No. 720,568. PATENTED FEB. 17, 1903.

L. DE FOREST.

SPACE TELEGRAPHY.

APPLICATION FILED MAR. 6, 1901.

NO MODEL. 2 SHEETS—SHEET 1.

Fig. 1.

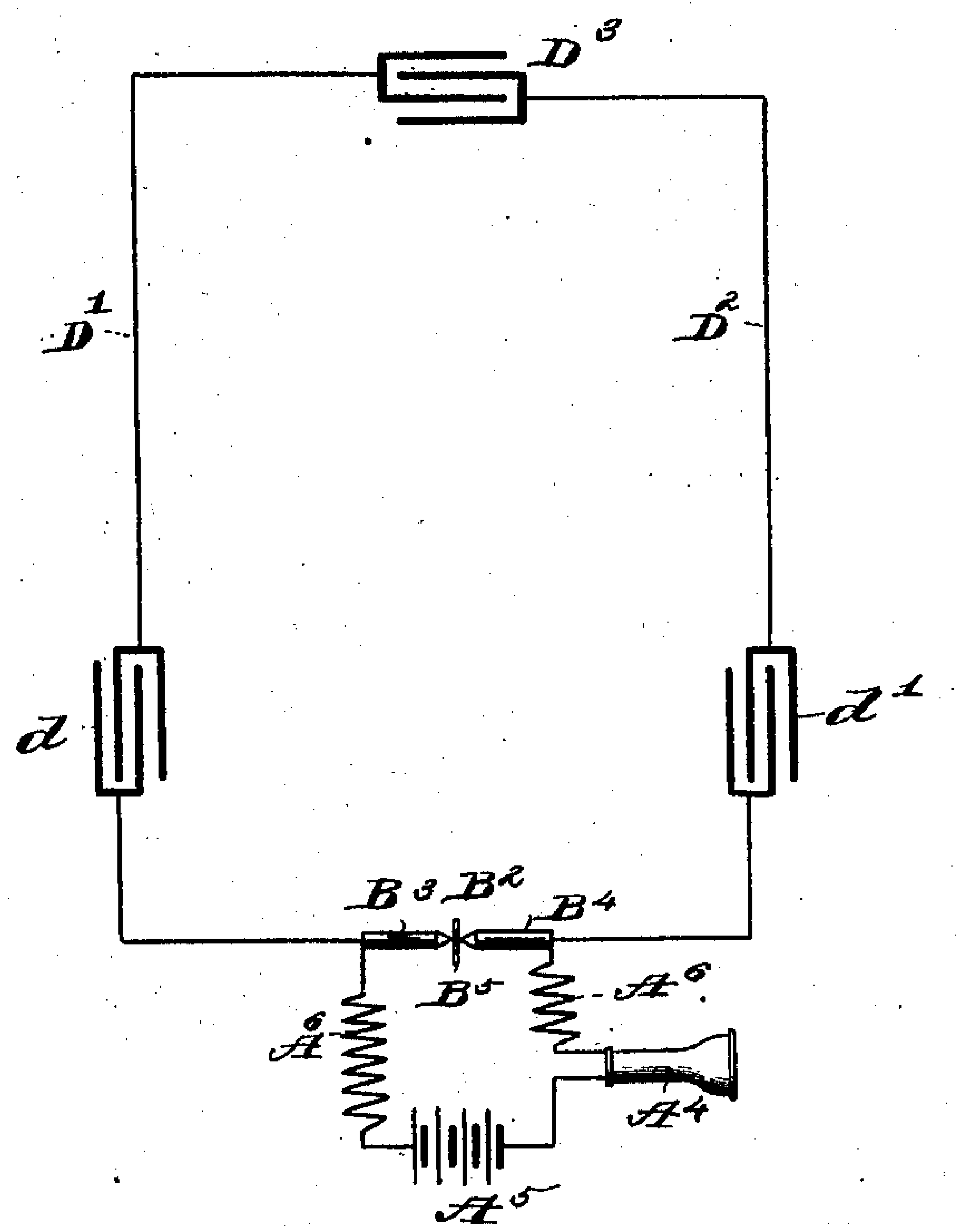


Fig. 2.

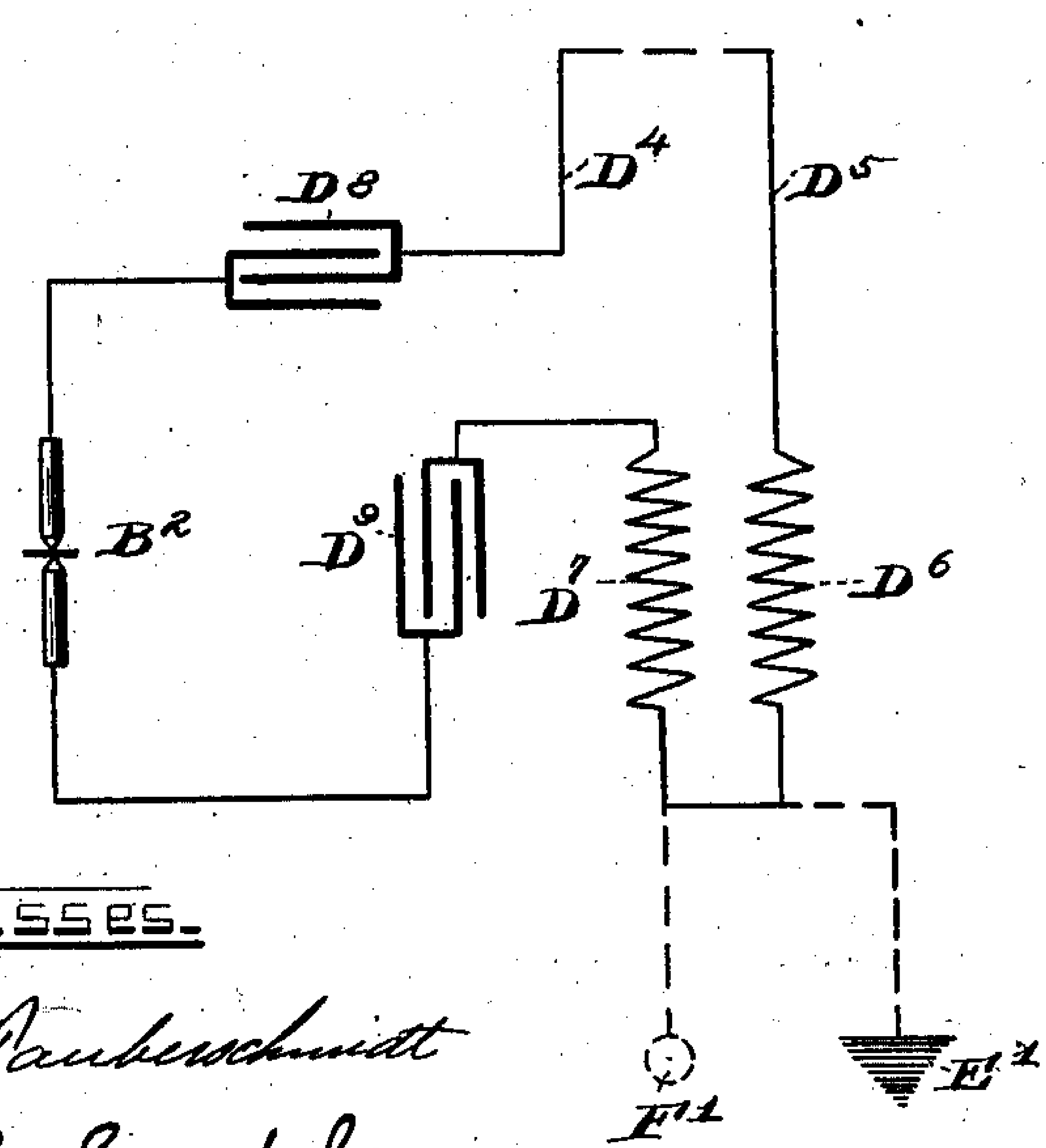
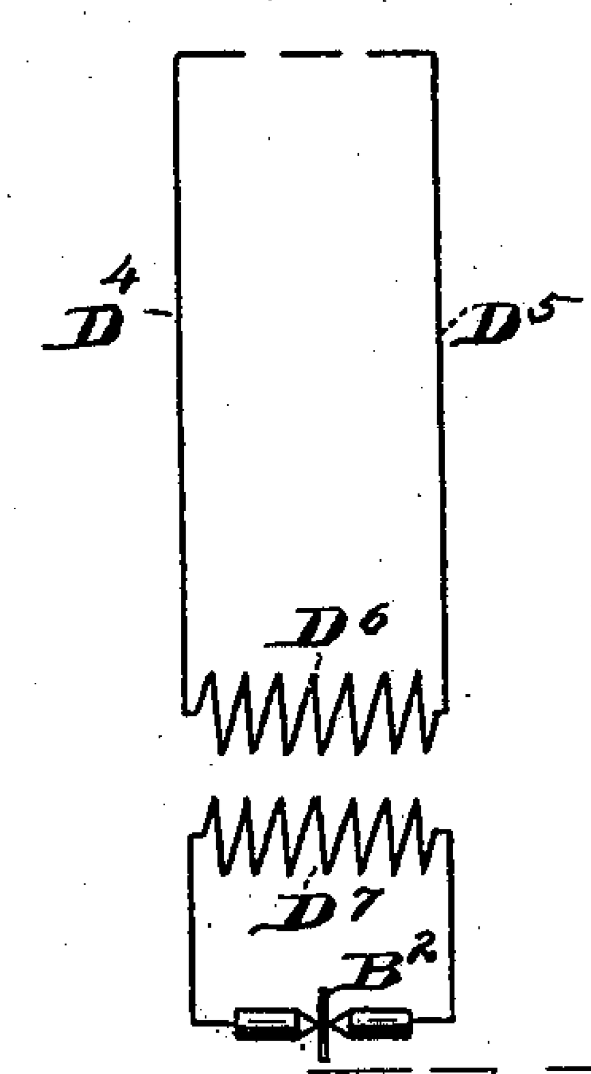


Fig. 3.



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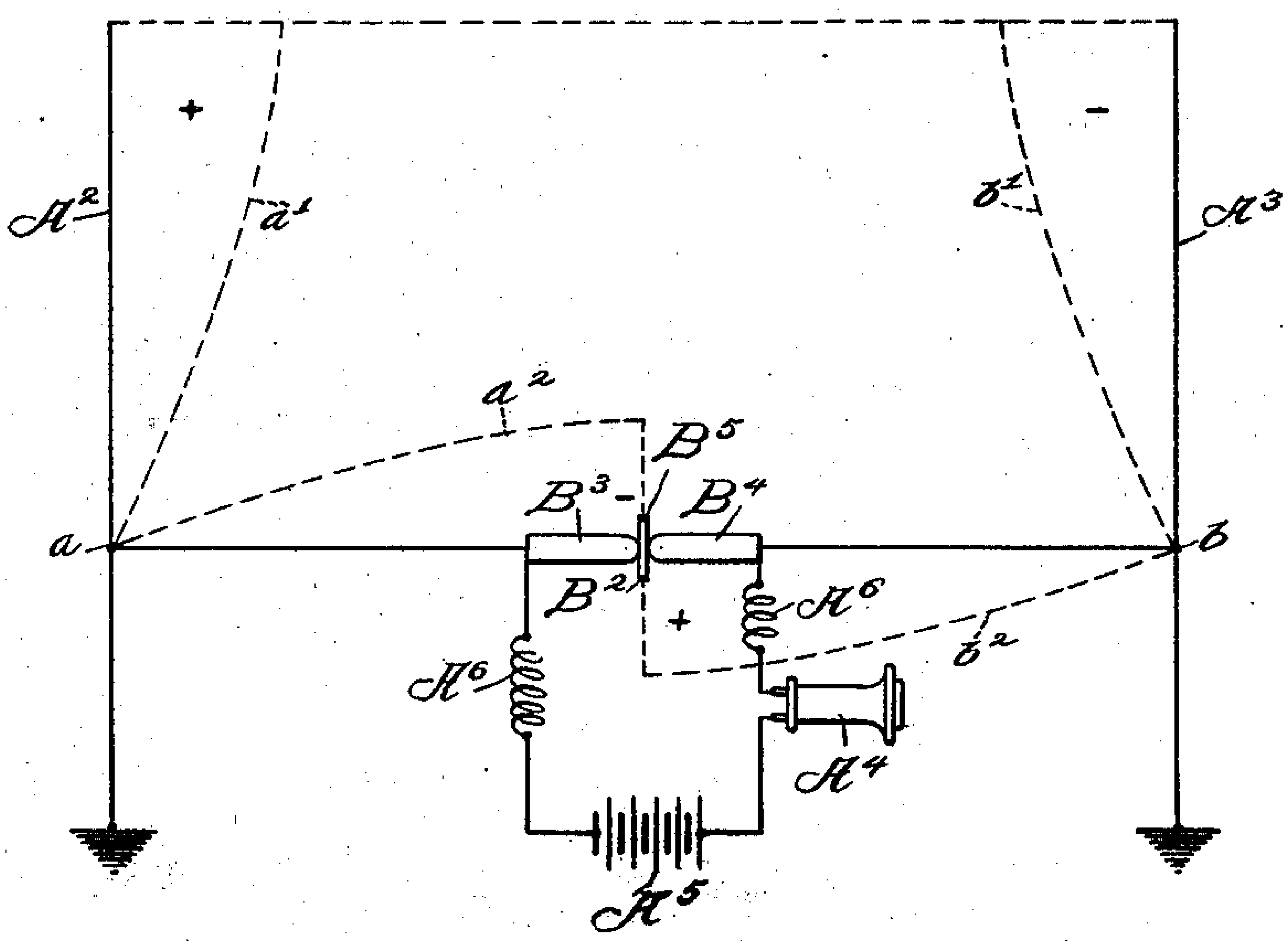
SPACE TELEGRAPHY.

APPLICATION FILED MAR. 6, 1901.

NO MODEL. 2 SHEETS—SHEET 2.

Fig. 4.



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UNITED STATES PATENT OFFICE.

LEE DE FOREST, OF CHICAGO, ILLINOIS, ASSIGNOR TO WIRELESS TELEGRAPH COMPANY OF AMERICA, A CORPORATION OF NEW JERSEY.

SPACE TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 720,568, dated February 17, 1903.

Application filed March 6, 1901. Serial No. 50,078. (No model.)

To all whom it may concern:

Be it known that I, LEE DE FOREST, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented a new and useful Improvement in Space Telegraphy, of which the following is a specification.

This invention relates to improvements in space telegraphy.

The object of the invention is to provide means which are simple in construction and arrangement for increasing the efficiency of apparatus used in space signaling.

A further object of the invention is to provide means which permit simultaneous transmission or reception of several messages.

A further object of the invention is to provide means whereby the receiving apparatus is selective of the energy-waves to which it is responsive.

Other objects of the invention will appear more fully hereinafter.

The invention consists, substantially, in the construction, combination, location, and arrangement, all as will be more fully hereinafter set forth, as shown in the accompanying drawings, and finally pointed out in the appended claims.

Referring to the accompanying drawings, and to the various views and reference-signs appearing thereon, Figure 1 is a view somewhat diagrammatical, illustrating an arrangement of apparatus at the receiving-station and embodying the principles of my invention. Figs. 2 and 3 are similar views illustrating modifications embraced within the spirit and scope of my invention. Fig. 4 is a diagrammatical view illustrating an arrangement of apparatus at the receiving-station and embodying the principles of my invention.

In apparatus of the class to which the present invention relates electrical oscillations or energy-waves are sent out from a transmitting or sending station and which, traversing space, finally reach and fall or impinge upon an aerial receiving-conductor, which conductor is coupled up in suitable manner with a receiving device. The present invention resides particularly in the construction and arrangement of parts at the receiving-station, and a special purpose of the invention is to provide such an arrangement of receiving apparatus that the maximum effect of the radiated energy-waves is produced upon the receiving apparatus, thereby enabling the transmission of signals through the longest possible distance.

In order to secure the best results, the coherer or other receiving device employed at the receiving-station should be so placed and located that a maximum of positive potential and a maximum of negative potential shall occur at the two terminals thereof simultaneously. This result is not accomplished in the arrangement of the apparatus heretofore employed wherein a single aerial receiving-conductor is used—such, for instance, as is disclosed in Patent No. 586,193, issued July 13, 1897, to Marconi—said conductor being connected to earth through a coherer or other form of resistance device, for in such case one terminal of the coherer or resistance device being connected to earth is at zero potential. In carrying out my invention, therefore, I propose to employ two or a coöperating pair of aerial receiving-conductors, in each of which stationary waves are produced by the cutting thereof of the lines of force or waves of energy radiated from the transmitting-station, as above explained, and I propose to so place the coherer or other resistance device at such a point where occurs a loop of positive potential in the stationary waves of one receiving wire or conductor and a loop of negative potential in the stationary waves of the other receiving wire or conductor, thus securing a maximum effect. Many different arrangements for accomplishing this result may be employed. One arrangement is shown in Fig. 1, wherein reference-sign D′ designates one of the aerial receiving-conductors, and D^2 the other. B^2 designates the resistance device employed. Any form of resistance device may be used. I have shown a form of receiving device of the nature referred to in the application of De Forest and Smythe, Serial No. 28,722, filed September 1, 1900, wherein contact-points B^3 B^4 are employed and arranged in series in a wire or conductor connecting the aerial receiving-conductors D′ D^2, a porous or other body B^5

being interposed in series between the adjacent or proximate ends of contacts B^3 B^4 in order to support or maintain a fluid or other substance in the space between said contacts. A^4 designates the signal device, which may be of any suitable form, such as a telephone-receiver. A^5 is a local battery, and A^6 suitable choke-coils. The choke-coils, the signal instrument A^4, the battery A^5, and the contacts B^3 B^4 are all arranged in series in the local-battery circuit, the contacts B^3 B^4 being also located in series with the aerial receiving-conductors D' D^2.

In order to secure the objects of the invention, the resistance device B^2 should be placed at a point in the circuit connecting the two aerial receiving-conductors D' D^2 at which occurs at one of the contacts B^3 B^4 a maximum of positive potential and at the other a maximum of negative potential. This occurs where the conductors D' D^2 are spaced a half wave length apart and the resistance device is midway therebetween or one-quarter wave length distant from each, and where the conductors D' D^2 are not spaced a half wave length apart, but are in closer relation or farther apart, it is necessary and desirable to provide means whereby a change of phase is produced in the stationary electrostatic waves of one or the other of such conductors in order that the receiving device may occupy the desired position. Such an arrangement is shown in Fig. 1, wherein the receiving-conductors D' D^2 are spaced less than a half wave length apart. In this arrangement I introduce suitable condensers or other capacity d d', one of which operates to produce a change of phase of one-quarter wave length in one of the conductors and the other a change of phase of three-quarters of a wave length in the other conductor. In this event the receiving or resistance device B^2, which is in series with the condensers or other capacity, will occupy the position of maximum efficiency or a distance corresponding to one-quarter wave length from each condenser. I prefer ordinarily to insert in the two conductors a simple capacity over which the waves pass from the receiving-conductors, and which capacity represents or covers a considerable portion of the wave length. Thus the capacity becomes the equivalent of a certain length of a conductor, and just so much of the stationary wave is taken up by the capacity in either or both of the conductors as would be taken up by the equivalent length of conductor. An analogous effect occurs in acoustics in the case of a weighted vibrating string. By weighting the string the natural period of vibration thereof is increased—that is, its original length must be reduced to maintain the same period of oscillation after weighting the same. In other words, the attached weight becomes the equivalent of a certain length of the string or will cover a certain portion of the stationary wave on the string, or, to express the same idea differently, a change of phase takes place in the wave at the point where the weight is attached. This same phenomenon occurs with stationary electric waves, as above explained, when a suitable condenser or other capacity is arranged in the manner above set forth. The weighted portion of the circuit, due to the presence therein of the capacity, will be the equivalent of a certain length of the stationary wave, the amount of its equivalency depending on the size and shape of the capacity inserted in said circuit. By such means I am able to change the wave in one branch of the circuit through one-quarter wave length and that in the other by three-quarters of a wave length. In this manner I am enabled to secure all the advantages of employing a plurality of receiving-conductors, which may be placed any suitable or convenient distance apart and still secure the location of the receiving device at the point of maximum efficiency.

In the arrangement shown in Fig. 4 the conductors A^2 A^3 are preferably one-quarter wave length in length and are spaced apart a distance of one-half wave length. Now by respectively connecting the conductors A^2 A^3 at the lower ends thereof to earth it will be seen that the electrostatic waves generated or produced in the two vertical receiving-conductors will have nodes at the points a b, the lines a' a^2 being graphic representations, respectively, of the positive and negative stationary waves having the point a as their node and reference-signs b' b^2 representing similarly and respectively the negative and positive waves having the point b as their node, and the location of the resistance device B^2 at a point midway between the points a b will bring the terminals of such resistance device at points where occur a loop of positive potential on one side and a loop of negative potential on the other side, and hence at a point where the maximum effect is secured and the greatest possible advantage derived.

If desired, the vertical receiving-conductors may be connected together at their upper ends, as indicated in dotted lines in Figs. 2 and 3. By this means a closed resonant system is produced which is more persistent in its oscillation and which prevents or retards loss of energy from radiation, and if a condenser or other capacity D^3 be introduced in this connection at the top ends of the conductors nodes instead of loops of electrostatic waves will be produced at the upper ends of the receiving-conductors and loops instead of nodes at the lower ends thereof.

The advantage of employing a plurality of aerial receiving-conductors is that they may be placed in the same vertical plane, which by the rotation of said plane about a vertical axis will cause the receiving apparatus to detect and locate the direction whence the signals are coming. This is true whether the two aerial conductors are spaced one-half wave length or more apart or fairly close together; but in the one case the plane of the conductors must coincide with the direction in which the signals are received and in the other case this plane should be perpendicular to the direction of propagation.

In Fig. 3 is shown a closed resonating system wherein the aggregate length of the closed circuit which includes the receiving-conductors D^4 D^5 represents a multiple of one-half wave lengths, said conductors being connected at the top and bottom, the bottom connection being a coil D^6. This coil should be of such dimensions that its natural period of electrical vibration is a multiple of half-periods of the impressed oscillation and should also be so wound as to avoid interferences between its various sections to give maximum efficiency—that is, the windings thereof should be heaped up at points where occur loops of electromagnetic waves, and no single section of the coil should be greater in length than one-half wave length of the wave for which the system is designed. In this arrangement, as indicated in Fig. 3, I employ a secondary coil D^7, wound on similar principles, with its various sections corresponding to and wound around or in juxtaposition with respect to those of the primary, but of a larger number of half wave lengths in length; but the sections thereof should be wound or so disposed relatively to each other that two currents will not traverse the same section in opposite directions at the same time. Now if this secondary coil is of a definite number of half wave lengths in length with the loops of stationary electrostatic waves of opposite signs at its two terminals a receiving instrument placed across these terminals, as at B^2, will be at the point of maximum efficiency. A modification of this arrangement is shown in Fig. 2, wherein a condenser or capacity is shown connected with one of the vertical conductors, as D^4, or with the secondary coil-terminals in order to change the phase in either leg of the circuit or to better define the position of the nodes and loops. In the arrangement shown the primary and secondary coils D^6 D^7 are connected together in series and condensers D^8 D^9 are interposed in series with the receiving device B^2 and the receiving-conductor D^4 and secondary step-up coil D^7. If, however, the primary coil D^6 be earthed, as indicated at E′, instead of being connected in series with coil D^7, and said coil D^7 be connected to a suitable capacity, (indicated at F′,) the number of turns on the two coils may be the same and the device employed merely for transforming the phase of the electrostatic stationary waves through one hundred and eighty degrees. In this event the capacities D^8 D^9 will place the receiving device B^2 at loops instead of nodes of the stationary electrostatic waves, and therefore in the most efficient relation. Where coils are employed, I propose to lead off wires to condensers, earth, or other capacity at the various electrostatic nodes therein occurring. The purpose of this is to filter out and destroy by reflection and interference all waves other than those for which the system is designed and to which it is desired the receiver shall respond, thus rendering the receiving-station responsive only to certain predetermined energy-waves and avoiding responsive action to foreign vibrations. By thus connecting condensers or other capacity or capacities at points where occur nodes of the electrostatic wave, which wave has the period for which the receiving circuit or connections is tuned, it will be seen that waves having other periods and other wave lengths, for which lengths the nodes will not occur at these points of capacity or connections to capacity, will be thus destroyed by mutual interferences, or, as stated above, the proper oscillations will be filtered out.

The art and theory of Hertzian waves in wires teaches that if such a wire be coiled mutual interferences will occur between adjacent sections of the coil, if such sections represent simultaneously portions of the wave differing greatly in phase. For instance, if one of the adjacent windings represents phases of the wave differing more than one hundred and eighty degrees or a half-period the interference may be such as to almost completely prevent the passage of the oscillation through the coil. A sudden change in the coefficient of self-induction in a wire produces a reflection of the electric wave at that point and a static node may result there. Thus if at the foot of an aerial conductor where a static node naturally occurs one end of a coil, but a single layer, is connected and said coil is so dimensioned that the wire thereon is the equivalent of one-half a wave length or the equivalent of twice the length of wire of the upright conductor and the other end of said coil is connected to earth or to a suitable capacity a natural vibrating system is produced with a static node at either end of the coil. Standing waves will result in the coil and the aerial conductor will not attain maximum amplitude, because the system is more resilient to properly-tuned vibrations than if the coil were of a less length. The electromagnetic or current loops will occur at or near either end of this coil, and here at these points should therefore be placed the secondary windings. If it is to be a step-up transformer, the length represented in the secondary coil must of course be greater than that of the primary coil covered by the secondary. Hence the secondary windings must be heaped up. The primary, however, should be in one single layer; but, as above explained, a single heaped-up coil must not represent more than one-half wave length. Therefore near one or both ends of the primary of single winding I place the secondary coils in several sections of not more than one-half wave length each and connected in series, and these may be used in connection with condensers, as shown most clearly in Fig. 2.

As above indicated, where the receiving-conductors are arranged close together and a less distance apart than a half wave length the plane containing said conductors should be at right angles to the direction of propagation of arriving wave-trains, for otherwise the one conductor would "shield" (so to speak) the other, and consequently the best results would not be secured; but by placing said receiving-conductors in a plane at right angles to the plane of propagation of arriving energy-waves similar stationary waves are generated in said conductors, which may be transformed as desired by the introduction of suitably-adjusted capacities—such, for instance, as condensers—as above explained, so that the receiver may be placed at the point where the maximum efficiency results, thus also affording a means for determining the direction of the arriving energy-waves, for any variation or deviation of the plane of the receiving-conductors in the arrangement shown from a position at right angles to the plane of propagation of the radiated waves would be noted by a loss of efficiency in the receiving apparatus.

It is obvious that many variations and changes in the details and arrangements would occur to persons skilled in the art and still fall within the spirit and scope of my invention. I do not desire, therefore, to be limited or restricted to the construction and arrangement above set forth; but,

Having now explained the object and nature of my invention and various constructions and arrangements embodying the principles thereof and having explained the purpose, function, and mode of operation, what I claim as new and useful and of my own invention, and desire to secure by Letters Patent, is—

1. In an apparatus of the class described, a receiving apparatus comprising aerial receiving-conductors, receiving devices and means for changing the phases of the energy-waves produced in one or the other of said conductors, whereby said receiving devices may be so located that a maximum of positive potential and a maximum of negative potential occur simultaneously at the respective terminals of said receiving devices, as and for the purpose set forth.

2. In an apparatus of the class described, receiving-conductors, a receiving instrument arranged in the circuit of one or both of said conductors, and a capacity also arranged in said circuit and operating to change the phase of energy-waves of one or the other or both of said conductors, whereby a maximum of positive potential and a maximum of negative potential occur simultaneously at the terminals of said receiving instrument, as and for the purpose set forth.

3. In an apparatus of the class described, receiving-conductors, terminals in series with each other and said conductors, a local-battery circuit, said terminals also being included in said local-battery circuit, a receiving instrument arranged in said local-battery circuit, and a capacity arranged in the circuit of said terminals, as and for the purpose set forth.

4. In an apparatus of the class described, a plurality of receiving-conductors, a capacity arranged in series with each of said conductors, and a receiving apparatus arranged in series with said capacities, as and for the purpose set forth.

5. In an apparatus of the class described, a plurality of receiving-conductors, a receiving device arranged in the circuit of said receiving-conductors, and a capacity placed in series with one or the other or both of said receiving-conductors at a point where occurs a node of the electric waves therein produced, as and for the purpose set forth.

In witness whereof I have hereunto set my hand, this 28th day of February, 1901, in the presence of the subscribing witnesses.

LEE DE FOREST.

Witnesses:

CHAS. H. SEEM,

S. E. DARBY.