J. H. CUNTZ.
ELECTRIC CABLE.
APPLICATION FILED APR. 13, 1905.

1,119,246. Patented Dec. 1, 1914.

2 SHEETS—SHEET 1.

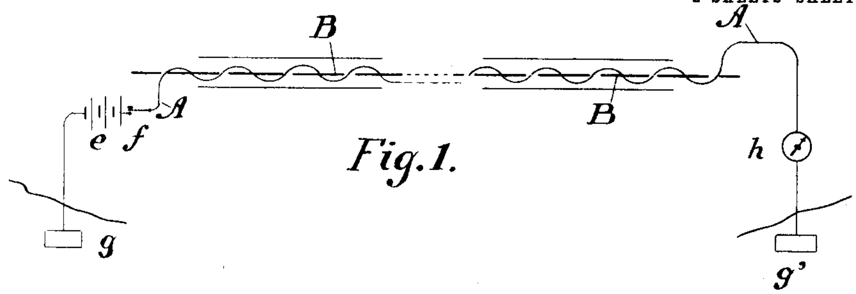


Fig. 1.

Fig. 2a.

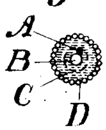


Fig. 2.

Fig. 2b.

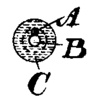


Fig. 3a.

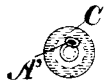


Fig. 3.

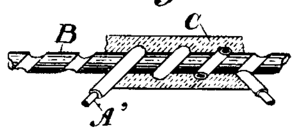


Fig. 4.

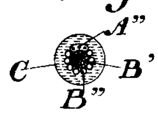


Fig. 5a.

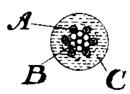
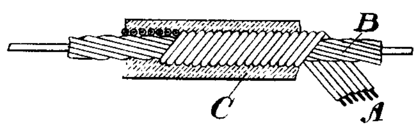


Fig. 5.



WITNESSES:

[illegible]

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2 SHEETS—SHEET 2.

Fig. 6.

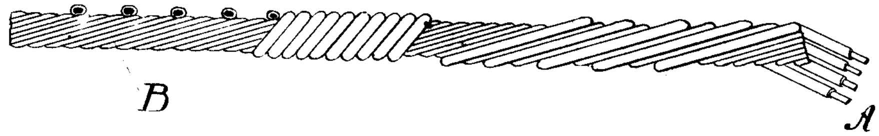


Fig. 7a.

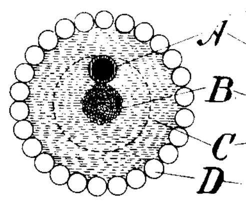


Fig. 7.

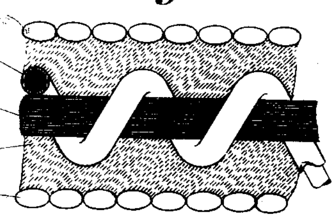


Fig. 8a.

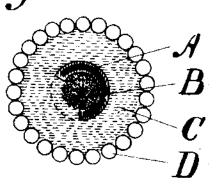


Fig. 8.

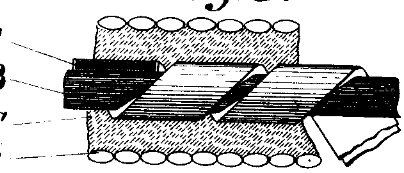


Fig. 9a.

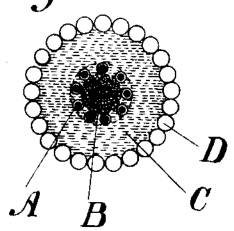
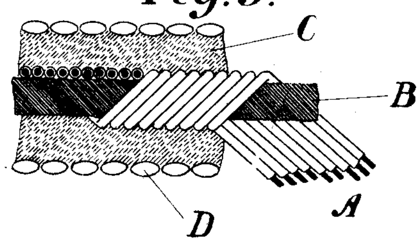


Fig. 9.



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UNITED STATES PATENT OFFICE.

JOHANNES H. CUNTZ, OF HOBOKEN, NEW JERSEY.

ELECTRIC CABLE.

1,119,246. Specification of Letters Patent. Patented Dec. 1, 1914.

Application filed April 13, 1905. Serial No. 255,431.

To all whom it may concern:

Be it known that I, JOHANNES H. CUNTZ, a citizen of the United States, and resident of Hoboken, in the county of Hudson and State of New Jersey, (whose post-office address is Hoboken, New Jersey,) have invented certain new and useful Improvements in Electric Cables, of which the following is a specification, reference being had to the accompanying drawings, forming a part hereof.

In the transmission of varying electric currents along conductors, the influences which prevent their passage without modifications become of serious importance when the length of the conductor is relatively great. These modifications are such as distortion and attenuation, which are terms now generally understood as denoting certain phenomena. The cause of such modifications is the combined influence of the resistance, the capacity and the inductance of the line. In ordinary long distance lines, particularly on submarine and underground cables, the capacity and the resistance are primarily instrumental in producing attenuation, while the capacity causes distortion also. On such lines the capacity is substantially uniformly distributed along their length.

My invention relates to the construction of cables and to methods for wholly or in part counteracting the effects of the capacity.

In order to apply my system of long distance electric wave transmission my prime object is to increase the inductance of the line sufficiently to substantially or partly, as the case may demand, counteract the effects of the distributed capacity of the line. as electric lines of this sort may be used in various ways, as submarine, underground or aerial, the capacity which it is necessary to counteract varies accordingly and between very wide limits. In the case of submarine cables there is large capacity which, therefore, demands a large amount of inductance, particularly where the length of such cables is great. By my construction a cable can be produced with an inductance as large as may be required for the given conditions, and what is more important, the amount can be predetermined and the dimensions of the elements of my cable so adjusted as to secure the proper amount in a way mechanically simple and commercially practicable. I am aware that there have been suggestions of constructions intended to increase inductance in a line, but which invariably do not show means whereby such inductance can be sufficiently increased for my purpose; or such constructions have involved defects which would prevent successful operation of the line; more than this, in such suggestions it has not been shown how the exact amount of inductance can be predetermined.

In my construction I carry my conductor in a helical path, which increases the inductance of the line to an extent that in some cases may be sufficient; and moreover I use a core of paramagnetic material about which the conductor is helically wound, which enables me to very materially further increase the inductance. As I can determine with exactness the various electrical and magnetic properties of the elements of my construction which bear upon the results, I can proportion the material in and the arrangement of the parts of my cables to accomplish the desired results with certainty, and moreover can so select and arrange them as to prevent complications which existed in suggestions which have at times been made, or which might exist except for the proper material and arrangement which I show and hereinafter more specifically describe, and, particularly, when in my construction a magnetizable core is used, the arrangement is such that the magnetization is so small as to avoid any deleterious effects.

In the accompanying drawings, Figure 1 diagrammatically shows the embodiment of my improvement in a long distance transmission system. Fig. 2 shows a portion of a cable, partly in section, embodying the essential elements of my invention, Fig. 2ª being a section of the same with its sheathing, while 2ᵇ shows a section of the same without sheathing. Fig. 3 is a portion of a construction intended to secure permanency in the relative arrangement of parts, while 3ª shows the same in section. Fig. 4 shows a section of cable modified in certain details. Fig. 5 shows a portion of cable in which more detail of core and arrangement of conductors is illustrated, while 5ª shows the same in section. Fig. 6 shows a portion of cable modified in form for mechanical requirements of manufacture. Figs. 7, 8 and 9 show portions of three forms of cable with the parts properly proportioned for certain given conditions and differing only in arrangement, while Figs. 7ª, 8ª and 9ª show respectively the sections of these different arrangements.

In Fig. 1 A is an electrical conductor, B is a core or support for the conductor, *e* is a source of electric energy, *f* is a key which, with *e*, shows conventionally means of imparting electrical impulses to the conductor A, while *g* indicates a connection to earth. *h* indicates an instrument to receive electrical impulses, and *g′* indicates a connection to earth. C is insulation. The electrical impulses or waves emanating from *e f* pass along the conductor A to the instrument *h*. In this drawing the conductor is shown as broken away in the middle, to indicate length.

In Figs. 2 and 2ª the conductor A with its small amount of insulation is wound helically around the core B and this is incased in insulation C about which is the sheathing D which can be used to take the strain to which the cable may be subjected, while in other cases the construction shown in Fig. 2ᵇ without sheathing may be used and the strains, if there are any, taken by the core.

In Figs. 3 and 3ª the core B is so made as to present a helical groove which is followed by the conductor A′, while A′ is flattened as may be desirable in cases as hereinafter shown, and should the core be of electrically conducting material, A′ is insulated as shown. This construction might be used where the capacity of a line is relatively small and the desired inductance can be obtained simply from the helical disposition of the conductor, and where it might be desirable to avoid the use of a paramagnetic core.

In Fig. 4, the conductor in several strands A″, properly insulated, is laid around the central portion of the stranded core B′, so as to be substantially flush with the outer layer of the core B″. This would have mechanical advantages in affording a more compact construction, in which also the outside strands of the core would coöperate to hold the conductor in its helical position; in addition to which I am hereby enabled to more completely fill the area inclosed by my helical conductor with paramagnetic material.

In Figs. 5 and 5ª the core B is shown more in detail, revealing the strands, the construction which I would generally use in the practical embodiment of my invention, while my conductor as here shown consists of a plurality of wires, each individually insulated for mechanical simplicity, although the insulation between the conducting material and the core is primarily important, and which I may accomplish by wrapping the bunch of conductors within insulation in such a way that only the convolutions of the sets of conductors will be insulated from each other. In this arrangement it will be seen that the conductors are wound in the opposite direction from the strands of the core, which under certain conditions will give me better electro-magnetic results. The conductor is wound in opposite directions from the strands of the core, so as to cross the latter more nearly at right angles, in view of which any eddy currents which might possibly be induced in the core strands will be reduced to a minimum.

In the use of my invention for certain conditions of line and also for possible mechanical requirements in construction I find that advantages may be obtained by using the arrangement as shown in Fig. 6. In this the conductor, or its several parts, is wound around the stranded core in the same direction as the surface strands of the core and for a certain length at the same pitch. This will insure the conductor fitting the surface of the core more closely, preventing among other things displacement, while portions of the conductor are then wound at a decreased pitch, this increasing the number of turns sufficiently to give the required inductance. In my construction of cable in all its various forms where a core of paramagnetic material is used, said core is of that material solely to increase the inductance of the line and is not intended to carry current.

In Figs. 7, 8 and 9 there is shown a practical form of cable designed to satisfy the conditions of a concrete case. The only difference in the three figures is the disposition of the conductor, except that in Figs. 7 and 8 the strands of the core are simply indicated as parallel to its axis, whereas in Fig. 9 the strands are shown in the preferred arrangement. I have here assumed a submarine cable with capacity and resistance such as are encountered in actual practice, and I have calculated the amount of inductance necessary to be given to such a line in order to permit the transmission of telephonic messages. I find then that in order to secure the proper amount of inductance, the dimensions and arrangement of core and conductor are substantially as shown. In the three illustrations the total area of section of conductor is the same. In Fig. 8 the conductor is flattened. This permits of a more compact, mechanical construction and at the same time makes it a better conductor for rapidly alternating currents, as it affords a larger surface for the same cross section. It is true that this increased surface would also increase the capacity, but its mechanical arrangement permits a greater thickness of insulation for a given outside diameter of cable, which greater thickness of insulation will reduce the capacity. In Fig. 9 I divide my conductor in order to give greater security against parting of the conductor, and also to secure a more simple and commercially practicable method of manufacture. In this the conductor consists of a plurality of wires, each insulated.

When varying electric currents are transmitted over long circuits they are attenuated in a manner which is indicated by the formula

$$e^{-px} \text{ or } \frac{1}{e^{px}};$$

that is, at any distance x from the source of current, its strength will have decreased from unity to e^{-px}, or in that proportion: where e is the base of the Naperian system of logarithms, x is the distance, in any convenient units of length, and p, which may be termed the attenuation constant, is equal

$$\sqrt{\frac{C\omega}{2}\{[R^2+L^2\omega^2]^{\frac{1}{2}}-L\omega\}}.$$

In this formula, C is the electrostatic capacity, R the resistance, and L the inductance, all per unit length, and ω is equal to 2π times the frequency of the current. When a current is composed of waves of different frequencies, these component waves will be attenuated in different degrees, and the resulting current, or combined wave, will be not only attenuated but distorted. This is notably the case in telephonic transmission. When the inductance of a circuit, L, is practically zero, the above formula reduces to

$$p=\sqrt{\frac{C\omega R}{2}}.$$

When, however, the inductance, L, is made large compared with the resistance, R, the expression for p becomes

$$\frac{R}{2}\sqrt{\frac{C}{L}}$$

which is independent of the frequency, so that currents made up of waves of different frequencies will have their components attenuated in the same degree and will not suffer distortion. And also, by increasing L, the attenuation can be minimized.

The inductance of a circuit constructed on my system can be calculated by the formula

$$L=\frac{4\pi N^2 l \mu A}{10^9},$$

where L is the inductance, in henries, N is the number of turns of the helix per unit length, l is the length of the portion of circuit under consideration in the same units, μ is the permeability of the medium inclosed by the helix, or of the core, and A is the cross-sectional area of the core. As an example, I shall consider a cable intended primarily for submarine work, of a length of 2,000 nautical miles. I take a conductor of .164 square centimeters in cross-sectional area, having a resistance of 2 ohms to a nautical mile, and a capacity of 0.3 microfarads per nautical mile; and a core of 0.5 square centimeters in area, which will be 0.8 centimeters in diameter; the pitch of the helical conductor I make equal to 2 centimeters. Then, making allowance for the thickness of conductor and insulation, as well as the compression of the insulation and other minor features, the average diameter of the helix is brought to one centimeter. On such a line the length of the conductor is increased in the ratio of 1.85 to 1, and the resistance of the conductor, therefore, equals 3.7 ohms per nautical mile; allowing that the capacity is increased in the same proportion, it will be 0.555 microfarads per nautical mile. The attenuation constant will then be

$$p=\frac{R}{2}\sqrt{\frac{C}{L}}=\frac{3.7}{2}\sqrt{\frac{.555\times10^{-6}}{.0524}}=.006$$

and the attenuation therefore will be:

$$e^{-px}=\frac{1}{e^{px}}=\frac{1}{e^{(.006\times2000)}}=\frac{1}{e^{12}}$$

and this for a cable of 2,000 nautical miles; and this attenuation in my construction is, furthermore, independent of the frequency.

As a partial basis of comparison to show the relative entire impracticability of an ordinary cable, as compared with one of my construction, consider such an ordinary cable 2000 nautical miles in length, with a resistance of 2 ohms and a capacity of 0.3 microfarads per mile. The inductance of such a cable is extremely small, and the formula for the attenuation constant is therefore:

$$p=\sqrt{\frac{C\omega R}{2}}.$$

Substituting the above values, and assuming the frequency to be 500,

$$p=\sqrt{\frac{0.3\times2\pi\times500\times2}{10^6\times2}}=\frac{1}{10^3}\sqrt{942}=.031.$$

The attenuation for a 2000 mile cable will therefore be:

$$\frac{1}{e^{px}}=\frac{1}{e^{(.031\times2000)}}=\frac{1}{e^{62}}=\frac{1}{10^{26}},$$

approximately. Moreover, this attenuation will vary with the frequency.

I make the strands of the core of fine soft-iron wire. These wires may be insulated from each other by a coating of their oxid, or they may have a thin coating of insulating compound. In cases where it might be found advantageous to have the core electromagnetically non-continuous longitudinally, the plurality of strands in my preferred form afford the opportunity of still preserving mechanical continuity by staggering the joints.

I do not wish to confine myself to the exact constructions or dimensions of parts as herein specifically set forth, but what I desire to secure by Letters Patent is a construction of cable which will enable me to accomplish the results mentioned, and the method of accomplishing said results.

What I claim as my invention is:—

1. The method of counteracting the capacity of an electric cable which consists in increasing the inductance of the cable substantially uniformly throughout its length, and increasing its capacity in a lesser degree, substantially as described.

2. The method of counteracting the capacity of an electric cable, which consists in increasing the effective inductance of the cable throughout all portions of the length thereof, and increasing its resistance in a lesser degree.

In testimony whereof, I have signed my name to this specification, in the presence of two subscribing witnesses, this 12th day of April, 1905.

JOHANNES H. CUNTZ.

Witnesses:

WM. P. KENNEDY,
HERMAN F. CUNTZ.