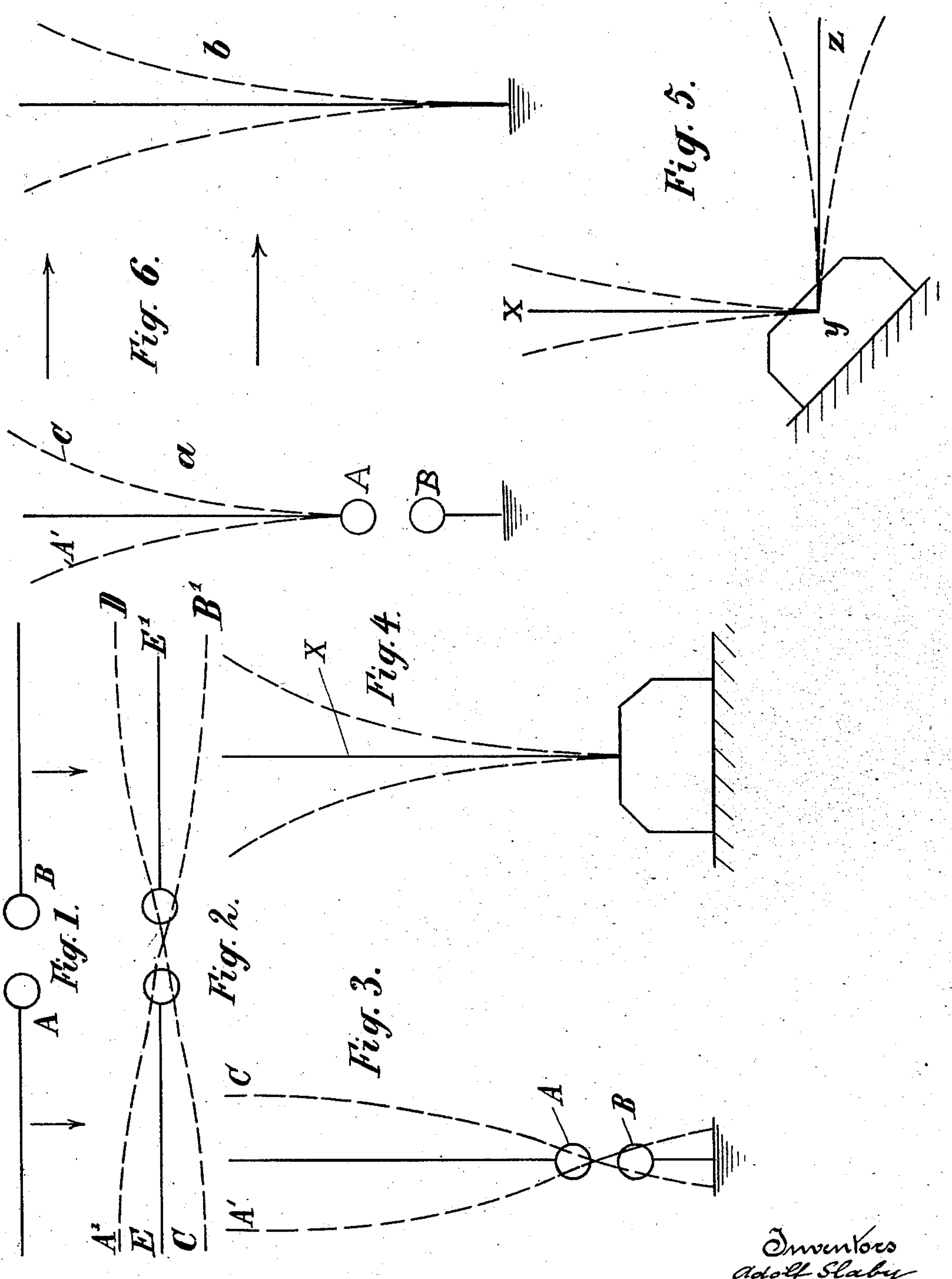
No. 750,496. PATENTED JAN. 26, 1904.

A. SLABY & G. G. ARCO.

SPARK TELEGRAPHY.

APPLICATION FILED APR. 9, 1901.

NO MODEL. 4 SHEETS—SHEET 1.



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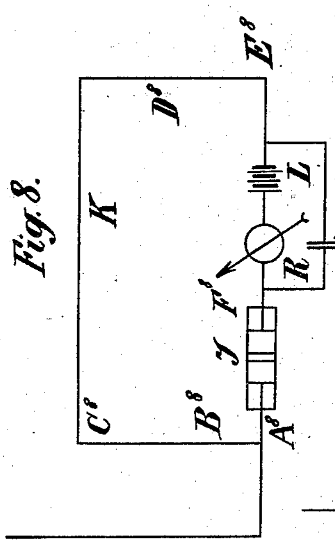
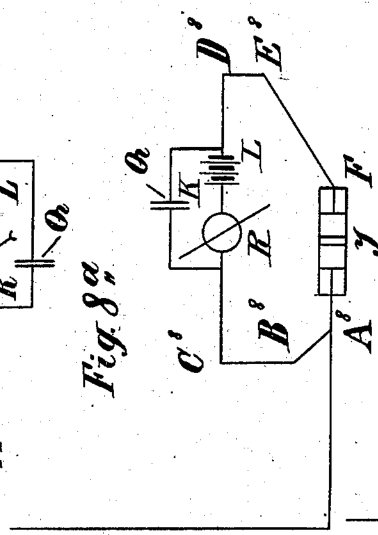
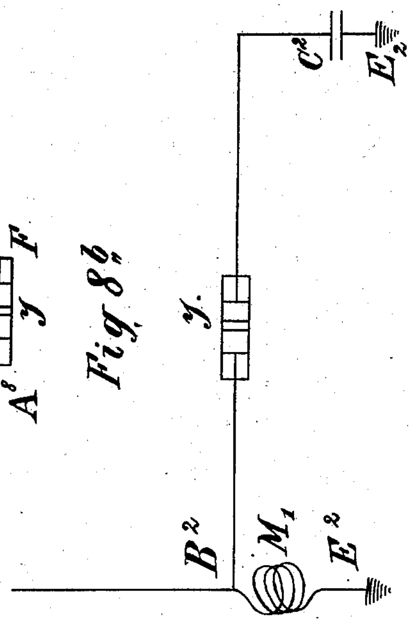
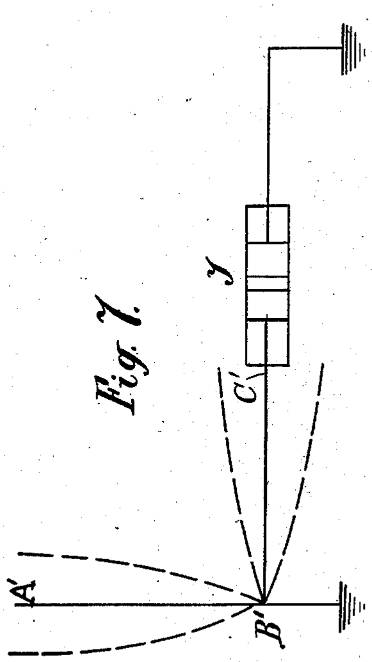
NO MODEL. 4 SHEETS—SHEET 2.









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NO MODEL. 4 SHEETS—SHEET 3.

Fig. 9.

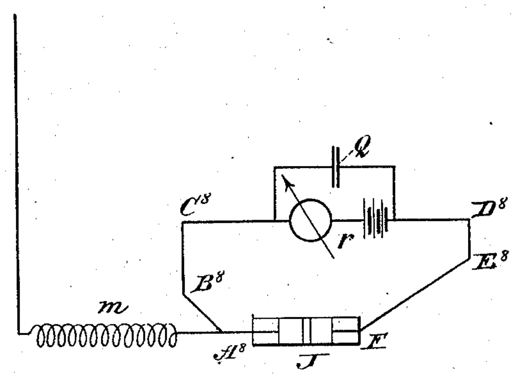
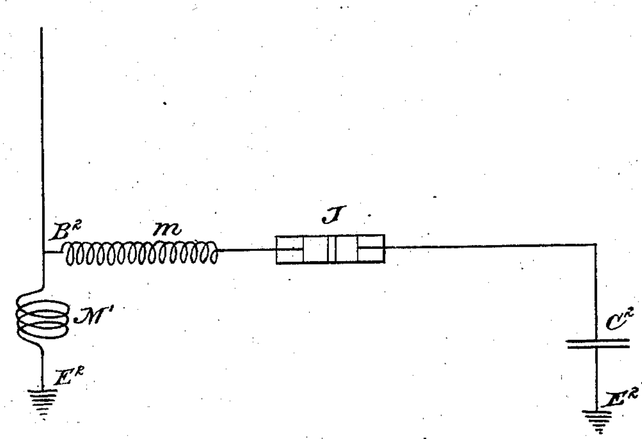


Fig. 10.



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SPARK TELEGRAPHY.

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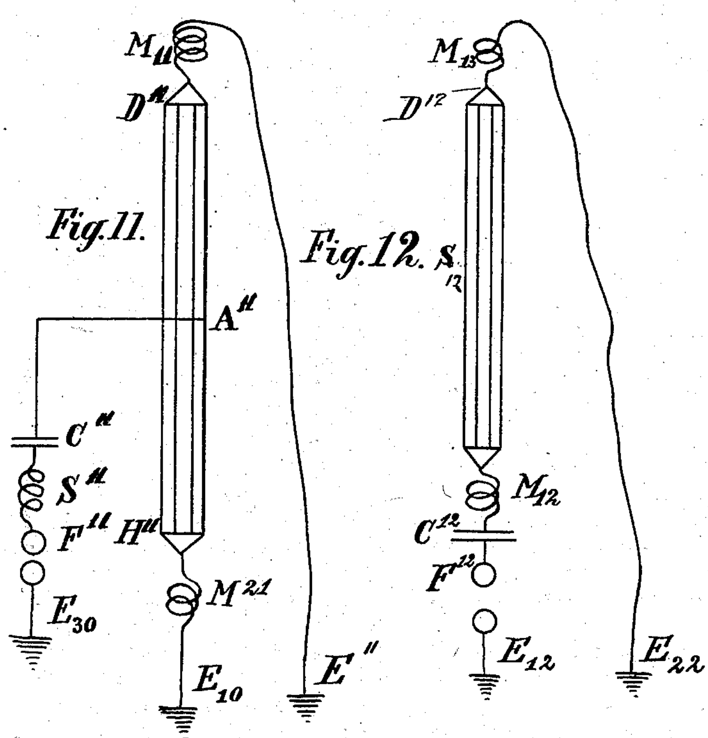
NO MODEL. 4 SHEETS—SHEET 4.



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No. 750,496. Patented January 26, 1904.

UNITED STATES PATENT OFFICE.

ADOLF SLABY, OF CHARLOTTENBURG, AND GEORG GRAF ARCO, OF BERLIN, GERMANY.

SPARK TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 750,496, dated January 26, 1904.

Application filed April 9, 1901. Serial No. 54,990. (No model.)

To all whom it may concern:

Be it known that we, ADOLF SLABY, residing at Charlottenburg, and GEORG GRAF ARCO, residing at Berlin, Germany, both subjects of the German Emperor, have invented certain new and useful Improvements in Spark Telegraphy, of which the following is a specification.

Our invention relates to spark telegraphy, otherwise known as "wireless" telegraphy, and has for its object principally to efficiently transmit signals from one station to another by means of so-called "Hertzian" or "Maxwell" oscillations or waves.

By our invention, as hereinafter described, we secure a very sensitive action, owing to a particular arrangement of the wave-detector, which in our invention is actuated upon by the waves of fundamental frequency where the said waves have a maximum of intensity, whereas heretofore wave detectors or coherers have responded to the higher harmonics accompanying the waves of fundamental frequency.

Our invention also has for its object to provide means for tuning or harmonizing the instruments, so that a receiving instrument will respond to a transmitter of a certain definite wave length of frequency and to no other.

Our invention further consists in so constructing the apparatus that a number of messages may be received at the same time.

The accompanying drawings are partly diagrams illustrating the principles upon which our invention is based and partly illustrations of several forms of apparatus for carrying out our invention.

Figures 1 to 6, inclusive, are illustrative diagrams serving to explain the principles of our invention. Fig. 7 is a diagram showing in a theoretical way a simple form of receiving-station embodying our invention. Figs. 8, 8^a, and 8^b illustrate practical developments such as we have found suitable for practical use at the receiving-station. Figs. 9 and 10 are figures corresponding to Figs. 8^a and 8^b, respectively, showing the use of an intensifying coil or multiplier. Figs. 11 and 12 illustrate two forms of transmitting-stations.

We shall first explain the phenomena taking place at the transmitting-station.

Referring to Fig. 1, this shows a common ball-oscillator A B, the spark being produced between the balls in any desired way, and with these balls are connected two equally long alined straight wires. If an oscillating discharge is produced between the balls, the wires will send out electric waves of a certain definite length, which waves pass through space with the rapidity of light. The curves indicating the distribution of electric tension of the said vibrations on the sending-wire are shown by the dotted lines A′ B′ C D in Fig. 2. E E′ corresponds to one-half of the wave-length. If one pole of the oscillator is connected with the earth, as in Fig. 3, the character of the vibrations and the length of the waves will not be changed, provided that the distance from the spark-ball A to the upper end of the oscillator in Fig. 3 is one-half the total length E E′ of the oscillator shown in Fig. 2. The electrical vibrations may be considered analogous to the mechanical vibrations of a vertical steel spring X, held fast at one end, Fig. 4. The vibrations described by the free end of the steel spring are analogous in amplitude to the electrical vibrations set up in the wire by the spark. A steel spring bent at right angles, as indicated at x y z in Fig. 5, and held at its center will upon receiving an impulse at x transfer its vibrations to the arm y z, so that the standing wave in the arm x y will reproduce itself through the bend y. This, however, occurs only when the length of one arm x y is equal to the other arm y z. These phenomena are similar in the case of electric waves, except that in this case it is not necessary that the two vibrating portions be of the same length, but the two portions should have the same constant obtained by multiplying the capacity by the coefficient of self-induction.

Fig. 6 shows the transference of the electric oscillations from the transmitter a to the receiver b in the system illustrated by Fig. 3 and the nature of the oscillations in the sending and in the receiving wire, the oscillations being indicated by dotted lines lettered as above. Let us imagine that there is located between the lower end of the receiving-wire and the earth a wave-indicator—for instance, a coherer of a capacity of about .0001 microfarad—while the length of the receiving-wire is about thirty meters. In this event the capacity of the receiving-wire, provided the same be vertical, will be equal to that of the coherer. Thus two capacities are connected in series, that of the aerial receiving-wire and that of the coherer. The latter, in this case, is located at a point intermediate between the nodal point and the point of greatest amplitude, and the coherer therefore responds, not to the vibrations of fundamental frequency, but to the higher harmonics which accompany the fundamental vibrations. The coherer thus does not get the advantage of the maximum amplitude of the fundamental vibrations developed in the receiving-wire. The sensitiveness of the receiver or coherer is therefore relatively small, for the reason that the tension or amplitude of the fundamental vibrations at that point in the receiving-wire at which the receiver or coherer is located is very small, or, in other words, because the receiver or coherer is so near the grounded end of the receiving-wire, and consequently so near the nodal point of the fundamental vibrations developed in said wire. The oscillations which effect the coherer are therefore largely those which are higher harmonics of the fundamental vibrations, and the sensitiveness of the coherer is still further reduced, because these higher harmonics are not so well defined as the fundamental vibrations. We accordingly effect the correct transference and full utilization of the fundamental electric vibrations taken up by the receiving-wire to the coherer or wave-indicator by placing the latter at the point of greatest amplitude or tension, such an arrangement being shown in Fig. 7. Here the receiving-wire or collector is connected with the earth at B′ and is provided with a continuation B′ C′, the length of which is equal to A′ B′. At C′ there is obtained a maximum of the tension of the fundamental vibrations, as this is the point of greatest amplitude. A further advantage besides the intensity of the resulting effect is that all other waves which do not meet the requirement that one-fourth of their length should be equal to A′ B′ and to B′ C′ will not reach their greatest intensity or amplitude at the point C′.

Multiplex telegraphy may be obtained as follows: A series of transmitters, each having sending-wires of the same height, if desired, are adjusted or tuned by arrangements described below, each to its individual wave length. The corresponding receivers are so constructed or proportioned as to wire length that the point of maximum tension or wave amplitude of each will occur at C′. The several receivers may be entirely separate and independent of each other. It is possible, however, to connect several receiving instruments with the same receiving-wire and to have each receiving instrument respond independently of the others to the oscillations of proper wave length. These several receiving instruments may be connected to one and the same horizontal wire at different points; but it is preferable to employ a separate horizontal wire for each of the receiving instruments, these horizontal wires being connected with the same system of receiving-wires. In carrying out this part of our invention B′ A′ is a constant, but B′ C′ is given such a length that A′ B′ plus B′ C′ equals one-half of the wave length of the corresponding transmitter. Thus B′ will not coincide exactly with the nodal point. Experiments have shown, however, that two telegrams may be received separately and simultaneously without error if they are transmitted one with waves of a length double the wave length of the other and if B′ A′ is made equal to one-quarter of the shorter wave length.

In Fig. 8 we have illustrated a receiving-circuit having no ground connection. At the point A^8, where the indicator J is located, is the point of maximum amplitude of tension or antinodal point. F^8 indicates the other pole of the indicator, and between the two poles A^8 F^8 is inserted a length of wire A^8 B^8 C^8 D^8 E^8 F^8, which equals one-half of the wave length, and must therefore have a node at some point—for instance, at K. L is the local battery, R the relay, and Q a condenser connected in a shunt to the battery and relay. In order not to influence the amplitude or tension at F^8 by the resistance of the relay or the condenser, the relay R and the battery L are preferably inserted at the nodal point K in the receiver-circuit, as shown in Fig. 8^a. To obtain still better results, the point K may be grounded. The wire length B^8 C^8 D^8 E^8 F^8 is not set in a straight line, but generally coiled, The diameter of the coil, however, should be large and the distance between the windings should be considerable. The capacity of the horizontal portion of the receiving-wire, which extends very close to the earth, is larger than that of the vertical portion of said wire, and therefore it is not necessary in these arrangements to give the horizontal portion of the receiving-conductor the same length as the vertical portion. The purpose of the condenser Q is to eliminate the self-induction of the relay R from the circuit in which the vibrations take place.

Instead of having a ground connection from the nodal point arranged within the receiving-circuit the ground connection may be made from a nodal point arranged outside the circuit, as shown in Fig. 8^b. In this case the coil M′ is inserted between B^2 and the ground connection E^2 and creates a sine-wave maximum or an antinodal point where the indicator J is located, the other pole of this indicator being grounded through a condenser C^2. The potential is so distributed over the conductor that a minimum of tension or node occurs at the earth connection E^2 adjacent to the coil M′, and the tension increases from said point and reaches its maximum at the upper end of the receiving-wire and at the wave-indicator J. The condenser C^2 being of a very large capacity relatively to that of the wave-indicator J, the connection with the condenser accomplishes practically the same result as if the corresponding pole of the indicator were connected with the earth directly. In order to obtain a higher rate of sensitiveness and a more energetic action, it is preferable to coil that portion of the receiving-wire which is adjacent to the earth, or, in other words, the portion which corresponds to that lettered *y z* in Fig. 5. If the two wire portions—that is, the vertical portion and the horizontal portion—are straight, the amplitude at the ends will be the same. If, however, the horizontal wire portion is coiled, the capacity of this portion is reduced very considerably, while the self-induction is increased in the same proportion. The result is that by thus coiling the horizontal portion of the wire or part of such portion the tension amplitude at the end of the horizontal portion becomes much greater than that at the end of the vertical wire portion. For this reason we have applied the term "multiplier" to a coil which is located in the horizontal portion of the receiving-wire or which constitutes such portion of the wire. The intensifying action which we have just referred to can therefore be secured in each of the circuit arrangements illustrated by Figs. 7, 8, 8^a, and 8^b by simply coiling that portion of the receiving-wire which is between the lower end of the vertical wire and the wave-indicator, as indicated at *m* in Figs. 9 and 10. The action produced by thus substituting a coil for a portion of the horizontal receiving-wire or for the entire horizontal wire may be explained as follows: Two electrical systems attuned so as to harmonize them, and which therefore have the same product of self-induction and capacity, are to be so proportioned that in the one the capacity will be larger and the self-induction smaller, while in the other the reverse relation is to obtain. Two such systems, one of which serves as a transmitter and the other as the corresponding receiver, are in the same relation to each other as the two circuits of a transformer. There is a transformation of energy. The energy contained in both circuits is the same, (abstraction being made of losses;) but in the one circuit such energy has a greater kinetic component and a smaller potential component, while in the other circuit the amperage or kinetic component is smaller and the potential component greater. Therefore the coiling of the horizontal portion of the receiving-wire has for its object to bring about a transformation of energy with an increase of potential in the circuit which contains the small capacity of a wave-indicator, (.0001 microfarad.) The indicator should be located where the amplitude or potential is the greatest—that is, between the end of the coil and the large capacity, such as the earth or a condenser. In practical construction the multiplying-coil, such as hereinbefore referred to, may simply consist of a single layer of insulated wire wound upon a suitable core. If such a coil is connected at one end with a circuit of high frequency, a very considerable increase of tension is observed at the other end, provided the apparatus has been attuned. This attuning is effected by means of a coil, such as M′. (See Fig. 8^b.) Supposing the frequency of the oscillations set up in the transmitter is smaller than the rate of vibrations of the receiving-wire connected with the earth, the purpose of the coil M′ is to add so much self-induction to the aerial receiving-wire as to reduce the rate of vibrations of the receiving-wire to a point where it will be equal to that of the sending-wire. The horizontal branch wire which leads from the aerial wire to the indicator J is to be made of such a length that this rate of vibration in the circuit grounded through the coil M′ will be equal to that of the vertical receiving-wire and also to that of the sending-wire. This rule applies whether the horizontal wire be straight, as in Figs. 7, 8, 8^a, and 8^b, or coiled, as in Figs. 9 and 10. If, however, the individual rate of vibration of the receiving-wire without the use of the coil M′ is smaller than that of the sending-wire, then the inclusion of the coil M′ serves to further reduce the rate of vibration of the receiving-wire until the frequency of vibrations at the receiving-wire will be three-fourths of the rate of vibrations of the sending-wire. In this case, too, a horizontal branch wire will be so constructed that a maximum of potential will occur at the indicator as well as at the upper portion of the aerial conductor. In this case when the receiving-wire has vibrations the wave length of which is three-fourths of the wave lengths at the sending-wire there will be two nodes in the aerial conductor, one of them in the ground at E^2 and the other between this point and the upper end of the aerial conductor. In both cases the product of self-induction multiplied by capacity will be the same in the aerial conductor relatively to the earth as it is in the branch wire or indicator-circuit relatively to the earth, and this product will also be the same in the corresponding sending-wire.

Turning now to the transmitters, we find that for greatest efficiency the following points should be observed: First, they should be capable of transmitting or producing an effect at a great distance; second, waves of a predetermined length should be produced irrespective of the height of the sending-wire, and, third, the electric vibrations should be generated with the greatest possible purity—that is, avoiding as much as possible the formation of higher harmonics. The transmitter, as is well known, consists of a single wire or several wires or conductors which extend into the air and which are of different lengths, according to the distance to which it is desired to transmit a message. These wires may be vertical or inclined. When these conductors receive an electrical impulse, as by an electric spark, they vibrate electrically, these vibrations being similar to a pendulum motion, occurring about what may be termed an "electrical center of gravity." On account of losses of energy a damping action takes place, which causes the vibrations to stop after a few pendulum motions. The node of potential (which corresponds to the greatest amplitude of the current) is situated at the point of the connection to the earth. The greatest potential amplitude (which corresponds to the current-node) we find at the upper end of the aerial conductor and also in the earth at an equal distance from the potential-node. In the transmitter illustrated by Fig. 6 the electrical vibrations of the sending-conductor are produced by interrupting the conductor adjacent to the potential-node by a spark-gap. The high-tension current is thus directed partly to the earth and partly to the insulated aerial conductor. When a spark is produced, a series of oscillations are set up in the aerial wire and in the earth, as described, the amplitude of the successive oscillations of the series decreasing as the originally available energy is used up. In order to increase the capacity of the aerial conductor to receive energy, we have in Fig. 11 shown a construction of the transmitter in which that part from which the impulses radiate into space is composed of several wires, as indicated, between the points H^{11} D^{11}. If the distance between the several wires is very large, and therefore the mutual induction of the wires very small, the energy would be increased in proportion to the number of wires—that is, four wires would give four times the energy that one wire would produce. For practical reasons the wires are placed rather close together—say from one-quarter to two meters—and the increase of energy, therefore, is not quite so much as the theoretically possible increase. These conductors are connected with the earth at E^{10}, and a coil M^{21} is interposed in this connection for the purpose of reducing the damping action, so that while less energy is radiated during the first oscillations the number of oscillations is increased. If the attuned receiver should not respond to the first vibration, it will very soon respond to one of the subsequent vibrations, since the amplitude gradually increases. The other end of the aerial conductor D^{11} may also be connected with the earth, as at E^{11}, and this has for its object to increase the capacity of the portion D^{11} H^{11} to receive electrical energy. For this purpose the earth connection D^{11} E^{11} is located adjacent to the wires H^{11} D^{11}. The two parts of the vibration system form, as it were, the two terminals of a condenser the insulation of which is formed by air, the capacity of such condenser increasing as its two parts approach each other. The device for giving impulses to this transmitter can be located in a shunt, as shown in Fig. 11, or directly in the main circuit, as shown in Fig. 12. In Fig. 11 C′ is the condenser, which furnishes the spark-producing energy. S^{11} is a regulating-coil. F^{11} indicaets the terminals of the spark-gap and E^{30} the connection to the earth. By properly adjusting the coil S^{11} the rate of vibration of the circuit containing C^{11} S^{11} F^{11} can be made equal to the rate of vibration which the transmitting-conductor has by its capacity and self-induction. The connection at A^{11} need not be in the center, but may be as far down as H^{11}. The ground connection at E^{30} may be omitted. There is produced in such a transmitter a quick vibration corresponding to the frequency of a wave the length of which is equal to four times the length of the elevated conductor and also a second series of slower vibrations which extend through the entire circuit and are therefore dependent upon the self-induction of the entire circuit. These secondary vibrations are not employed for transmitting messages, for the reason that their frequency is relatively low and that the wave-indicator does not respond to wave lengths of several kilometers.

In Fig. 12 the condenser C^{12}, which is inserted in the ground connection E^{12}, is charged by the high-tension current. The capacity of this condenser should be a multiple of that of the aerial conductor M^{12} D^{12}. F^{12} is the spark-gap, located between the condenser and the earth. The other end of the conductor is connected to the earth at E^{22}, this wire extending in proximity to the transmitting-wires M^{12} D^{12}. A coil M^{13} is preferably located in this connection, this coil, as well as those lettered M^{11} M^{12}, serving to reduce the damping action, as has been explained with reference to the coil M^{21}. When the sparks are produced at the gap F^{12}, the entire system vibrates electrically, the frequency being somewhat reduced, owing to the increase of capacity which is due to the proximity of the earth connection E^{22} to the transmitting wires or conductors M^{12} D^{12}. The point of greatest potential amplitude is not exactly at the upper end D^{12} of the aerial wires, but slightly above the same.

It will be understood that the ships' masts and other existing vertical or inclined conductors may be utilized for the purpose of our invention, dispensing with the erection of posts or towers.

We claim as our invention and desire to secure by Letters Patent—

1. In a receiver for wireless telegraphy, an aerial conductor having a ground connection, a wire branched on said conductor adjacent to the node of potential, an indicator one pole of which is connected with said wire, and a ground connection at the other pole of the indicator, the self-induction and capacity of the branch circuit in which the indicator is located being so proportioned as to produce a maximum of potential at that pole of the indicator which is connected with said wire.

2. In a receiver for wireless telegraphy, an aerial conductor, a wire branched on said conductor adjacent to the node of potential, an indicator one pole of which is connected with said wire, and a capacity connection from the other pole of the indicator, the self-induction and capacity of the branch circuit in which the indicator is located, being so proportioned as to produce a maximum of potential at that pole of the indicator which is connected with said wire.

3. In a receiver for wireless telegraphy, an aerial conductor, a wire branched on said conductor adjacent to the node of potential, an indicator one pole of which is connected with said wire, and a capacity connection from the other pole of the indicator, the self-induction and capacity of the branch circuit in which the indicator is located, being so proportioned as to produce a maximum of potential at that pole of the indicator which is connected with said wire, a portion of said branch circuit being in the form of a coil to intensify the potential amplitude at the indicator.

4. In a receiver for wireless telegraphy, an aerial conductor, a wire branched on said conductor adjacent to the node of potential, an indicator one pole of which is connected with said wire, and a capacity connection from the other pole of the indicator, the self-induction and capacity of the branch circuit on which the indicator is located, being so proportioned as to produce a maximum of potential at that pole of the indicator which is connected with said wire, a portion of said branch circuit, between the aerial conductor and the indicator, being in the form of a coil to intensify the potential amplitude at the indicator.

5. In a receiver for wireless telegraphy, an aerial conductor having a period equal to that of the waves to be received, an approximately horizontal wire of the same period connected with said conductor at the nodal point, and an indicator connected with the said wire, at the antinodal point.

6. In a receiver for wireless telegraphy, a conducting system adapted to vibrate electrically in response to vibrations sent from a transmitter, and an indicator connected with said system at a point of maximum potential.

7. In a receiver for wireless telegraphy, a conductor adapted to vibrate electrically in response to vibrations sent from a transmitter, a branch wire of the same vibratory period as the conductor connected with the latter at the nodal point, and an indicator connected with said wire at the antinodal point.

8. A transmitter for wireless telegraphy, comprising a sending-wire connected with the earth, a wave-generator connected with the said wire directly, and an intensifier in the sending-circuit.

9. A transmitter for wireless telegraphy, comprising a sending-loop grounded at both ends, and a wave-generator connected with said loop.

10. A transmitter for wireless telegraphy, comprising a sending-loop grounded at both ends and having unevenly-distributed self-induction, and a wave-generator connected with said loop.

11. A transmitter for wireless telegraphy, comprising a sending-loop grounded at both ends and having unevenly-distributed self-induction, a wave-generator connected with the said loop, and a regulating-coil in circuit with the wave-generator.

12. A transmitter for wireless telegraphy, comprising a sending-wire connected with the earth, a wave-generator connected with said wire directly, and a regulating-coil in circuit with said wave-generator.

13. In a receiver for wireless telegraphy a conducting system adapted to vibrate electrically in response to vibrations sent from a transmitter, a local battery in the receiving-circuit, a condenser in a shunt to the battery, the battery and condenser being located at the nodal point of the vibrations of the receiving-circuit, and an indicator located at the antinodal point.

14. In a receiver for wireless telegraphy, an aerial conductor adapted to vibrate electrically in response to impulses sent from a transmitter, a ground connection from said conductor, a regulating-coil in said ground connection, a branch wire connected with said conductor at its nodal point, and an indicator connected with said wire at its antinodal point.

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