Jan. 29, 1929.

J. J. GILBERT

1,700,476

SUBMARINE SIGNALING CABLE

Original Filed Feb. 27, 1926

Fig. 1

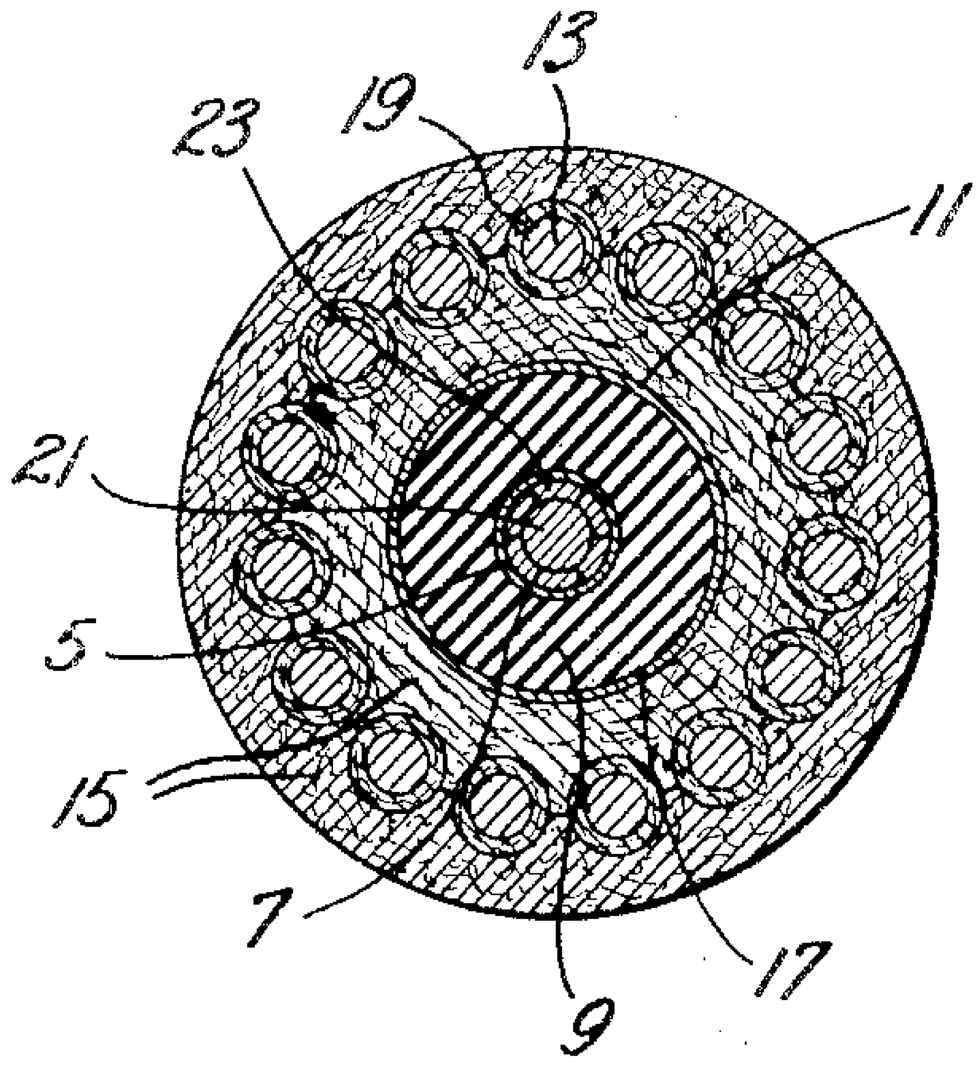


Fig. 2

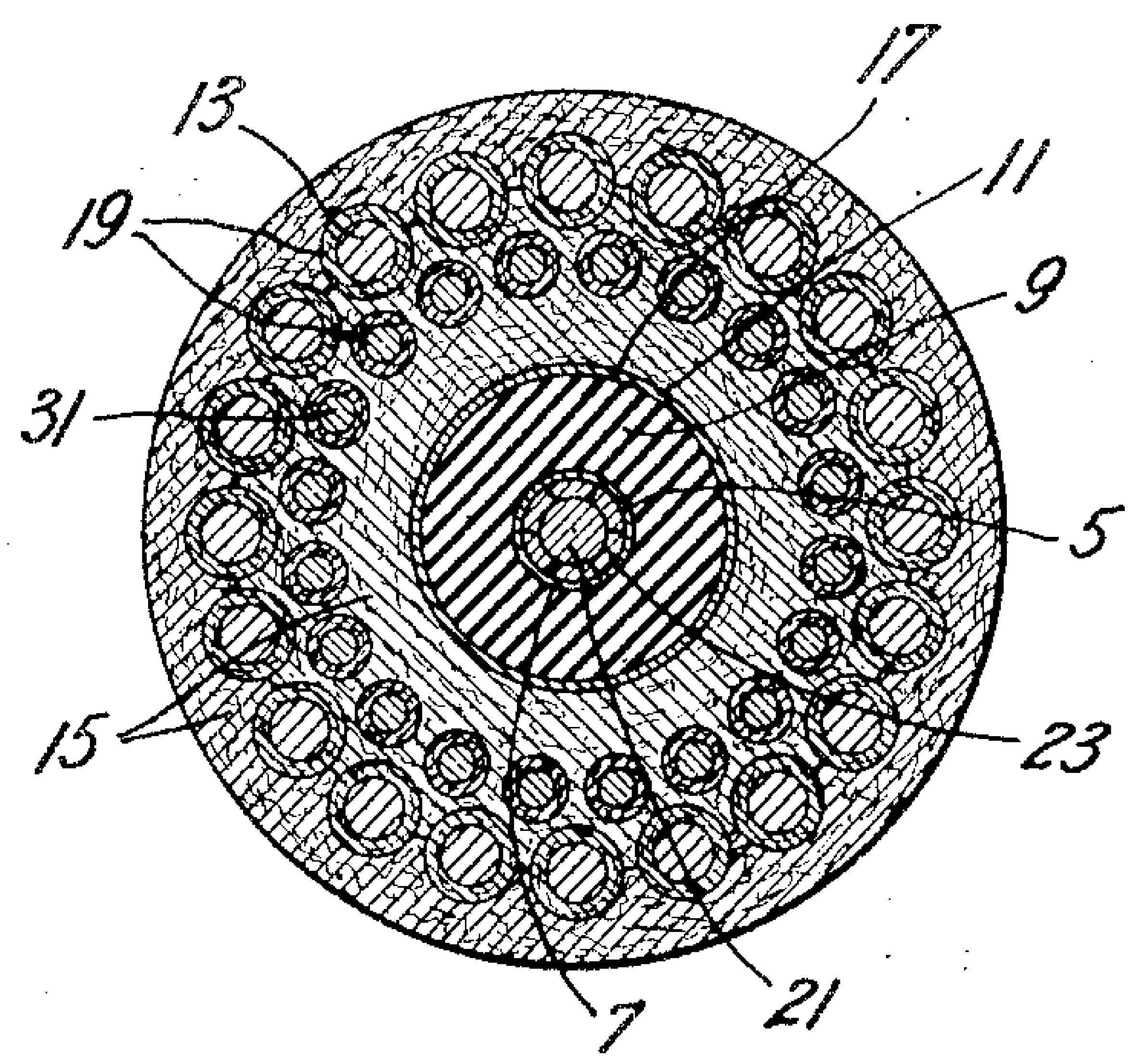
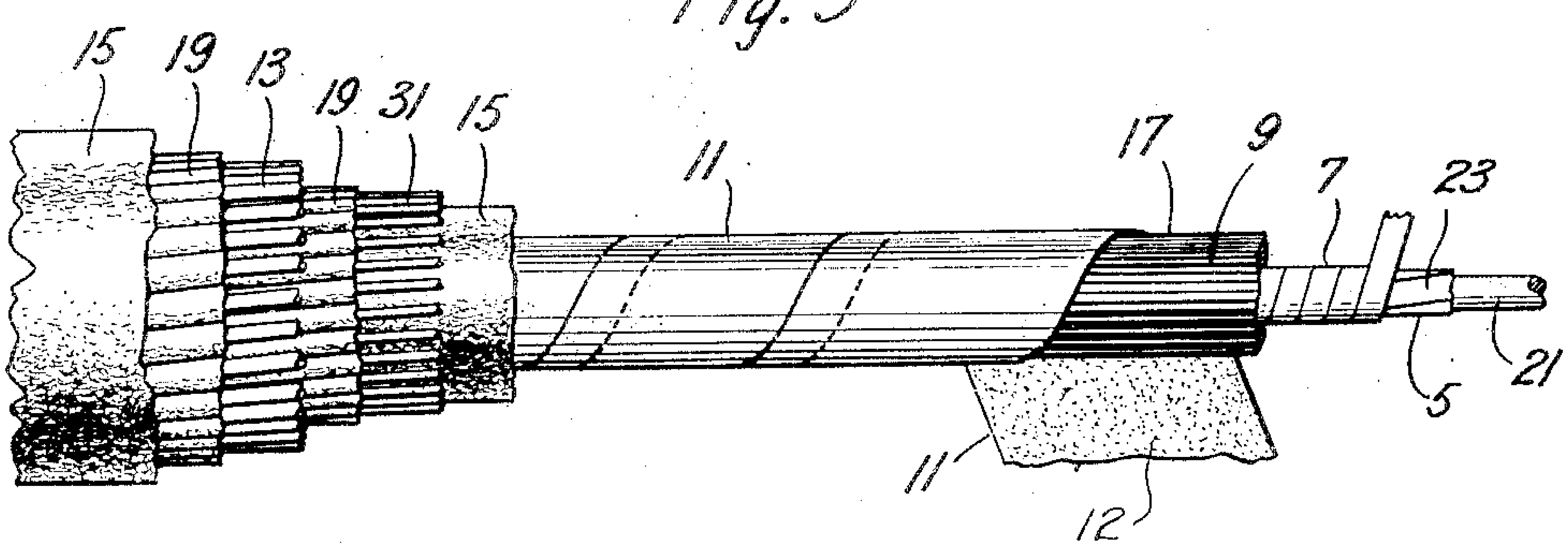


Fig. 3



Inventor:
John J. Gilbert

by E. W. Griggs Att'y.

UNITED STATES PATENT OFFICE.

JOHN J. GILBERT, OF DOUGLASTON, NEW YORK, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

SUBMARINE SIGNALING CABLE.

Application filed February 27, 1926, Serial No. 91,194. Renewed June 21, 1928.

This invention relates to submarine signaling.

An object of the invention is to increase the transmission efficiency of submarine signaling cables.

It is also an object of the invention to reduce the increment of effective resistance of a submarine signaling cable due to the presence of teredo tape employed to protect insulation of the cable from ravages of teredo worms.

It is also an object of the invention to provide an efficient return path for signaling currents of comparatively high frequencies in a submarine cable.

It is customary to give protection against teredo worms to gutta percha or like insulation of portions of a submarine signaling cable lying in shallow water by applying directly upon the core a thin tape of copper or brass with sufficient overlap to exclude the teredo worms.

It has been found that when a cable is provided with both teredo tape and continuous loading, the loading having the form of one or more helical members of high permeability at low magnetizing forces, a material loss of efficiency is occasioned by reason of the fact that a considerable increment in the effective resistance of the cable can arise from the losses in the teredo tape, these losses resulting from currents, which for convenience may be termed eddy currents, flowing in the tape in consequence of electromotive forces set up in the tape by the varying magnetic flux created in the loading material by signaling current flowing in the cable. In accordance with this invention, this increment of effective resistance is reduced by employing a tape or like protective layer having high resistivity. Also, in accordance with this invention, this increment of effective resistance is reduced by increasing the pitch or length of lay of the tape, as for example, by increasing its width, and insulating adjacent turns of the tape from each other. Where the signaling involves frequencies sufficiently high to render a metallic return path for the signals advisable, in accordance with the invention there is provided such a return path comprising helical conductors having high conductivity and having a large pitch or length of lay. In accordance with the invention these return conductors may lie within the helix of the steel armor wires for the cable, whereby these armor wires will retain the return conductors on the cable and thus enable their pitch to be made greater than would otherwise be practicable. This long lay tends toward reduction of the resistance of the return path, for any given amount of material in that path, or tends to enable reduction in the weight of the material in the return path, for any given resistance of the path. In the case of a cable loaded as mentioned above, this long lay also tends to reduce losses due to eddy currents in the return path, these eddy currents resulting from electromotive forces set up in the material of the return path by the varying magnetic flux created in the loading material by the signaling current.

Other objects and advantages of the invention will be apparent from the following description in connection with the accompanying drawings wherein:

Fig. 1 is an enlarged cross-sectional view of a submarine signaling cable embodying one form of the invention;

Fig. 2 is an enlarged cross-sectional view of a submarine signaling cable embodying another form of the invention; and

Fig. 3 is a longitudinal elevation of a section of the cable of Fig. 2 with parts broken away, this figure being drawn to a smaller scale than Fig. 2.

In Fig. 1 the cable comprises a central conductor 5, a loading wire or tape 7 surrounding the conductor 5, a layer of gutta percha or like insulation 9 preferably having a wall thickness of from one to several millimeters surrounding the conductor 5 and loading material 7, a teredo tape 11 surrounding the insulation 9, and a layer of helical steel armor wires 13 embedded in jute 15 and surrounding teredo tape 11 and the core 17 constituted by elements 5, 7 and 9.

The armor wires 13 may be individually wrapped with fabric tape 19 and impregnated with a preservative compound. This tape serves the double purpose of protecting the wires and making the cable more flexible by keeping the wires separated, and moreover serves the purpose of reducing eddy currents in the wires as will be pointed out hereinafter.

The central conductor consists of a central strand 21 surrounded by a plurality of strands 23 of such shape as to give the composite conductor a smooth cylindrical surface. The loading member 7 is a helical wrapping of magnetic material having high permeability at low magnetizing forces and having high resistivity. Preferably this tape or wire is one of a certain group of alloys consisting principally of nickel and iron. The construction and advantages of such a loaded cable conductor are described in U. S. patents to O. E. Buckley 1,586,874, June 1, 1926, G. W. Elmen 1,586,884, June 1, 1926, and O. E. Buckley 1,486,863, March 18, 1924.

The teredo tape 11, for protecting the insulation 9 from the attacks of the teredo worm, is a helical wrapping surrounding a portion of the core that lies in neighborhoods where the teredo worm is found. The length of the core that is supplied with teredo tape consists of the portion of the cable that lies in water of a depth less than about 100 fathoms. It is found that the teredo worm does not ordinarily operate in depths greater than this. The teredo tape is wound on the core with sufficient overlap of the adjacent turns to insure against gaps in the metallic layer formed by the tape. For reasons explained hereinafter, this tape is preferably of material having high resistivity, for example, nichrome, Driver-Harris 193 alloy (nickel-iron-chromium), or Therlo (copper-manganese-aluminum). These alloys have resistivity of 5 to 10 times that of brass, and also resist corrosion, so that they are suitable for use in sea-water. The teredo tape may be of the order of .004″ thick, and, for reasons explained hereinafter, its pitch or length of lay is preferably substantially as great as it can be made without undue risk of injury to the insulating material of the core. In general the width of the teredo tape may be three times the diameter of the core, so that for a core about 1/2 inch in diameter, the width of the tape is preferably about 1-1/2 inches.

As has been shown in U. S. patent to O. E. Buckley, 1,586,962, June 1, 1926, in the case of a conductor which is loaded by means of a tape or wire of magnetic material wound helically on the conductor as described above, the lines of magnetic induction produced by current in the conductor tend to follow the helical path afforded by the tape or wire, this tendency being greater the higher the permeability of the loading material. That is, the lines of magnetic induction are not single loops around the conductor, but have the form of a helix which takes a large number of turns around the conductor in one turn of the loading tape before crossing an air gap to an adjacent turn of the loading tape, the pitch of the helix of the lines of induction being slightly less than the pitch of the tape, so that a line of induction follows the tape for, say, twenty turns around the conductor, then reaches the rear edge of the tape and jumps backward across the small air gap to the adjacent turn and continues following the tape in the original direction and sense for another twenty turns, then again slips back across an air gap and continues following the tape in a spiral path leading forwardly, etc. (If the loading tape were strictly uniform and continuous from one end of the cable to the other and if the cable carried a steady, direct current and were not subject to the effect of the earth's field, the lines of induction would be continuous from one end of the cable to the other.) There exists, therefore, in the loading material a component of the magnetic induction parallel to the axis of the conductor, which may be termed the longitudinal or axial component of the induction, this component being approximately proportional to the permeability and to the thickness of the loading material. It is also dependent upon the angle of lay of the loading tape or wire. All other conditions being the same, the component of magnetic induction parallel to the axis of the conductor will be greater the greater the width of the loading material. When the signal currents flow in the cable conductor 5, electromotive force will be set up in the helical layer of the teredo tape 11 surrounding the conductor, which is proportional to the time rate of change of the axial or longitudinal component of magnetic induction. This electromotive force causes a current to flow in the tape, and the energy losses resulting from this current flow are taken from the energy of the signaling current in the conductor. In other words, the losses in the teredo tape give rise to an increment in the effective resistance of the cable conductor. This resistance increment can be shown to be proportional to the square of the frequency of the sinusoidal current, and to vary inversely with the thickness and resistivity of the teredo tape, and to fall off rapidly as the pitch or lay of the teredo tape is increased, provided that its adjacent turns are insulated.

It has been found from measurements of actual wire and tape loaded conductors for submarine cables that at a frequency of 60 cycles per second, the increase in effective resistance due to ordinary brass teredo tape may amount to .1 ohm per mile. In the case of a fairly heavy telegraph cable, the effect of this resistance increment is to increase the attenuation constant of the taped sections by as much as 3%. For cables of lighter weight than this, the effect on the attenuation constant will be less, since the resistance of the central conductor is higher. The effect is not very serious in the case of a long telegraph cable, since the frequency of signaling is low and ordinarily the taped portion of the cable is comparatively only a small fraction of the total cable length. For a telephone cable where the signaling frequency is comparatively high and the cable is taped for a large fraction of its length, the effect is more serious. In either case the magnitude of the resistance increment due to the electromotive forces induced in the teredo tape, can be reduced by using in place of the customary brass tape, as described above, suitable material such as nichrome, Driver-Harris 193 alloy, or Therlo. As noted above, these alloys have resistivity of 5 to 10 times that of brass, and the currents due to the electromotive forces set up in the teredo tape are proportionately less, as are also the corresponding values of resistance increment in the cable conductor.

It is also of advantage to increase the lay of the teredo tape, by increasing its width to, for instance, a value of the order of three times the diameter of the core, and to insulate adjacent turns of the tape, especially where they overlap. This insulation, shown at 12, Fig. 3, may be effected by providing the teredo tape with an insulating cover of oxide, for example, or by applying to it an insulating compound at the time it is being served on the core. In this way the resistance afforded by the tape to the inducing electromotive force is increased, since the current is caused to flow in the direction of the tape rather than in the shorter direction in a plane at right angles to the central conductor, which is the direction of the inducing electromotive force. Even where brass tape is used, this is of advantage,

Although it has already been found of advantage, so far as transmission of high frequencies through a submarine cable is concerned, to furnish the cable with a return conductor consisting of a copper sheath made of tape wound helically around the core, nevertheless, as pointed out in my copending application, Serial No. 680,170, filed December 12, 1923, entitled Submarine cables, it is found that this method is not practical for low frequencies, for instance, frequencies of a range from zero to 100 cycles per second. For, unless the resistance of the sheath alone is comparable in magnitude with the sea-water resistance without the copper sheath the return resistance will be increased by the addition of the copper sheath. This is because the screening action of the sheath is such as to confine to the sheath the greater part of the return current. In the range of frequencies from zero to 100 cycles per second with cables such as are now in use for transoceanic operation, this condition would require such a large amount of copper in the sheath that the cost and weight of the cable would be increased beyond practical limits. That application therefore proposes to decrease the sea-return resistance for the signaling frequency range just mentioned and, in some instances, much higher frequencies, by employing, in place of the usual steel armor wires for the cable, armor wires of high resistivity material, for example, nickel steel, chromium steel, or Krupp steel.

Where the cable of Fig. 1 is to be employed for signaling frequencies of the range just mentioned, its armor wires may, accordingly, be of such high resistivity material. Where the cable is loaded as in the case of the cable of Fig. 1, the high resistivity of the armor wires has the additional advantage of reducing eddy current losses produced in the armor wires by the flux in the loading material in the same manner in which that flux produces eddy current losses in the teredo tape.

Fig. 2 shows a cable similar to that of Fig. 1 but having a metallic return path for signaling currents, the return path comprising material of high electrical conductivity compared to that of steel. Identical elements in the two figures are indicated by the same reference characters. The metallic return path is constituted by a layer of helical copper wires 31 or strips embedded in the jute 15 and lying between the steel armor wires 13 and the teredo tape 11 and surrounding the core 17 and tape 11. This return path is especially useful where the cable is to be employed for transmitting fairly high frequencies, for instance, frequencies of the voice range or somewhat higher. The wire conductors 31 may be individually wrapped with tape 19 as in the case of the armor wires 13. The eddy current losses produced in the return conductors 31 by the flux in the loading material in the manner in which such losses are produced in the teredo tape by that flux, will not be unduly large because the conductors 31 are insulated from each other and are given a long lay, for example, a pitch of the order of three feet, so that the currents produced in these conductors by the axial component of the magnetic flux in the loading material are forced to traverse a long path. The length of this path is also due partly to the fact that the conductors 31 are spaced a considerable distance from the teredo tape 11, thus making the diameter of the helix of wires 31 large, and also increasing the maximum permissible length of lay of the wires 31. As shown in Fig. 3, the pitch of the conductors 31 is greater than that of the steel armor wires 13. It is possible to give the conductors 31 this greater pitch even where the pitch of the armor wires 13 is substantially the maximum value permissible, since the wires 31 are prevented from falling off the cable by the wires 13. The long pitch of conductors 31 also has the advantage that it increases the efficiency of the copper return path as a longitudinal conductor. On this account the conductors 31 may contain approximately 20% less copper than would be necessary, for a given resistance of return conductor, if the return conductor were in the form of a helical tape laid on the core. With such a tape it is necessary to use a comparatively short lay in order to avoid injury to the insulating material of the core.

Where desired, for instance where the cable is to transmit frequencies so high that loading is impracticable or inadvisable, the loading material may be omitted from the cable of Fig. 2, the spacing of the return conductors from the central conductor being made sufficient to give the cable the desired inductance. It is pointed out in my copending application, Serial No. 585,619, filed September 1, 1922, entitled Submarine signaling cables, that an unloaded cable with a concentric return conductor of high conductivity so spaced from the central conductor can have comparatively high efficiency for frequencies at which loading would be inadvisable on account of the large eddy current losses which would occur in the loading material.

Similarly, if desired, the loading material may be omitted from the cable of Fig. 1, where the frequencies to be transmitted by the cable are high, and some or all of the armor wires 13 may then be composed of or individually coated with or surrounded by copper. It is pointed out in the above mentioned application, Serial No. 585,619, that an unloaded cable with armor wires so provided with copper to serve as a return circuit for the cable can well serve to transmit high frequencies. By making the pitch of the armor wires as great as is practicable, the efficiency of the copper path as a longitudinal return conductor may be made large.

In another aspect the present invention covers the use of a teredo layer having high permeability, as well as one or more of the characteristics described above as desirable for teredo protection. In such cases the layer will be constituted of material being sufficiently permeable to act as additional inductive loading which becomes more effective as its spacing from the high conductivity metallic return is decreased.

Although it is of advantage from the point of view of eddy-current losses to have the width and the pitch of the teredo tape large, it is of advantage from the same point of view to have the width and the pitch of the loading tape small, since, as noted above, the component of magnetic induction parallel to the axis of the central conductor will be greater the greater the width and the pitch of the loading tape or wire, if other conditions remain unchanged. The pitch of the teredo tape is preferably considerably greater than that of the loading tape or wire.

Although the high resistivity metallic layer for affording protection against the teredo has been specifically shown and described as a helical tape, it should be understood that such disclosure is not intended as precluding a broader view of the invention.

What is claimed is:

1. A continuously loaded submarine signaling cable core comprising an electrical conductor having loading material applied thereto, the loading material being surrounded by insulation, a helical metallic tape on said core, said tape having its adjacent turns overlapping, and insulation between the overlapping portions.

2. The combination with a continuously loaded submarine signaling cable core comprising an electrical conductor surrounded by helical loading and by a layer of insulation having a wall thickness of at least a millimeter, of a helical metallic tape on said core, said tape having a thickness of the order of several thousandths of an inch and having resistivity at least twice that of brass.

3. A continuously loaded submarine signaling cable core, and a helical metallic tape thereon having a pitch substantially greater than twice the diameter of said core and having its adjacent turns overlapping and insulated from each other.

4. A continuously loaded submarine cable core comprising an electrical conductor surrounded by insulation and a helical metallic tape on said core, said tape having resistivity at least several times that of brass, and having its adjacent turns overlapping and insulated from each other.

5. A continuously loaded submarine cable comprising a conductor, loading material, insulation around said conductor and loading material, a metallic layer outside said insulation serving as protection against the teredo, said loading material being so associated with said conductor that a component of flux is set up through the coil formed by said metallic layer in the direction of the length of the cable by the signaling currents in said conductor, the resistivity of said protective material being high compared with that of iron.

6. A continuously loaded submarine signaling cable core comprising an electrical conductor surrounded by a layer of loading material, a layer of insulation around said loading material and a strip of metal of high resistivity compared with brass around said insulation with contiguous edges thereof overlapping and insulated from each other.

7. A submarine signaling cable, comprising a central conductor continuously loaded with a helical loading member having high permeability at low magnetizing forces, a substantially concentric return conductor for said central conductor, and electrical insulation between said conductors, said return conductor having high electrical conductivity compared to that of steel, and said return conductor comprising helical elements having a pitch of the order of at least a foot.

8. A submarine signaling cable comprising a central conductor continuously loaded with

a helical loading member having high permeability at low magnetizing forces, a substantially concentric return conductor for said central conductor, electrical insulation surrounding said central conductor, teredo tape on said insulation, material of low conductivity spacing said return conductor from said teredo tape, said return conductor having high electrical conductivity compared to that of steel and having a pitch of the order of at least one foot.

9. A submarine cable comprising a central conductor, electrical insulation surrounding said central conductor, a layer of helical wires surrounding said insulation, said wires having conductivity high in comparison to that of steel, and helical metallic armor members surrounding said helix of wires, said wires having a pitch greater than that of said armor members.

10. A continuously loaded cable comprising a central conductor, a helical element of high permeability and high resistivity forming a layer thereabout, insulation surrounding said layer, and a layer of helically laid tape outside said insulation having high resistivity compared with brass and having a greater pitch than said first mentioned helical element.

11. A submarine signaling cable comprising a loaded conductor, insulation thereabout, teredo tape external to the insulation, a return path external to the teredo tape, said path comprising a plurality of wires of metal highly conductive as compared to iron, separated from each other and from the teredo tape by material of conducting properties very poor as compared to iron.

12. A submarine signaling cable comprising a continuously loaded central conductor, insulation surrounding said conductor, teredo tape external to said insulation, a return path external to said teredo tape, said path comprising a plurality of wires of metal highly conductive as compared to iron, separated from each other and from the teredo tape by material of conducting properties very poor as compared to iron, armor wires surrounding said return path and poor conducting material, the wires of said return path having a pitch greater than that of said armor wires.

13. A signaling cable comprising a signaling conductor, a return circuit path spaced from said signaling conductor comprising armor wires and a separate layer of wires underlying said armor wires comprising material of considerably greater conductivity than the armor wires, said separate layer of wires being spaced from each other and from the armor wires by material having insulating properties similar to jute.

14. A cable in accordance with claim 13 in which the conductor is provided with plastic insulation and the armor wires are spaced from the plastic insulation by material having insulating properties similar to jute.

In witness whereof, I hereunto subscribe my name this 26th day of February, A. D. 1926.

JOHN J. GILBERT.