possess all the advantages hereinbefore set forth as possessed by condensers having air or other gaseous dielectrics.

In the drawings which accompany and form a part of this specification, Figures 1 and 2 are diagrams already referred to. Fig. 3 is a diagrammatic illustration of apparatus and arrangements of circuits constituting a space-telegraph transmitting system. Fig. 4 is a diagrammatic illustration of apparatus and arrangements of circuits constituting a space-telegraph receiving system.

In the figures, V is an elevated conductor. M M′ are transformers. I_1 I_2 are respectively the primary and secondary windings of the transformer M, and it is to be understood, as a matter of course, that this transformer may be a step-up or a step-down transformer, according to its position in the system. L is an inductance. C is a condenser. Q represents the dielectric of condenser C, which is preferably made of fused quartz-glass. F is a magnetic core of the usual construction, upon which the windings of the step-up transformer M′ are wound. F′ is a core consisting of finely-divided iron embedded in a dielectric matrix. *s* is a spark-gap. *k* is a key. A is an alternating-current generator or other suitable source. K is a receiver, which may be a coherer. B is a battery. R is a relay or signal-indicating device.

For details of construction of the parts not herein specifically described and for the operation of the systems reference may be had to my Letters Patent Nos. 714,756 and 714,832. Suffice it here to say that the discharge of the energy stored in the condenser C across the spark-gap *s* sets up in the sonorous circuit *s* C I_1 L electric vibrations of definite frequency, which are substantially simple harmonic in form and that therefore forced electric vibrations of corresponding frequency are developed in the elevated conductor V, that these electric vibrations so developed in the elevated conductor V cause the radiation of substantially simple harmonic electromagnetic waves of corresponding frequency which create electromotive forces of like frequency in the elevated conductor V at the receiving-station, and that by means of the resonant circuit I_2 C′ C L, associated with said elevated conductor, the energy of the oscillations created in the elevated conductor by electromagnetic waves of the frequency to which said resonant circuit is attuned is absorbed to the exclusion of the energy of electric oscillations of other frequencies, thereby creating a maximum difference of potential at the terminals of the condenser C and effecting a change in the resistance of the receiver K, and consequently effecting the operation of the relay or signal-indicating device R.

I claim—

1. In a system of space telegraphy, an elevated conductor associated with a sonorous circuit which includes a condenser having a dielectric of fused quartz-glass.

2. In a system of space telegraphy, an elevated conductor associated with a sonorous circuit which includes a condenser having a dielectric of fused quartz-glass and which also includes a coil having a core of finely-divided paramagnetic material embedded in a dielectric matrix.

3. In a system of space telegraphy, an ele-

vated conductor, a sonorous circuit associated with said elevated conductor and including a coil having a core of finely-divided paramagnetic material embedded in a dielectric matrix.

4. In a system of space telegraphy, a persistently-oscillating circuit including a condenser having a dielectric of fused quartz-glass.

5. In a system of space telegraphy, a persistently-oscillating circuit including a condenser having a dielectric of fused quartz-glass and also including a coil having a core of finely-divided paramagnetic material embedded in a dielectric matrix.

6. In a system of space telegraphy, a persistently-oscillating circuit including a coil having a core of finely-divided paramagnetic material embedded in a dielectric matrix.

7. In a system of space telegraphy, a persistently-oscillating circuit including a condenser which has a solid dielectric substantially free from dielectric hysteresis and of a specific inductive capacity greater than that of air.

8. In a system of space telegraphy, a persistently-oscillating circuit including a condenser which has a solid dielectric substantially free from dielectric hysteresis and also including a coil having a paramagnetic core substantially free from magnetic hysteresis.

9. In a system of space telegraphy, a resonant circuit including a coil having a paramagnetic core substantially free from magnetic hysteresis.

10. In a system of space telegraphy, an elevated conductor associated with a resonant circuit which includes a condenser having a dielectric of fused quartz-glass.

11. In a system of space telegraphy, an elevated conductor associated with a resonant circuit which includes a condenser having a dielectric of fused quartz-glass and which also includes a coil having a core of finely-divided paramagnetic material embedded in a dielectric matrix.

12. In a system of space telegraphy, an elevated conductor, a resonant circuit associated with said elevated conductor and including a coil having a core of finely-divided paramagnetic material embedded in a dielectric matrix.

13. In a system of space telegraphy, a resonant circuit including a condenser which has a solid dielectric substantially free from dielectric hysteresis and of a specific inductive capacity greater than that of air.

14. In a system of space telegraphy, a resonant circuit including a condenser which has a solid dielectric substantially free from dielectric hysteresis and also including a coil having a paramagnetic core substantially free from magnetic hysteresis.

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

JOHN STONE STONE.

Witnesses:
G. ADELAIDE HIGGINS,
ELLEN B. TOMLINSON.

Corrections in Letters Patent No. 7...

It is hereby certified that in Letters Patent No. 767,977, granted August 16, 1904 upon the application of John Stone Stone, of Cambridge, Massachusetts, for an improvement in "Space Telegraphy," errors appear in the printed specification requiring correction, as follows: On page 2, line 38, a comma should be inserted after the word "frequency," and in line 39, same page, the comma after the word "frequency" should be stricken out; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 4th day of July, A. D., 1905.

[SEAL.]

F. I. ALLEN,
Commissioner of Patents.

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