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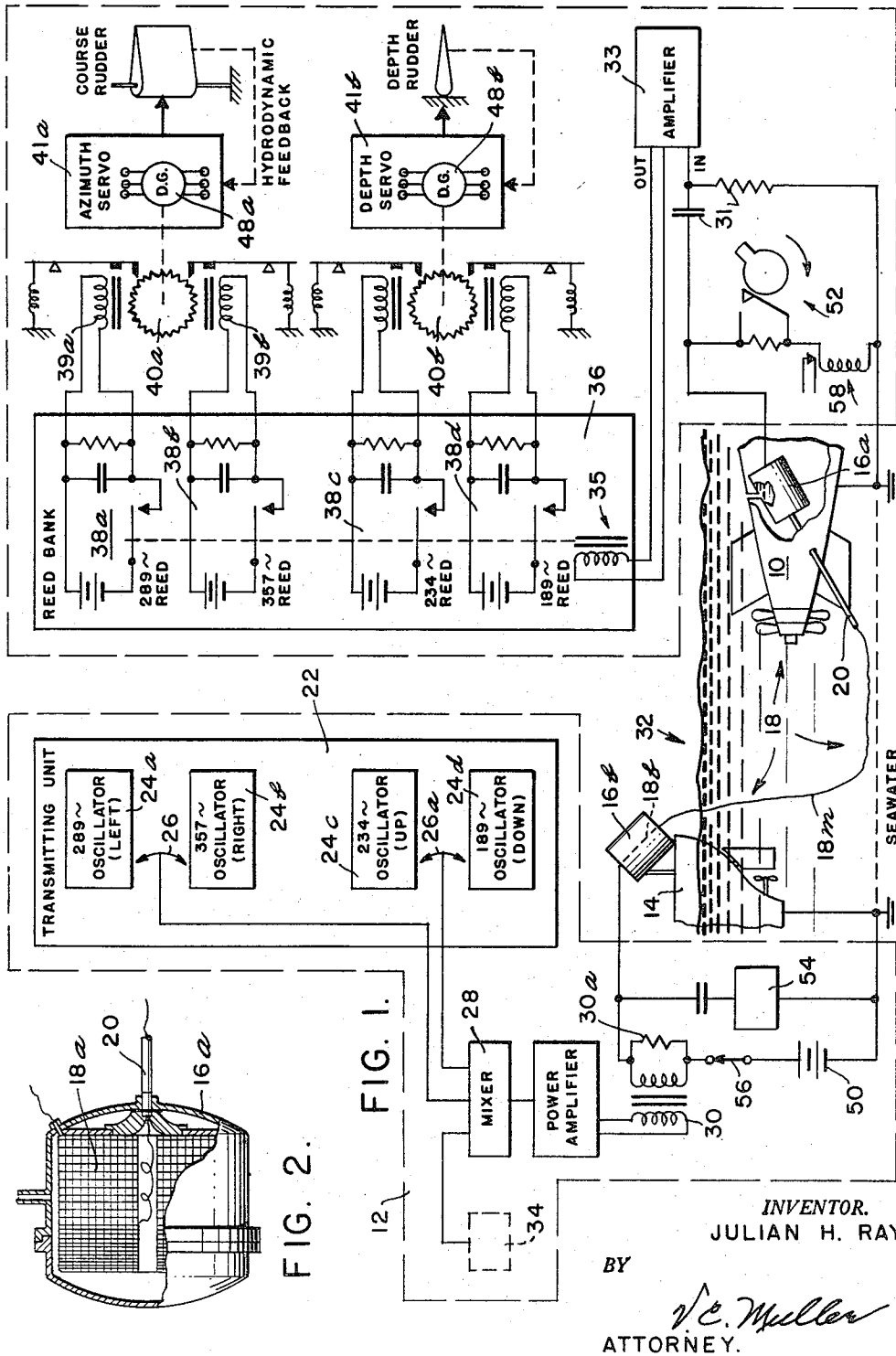
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3,148,651

TORPEDO CONTROL APPARATUS

Filed Oct. 31, 1960

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

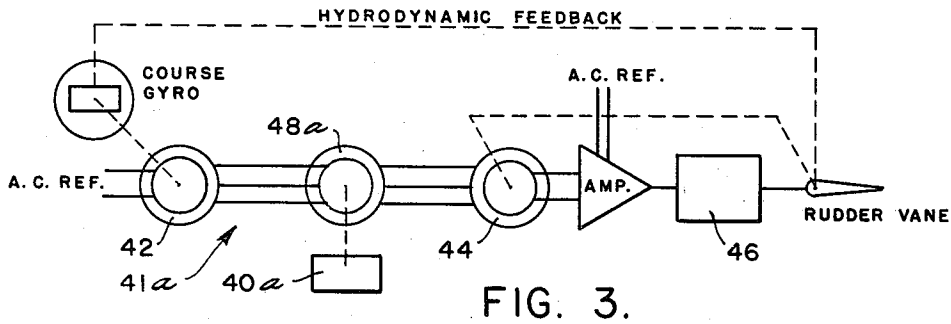
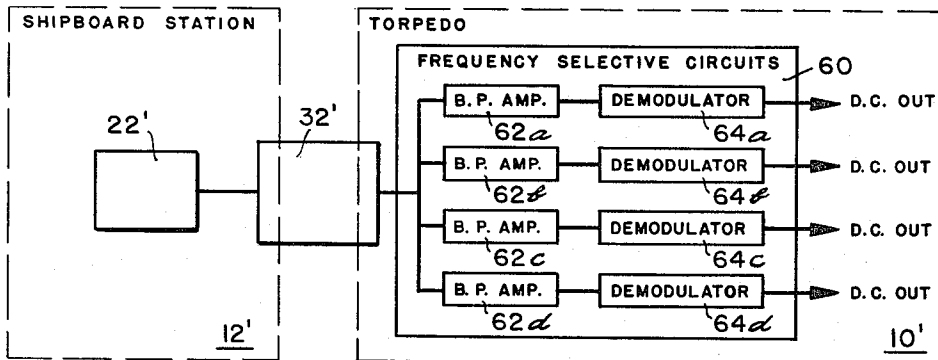


FIG. 4.

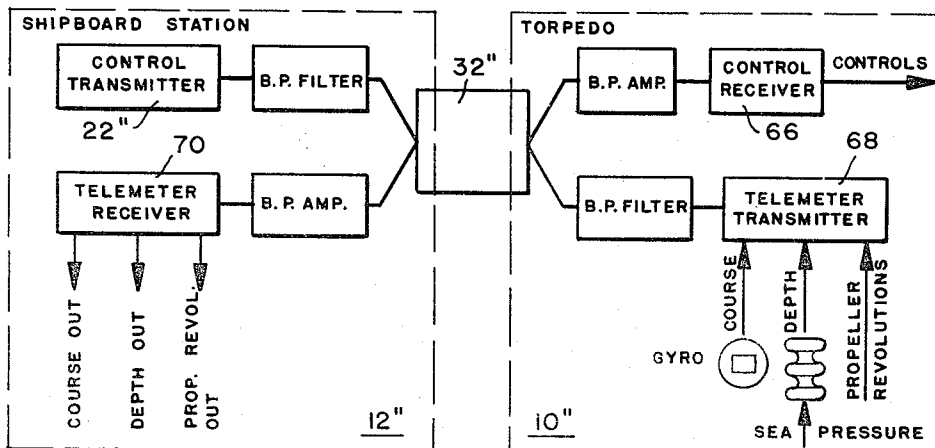


FIG. 5.

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TORPEDO CONTROL APPARATUS

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9 Claims. (Cl. 114-21)

This invention relates to guidance and control apparatus for naval torpedoes and more particularly to apparatus of the type wherein intelligence is communicated between the torpedo and a remote station through an extensible conductor connecting same, sometimes called "wire guided torpedo" apparatus.

While evidence is available that the broad concept of guiding a torpedo by electric signals transmitted through an extensible conductor connecting the torpedo and a control station is old, probably having originated in a foreign country, such concept was ostensibly employed with direct current communicating techniques and, so far as known, the control station was stationary.

In accordance with generally known principles, D.C. communication techniques are somewhat limited in their capability to provide a plurality of communication channels and also limited in their capability to provide two-way communication. It has been found that these limitations can be obviated using the principles and apparatus to be subsequently described.

The principal object of the present invention is to provide wire guided torpedo apparatus capable of simultaneously controlling a greater number of torpedo control functions than heretofore possible, and capable of simultaneously telemetering torpedo performance data from the torpedo to the remote station.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description in connection with the accompanying drawings wherein:

FIG. 1 is a schematic diagram of one form of the torpedo apparatus of the present invention;

FIGS. 2 and 3 are details of FIG. 1;

FIG. 4 is a block diagram of another form of invention; and

FIG. 5 is a block diagram of a still further form of invention.

Referring now to FIG. 1 of the drawing, the invention comprises, in general, wire guided torpedo apparatus which may be employed in various tactical organizations wherein a torpedo is to be controlled from a remote guidance locus, such as a ship, submarine, harbor defense station, hovering aerial vehicle, floating buoy linked by radio relay apparatus to another station or the like, one of which is illustrated in FIG. 1 as a torpedo 10 to be guided from a guidance station 12 aboard a ship 14.

Housed in the torpedo is apparatus for dispensing wire as the torpedo runs through the water, of any suitable form, but preferably as hereinafter described and shown in FIGS. 1 and 2, comprising a dispenser housing 16a containing a stationary coil of wire 18a which at the start of the run has a length equal to the range of the torpedo. The wire is a single conductor wire having an insulation thereabout, which insulation is preferably of a type exhibiting a combination of a low dielectric constant in seawater which is uniform over the audio frequency range, and abrasion resistant. By way of illustration, satisfactory results may be obtained using No. 24 hard drawn copper wire as the conductor and an insulation comprising a polyethylene inner sheath 11 mils thick to provide the desired dielectric characteristics tending to lower the shunt distributed capacity between the conductor and

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the seawater medium, and a nylon outer sheath 5.5 mils thick to provide the requisite resistance and strength. Polyethylene has a dielectric constant equal to 3.3 and nylon has a dielectric equal to 6.0. Coil 18a is formed as a conventional multilayer helical coil, having an axial hollow core extending therethrough, with one end of the length of wire appearing at the innermost coil layer adjacent the core and the other end appearing at the outermost layer. Further, the coil is so wound, as by application of twist in forming each coil turn and application of a suitable light adhesive to prevent tangling, that the end appearing at the innermost layer may be freely and easily uncoiled and pulled from the core by a slight pull in an axial direction. This end is threaded through a guide tube 20 and then extends into the seawater medium between the torpedo and ship, and the other end is passed through a gland in the housing 16a into the torpedo. Housing 16a is flooded with seawater admitted therein through a venting arrangement and the coil is mounted in the housing in spaced relationship relative to the housing wall to provide full immersion of the coil in the seawater. A like housing 16b and like coil 18b may be carried by ship 14 with the housing suitably filled with seawater and with the freely uncoilable end extending into the seawater medium.

The uncoiled ends of coils 18a and 18b are joined together by a suitable water-tight splice, not shown, so that the wire of coils 18a and 18b in effect constitute a continuous wire 18 with a midportion 18m extending through the seawater medium between the ship and torpedo. Shortly after start of the torpedo run a reactive or resistive force comprising inertia and friction forces associated with midportion 18m overcomes the tendency for relative movement between the torpedo and ship to pull the wire through the water. Thereafter the reactive force pulls wire from each coil under relative movement between the respective coil and the midportion 18m. It will be apparent that with such arrangement the tension in midportion 18m never exceeds the force necessary to uncoil and pull the wire from the coils and that such arrangement permits both the torpedo and the ship to maneuver at will. Both the torpedo and ship in effect run away from the stationary wire midportion 18m dispensing wire into the sea to extend the length of the midportion.

In order to communicate signals for controlling the torpedo's azimuth course and depth course from guidance station 12 to the torpedo there is provided an A.C. signal transmitting unit 22 comprising a series of four fixed frequency audio frequency oscillators 24a, 24b, 24c, 24d for producing A.C. sine wave electrical energy characterized by separate frequencies of operation. Oscillators 24a and 24b form a pair to provide command signals for "left" and "right" course changes, respectively. A suitable keying arrangement 26 is provided to selectively produce a signal output in the form of an A.C. pulse from one or the other of the oscillators. Similarly, oscillators 24c and 24d, having a similar keying arrangement 26a, are paired to provide "up" and "down" depth change signals. These signal outputs are fed to a conventional mixer 28 which combines them into a single resultant signal of A.C. electrical energy having as frequency components the frequencies of the inputs, permitting simultaneous transmission of azimuth and depth change signals. The output of the mixer is then fed through a power amplifier to a matching transformer 30, and the transformer output winding together with a parallel resistor 30a, are connected between the shipboard end of wire 18 and a seawater ground. Wire 18 forms one conducting path and the conductivity of the seawater medium between the ship and torpedo forms another conducting path of a transmission line extending between the ship and torpedo which conducts the signal from the ship to

the torpedo where it appears across a capacitor and resistor network 31 which is connected between the torpedo end of wire 13 and a seawater ground. Together, dispenser housing 16a, 16b, wire coils 13a, 13b, wire midportion 18m, and the aforesaid seawater ground return networks in the ship and torpedo, form wire dispensing and communication circuit apparatus 32. Network 31 also forms the input of an amplifier 33. It is a characteristic that the attenuation loss across apparatus 32 increases during the torpedo run, causing the level of signal at amplifier 33 to vary. If desired amplifier 33 may be of the automatic volume control type having in combination therewith suitable circuitry for controlling its amplification in accordance with the level of input signal, and there may be provided an additional oscillator 34 at the shipboard station to provide a separate and distinct continuous signal to be fed to mixer 28, to be passed over the transmission line to operate the amplification control circuit, maintaining the amplifier output within desired limits. The output of amplifier 33 is passed to the input solenoid 35 of conventional resonant reed relay apparatus 36 for separating the resultant A.C. signal into its component frequency signals and converting them to a D.C. output. Apparatus 36 has a series of four frequency selective relays 38a, 38b, 38c, 38d. Each relay has a vibrating reed element magnetically coupled to the magnetic field of solenoid 35 and tuned to physically vibrate when a predetermined frequency component is present in the input to solenoid 35. By means of a suitable pulse forming network, including an R-C network, the vibration is converted to a D.C. output. Relays 38a, 38b, etc. are tuned to operate at frequencies corresponding to those of the series of oscillator 24a, 24b, etc., with the oscillator and the relay having the same suffix letter constituting a matched set for transmitting and receiving. When the oscillator of a set is keyed to provide a pulse signal its matching reed relay receives the signal and produces a D.C. output pulse. The frequencies allocated to the oscillator and reed relay sets are from a series of frequencies chosen to avoid cross interference by harmonics and other modulation products to permit simultaneous operation of the matched sets so that each matched set provides a separate and distinct frequency channel of communication. By way of illustration, satisfactory results may be obtained by allocation of frequencies from the series consisting of 289 c.p.s., 357 c.p.s., 234 c.p.s. and 189 c.p.s. as shown in the drawing. As will be apparent, additional matched sets of oscillators and reed relays may be employed to provide additional channels of communication to control other torpedo control functions such as the enabling of the warhead, illustration of which has been omitted in the interests of clarity.

In the torpedo there is provided an azimuth steering control channel responsive to the D.C. pulse signals produced at the output of frequency selective relays 38a and 38b, of any suitable form, but preferably as hereinafter described. The outputs of relay 38a and 38b are fed to first and second input solenoids 39a, 39b which actuate the ratchets of a combination electromagnet and ratchet mechanism 40a having a ratchet wheel which is rotated through a small angular step in either of opposite directions of rotation depending upon which of the input solenoids is energized. Torpedo 10 has a conventional gyro controlled synchro type steering servo 41a best shown in FIG. 3 comprising a gyro pickoff synchro generator 42, which provides an error signal when the torpedo deviates from a preset reference course and a synchro control transformer 44 which controls a rudder actuator 46 to maintain the torpedo on the reference course in response to the error signal. The ratchet wheel of mechanism 40a drives the rotor of a synchro differential generator 43a inserted in the servo between generator 42 and control transformer 44. In accordance with well known principles, rotation of the differential rotor modifies the electrical signal "seen" by the control transformer by an

amount corresponding to the magnitude of rotation. Accordingly, each step of angular rotation of mechanism 40a and in turn the rotor of the differential generator produces a simulated error signal and the control transformer then operates the rudder actuator to cause the torpedo to turn to correct this simulated error signal and maintains the torpedo on new course with gyro control. In other words, each step of angular rotation of mechanism 40a alters the gyroscopic controlled course by a small angular step. In similar manner, the depth steering servo 41b is of a synchro type responsive in operation to a suitable depth sensing device which provides an error signal in accordance with deviation from a reference depth, and the output of relays 38c, 38d are fed to a like electromagnet and ratchet mechanism 40b to effect incremental angular rotation in a differential generator 43b similarly inserted in the depth servo to alter the depth course steering in incremental steps of depth. Preferably both the azimuth course and the depth servo are of the type providing proportional steering control to permit stable maneuvering at high speeds.

If desired, transmission of a telemeter signal of the torpedo propeller revolution count from torpedo 10 to control station 12 may be achieved by provision of a low impedance D.C. source 50 in the shipboard D.C. seawater ground return for the wire 13, and a contactor 52 mechanically connected to the propeller shaft and arranged to short out a resistance in a D.C. seawater ground return for wire 13 in the torpedo. The D.C. source causes flow of a D.C. current through the circuit through the same wire conductor and seawater medium conducting path as used to communicate the A.C. signals. Every time contactor 52 shorts out the resistance there is a momentary rise in voltage in the shipboard station which operates a suitable counting and indicating device 54 in the remote station. This information is desirable for use in dead reckoning techniques to track the torpedo position, which in turn permits higher quality guidance control.

Also, provision may be made to stop the torpedo run from the control station by a "stop" switch 56 inserted in series in the shipboard D.C. seawater ground return of wire 13 and a "stop" relay 58 in the D.C. seawater ground return of wire 13 in the torpedo, relay 58 having its contacts connected to the propulsion motor control circuit. Opening of switch 56 interrupts the flow of D.C. current through relay 58 shutting down the propulsion motor. Relay 58 is also de-energized in event wire 13 breaks or develops substantial leakage and thereby provides a fail-safe shut down feature.

FIG. 4 shows apparatus for controlling a torpedo from a shipboard station differing from that of the device of FIG. 1 in that a conventional filter circuit type frequency selective network 60 is employed to separate the resultant A.C. signal, provided at the output of the wire dispensing and communication circuit apparatus 32', into its component signals. Apparatus 60 has a series of four filter circuit type narrow band pass amplifiers 62a, 62b, etc., matched to the oscillators in transmitter unit 22'. The output of each band pass amplifier is converted to a D.C. signal by suitable demodulators 64a, 64b, 64c, 64d. In accordance with generally known principles, the aforesaid filter circuit type apparatus is capable of operating at higher frequencies than the resonant reed relay apparatus of the device of FIG. 1.

FIG. 5 shows wire guided torpedo apparatus employing wire dispensing and communication circuit apparatus 32'' like that of the device of FIG. 1. One portion of the available transmission band pass through the apparatus 32'' is allocated as a communication channel for signals for controlling the torpedo from a shipboard station. Another portion is allocated as a communication channel for signals for telemetering torpedo performance data, including torpedo heading as measured by a suitable gyro device, torpedo depth as measured by a suitable pressure sensing

device, and torpedo revolution count. Control of the torpedo is achieved by apparatus of the type hereinbefore described including a control signal transmitter 22" having its output signals within the frequency range allocated for the communication of control signals and feeding its output to the shipboard end of apparatus 32" through a suitable band pass filter. The signals are communicated through apparatus 32" to the torpedo where they are fed to a suitable band pass amplifier and thence to a matching receiving unit 66, similar to receivers 36 or 60, capable of separating the control signals. Telemetering is achieved by a matched set consisting of a suitable telemetering transmitter 68 in the torpedo, capable of producing A.C. telemetering signals in accordance with the measured performance data, and a matching telemetering receiver 70 at the shipboard station capable of separating the telemetering signals, of any suitable type known in the art, both operating over the portion of the transmission band pass allocated for telemetering. The output of transmitter 68 is fed to the torpedo end of apparatus 32" through a suitable band pass filter. Apparatus 32" communicates the telemetering signals to its shipboard end where they are fed to receiver 70 through a suitable band pass amplifier. Knowledge of such torpedo performance data at the ship is desirable to permit accurate tracking of the torpedo by dead reckoning techniques, which information in turn is used in solving the guidance problem.

The wire dispensing and communication circuit apparatus 32, 32' and 32" of the devices of FIGS. 1, 4 and 5, respectively, has been found to be particularly efficient for A.C. signalling. The attenuation loss exhibited by this apparatus is lower than that of a double conductor line of the same weight and bulk per unit length. When apparatus 32 is employed with transmitting and receiving circuitry and over a distance equal to the maximum required torpedo range, a practical transmission band pass can be achieved extending through the frequency range required for so-called "audio frequency" signalling techniques, which extends from a nominal zero frequency through 20,000 c.p.s. The upper practicable band pass cut-off for multi-frequency channel signalling techniques as hereinbefore disclosed occurs at approximately 30,000 c.p.s. where the slope, of the characteristic curve of attenuation loss versus frequency, increases to a magnitude producing undesired non-linear distortions.

It will be apparent that in controlling a torpedo at distances up to maximum required torpedo range the number of coils 16 could sometimes decrease considerably during a single torpedo run. Thus the inductive impedance presented by the coils, which decreases with decrease in number of turns, could therefore vary considerably during the run. The seawater return portion of the transmission line formed by the uncoiled portion of the wire 18m that is immersed in the seawater medium has been found to exhibit a relative high distributed inductance per unit length, approaching the inductance exhibited per unit coil length of coils 18a, 18b. Such greater distributed inductance is desirable because it provides more nearly uniform inductive loading of the transmission line as the ratio of the length of wire in coils 18a, 18b to the length of uncoiled wire 18m changes during the torpedo run, thereby reducing the variation in attenuation experienced during a run. Minimizing the variation in attenuation during a run is particularly desired in the device of FIG. 5 where the frequency separation required between communication channels of opposite direction, and therefore the signal traffic handling capacity, is determined by the magnitude of such variation in attenuation. It is not fully understood why this relatively high distributed inductance occurs, but it is believed that it is in some way connected with the fact that the combination of a single wire and seawater conducting paths form a configuration somewhat analogous to that of a co-axial cable with the single wire representing the inner conduc-

tor, the insulation representing the dielectric separators, and the seawater medium representing the outer conductor. The order of magnitude of the increased distributive inductance may be best envisaged by the fact that the distributed inductance has been found to be approximately 10 times greater than that which would be exhibited by a co-axial cable with like inner conductor, a like dielectric separation but having a metallic outer conductor having a conductivity equivalent to the conductivity of seawater. This property, of a high distributed inductance, very materially contributes to maintaining variation in attenuation of the system within desired limits.

Flooding dispenser housing 16a, 16b as heretofore described have been found to substantially reduce the attenuation losses exhibited by the transmission line, and also obviates certain bothersome resonance effects. This margin of improved attenuation is especially significant in the device of FIG. 5 where it critically effects the frequency separation required between communication channels of opposite direction, and therefore the signal traffic handling capacity.

The apparatus shown in the drawings and above described are simple exemplary forms of construction by which the desired results and modifications thereof may be secured. For example, further segregation of communication channels may be obtained, such as by use of commutating techniques and the use of frequency modulation techniques.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In multi-channel telecommunication apparatus for communicating electrical signals between two stations consisting of a torpedo and a remote telecommunication station, the combination, comprising:
 - (a) two or more sets of matched signal generation and signal detection means employing a bandpass under 30,000 cycles per second, each set of matched means forming a separate communication channel and comprising a signal generator producing a distinctive signal disposed at one of said stations, and signal detector means responsive to said distinctive signal, only, disposed at the other station,
 - (b) the signal generators and signal detectors of the matching sets being coupled through a common signal transmission circuit comprising a first electrical conduction path through an insulated single conductor wire and a second electrical conduction path through the saline ocean water medium between the torpedo and the remote station,
 - (c) said insulated wire being of fixed length composed of a first portion initially carried by the torpedo and forming a coil which is progressively dispensed into the ocean medium between the torpedo and the remote station under movement of the torpedo, whereby a progressively lengthening uncoiled portion of wire is disposed in the ocean medium between said stations,
 - (d) said uncoiled portion of the wire and the water medium effectively forming a co-axial transmission line in which the ocean water medium surrounds the conductor of the wire and the insulation of the wire disposed between the ocean water and the conductor, said insulated conductor wire having an outer protective sheath of insulation and an intermediate sheath of insulation between the outer sheath and the conductor, said intermediate sheath being of substantial thickness and made of a material having a lower value of dielectric constant than the insulation material of the protective sheath to lower the shunt distributed capacity of the co-axial transmission line, whereby the ocean water medium surrounding the

wire cooperates with same to provide a co-axial transmission line configuration which exhibits substantial distributed inductance, to thereby compensate for variation of attenuation due to progressive uncoiling of the coiled portion of the wire,

(e) said first coiled portion of the wire carried by the torpedo in a first compartment flooded with said saline water medium, said first coiled portion forming a first multi-layer coil of annular shape having an axial aperture extending between its ends, said annular coil being supported in substantially spaced relation to the walls of the compartment, whereby the coil is substantially surrounded by and its axial aperture is filled with said saline water medium to obviate undesired gross non-linearities in the bandpass of the coupling circuit.

2. Apparatus in accordance with claim 1, wherein

(f) the outer protective sheath of insulation is made of nylon and the intermediate sheath of insulation is made of polyethylene.

3. Apparatus in accordance with claim 1,

(g) said first annular coil being of the type in which the wire end adapted for dispensing is disposed adjacent said axial aperture and may be unraveled therefrom in response to a nominal axial pulling force, and

(h) a wire dispensing tube having its receiving end disposed adjacent one end of the annular coil and aligned along its axis, and having its dispensing end projecting from the hull of the torpedo.

4. Apparatus in accordance with claim 1, wherein

(i) said signal generator and said signal detector means of each matched set comprises an oscillator having a predetermined frequency of oscillation and a frequency selective circuit tuned to said predetermined frequency, respectively.

5. Apparatus in accordance with claim 4, wherein

(j) the signal generator of a first matched set is disposed at one of said stations and the signal generator of a second set is disposed at the other station.

6. Apparatus in accordance with claim 1, wherein said remote station is also carried by a movable vehicle,

(k) said length of insulated wire being also composed of a second portion initially carried by the movable vehicle and forming a coil which is progressively dispensed into the ocean medium between the torpedo and the remote station under movement of the vehicle,

(l) said second coiled portion of the wire carried by the movable vehicle in a second compartment flooded with said saline water medium, said second coiled portion forming a second multi-layer coil of annular shape having an axial aperture extending between its ends, said annular coil being supported in substantially spaced relationship to the walls of the compartment.

7. In combination with a torpedo, multi-channel telecommunication apparatus, employing a predetermined bandpass under 30,000 cycles per second, for communicating electrical signals between the torpedo and a remote station, said multi-channel telecommunication apparatus being of a type normally provided with a radio-type signal transmission circuit having essentially fixed attenuation characteristics and having linearly operating characteristics over said bandpass, whereby the dynamic range for reliable operation of multi-channel apparatus is not exceeded, but said telecommunication apparatus having insufficient dynamic range for reliable operation in the presence of non-linear distortions in said bandpass, the improvements comprising;

(a) a wire line transmission circuit of the type which is progressively dispensed from a coil, said wire line inter-connecting the torpedo and the remote station in lieu of the radio-type signal transmission circuit,

said wire line transmission circuit comprising a fixed length of single conductor insulated wire-forming a first electrical conduction path between the torpedo and the remote station, said fixed length of wire initially forming a coil carried by the torpedo and which is progressively dispensed into the ocean medium between the torpedo and the remote station under movement of the torpedo,

(b) said wire line transmission circuit being adapted to form a second electrical conduction path through the saline ocean water medium between the torpedo and the remote station,

(c) said wire which is dispensed in the ocean medium and the water medium effectively forming a co-axial transmission line in which the ocean water medium surrounds the conductor and the insulation is disposed between the ocean water and the conductor, said insulator comprising a sheath of insulation including a substantial thickness of low dielectric insulation material, the construction of the sheath of insulation being such as to lower the shunt distributed capacity of the co-axial transmission line, whereby the ocean water medium surrounding the wire cooperates with same to provide a co-axial transmission line configuration which exhibits substantial distributed inductance, to thereby compensate for variation of attenuation due to progressive uncoiling of said coiled portion of the wire and thereby minimize distortion of bandpass,

(d) means carried by the torpedo for flooding said coil carried by the torpedo to obviate undesired resonance-like non-linearities of bandpass exhibited by the coil.

8. Apparatus in accordance with claim 7, wherein

(e) the value of dielectric constant of the low dielectric material in the insulation sheath is under four.

9. Dispensable wire apparatus for providing an electrical conduction path between two stations consisting of a torpedo and a torpedo remote telecommunication station on a maneuverable vehicle, comprising,

(a) a single continuous insulated electric conductor having a first portion formed into a coil and carried by the torpedo, a second portion formed into a coil and carried by the maneuverable vehicle, and a mid-portion joining said first and second portions disposed in the water between the torpedo and the maneuverable vehicle,

(b) said coiled portions forming a multi-layer coil of annular shape having an axial core aperture extending therethrough and of the type in which the end of the coil appears at innermost layer adjacent the axial aperture joined to the mid-portion and may be unraveled therefrom in response to a nominal axial pulling force,

(c) whereby the wire is dispensed from the respective coils into the water medium under movement of either the torpedo or of the vehicle relative to the midportion of the wire with said midportion remaining essentially stationary with reference to the water medium and experiencing no more than nominal tension forces therein.

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