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ELECTRIC WAVE TRANSMISSION.

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**1,314,311.**

Patented Aug. 26, 1919.

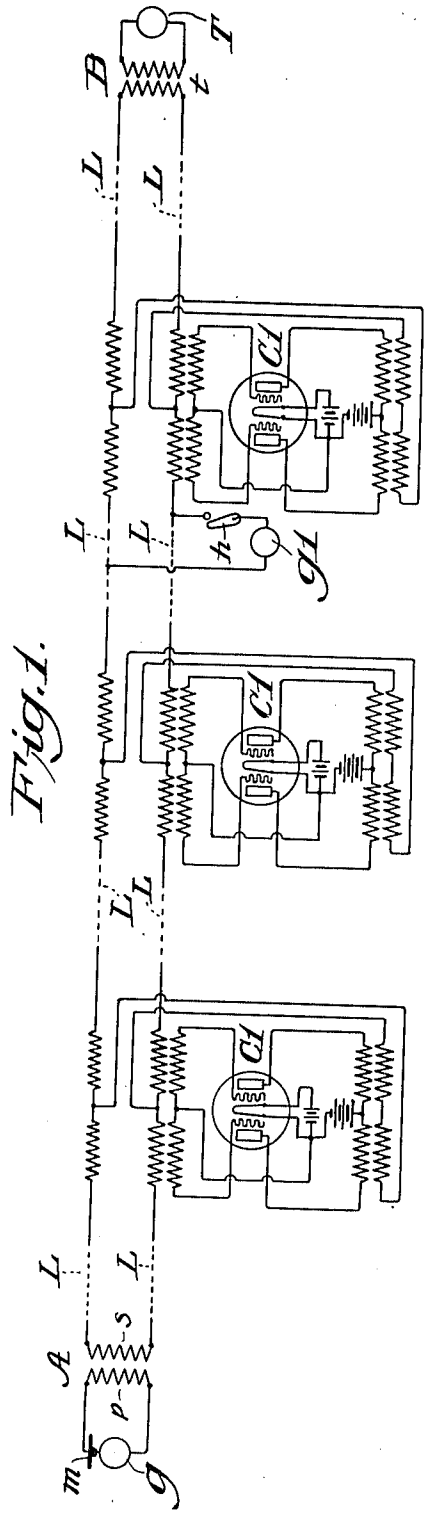



Fig. 1.

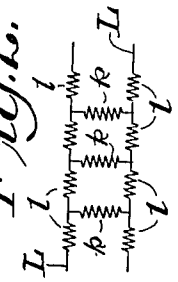



Fig. 2.

INVENTOR

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## ELECTRIC-WAVE TRANSMISSION.

1,314,311. Specification of Letters Patent. Patented Aug. 26, 1919.

Application filed February 1, 1918. Serial No. 214,794.

*To all whom it may concern:*

Be it known that I, CORNELIUS D. EHRET, a citizen of the United States, residing in the city and county of Philadelphia, State of Pennsylvania, have invented a new and useful Electric-Wave Transmission, of which the following is a specification.

My invention relates to the transmission of fluctuating or alternating current over a circuit which is long as compared with the wave length of the fluctuating or alternating current, for the purpose of transmission of signals or intelligence, and more specifically for the transmission of speech or sound waves.

So far as I am aware the best commercial long distance telephony has involved circuit conductors of relatively low resistance with loading coils serially connected therein at intervals to increase the effective inductance of the circuit, reduction of resistance and increase of inductance coöperating to maintain distortion and attenuation at suitably low magnitudes, the current being ordinary telephonic current, as distinguished from carrier waves. In some cases, in addition there have been employed amplifiers intermediate the transmitting and receiving stations to add energy to the attenuated waves. So far as I am aware, in such long distance telephone systems the resistance of the line wire has been as low as approximately 2.5 ohms per mile and has never been greater than that of a number 10 or 12 Brown and Sharpe gage copper wire, approximately 5.5 or 8.5 ohms per mile, because of the necessity for keeping the ratio of resistance to inductance small enough to keep the distortion and attenuation within suitably small and practical limits.

By my invention, however, in long distance transmission, that is, between stations from about one hundred to thousands of miles apart, the resistance of the line wire, solid or stranded, whether strung upon poles or disposed in an aerial, subterranean or submarine cable, is increased several hundred per cent., as to at least 25 ohms and 50 ohms per mile respectively for pole line and cable use. These resistances are approximately provided by copper wires of numbers 17 and 20 Brown and Sharpe gage, of approximately 45 and 32 mils diameter, though my invention comprehends much smaller wire and higher resistance. Conductors of these high resistances are of materially decreased diameter and weight and exhibit less capacity.

For such high resistance line wire a material of high conductivity, as copper, is preferred, because for a given high resistance per unit length of line the wire will be of smaller diameter and will have smaller capacity per unit length, and for both reasons is particularly suitable in case the line wire is disposed in a cable.

The line wire may, however, have the aforementioned high resistance when of other materials, as, for example, iron or steel, or aluminum. With the same resistance per unit length, iron, steel or aluminum wire will of course be larger in diameter than a wire of copper, and will have greater capacity per unit length.

Upon such a high resistance circuit I impress a carrier wave modulated or controlled in accordance with the signal or message and employ amplifiers of any suitable type at one or more points between the transmitting and receiving stations, as few amplifiers as practicable being employed, and to this end they are preferably spaced a plurality of wave lengths from the transmitter and a plurality of wave lengths from each other.

The energy transmitted is in the form of a carrier wave or fluctuating or alternating current of high frequency, the frequency ranging from an inaudible frequency, for example, 20,000 or 30,000 cycles per second, upwardly to 200,000 cycles per second, or higher.

By the employment of such high frequency energy the high resistance of the line wire is not of prohibitive effect as to distortion, for with the higher frequencies the transmission is practically distortionless, and the attenuation, though great, is not as great as apparently would be caused by the high resistance of the guiding wire and the energy is amplified and at the receiving instrument is of sufficient magnitude for practical purposes, and may be as high as one hundredth of the transmitted energy or any other suitable greater or lesser magnitude.

My invention resides in the system and method of electric carrier wave transmission of the character hereinafter described and claimed.

For an illustration of some of the many

various forms of my invention, reference may be had to the accompanying drawing, in which:

Figure 1 is a diagrammatic view of a system of electric wave transmission embodying my invention.

Fig. 2 is a fragmentary diagrammatic view illustrating the employment of loading coils and leaks.

Referring to Fig. 1, A is a transmitting station and B a receiving station, distant from each other from about 100 miles to several thousands of miles.

At the transmitting station there is shown a telephone transmitting device, as a microphone $m$, connected in circuit with a suitable source $g$ of carrier wave energy and the primary $p$ of a transformer whose secondary is $s$. The terminals of the secondary $s$ are connected to the line wires L extending between the transmitting and receiving stations, and constituting, since return and outgoing wires are employed, what is termed a metallic circuit, though it will be understood that one line wire only may be employed, with a return through the earth, though the metallic circuit is preferred. At the receiving station the line wires connect to the terminals of the primary of a transformer $t$ in the circuit of whose secondary is connected the translating instrument, as a telephone receiver T.

The line wires L are preferably of copper, though any other suitable material may be employed, or a composite conductor of a plurality of different materials may be employed. The conductors L may be strung upon poles or other suitable supports, or may be disposed in an aerial, subterranean or submarine cable, though for a part of the distance between the transmitting and receiving station they may be disposed upon poles and for another part in a cable.

Of chief importance, however, is the resistance of the conductor L, which is made far higher than the resistance of the line conductor of any long distance wave transmission system in practical or commercial use of which I am aware. The resistance of the line wire of each side of the metallic circuit is not less than 25 ohms per mile for a pole line and not less than 50 ohms per mile for a cable; and these resistances may be several times greater. For these resistances the line wires, when of copper, are not larger than Nos. 17 and 20 Brown and Sharpe gage. Accordingly the resistances contemplated by my invention are materially greater than the resistance of the line wire heretofore employed in practice in telephone systems of upward of 100 miles between transmitting and receiving stations.

By preference the current component of the energy impressed upon the circuit at the transmitting station is made small, and therefore the potential or voltage component is made high, so that the circuit as a whole may be considered a high potential circuit. To the end of so making the current component small, any suitable terminal transmitting apparatus may be employed, as for example, a transformer $p$, $s$ with suitably high ratio of transformation. Such increase in the voltage component of the transmitted energy should not, however, be carried to such extent as to endanger rupture of the insulation of the line, particularly when disposed in a cable.

At a plurality of points on the line between transmitting and receiving stations are employed amplifying or boosting apparatus of any suitable character or type. In the example illustrated, three amplifying apparatus are shown. Each amplifier $C^1$ is of the audion or thermionic type which need not be described with particularity, because of well known structure and mode of connection.

The decrease in diameter of the line wire attendant upon the use of a line wire of higher resistance, decreases the distributed capacity and increases the inductance, both of which are desirable for wave transmission. However, the attenuation is great and is compensated for by amplification. The number of amplifiers in the line is made as small as possible, and the distance of the first amplifier from the transmitter and the distance between amplifiers is accordingly made as great as consistent with good transmission.

There is impressed upon the line fluctuating or alternating current of high frequency, that is, a frequency higher than the highest essential frequencies in speech, and preferably of a frequency above audibility ranging from about 20,000 upwardly to 200,000 cycles or more per second. For this purpose, there is used at the transmitting station A any suitable source $g$ of such high frequency current, either as a sustained oscillation circuit, as that of an arc or oscillating audion, or a high frequency dynamo-electric generator. There is then impressed upon the line through the transformer $p$, $s$ high frequency current whose amplitude is modulated in accordance with speech by suitable transmitting instrument, as the microphone $m$. And at the receiving station B the translating instrument or telephone receiver T of any type for high frequency current is inductively connected to the line circuit by the transformer $t$; or the translating instrument T may be connected directly in the line circuit.

Where high frequency current is so impressed upon the line, the distortion even with a line wire of the high resistance described is not too great for practical trans-

mission; in fact, the distortion is inconsequential. Where such high frequency currents are used, and particularly with the higher range of frequencies, the line wire, particularly when in a cable, may be smaller than No. 20 Brown and Sharpe gage, particularly when of copper, and may be much finer or smaller in diameter, as for example, about No. 30 Brown and Sharpe gage in long distance lines 100 miles or even thousands of miles in length.

The amplifiers for such high frequency or carrier wave system may be spaced 50 to more than 100 miles apart and the first amplifier even a greater distance from the transmitting end of the line.

Though the wave length of the high frequency current is shorter than the current waves of telephonic frequencies, the attenuation is not fatal to good transmission with amplification at intervals above mentioned. The distance between the transmitter and the first amplifier as well as the distance between amplifiers is preferably at least a plurality of wave lengths, and in the case of telephony is preferably at least a plurality of wave lengths corresponding to the highest frequency of the sound waves to be conserved. And, as above stated, the wave length of the carrier wave being shorter than the current waves of the conserved sound wave or telephonic frequencies, the spacing respecting amplifiers is at least a plurality of wave lengths of the carrier wave.

In the case of a wire guiding high frequency currents the apparent resistance of the wire is higher than that offered to low frequency or direct current. It will therefore be understood that the resistance of the line wire referred to is that offered to low frequency or direct current; though where the frequency of the current is high and the wire is fine or of small diameter, the aforementioned apparent resistance and the resistance to low frequency or direct current do not differ as widely as in the case of conductors of larger diameter.

In carrier wave or high frequency current transmission the line wire may be considered more as a guide than as a true conductor, inasmuch as energy transmission occurs to large extent in the medium surrounding the wire, and this, I believe, accounts at least in part for the possibility of procuring really long distance transmission with amplification at reasonably long intervals of high frequency currents guided by a wire of a diameter and resistance of new order of magnitude as compared with the hereinbefore described common practice in long distance telephony.

While my preferred arrangement does not involve the loading of the line L, by increasing its inductance, that is, while my line L is preferably a non-loaded line though it may comprise iron or other magnetizable material, the line may be loaded, as for example, by introducing, as at a plurality of points within a wave length, inductance sources or loading coils 1, as indicated in Fig. 2. These coils 1 may consist of single layer air core helices.

Leakage, if desirable, may be applied, as by leaks $k$, Fig. 2, bridged across the line. These leaks may be either inductive or non-inductive, of suitably high resistance or impedance. If the leakage is made substantial or considerable, the amplifiers will necessarily be spaced shorter distances from each other.

Either the loading inductances alone, or leaks alone, or both, may be employed. It is to be understood, however, that neither leaks nor inductances are essential.

Though in the drawing the amplifiers are shown at a distance from the terminal stations, it will be understood that an amplifier may also be used directly at the transmitting and another directly at the receiving station, or at both. And when an amplifier is used at the receiving terminal, the line delivers weak energy to the amplifier and the amplifier delivers increased energy to the translating instrument or telephone receiver, all as well understood in the art.

In a high frequency system of the character referred to a source of high frequency current may be located at some suitable point, preferably about midway, between the transmitting and receiving stations. Such a source of high frequency current is indicated at $g^1$, which upon closure of the switch $h$, will impress high frequency current upon the line. In this case the generator $g$ at the station A may be omitted and a battery may take its place and a similar transmitting apparatus supplied at station B, and a translating instrument or telephone receiver at each station.

Or at each terminal station there may be supplied high frequency transmitting apparatus of a known type wherein energy is transmitted upon the line only when the microphone $m$ is actuated or affected by speech or sound waves. In such case, of course, there would be at each station a suitable translating or receiving instrument.

What I claim is:

1. The method of transmitting signals over a line upward of 100 miles in length, which consists in impressing signal energy in the form of high frequency current upon a line conductor having a resistance of more than 25 ohms per mile, and amplifying the energy at a point distant a plurality of wave lengths from the transmitting station.

2. The method of transmitting signals over a line upward of 100 miles in length, which consists in impressing signal energy

in the form of high frequency current upon a non-loaded line conductor having a resistance of more than 25 ohms per mile, and amplifying the energy at a plurality of points along the line distant a plurality of wave lengths from each other.

3. The method of transmitting speech over a line upward of 100 miles in length, which consists in impressing alternating or fluctuating current of a frequency above audibility modulated in accordance with speech upon a line conductor having a resistance greater than 25 ohms per mile, and amplifying the energy at a point distant a plurality of wave lengths from the transmitting station.

4. The method of transmitting speech over a line upward of 100 miles in length, which consists in impressing alternating or fluctating current of a frequency above audibility modulated in accordance with speech upon a line conductor having a resistance greater than 25 ohms per mile, and amplifying the energy at a plurality of points along the line a plurality of wave lengths from each other.

5. An electrical signaling system upward of 100 miles in length comprising a line wire extending between stations and having a total resistance greater than 25 ohms per mile and comprising at least in part a cable in which the line wire has resistance higher than 50 ohms per mile, means for impressing thereon high frequency carrier waves, and means for amplifying the energy at a point distant a plurality of wave lengths from the terminal station.

6. An electrical signaling system upward of 100 miles in length comprising a line wire extending between stations and having a total resistance greater than 25 ohms per mile and comprising at least in part a cable in which the line wire has resistance higher than 50 ohms per mile, means for impressing thereon high frequency carrier waves, and a plurality of amplifiers at points along the line distant a plurality of wave lengths from each other.

7. An electrical signaling system upward of 100 miles in length comprising a non-loaded line wire having a resistance greater than 25 ohms per mile, means for impressing high frequency current thereon, means at transmitting and receiving stations controlling and translating said current, and a plurality of amplifiers at points along the line distant a plurality of wave lengths from each other.

8. An electrical signaling system upward of 100 miles in length comprising a non-loaded line wire extending between stations and having a total resistance greater than 25 ohms per mile and comprising at least in part a cable in which the line wire has resistance higher than 50 ohms per mile, means for impressing high frequency current upon the line, and a plurality of amplifiers at points along the line distant a plurality of wave lengths from each other.

9. A long distance system for electrically transmitting inteligence comprising a line upward of 100 miles in length comprising a line wire extending between stations and having a resistance greater than 25 ohms per mile, means for impressing upon the line high frequency current controlled in accordance with the intelligence to be transmitted, a receiver for translating the received energy, the resistance of the line wire and the frequency of the current being such that the distortion lies within practical limits, and means for amplifying the energy in transit at points a plurality of wave lengths apart.

10. A long distance telephone system upward of 100 miles in length comprising a line wire having a resistance greater than 25 ohms per mile, means for impressing upon the line wire current of inaudible high frequency modulated in accordance with sound waves, a receiver for translating the received energy, and means for amplifying the energy in transit at points a plurality of wave lengths apart.

11. A long distance telephone system upward of 100 miles in length comprising a line wire disposed in a cable and having a resistance higher than 50 ohms per mile, means for impressing upon the line wire current of inaudible high frequency modulated in accordance with sound waves, a receiver for translating the received energy, and means for amplifying the energy in transit at points a plurality of wave lengths apart.

12. A long distance telephone system upward of 100 miles in length comprising a line wire having a resistance greater than 25 ohms per mile, means for impressing upon the line wire current of inaudible high frequency modulated in accordance with sound waves, a receiver for translating the received energy, and means for amplifying the energy in transit at points not less than 50 miles apart.

13. A long distance telephone system upward of 100 miles in length comprising a line wire, means for impressing upon said line wire current of inaudible high frequency modulated in accordance with sound waves, a receiver for translating the received energy, and means for amplying the energy in transit at points upward of 50 miles apart, the frequency of said current and the resistance of said line wire being such that the distortion of the amplified energy arriving at said receiver is sufficiently small to render the translated energy intelligible.

14. A long distance telephone system up-

ward of 100 miles in length comprising a line wire having a resistance greater than 25 ohms per mile, means for impressing upon the line wire current of inaudible frequency modulated in accordance with sound waves, a receiver for translating the received energy, and thermionic means for amplifying the energy in transit disposed at points upward of 50 miles apart.

15. A long distance telephone system upward of 100 miles in length comprising a non-loaded line wire having a resistance greater than 25 ohms per mile, means for impressing upon said line wire high frequency carrier current modulated in accordance with sound waves, a receiver for translating the received energy, and thermionic means for amplifying the energy in transit disposed at points upward of 50 miles apart.

16. A long distance system for electrically transmitting intelligence comprising a line upward of 100 miles in length comprising a line wire of non-magnetic material extending between stations and having a resistance greater than 25 ohms per mile, means for impressing upon the line current of inaudible high frequency modulated in accordance with the intelligence to be transmitted, a receiver for translating the received energy, and means for amplifying the energy in transit at intervals of more than 50 miles.

17. A long distance telephone system upward of 100 miles in length consisting of a non-loaded line comprising a line conductor extending between stations and having a total resistance greater than 25 ohms per mile and comprising at least in part a cable in which the conductor resistance is higher than 50 ohms per mile, means for producing on said line carrier wave current modulated in accordance with sound waves, a receiver for translating the received energy, and means for amplifying the energy at points a plurality of wave lengths apart.

18. A long distance telephone system upward of 100 miles in length comprising a non-loaded line conductor having a resistance greater than 25 ohms per mile, means for producing upon the line wire carrier wave current modulated in accordance with sound waves, a receiver for translating the received energy, and means for amplifying the energy at points a plurality of wave lengths apart.

19. A long distance system for electrically transmitting intelligence comprising a line upward of 100 miles in length comprising a non-loaded line wire of non-magnetic material extending between stations and having a resistance greater than 25 ohms per mile, means for impressing upon said line wire a carrier wave current, means for controlling said current in accordance with the intelligence to be transmitted, a receiver for translating the received energy, and means for amplifying the energy on said line wire at intervals of a plurality of wave lengths of said current.

20. A long distance system for electrically transmitting intelligence comprising a line upward of 100 miles in length comprising a non-loaded line wire of non-magnetic material extending between stations and having a resistance greater than 25 ohms per mile, means for impressing upon said line wire a carrier wave current, means for controlling said current in accordance with the intelligence to be transmitted, a receiver for translating the received energy, and means for amplifying the energy on said line wire at points distant from each other at least a plurality of wave lengths of said current and less than 100 miles.

21. A long distance telephone system upward of 100 miles in length comprising a non-loaded line wire having a resistance greater than 25 ohms per mile, means for impressing upon said line wire high frequency carrier current, means for modulating said current in accordance with sound waves, a receiver for translating the received energy, and thermionic amplifiers associated with said line wire at points distant from each other at least a plurality of wave lengths.

In testimony whereof I have hereunto affixed my signature this 23rd day of January, 1918.

CORNELIUS D. EHRET.