No. 876,165. PATENTED JAN. 7, 1908.

L. DE FOREST.

WIRELESS TELEGRAPH TRANSMITTING SYSTEM.

APPLICATION FILED MAY 11, 1904.

Fig. 1.

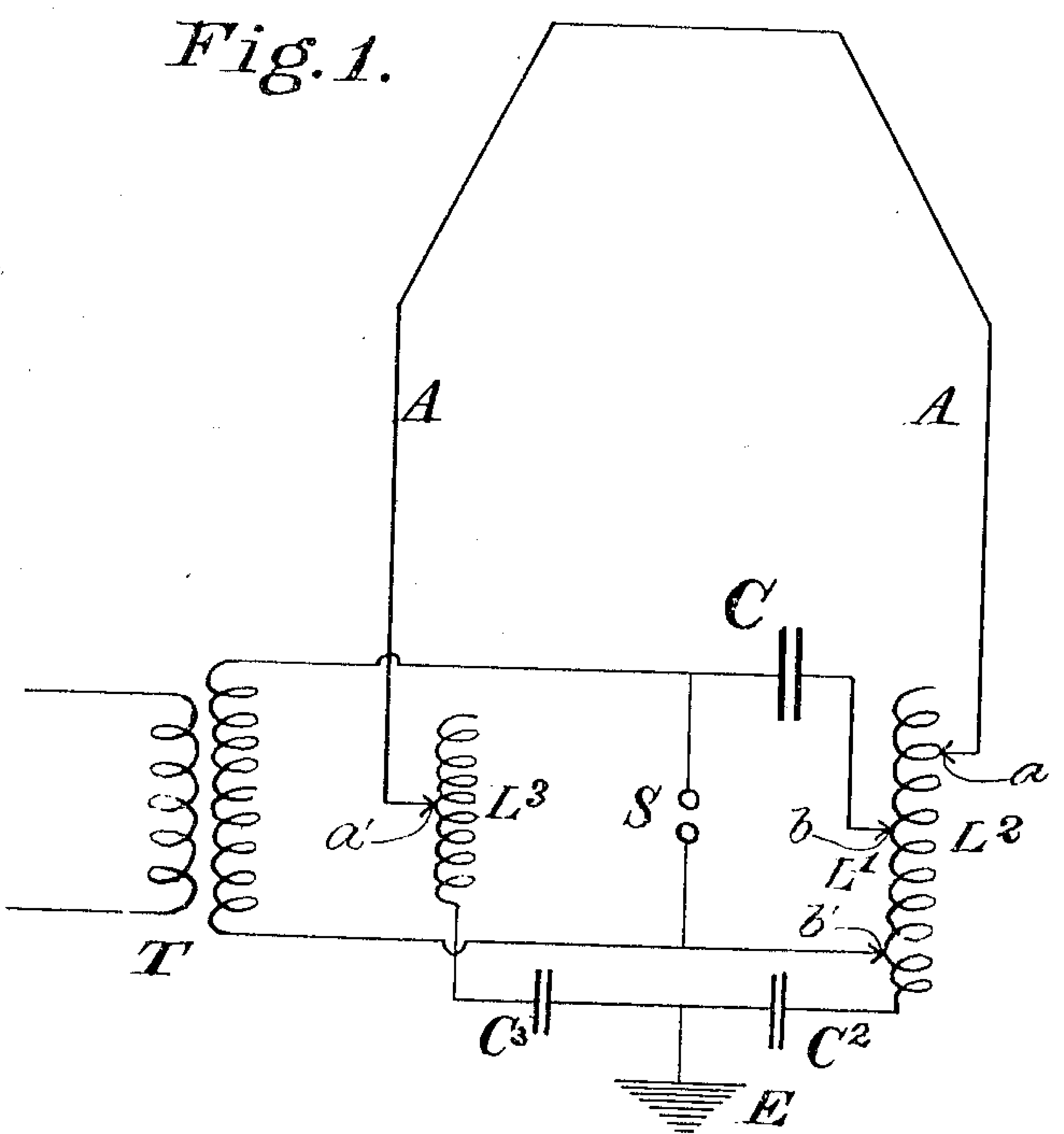
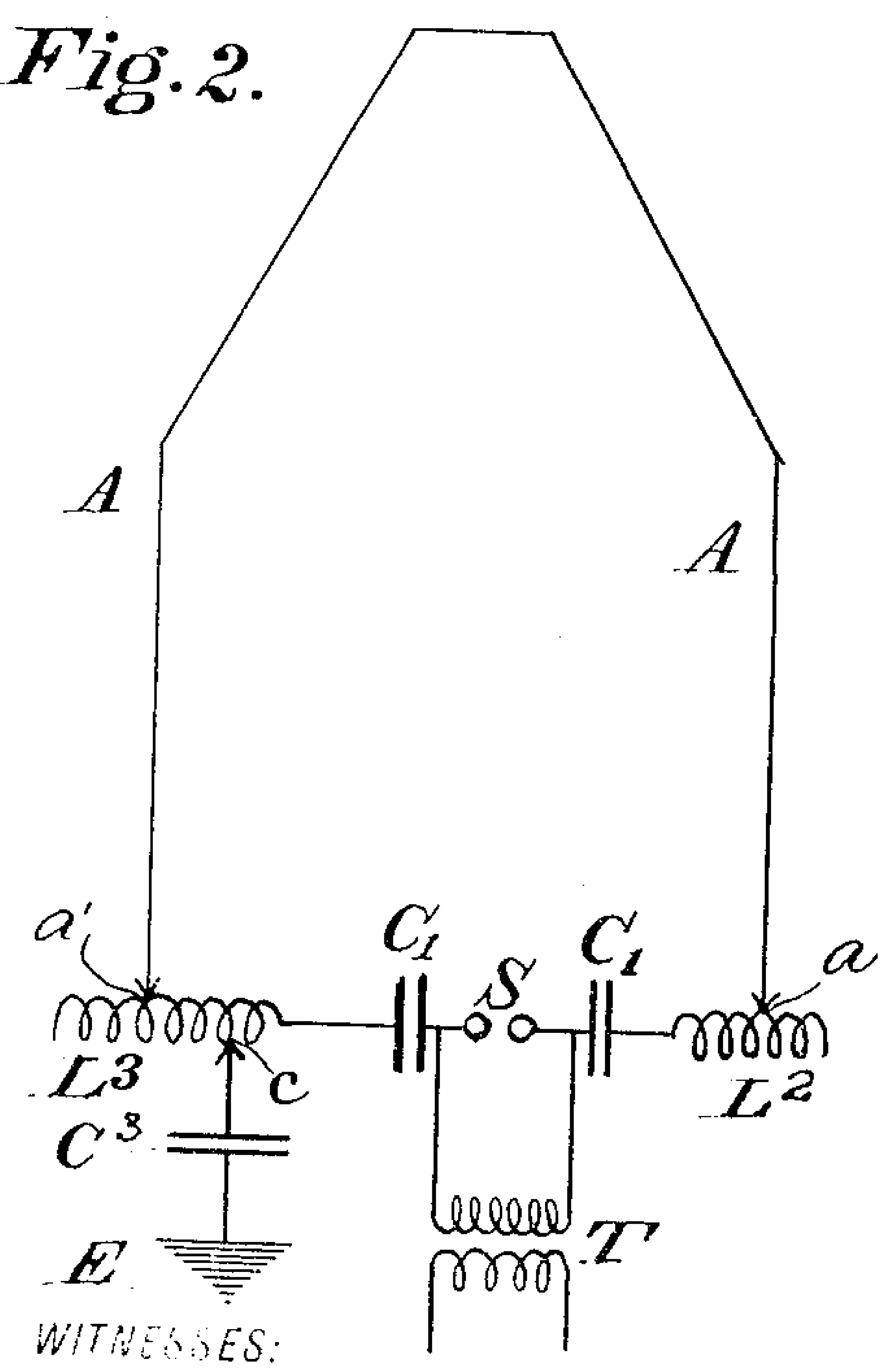


Fig. 2.



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WIRELESS TELEGRAPH TRANSMITTING SYSTEM.

No. 876,165. Specification of Letters Patent. Patented Jan. 7, 1908.

Application filed May 11, 1904. Serial No. 207,383.

To all whom it may concern:

Be it known that I, Lee de Forest, a citizen of the United States, and resident of the city, county, and State of New York, have invented certain new and useful Improvements in Wireless Telegraph Transmitting Systems, of which the following is a specification.

My invention relates to systems for developing and transmitting electromagnetic signal waves and has for its object a system embodying certain novel circuit arrangements whereby the efficiency of such wave development and transmission is increased.

It is a well-recognized fact in electro-physics that a closed-circuit oscillator may be made a much more persistent vibrator and a much poorer radiator than the open-ended or linear oscillator; and also that it may be made to have a much more strongly pronounced natural period than such linear oscillator.

In linear oscillators, such as are exemplified by the Hertzian oscillator or by the Righi exciter, which was introduced by Marconi as a wireless telegraph transmitter, the damping losses, occasioned by the intense radiation in the form of electromagnetic waves of the energy developed in such oscillators, by the dissipation of energy in the spark-gap, and by the imperfect reflection at the open end or ends thereof, are so great that linear oscillators are practically aperiodic. In fact, the waves radiated by such oscillators are so strongly damped that, instead of having a definite frequency or rate of vibration, they possess a vast number of frequencies, which of course would not be the case if the oscillator had a sharply defined natural rate of vibration.

The amount of electrical energy which may be stored in the form of potential energy in a linear oscillator is a direct function of the electrostatic capacity of such oscillator and structural difficulties oppose a limitation to the magnitude of such capacity. It therefore eventually became the practice in this art to associate a closed-circuit oscillator either inductively or conductively with a metallically continuous open-circuit oscillator, so as to obtain electromagnetic waves of more definite frequency and greater persistency, and also so as to secure by means of a condenser in said closed-circuit oscillator the absorption from the prime source of energy of a much larger amount of potential energy than could be so absorbed by said open-circuit oscillator. By thus developing persistent trains of waves of a well defined frequency and wave length, in lieu of aperiodic impulses, it became possible to select signals transmitted by waves of a given wave length by means of receiving circuits adjusted to such wave length in virtue of the cumulative or building-up effects, or "resonance effects," of such waves of given wave-length on said adjusted or tuned receiving circuits; and by thus absorbing from the prime source of energy by means of a condenser in the closed-oscillator a much greater amount of energy than could be so absorbed by the open-oscillator, it became possible to radiate in the form of electromagnetic waves a far greater amount of energy than could have been radiated by the disruptive discharge of a charged open-oscillator.

Another advantage of such so-called "coupled systems" resides in the amplification both of the intensity and of the tension of the oscillations developed in the open oscillator or transmitting antenna which is arrived at by according the natural periods of said antenna and its associated closed oscillator.

The open-oscillator coupled system, while marking a great advance over the now long since discarded Righi exciter, nevertheless is subject to certain limitations, which I have been able to overcome by employing a closed, persistently-oscillating, radiator or transmitting antenna preferably coupled with a closed, persistently - oscillating, energizing circuit as hereinafter more fully described. Such a transmitting system is as great an advance over the open-oscillator, coupled-systems as the latter is over the Righi exciter, and it possesses a number of advantages, some of which will now be set forth:

Owing to the great radiative power of the open oscillator and the large damping factor thereby introduced in the associated closed oscillator, there is interposed a limit both to the increase in the persistency of the transmitted waves and to the aforesaid amplification of the oscillations creating them. The loop-antenna of the present invention, having less radiative power than the open antenna and being, therefore, a more persistent oscillator, overcomes these limitations, for by virtue of such greater persistency, there is developed therein oscillations of far greater amplitude, tension and persistency than could by any possibility be developed with the same amount of available primary energy, in an open oscillator or antenna of equivalent capacity. Thus I make up for the loss in radiative power by the resulting gain in the persistency and amplification of the oscillations developed in the antenna by its associated closed-oscillator and hence of the waves created by said oscillations.

The waves radiated by the loop-antenna have a more definite frequency than those radiated by an open-antenna coupled-system, for the aforesaid reflection losses which exist to such marked degree in a simple linear oscillator and which exist to a certain extent in the open-oscillator coupled-system do not exist at all in the closed-oscillator transmitting antenna of my present invention.

In all coupled systems it is desirable to attune the open-oscillator and closed-oscillator to the same frequency. In the open-oscillator coupled-systems of the prior art, in which the open-end antenna is linked at its base to a closed oscillating system, either directly or by a Tesla transformer, it is usually the case that the natural period of the closed-oscillating circuit is greater than that of the open-end antenna. This is especially true, when large power is used in the transmitter, as in long distance systems, for in such case a condenser of large electrostatic capacity is required in order to absorb from the prime source of energy a sufficient amount of electrical energy to develop oscillations of the requisite power. Now the greater the aforesaid electrostatic capacity, the larger or higher the natural period of the oscillating circuit containing the said capacity, the lower the frequency of the oscillations resulting in said circuit and the longer the wave-length of the radiated waves. A certain amount of inductance must necessarily exist in the circuit in order to maintain the persistance of the circuit and to link the circuit to the antenna, and the greater this inductance, the longer the wave-length of the radiated waves. Therefore, for long distance transmission, where large amounts of power are required, it is necessary to use energizing circuits of relatively large or high natural period; and it is impossible, with open-oscillator, coupled-systems, to use closed-oscillator energizing-circuits of said large or high natural period, for inasmuch as the open oscillator always has a relatively low natural period, it follows that, in such cases, the two elements cannot be efficiently attuned to each other. This disadvantage, however, is overcome by the use of the system described in this application, for the loop-antenna can be made to possess, and in general does possess, a very high natural period so that the waves natural to it are relatively long and are of relatively low frequency. This means then that the original oscillating circuit, or closed persistently-oscillating energizing circuit, may have the large capacity requisite for long distance working, and may have the inductance requisite for maintaining the desired persistence and for adequate linkage, and still may be attuned to the loop-antenna, the periods of the two elements of the system being of the same order; and unless the original or primary oscillating circuit and the antenna circuit are thus put into syntomy, it is not possible to transmit signals over very great distances. Moreover, the long wave length is of further advantage in that such waves are less dissipated by obstacles and obstructions, less apt to be reflected by conductors or semi-conductors which lie in their path, such as buildings containing metallic structural parts, precipitous hillsides, etc., and are eminently better suited for long distance working over land, as well as over water.

I am aware that it has long since been proposed to employ an unloaded loop antenna provided with a spark-gap as a transmitting antenna and a similar loop antenna provided with a serially connected coherer as a receiving antenna; but such antenna so arranged are not persistently oscillating circuits and have no advantage whatever over the Righi exciter, they have never come into practical use and will not accomplish the results which are effected by the present invention.

Having thus set forth in general the principles upon which my invention depends and having shown the particular improvements effected over the prior art, I shall now particularly describe two simple embodiments thereof which I have shown diagrammatically in the accompanying drawings for the purpose of more fully disclosing my invention; but it is to be understood that such diagrams show only two of the numerous possible embodiments of my invention which I have successfully used in practice and that I do not limit myself thereto inasmuch as many modifications may be devised by those skilled in the art without departing from the spirit of my invention.

In the drawings, Figure 1 represents the circuit arrangements of a wireless telegraph transmitting system and is the preferred form of my invention; and Fig. 2 represents a modification thereof.

The loop antenna shown in each figure may be constructed by directly connecting the wires A, A′, at their upper ends, and by connecting said wires at their lower ends through the inductances L^2, L^3, which are serially connected in the wires A, A′, respectively. The aforesaid inductances L^2, L^3 are located preferably at the base of each side of the loop antenna, as shown in the drawings. The inductances L^2, L^3 render the loop antenna sonorous or more persistent and of a more definitely marked natural period. The loop antenna itself thus forms part of a closed oscillating circuit of relatively large natural period and hence of a relatively low frequency corresponding to a relatively long wave-length. Each side of the loop antenna may consist of one or of several wires, and it is desirable to have the two sides of the loop antenna as far removed from each other as may conveniently be obtained in order to reduce their mutual inductance and their mutual capacity, and therefore to augment the self inductance and capacity to earth of the loop antenna considered as a whole and hence to increase the natural period thereof.

The base of the loop antenna should be connected to earth as at E when said antenna is employed in long distance transmission, for reasons now well understood by those skilled in this art and which have been explained by me in a paper published in the *Electrical World and Engineer*, May 17, 1902.

A condenser C^2 or C^3 may be inserted in either branch of the loop antenna illustrated in Fig. 1, or both condensers may be employed, each serially connected in its own branch or side of said loop antenna. When the system is not used for long distance transmission, or, stated more generally, when for any reason the frequency of the closed, oscillating, energizing circuit S C L′ is higher than that of the loop antenna because its condenser C is not required to have large capacity, the frequency of the loop antenna may be increased by the insertion of one or both of said condensers C^2, C^3, for thereby the effective capacity of the loop antenna is decreased. In like manner the condenser C^3 may be inserted in the earth lead of the loop antenna shown in Fig. 2 to reduce the natural period of oscillation of said loop antenna.

As explained above, a number of useful results are obtained when oscillations are excited in the loop antenna by another closed, oscillating circuit, such as the closed, oscillating, energizing circuit S C L′, including the spark gap S, condenser C and inductance L′, and said circuit S C L′ may be linked to the antenna either by an auto-transformer or by one having separated primary and secondary windings. It is necessary in order to obtain maximum efficiency to attune these two oscillating circuits together. This may be accomplished by means of the adjustable contacts *a*, *a′*, *b*, *b′* whereby the amount of inductance in either or both of said two oscillating circuits may be changed until the antenna circuit shows a maximum of electric energy oscillating therein, such maximum being determined by a hot-wire ammeter or other suitable measuring or indicating device. As shown in Fig. 1, four adjustable contacts are employed. The contacts *b*, *b′*, determine what portion of the inductance L^3 is to be included in the spark gap circuit S C L′. That portion of said inductance L^3 which is so included in said circuit is represented by L′. The contacts *a*, *a′*, determine what portion of the inductances L^2 L^3, respectively, are to be included in the sides A, A′, of the loop antenna. I find that when the initial energy from a high-potential source such as the transformer or induction coil T, is delivered to the closed, persistently-oscillating, non-radiating circuit S C L′ and said circuit is put in tune with the loop antenna or closed, persistently-oscillating, radiating circuit, very much better results are obtained than when said circuit S C L′ is suppressed and the energy delivered directly to the loop antenna, in the manner shown in Fig. 2.

In Fig. 1, the initial energy is supplied to a circuit inclosed entirely within the station house and therefore perfectly insulated. Losses by leakage from damp insulators and into damp or partially conducting atmosphere are thereby prevented. Moreover, the two linked circuits, each attuned to the same frequency, cause the radiation of wave-trains which are less damped and which have a more sharply defined period than could be produced without employing the circuit S C L′. However, it is possible to carefully insulate the antenna wires and use the loop antenna alone both for oscillator and radiator, as shown in Fig. 2. In Fig. 2, the natural period of the loop antenna may be altered by the adjustable contacts *a*, *a′*, which determine what portions of the inductances L^2, L^3, are to be included in the two sides A, A′, respectively, of said antenna. The condensers C^1, C^1, are analogous in function to the condenser C of Fig. 1, in that by their disruptive discharge across the gap S the system is set into electrical vibration. The condenser C^3 which may be employed if desired is equivalent in function to the correspondingly lettered condenser in Fig. 1. The adjustable contact *c* determines what portion of the inductance L^3 is to be included in the lead from the loop antenna to earth. As hereinafter explained, it is desirable that considerable inductance be included in said lead, so as to prevent the oscillations from running to earth through a straight wire.

When, by the proper adjustment of the inductances L^1 L^2 L^3 or by any other method, the natural periods of the closed persistently-oscillating radiator, or loop antenna, and the closed, non-radiating persistent oscillator CSL^1 of Fig. 1 are made equal, oscillations or currents of far greater intensity, tension and persistency are developed in the loop antenna than could by any possibility be developed, other things being equal, in an open oscillator or antenna insulated at its upper end. The fact that the persistency of the loop antenna is greater, and that its damping factor is less, than in the case of the open antenna means that its radiative power, which is in the nature of resistance in so far as the damping factors of the antenna and its associated circuit are concerned, is less than the radiative power of an open antenna; but the gain in the intensity, tension and persistency of the oscillations in the loop antenna more than offsets such lessened radiative power. The aforesaid increase in persistency depends, however, not only upon the reduction of the resistance equivalent of radiation, but also upon the fact that the loop antenna is metallically continuous so that its damping factor is not increased by the dissipative resistance of a serially connected spark gap, as well as upon the further fact that the ratio of inductance by capacity, which determines the persistence of an oscillating circuit, is of necessity greater for the loop antenna than for the closed oscillator C S L^1 because the capacity of the latter is necessarily far greater than that of the former.

The larger persistency of the loop antenna constructed as herein set forth has the effect, first, that both the intensity and tension of the oscillations developed in the antenna are greatly amplified by the building-up or cumulative effect of the properly timed impulses impressed upon the antenna by the circuit C S L^1, thereby resulting in the radiation of waves of greater power; and second, that the radiated waves have a persistency corresponding to that of the oscillations creating them, thereby rendering it possible for a receiving system better to select signals sent by such waves of given wave length than by waves of different wave length, because of the amplification of the oscillations created by said waves in a properly tuned receiving system due to the cumulative effect of such persistent waves.

None of the foregoing highly desirable results may be attained to the degree that I attain them unless there are present in the system two elements,—namely, a persistently-oscillating radiator and a non-radiating persistent oscillator.

The other two advantages of my invention,—namely, the ability to radiate waves of a more definite frequency and of longer wave length than can be radiated from an open antenna, are common to both the systems shown in the drawings; but the system shown in Fig. 1 is preferred by me in practice.

The circuits herein shown differ essentially from one in which the top of the antenna is provided with a separate ground connection through an impedance coil located at the top of the antenna. Such a device would act very differently and could not act in the manner of the circuits, which I have invented and hereinbefore described. Such a separate earth or ground wire leading to the top of the radiating fan or harp increases the capacity of said fan, so that the latter can absorb more energy. This wire does not enter into the high-frequency oscillations which are later set up in the fan itself; as the impedance coil inserted between this wire and the top of the fan acts as a choke coil to prevent the high-frequency currents from entering this ground wire and running thence to the earth. In my invention on the other hand, it is this very object that is desired, and both sides of the loop enter into the high-frequency oscillations to a like extent. The other arrangement or that with a choke coil at the top of the antenna, will oscillate exactly like the simple upright, open-end antenna, with the exception that its period is somewhat increased, due to the close proximity of the earthed wire which is run parallel to it. Moreover, in my invention it is desirable that considerable inductance be inserted at the base of each side of the loop, to prevent the oscillations from running at once into earth through a straight wire and thence being lost. In other words, each side of the loop must act as a persistent oscillator in order to render the entire loop a persistent oscillator.

While I have shown my invention embodied in certain apparatus, it is not to be inferred that such apparatus represents the only forms in which my invention may be embodied, but are illustrated and described only as illustrative of forms now preferred by me, and to make clear the principles and methods of application of my invention.

What I claim and desire to secure by Letters Patent is:

1. In a wireless telegraph transmitting system, the combination with a transmitting loop antenna, constituting a closed oscillating circuit, of a closed oscillating energizing circuit associated therewith and attuned thereto.

2. The combination, at a station for transmitting electric wave impulses, with a plurality of aerial conductors divided into two portions having their upper ends connected together, and connected to earth at their lower ends, to form a complete closed oscillating-radiating loop; of an oscillation source coöperatively associated with said loop; and means for tuning said source and loop with each other.

3. The combination, at a station for transmitting electric wave impulses, with a plurality of aerial conductors divided into two portions having their upper ends connected together, and connected to earth at their lower ends, to form a complete closed oscillating-radiating loop; of a separate original closed oscillation circuit in coöperative relationship with said loop; and means for tuning the loop and original oscillation circuit with each other.

4. The combination, at a station for transmitting electric wave impulses, with a plurality of aerial conductors divided into two portions having their upper ends connected together, and connected to earth at their lower ends, to form a complete closed oscillating-radiating loop; of two inductance coils, one for each side of said loop, means for adjusting said coils; and a separate original closed oscillation circuit adjustably connected to one of said inductance coils.

5. The combination, at a station for transmitting electric wave impulses, with a plurality of aerial conductors divided into two portions having their upper ends connected together, and connected to earth at their lower ends, to form a complete closed oscillating-radiating loop; of two inductance coils, one for each side of the loop; an oscillation source coöperatively associated with said loop; and means for tuning said source and loop with each other.

6. The combination, at a station for transmitting electric wave impulses, with a plurality of aerial conductors divided into two portions having their upper ends connected together, and connected to earth at their lower ends, to form a complete closed oscillating-radiating loop; of suitable electrical capacity connected and arranged in series in said loop; and suitable electrical inductance connected in said loop to increase the persistency and sharpness of tuning.

7. The combination, at a station for transmitting electric wave impulses, with a plurality of aerial conductors divided into two portions having their upper ends connected together, and connected to earth at their lower ends, to form a complete closed oscillating-radiating loop; of suitable electrical inductance connected and arranged to obstruct the free passage to earth of the high frequency oscillations in the radiating loop, and suitable electrical capacity connected in series in said loop.

8. The combination, at a station for transmitting electric wave impulses, with a plurality of aerial conductors divided into two portions having their upper ends connected together, and connected to earth at their lower ends, to form a complete closed oscillating-radiating loop; of two condensers, one in each side of said loop, and separate means associated therewith for generating oscillations in said loop.

9. The combination, at a station for transmitting electric wave impulses, with a plurality of aerial conductors divided into two portions having their upper ends connected together, and connected to earth at their lower ends, to form a complete closed oscillating-radiating loop; of both a capacity and an inductance in each side of said loop.

10. A wireless telegraph transmitting system, comprising a closed oscillating radiator, a closed non-radiating oscillator, and means for according the natural periods of said radiator and oscillator.

11. In a wireless telegraph system, a metallically-continuous loop-antenna, a persistently-oscillating circuit associated therewith, and means for according the natural periods of said antenna and its associated circuit.

12. In a wireless telegraph transmitting system, a metallically-continuous loop-antenna and a persistently-oscillating circuit associated therewith and adapted to develop therein electrical oscillations having the frequency of those natural to said antenna.

13. In a wireless telegraph transmitting system, a loop antenna, an inductance for giving the same any desired natural period, and means for developing in said antenna persistent electrical oscillations having the aforesaid natural period.

14. In a wireless telegraph transmitting system, a loop antenna, an inductance for giving the same any desired natural period, and means associated with said inductance for developing in said antenna persistent electrical oscillations having the aforesaid natural period.

15. In a wireless telegraph transmitting system, a loop antenna, inductances included respectively in the two sides thereof for giving the same any desired natural period, and means for developing in said antenna persistent electrical oscillations having the aforesaid natural period.

16. In a wireless telegraph transmitting system, a loop antenna, inductances included respectively in the two sides thereof for giving the same any desired natural period, and means associated with one of said inductances for developing in said antenna persistent electrical oscillations having the aforesaid natural period.

17. In a wireless telegraph transmitting system, the combination with a transmitting loop antenna, constituting a closed oscillating circuit, of a closed oscillating energizing circuit associated therewith and adjustable means for tuning said circuits so as to bring them into harmony.

18. In a wireless telegraph transmitting system, the combination with a transmitting loop antenna, constituting a closed oscillating circuit, of a closed oscillating energizing circuit associated therewith and adjustable inductances for tuning said circuits so as to bring them into harmony.

19. In a wireless telegraph transmitting system, a transmitting loop antenna constituting a closed persistently-oscillating radiating circuit, two condensers, one in each side of said loop antenna, a connection to earth intermediate of said condensers, and a closed oscillating energizing circuit associated with said loop antenna.

20. In a wireless telegraph transmitting

system, a transmitting loop antenna, two inductance coils, one in each side of said loop antenna, said inductance coils being constructed and arranged to render said loop antenna a persistently-oscillating circuit, a connection to earth intermediate of said inductance coils, and a closed oscillating energizing circuit associated with said loop antenna.

21. In a wireless telegraph transmitting system, a transmitting loop antenna, two inductance coils, one in each side of said loop antenna, said inductance coils being constructed and arranged to render said loop antenna a persistently-oscillating circuit, two condensers, one in each side of said loop antenna, a connection to earth intermediate of said condensers, and a closed oscillating energizing circuit associated with said loop antenna.

22. In a wireless telegraph transmitting system, a transmitting loop antenna constituting a closed persistently-oscillating radiating circuit, two condensers, one in each side of said loop antenna, a connection to earth intermediate of said condensers, and a closed oscillating energizing circuit associated with said loop antenna and attuned to the frequency thereof.

23. In a wireless telegraph transmitting system, a transmitting loop antenna, two inductance coils, one in each side of said loop antenna, said inductance coils being constructed and arranged to render said loop antenna a persistently-oscillating circuit, a connection to earth intermediate of said inductance coils, and a closed oscillating energizing circuit associated with said loop antenna and attuned to the frequency thereof.

24. In a wireless telegraph transmitting system, a transmitting loop antenna, two inductance coils, one in each side of said loop antenna, said inductance coils being constructed and arranged to render said loop antenna a persistently-oscillating circuit, two condensers, one in each side of said loop antenna, a connection to earth intermediate of said condensers, and a closed oscillating energizing circuit associated with said loop antenna and attuned to the frequency thereof.

In testimony whereof, I have hereunto affixed my signature this 26th day of April, 1904, in the presence of two witnesses.

LEE DE FOREST.

Witnesses:
ABRAHAM WHITE,
EZEKIEL C. M. RAND.