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J. S. STONE.

APPARATUS FOR INCREASING THE EFFECTIVE RADIATION OF ELECTROMAGNETIC WAVES.

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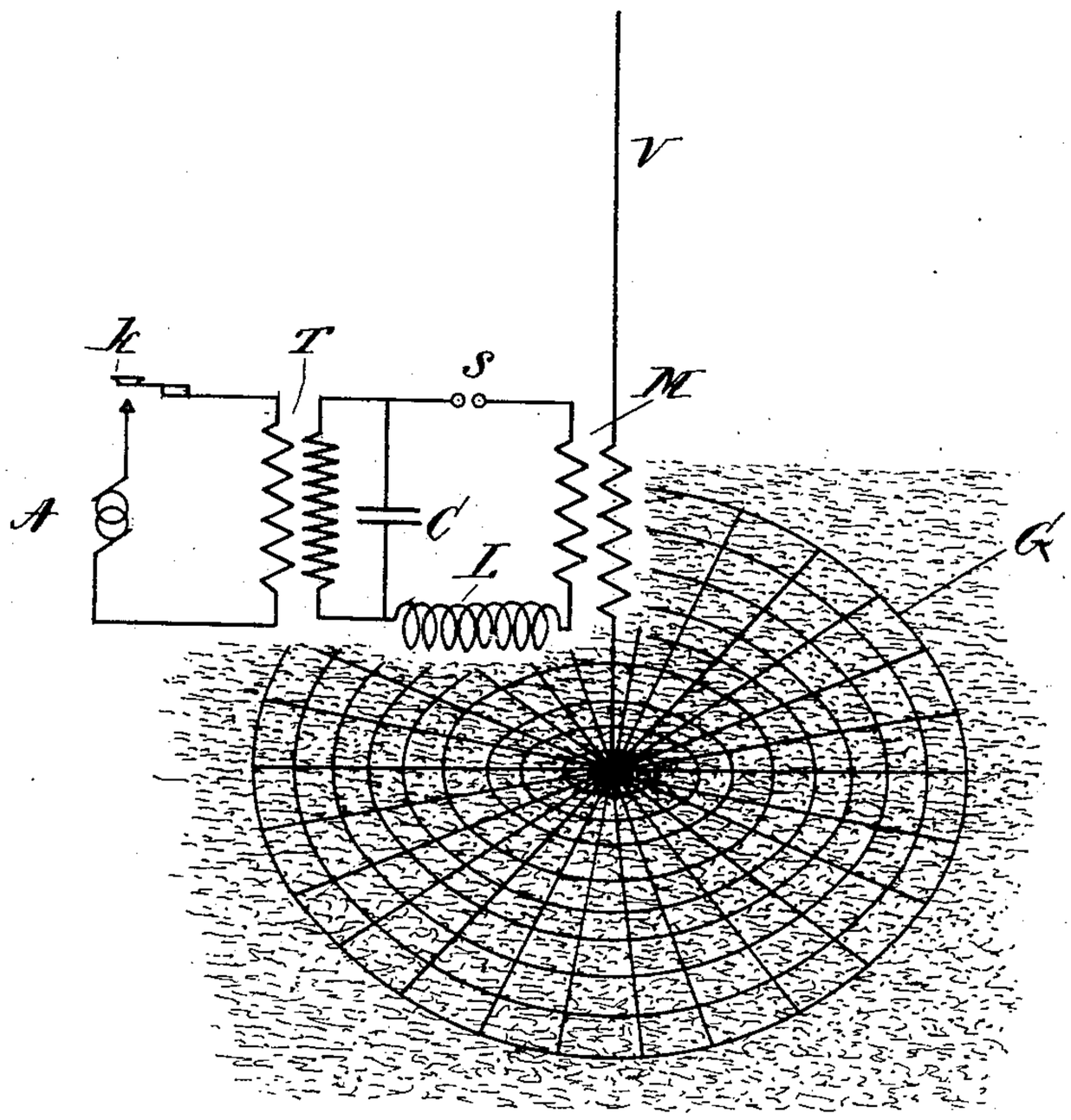
NO MODEL.



WITNESSES=

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UNITED STATES PATENT OFFICE.

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APPARATUS FOR INCREASING THE EFFECTIVE RADIATION OF ELECTROMAGNETIC WAVES.

SPECIFICATION forming part of Letters Patent No. 767,974, dated August 16, 1904.

Application filed October 30, 1903. Serial No. 179,223. (No model.)

To all whom it may concern:

Be it known that I, JOHN STONE STONE, a citizen of the United States, residing at Cambridge, in the county of Middlesex and State of Massachusetts, have invented certain new and useful Improvements in Apparatus for Increasing the Effective Radiation of Electromagnetic Waves, of which the following is a specification.

My invention relates to the transmission of signals by electromagnetic waves of a kind that were discovered and investigated by Prof. Andre Eugene Blondel, of Paris, in 1898, and it more particularly relates to apparatus for increasing the effective radiation of these waves from an elevated conductor.

The properties and characteristics of electromagnetic waves radiated from an elevated conductor have long been well known and are clearly set forth in the following publications: *Association Français pour L'Avancement des Sciences, Compte Rendu de la 27e Session*, Nantes, August 11, 1898, part 2, page 212, Prof. A. E. Blondel; *Seances de la Societe Français de Physique*, Paris, May 5, 1899, 2e fascicule, page 48, Dr. Andre Broca; *Electrical Review*, Vol. 44, May 5, 1899, London, page 746, Blondel; *Electrical Review*, Vol. 44, May 12 and 19, 1899, London, pages 795 and 799, J. E. Taylor; *Comptes Rendus des Seances de L'Academie des Sciences*, Tome CXXX, May 21, 1900, Paris, page 1383, Blondel. A brief exposition of the theory of the radiation of electromagnetic waves from an elevated conductor is also to be found in the United States Patent No. 706,746, dated August 12, 1902, to which reference is herein made for further information concerning their properties and mode of propagation. Attention, however, is called to an inaccuracy in the paper, hereinbefore referred to, read by Blondel before the French Association for the Advancement of Science—viz., that currents are developed by electromagnetic waves in a plate of conducting material interposed between the spark-terminals of a Hertz oscillator in the equatorial plane thereof, whereas this plate being in the equatorial—*i. e.*, the equipotential—plane of the oscillator will have no currents developed therein except such currents as are created therein in the immediate neighborhood of the oscillator, owing to the fact that the lines of electric force are not everywhere normal to the equatorial plane until a point equal to a quarter-wave length of the transmitted wave away from the oscillator is reached. Likewise when the elevated conductor is grounded no currents are created in the earth, which is then the equatorial or equipotential plane of the vertical oscillator or elevated conductor, except such slight currents as are created therein in the immediate neighborhood of the transmitting-wire, owing to the fact that the lines of electric force are not everywhere normal to said surface until the quarter-wave length is reached and also owing to the fact that the surface of the earth is not a perfect conductor and except such currents as are created therein when this surface over which the waves travel suddenly changes direction. Attention is further called to an inaccuracy in Patent No. 706,746, in which is repeated the same error which is to be found in the paper, above mentioned, by J. E. Taylor in the *London Electrical Review*—viz., that the energy received by a given aerial varies inversely as a given distance, whereas said energy varies inversely as the square of a given distance.

Having thus set forth the bibliography of electromagnetic-wave propagation from a grounded elevated conductor and having cautioned those wishing to practice this invention against the errors found in such bibliography, it will be necessary only to explain in this specification that these waves are radiated by creating electric oscillations in a grounded elevated conductor, preferably vertically elevated; that they consist of two components, one of which—the electric—is normal to the surface of the earth, and the other of which—the magnetic—is parallel to the surface of the earth, as set forth in my Letters Patent No. 725,634, April 14, 1903, and that they travel over the surface of the earth, water, or other natural media with which said elevated conductor or transmitting-wire is connected, even

although all parts of said surface of the earth, water, or other natural media do not lie in the same plane or in the same straight line. I have experimentally determined that the effective radiation of these waves can be increased by artificially increasing the natural electrical conductivity of the surface of the earth or other natural media in the immediate vicinity of the base of the transmitting-wire and maintaining said surface in a constantly-conducting state. I have also determined that the area of this surface necessary to be maintained in a more highly conducting condition in order that the radiation may be most effectively increased is the area of a circle whose center is the base of the elevated conductor and whose radius is equal approximately to a quarter-wave length of the transmitted wave. It has sometimes been observed that on hot dry days it is impossible to transmit electromagnetic waves from a grounded elevated conductor. I have experimentally determined that this breaking down of a wireless-telegraph transmitting system cannot occur if the natural electrical conductivity of the surface of the earth surrounding the base of the elevated conductor be increased by artificial means and maintained in such state of increased electrical conductivity in the manner described in this specification.

In the drawing which accompanies and forms a part of this specification the figure is a diagrammatic illustration of one embodiment of my invention.

In the figure, *a* is a source of varying electromotive force, which is here shown as an alternating-current generator. *k* is a key. T is a step-up transformer. C is a condenser. *s* is a spark-gap. L is an inductance. M is a transformer, preferably a step-up transformer. V is an elevated conductor or transmitting-wire. G represents in diagram means whereby the natural radial electrical conductivity of the surface of the earth in the neighborhood of the base of the elevated conductor is increased and maintained in a highly-conducting state.

For the construction of the transmitting apparatus and circuit arrangements and the mode of operation thereof reference may be had to my prior Letters Patent Nos. 714,756 and 714,832, dated December 2, 1902. It is sufficient to here state that by means of the apparatus made in accordance with the specifications of said Letters Patent electrical oscillations which preferably approximate the sinusoidal or simple harmonic form as closely as practicable are impressed or forced upon the elevated conductor either inductively or conductively connected with the sonorous or closed persistently-oscillating circuit M L C *s*. However, the transmitting apparatus and circuit arrangements herein shown are merely intended to be illustrative of any transmitting system, and it is to be understood that unless otherwise stated I do not desire my claims to be limited to any particular transmitting system, inasmuch as it is obvious that my invention may be used with any system whereby the radiation of electromagnetic waves is effected.

For making the surface of the earth more highly conducting and maintaining it in a constantly-conducting state a multiplicity of substances may be used. In the drawing I have illustrated one embodiment of my invention in which metallic wire-netting of large mesh, known as "chicken-coop" netting, is placed in electrical contact with the earth surrounding the lower end of the elevated conductor and is connected to the lower end of said conductor. Such netting has been used successfully for the purpose herein specified. I have also used a layer of commercial calcium chlorid, although any other deliquescent salt which by virtue of its moisture-absorbing properties will maintain the surface of the earth in a constantly-moistened condition may be used, and a layer of such salt may with advantage be spread upon the earth within the area covered by the wire-netting. A solution of water and any conducting salt may be used. In fact, I have restored to efficient working order a system by which radiation of electromagnetic waves was rendered impossible by heat and drought by merely moistening the earth with water for a distance from the base of the elevated conductor equal approximately to a quarter-wave length of the transmitted wave. Iron or other metallic wires disposed radially and circumferentially may be used and also rock salt, coarse common salt, charcoal, coke, and, in fact, any substance which exhibits a greater degree of electrical conductivity than the earth. When wire-netting or a system of radially and circumferentially extending metallic wires are so employed, it is to be noted that the effect is virtually a substitution of said netting or metallic wires for the earth as a natural guide for the electromagnetic waves.

I have discovered that in order to be most effective for the purpose above specified the means whereby the natural electrical conductivity of the earth or other natural media is increased must extend from the base of the elevated conductor a distance equal approximately to a quarter-wave length of the transmitted wave. The reason for this is that the true radiation of electromagnetic waves does not begin until a point about a quarter-wave length from the elevated conductor is reached, because it is well known that until this point is reached the electric and magnetic components of an electromagnetic wave are not in phase and that slight electric currents are created in the earth up to this point.

Although it is indicated by theory that any means employed to increase the natural electrical conductivity of the earth should extend

from the base of the elevated conductor a distance equal to a quarter-wave length of the transmitted wave, it is to be distinctly understood that this length is merely the maximum length which may be advantageously employed, while excellent results may be obtained by using a much-shorter length. In other words, the area of the netting or system of wires or other means specified herein may be much smaller than the area of a circle whose radius is equal to a quarter-wave length of the transmitted wave, although better results are obtained as this area is approximated.

In my application Serial No. 179,222, filed simultaneously herewith, I have fully set forth the theory of radiation of electromagnetic waves from an earthed elevated conductor.

Whereas heretofore it has been alleged that by means of a construction somewhat similar to that described herein, but in the form of a conducting-strip extending from the transmitting-station in the general direction of the receiving-station, a certain directive effect may be obtained, it is herein pointed out that no such directive effect can be obtained in the manner alleged. In explanation of the foregoing reference is to be had to Huyghen's principle, which is applicable to all free waves in an unlimited medium and by which the waves would proceed to spread in all directions as soon as they have passed beyond the limit of the conducting-strip laid upon the earth's surface in much the same way that sound-waves proceed to spread in all directions after leaving the end of an organ-pipe, in which they are limited, and passing out into the air. It is not with this alleged directive effect that this invention is concerned, and I desire it to be understood that I here disclaim the use of the invention herein described for such purpose.

Whereas heretofore it has been alleged that by means of a construction somewhat similar to that described herein the capacity and inductance of the vertical transmitting-wire are increased, or at least maintained constant, irrespective of climatic and other conditions, such as changes of electrical conductivity of the surface of the earth in the immediate neighborhood of said transmitting-wire due to salt spray, &c., it is herein pointed out that even when the surface of the earth has the minimum natural conductivity possible under the most unfavorable conditions the capacity of the vertical wire is definite and uninfluenced by the degree of conductivity of the surface of the earth for the same reason that the capacity of a condenser is uninfluenced by the degree of conductivity of the metal employed for the condenser-plates and that the inductance is completely determined entirely irrespective of the conductivity of the surface of the earth, being dependent solely upon the geometric constants and material of said wire. I therefore desire it to be understood that I here disclaim the use of the invention herein described for such purposes.

A method of increasing the effective radiation of electromagnetic waves from an earthed elevated conductor which may be carried out by the apparatus herein described has been claimed in my application Serial No. 179,222, filed October 30, 1903.

I claim—

1. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to a material of greater electrical conductivity than that of the earth, said material being in electrical contact with the earth and extending outwardly in all directions from the lower end of said conductor for a radial distance equal approximately to a quarter-wave length of the transmitted wave, in combination with means for developing electrical oscillations in said elevated conductor.

2. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to a material of greater electrical conductivity than that of the earth, said material being in electrical contact with the earth and extending outwardly in all directions from the lower end of said conductor for a radial distance equal approximately to a quarter-wave length of the transmitted wave, in combination with means for developing simple harmonic electrical oscillations in said elevated conductor.

3. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to a metallic netting, said netting being in electrical contact with the earth and extending outwardly in all directions from the lower end of said conductor for a radial distance equal approximately to a quarter-wave length of the transmitted wave, in combination with means for developing electrical oscillations in said elevated conductor.

4. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to a metallic netting, said netting being in electrical contact with the earth and extending outwardly in all directions from the lower end of said conductor for a radial distance equal approximately to a quarter-wave length of the transmitted wave, in combination with means for developing simple harmonic electrical oscillations in said elevated conductor.

5. In an apparatus for increasing the effective radiation of electromagnetic waves, an ele-

vated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to a metallic netting, said netting being in electrical contact with the earth, and a layer of a deliquescent salt disposed on the earth within the area covered by said netting.

6. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to earth, means for creating electrical oscillations in said elevated conductor and means for artificially increasing the electrical conductivity of the earth in all directions from said elevated conductor for a radial distance equal approximately to a quarter-wave length of the transmitted wave.

7. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to earth, the electrical conductivity of which for a radial distance equal approximately to a quarter-wave length of the transmitted wave is increased by means of a layer of calcium chlorid.

8. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to earth, the electrical conductivity of which for a radial distance equal approximately to a quarter-wave length of the transmitted wave is increased by means of a layer of a deliquescent salt.

9. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to earth, the electrical conductivity of which for a radial distance equal approximately to a quarter-wave length of the transmitted wave is increased by means of a material of greater electrical conductivity than that of the earth, substantially as described.

10. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to a material of greater electrical conductivity than that of the earth, said material being in electrical contact with the earth or other natural medium and extending outwardly from the lower end of said elevated conductor a distance sufficiently great for the purpose specified, in combination with means for developing electrical oscillations in said elevated conductor.

11. In an apparatus for increasing the effective radiation of electromagnetic waves, an elevated conductor, for radiating said electromagnetic waves, conductively connected at its lower end to a material of greater electrical conductivity than that of the earth, said material being in electrical contact with the earth or other natural medium and extending outwardly from the lower end of said elevated conductor a distance sufficiently great for the purpose specified, in combination with means for developing forced electrical oscillations in said elevated conductor.

In testimony whereof I have hereunto subscribed my name this 30th day of September, 1903.

JOHN STONE STONE.

Witnesses:

BENJ. F. HAINES,

ELLEN B. TOMLINSON.