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ELECTRICAL SPACE COMMUNICATION.

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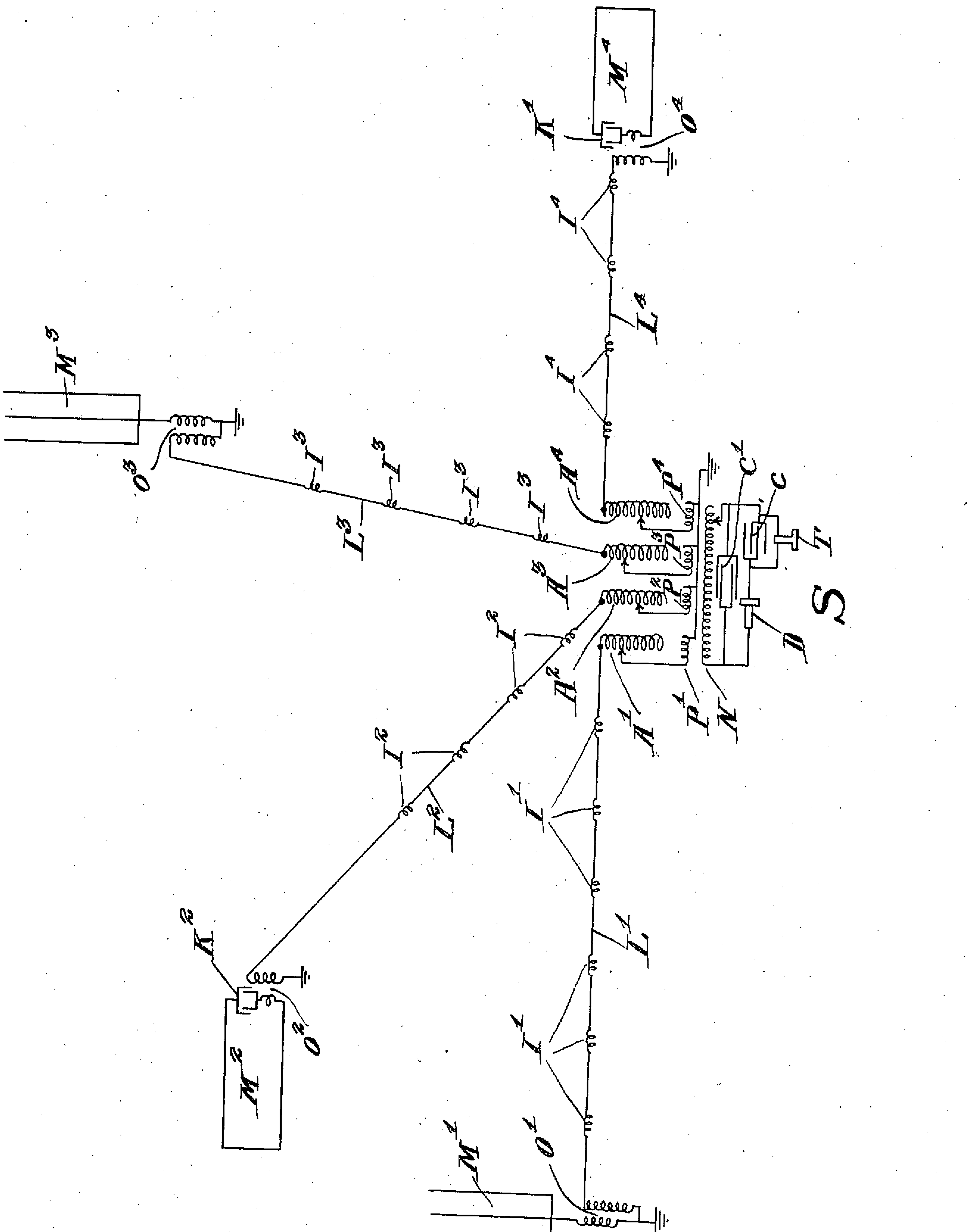
956,165. Patented Apr. 26, 1910.



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ELECTRICAL SPACE COMMUNICATION.

956,165. Specification of Letters Patent. Patented Apr. 26, 1910.
Application filed September 3, 1907. Serial No. 391,081.

To all whom it may concern:

Be it known that I, GREENLEAF WHITTIER PICKARD, a citizen of the United States of America, and a resident of the town of Amesbury, State of Massachusetts, have invented certain new and useful Improvements in Electrical Space Communication, the principles of which are set forth in the following specification and accompanying drawing, which disclose the form of the invention which I now consider to be the best of the various forms in which those principles may be embodied.

This invention relates to means for conveying intelligence transmitted by electromagnetic waves.

One object of the invention, among others, is to concentrate at the receiving device as much as possible of the energy which is employed in transmitting the intelligence.

The invention involves geographical separation of the wave conductors from the station where the local apparatus may be installed, and the provision of conducting lines suitably constructed and coöperating as hereinafter described, to permit the conveyance to or from the local apparatus of the oscillating electrical energy transmitted through space in the form of electromagnetic waves.

Space telegraphy is now practicable over moderate distances, of the order of a few hundred miles. But for longer distances, of the order of thousands of miles, the problem has heretofore been unsolved, as to how to collect or distribute an effectively large proportion of the transmitted energy for use at a given receiving station or plurality of such stations. It is now possible to operate over such distances, only by employing uneconomically large amounts of transmitting power and great extent of transmitting conductors; this being true even when the most sensitive form of local receiving devices are employed, and even when the largest practicable extent of receiving-station conductors is employed. Other things being equal, the energy collected at a receiving station has depended upon the necessarily limited extent of the receiving conductors thereat, and the consequent limited degree of interposition of such receiving station conductors in the path of the circumferentially widening waves. Owing to various mechanical and electrical considerations, the limits to the extent of receiving conductors at a receiving station are quite sharply defined. Even when the conductors are multiplied at the station, there is little gain. The losses are very great indeed in transmitting thousands of miles to a given receiving station, which is only one minute point on the circumference of the great circle of which the transmitting station is the center.

A means for concentrating at the local receiving devices a much greater amount of the energy transmitted from a far-distant source, and for other purposes, is diagrammatically shown in the drawing, wherein

S is the local station, shown for purposes of illustration as a receiving station, containing the suitable receiving devices indicated, T being a suitable indicating device, (such as a telephone receiver) D a suitable oscillation detector, (such as the thermo-junction or rectifying device of my United States Patent No. 836,531 of Nov. 20, 1906) C a suitable telephone-shunt condenser, and C^1 a suitable tuning condenser, all of which may be replaced by any suitable devices and circuits to constitute an operative combination of receiving devices; or by suitable local transmitting apparatus in any of the various known forms. There may or may not be a wave-conductor at the station S, but there are several such conductors (as many or few, even only one, as desirable or convenient) geographically separated, as at M^1, M^2, M^3, M^4, etc., which may be thousands of yards or more remote from local station S, and connected thereto by lines L^1, L^2, L^3, L^4, etc., suitably constructed as hereinafter described. By suitable means, hereinafter described, the effects of all these conductor-stations may be added together to operate the local circuit at station S. The practical or economical permissible length of the specially-constructed lines L may depend upon the power and distance of the transmitting station. Since the invention is useful in intercontinental or transcontinental communication, such for example as trans-atlantically, the conductor stations M^1, etc., may conveniently, when practicable as to amount of transmitted energy and energy losses in line transmission, be the existing series of Atlantic coast stations on the United States seaboard (or others more or less remote from each other), the lines L^1, etc., being led from local station S (which might conveniently be at the city of Washington), to each remote conductor-station M. The lines L may be any suitably constructed existing telegraph or telephone lines, or such lines of stranded copper conductors provided with loading inductances I, like the long-distance telephone devices well known in the art as "load coils", and inserted at more or less frequent intervals in general pursuance of existing practice on long-distance telephone lines, but distributed or arranged in the lines in accordance with this invention, with regard to the shorter wave-lengths in this art, of the transmitted impulses. In order to secure beneficial effects, the coils I, which are preferably in the form of air core inductances, may be inserted at least at intervals of $\frac{1}{\pi}$ wave length. The amount of inductance inserted per unit of length may be such as to increase the line inductance to at least four times its value without the coils. If high insulation and low dielectric dissipation can be secured on the line conductors, a higher ratio of loaded to unloaded inductance may be advantageously employed. By suitably loading these lines, the loss in transmission over them is very slight, even in the case of the high frequency currents which may be employed with the invention, and even when the lines L are a number of miles long. The loading to reduce transmission losses is extremely important for long lines. The lines L are shown grounded in the usual manner, but may if desired be completely metallic, and in that case loaded on each side in the manner of this invention.

The station-conductors M may be of any desired type, but for receiving intelligence along the Atlantic coast from any point in Europe or from transatlantic shipping, for example, they are of my magnetic loop type (as at M^2 and M^4, and described by me in the *Electrical Review*, New York, June 22, 1907 and in my U. S. Patent No. 876,996), each magnetic loop consisting of a vertical closed circuit inclosing a large area and having the vertical plane extending in the direction of transmission (east and west in this case), and, when receiving, producing oscillating currents magneto-electrically, without any operative direct or indirect earth connection or any equivalent thereof. As thus arranged, they can receive messages from the west as well as the east. The utility of the loaded lines herein, when the lines are long, is evident from the fact that the wave conductors M of any type cannot extend continuously from distant conductor-stations to the local station, on account of the limitations of such station-conductors to definite proportions of the length of the space-transmitted waves, as well as on account of the phase-difference which would result at a local station caused by the operation of conductor stations separated by various and substantial distances from the local station. For example, in the case of the magnetic loop, this particular type of wave-conductor ought not to have an electrical length in excess of a quarter of the length of the transmitted waves, because otherwise the reversals of direction of the magnetic lines and the consequent algebraic addition of positive and negative electromotive forces would reduce the effective energy; and the energy in such a wave-conductor would be further reduced by the presence of a material amount of loading inductance.

While in certain cases the loading of the conductors may be dispensed with, yet it is in all cases advantageous, as the energy loss in the resistance of the wire is considerable in a non-loaded line conveying high frequency oscillations. A loaded line acts as a high impedance line conveying energy at a high potential and with small current, so that the C^2 R losses are greatly reduced.

Each of the conductor-stations M may be tuned to the far-distant transmitting station, as hereinafter described. Also the condenser C^1 or inductance N at the local station S may be adjusted to syntonize the local circuit at station S with the station-conductors M. The magnetic loop is particularly valuable in this combination, not only on account of its inherent efficiency, but because all the conductor-stations may usefully coöperate with respect to a single far-distant transmitting station, so that the loops, fixed in one direction, will always be ready for the desired operation. Such receiving loops are even more particularly useful in this invention when used with a similar magnetic transmitting loop at the far-distant transmitting station. The loaded lines L may be inductively connected to the respective conductors M, by oscillation transformers O^1, O^2, etc., having a few turns in the primary and a larger number in the secondary. The lines L may be connected to the local circuit devices at station S by oscillation-transformer primaries P^1, P^2, etc., of say thirty or forty turns each, coöperating with the common secondary N of say, forty or more turns in the local circuit at station S. The exact ratio of transformation employed will of course be determined by the impedance of the lines when loaded. In general, the higher the loading or the impedance, the greater the ratio of transformation will be. Of course, the invention may be more efficiently employed by not increasing the lengths of lines L to such extent as to cause the sum of the C^2 R losses in all the lines to approximate the difference between the energy received by a single conductor-station M, and that received by the plurality of separated conductor stations. By using the special lines described above, however, the lengths of lines L may be made of comparatively great length.

As is indicated in the drawings at M^2 and M^4, the loop conductor need not be high, and it may be supported by poles lower than those for lines L or else by poles of the same height. At M^2 and M^4 is shown the simplest form of the magnetic loop, in which are employed the magnetic components of the waves. The tuning to the wave-frequency is by means of the variable condensers K^2 and K^4. I have found that the magnetic loop operates best, producing louder results in telephone T, when it is connected (with or without the line conductor) to the local detector circuit by the step-up oscillation transformer P^1, N, the primary P^1 having two or three turns, and the secondary N of forty or more turns, the circuit of the secondary permitting very close tuning by varying either N or C^1; and this stepping up of potential is advantageous with the loaded line, as that is of high impedance, working with high potential and small current flow. As a general rule the loop-circuit should have as low inductance as possible, and be limited to the inductance of its conductor; but the advantages of the transformer P^2, N more than compensate for the added inductance which the primary P^2 constitutes, even when said primary is included directly in the circuit of loop M^2, or when, as here, the primary of transformer O^2 is included in the loop-circuit. The oscillation transformer O^2, connecting M^2 with L^2, should preferably have a ratio of at least five to one, in order that the energy be delivered to the line at as high a potential as possible. At M^2 the length of the loop is horizontal, so that it need not be high, as stated above. The magnetic loop, however, may be used with its length vertically disposed, in order to enable the conductor to be advantageously used to receive the electrostatic as well as the magnetic components of the waves, as by an earth connection from the primary of the oscillation transformer and other suitable apparatus.

When all the conductor-stations M are substantially equally distant (effectively) from the far-distant transmitting station, or from the distant ship equipped with transmitting apparatus, such that the wave-fronts strike all the station-conductors at substantially the same time, (which is a simple matter to arrange for, particularly in very long distance transmission, where the wave front is nearly a straight line), the resulting oscillations will start along the lines L at the same instant, and will arrive at the local station S at times depending upon the length of the line and the velocity of the oscillations. If the various sets of oscillations do not reach the local station S at substantially the same time, or at least in the same phase, the maximum effect on the receiving devices will not be produced. By suitably adjusting the velocity of the oscillations, the time of travel from all conductor-stations M along all the lines L to the local station S may be made uniform, or in such ratio to each other that they will arrive in phase, irrespective of the lengths of the respective lines L. This adjustment of conditions governing velocity may be effected by adjusting the lines L in accordance with this invention, the velocity with which an oscillation travels along a conductor being represented by the equation,

$$V=\frac{1}{\sqrt{LC}}$$

where L is the inductance per unit length of the circuit, and C the capacity of the conductor per unit length. For the lines L, the element C would be a fixed quantity, and the velocity V can be adjusted by the variation of L, which can be made of any desired value by varying the inductance of load coils I. That is, in designing the lines L, in accordance with this invention, they are provided with such coils I as will not only reduce C^2 R losses in transmission, but as will serve to permit a definite velocity of oscillations as desired for a given length of line. The velocity for each line may also be controlled by the operator at local station S, by adjusting the variable inductances A^1, A^2, A^3, A^4, etc., to vary the total inductance of each line. The lines L will be similarly adjusted in cases where one or more of them lead from a conductor-station M which is struck by the waves materially earlier or later than other conductor-stations geographically separated from station S. In cases where it may be practicable to locate each of the stations M the same distance away from local station S, it will be unnecessary to employ the load coils for controlling the oscillation-velocity, provided the line-conductors having the same length, have also the same inductance. And in cases where there is ample energy or slight transmission loss, the load coils may not be required to reduce such losses.

In accordance with the above, the invention includes between the local station and the various conductor-stations, a corresponding number of transmission lines so adjusted as to bring all the oscillating currents in phase, to the local receiving station, and adapted as loaded lines, if desired, for minimum transmission losses. By means of properly loading the lines it is practicable to provide conductor-stations of such substantial distances from the local station as to collect a comparatively large proportion of the transmitted energy. The chief feature however is the means for collecting at a local station, and all in phase, the various amounts of energy received at distant conductor stations, to be added together in the local receiving circuit.

The invention is also useful, when local transmitting apparatus of any of the well-known types, and not necessarily provided with any wave-emitting conductor, is included at the local station represented by S, to transmit a message by waves from a distant wave-emitting conductor M, or to simultaneously transmit messages by waves from a plurality of conductor stations M^1, M^2, etc., acting as wave-sources; the energy being supplied over the lines L from the central source at S. Various other uses of the invention will be suggested by extended use, and the invention is hereby claimed for all its possible uses.

I claim:

1. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by various and substantial distances, and so located with respect to a distant transmitting station or stations as to operate effectively simultaneously with the wave-fronts; line conductors of correspondingly various lengths connecting the local station with the variously-distant conductor-stations; oscillation-transformers connecting the ends of the line conductors with the apparatus at the local and conductor-stations; and load coils in the line-conductors to reduce transmission losses and transmit all the oscillating currents in phase.

2. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by various and substantial distances, oscillation-transformers at the local station and at the respective conductor-stations; transmission lines of corresponding lengths connecting the transformers; and load coils in the transmission-lines.

3. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by various and substantial distances, line conductors of correspondingly various lengths connecting the local station with the variously-distant conductor-stations, and load coils included in the line conductors to cause the oscillations to arrive in phase at the local station.

4. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by substantial distances greater than one-half of the wave-length and so located with respect to a distant transmitting station as to be operative substantially simultaneously with respect to the wave-fronts, and line conductors of lengths corresponding to the distances between the local station and the various conductor-stations, and connecting the various conductor-stations with the local station.

5. Means for conveying intelligence communicated by electromagnetic waves from a far-distant transmitting station, which comprises a local receiving station, a plurality of vertical magnetic-loop receiving-conductor stations separated from the local station by substantial distances greater than one-half of the wave-length, the vertical plane of each of the loops substantially coinciding with the radii of transmission from the far-distant transmitting station; and line conductors of lengths corresponding to the distances between the local receiving station and the various magnetic-loop conductor-stations and connecting the distant magnetic-loop conductor-stations with the local receiving station.

6. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by substantial distances, line conductors connecting the distant conductor-stations with the local station, and means for controlling the velocity of oscillation transmission along the line conductors.

7. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by substantial distances, line conductors connecting the distant conductor-stations with the local station, and inductance coils included in said connecting line-conductors to reduce the transmission losses.

8. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by substantial distances, line conductors leading from the conductor stations to the local station, and oscillation transformers connecting the ends of said connecting line-conductors to the apparatus at the respective conductor-stations and the local station.

9. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor stations separated from the local station by various and substantial distances, line conductors of correspondingly various lengths connecting the distant conductor stations with the local station, said connecting line conductors being constructed to cause the time of oscillation transmission in each of them, irrespective of their lengths to be

such as to bring the oscillations in all of them in phase to the local station.

10. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by substantial distances greater than one-half of the wave-length, and line conductors connecting the distant conductor-stations with the local station.

11. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a conductor station separated a substantial distance therefrom, and a loaded transmission line connected and adjusted to transmit oscillations between the two stations with minimum transmission losses.

12. Means for receiving intelligence communicated by electromagnetic waves, which comprises a local receiving station, a receiving-conductor station located a substantial distance therefrom, and a loaded transmission line connected and adjusted to transmit oscillations from the conductor station to the local station with minimum transmission losses.

13. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by substantial distances, line conductors extending from the respective conductor-stations to the local station, and a transformer at the local station having a plurality of elements connected to the respective line conductors and a common element connected with the local station apparatus.

14. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local receiving station, a plurality of conductor stations separated from the local station by substantial distances, and loaded transmission lines connected and adjusted to conduct all the currents from the conductor stations to the local station in phase.

15. Means for receiving intelligence communicated by electromagnetic waves, which comprises a local receiving station, a plurality of magnetic loop conductors separated from the local station by substantial distances, line conductors connecting said loop conductors with the local station, and an oscillation transformer at the local station having a plurality of primaries each in circuit with one of the line conductors, said transformer having a common secondary coöperating with said primaries and with the receiving devices at the local station.

16. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by substantial distances, line-conductors connecting the conductor-stations with the local station, and means at said local station for controlling the velocity of oscillation transmission along the line conductors.

17. Means for conveying intelligence communicated by electromagnetic waves, which comprises a plurality of conductor-stations separated from the local station by various and substantial distances, line conductors of correspondingly various lengths connecting the distant conductor-stations with the local station, and means for producing such time of oscillation transmission along each of said connecting line-conductors as to bring the oscillations in all of them in phase to the local station.

18. Means for conveying intelligence communicated by electromagnetic waves, which comprises a local station, a plurality of conductor-stations separated from the local station by substantial distances, and loaded line conductors connecting the conductor-stations with the local station.

19. Means for receiving intelligence communicated by electromagnetic waves, which comprises a local receiving station, a plurality of conductor-stations separated from said local station by substantial distances greater than one-half of the wave-length, and means for collecting in phase at the local station to operate the same cumulatively, the various amounts of energy received from the transmitted waves by the various conductor-stations.

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Witnesses:

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