Feb. 10, 1970 H. A. ENGLE 3,495,209

UNDERWATER COMMUNICATIONS SYSTEM

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FIG. 1.

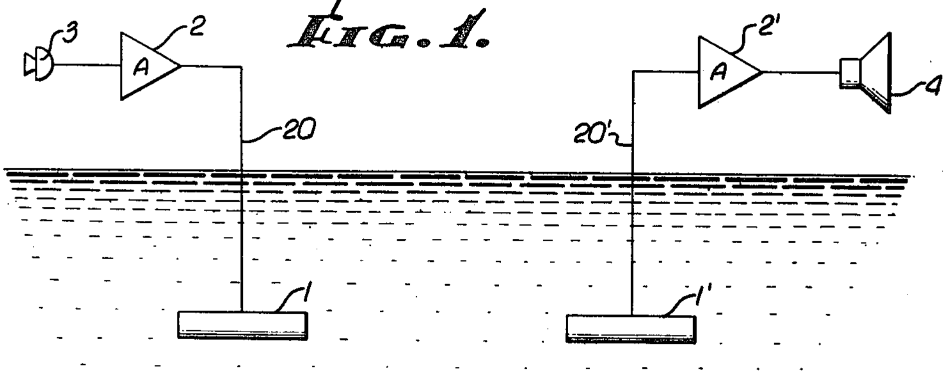


FIG. 2.

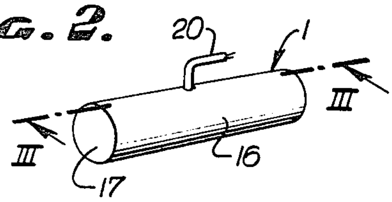


FIG. 3.

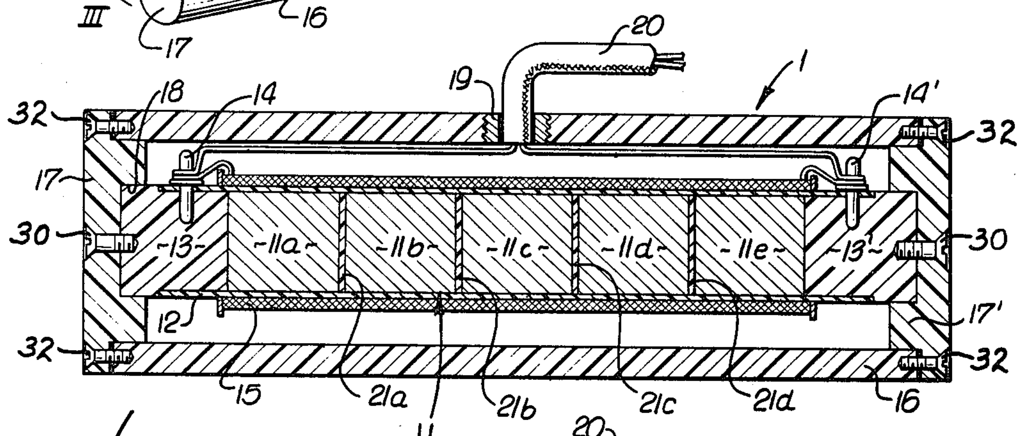
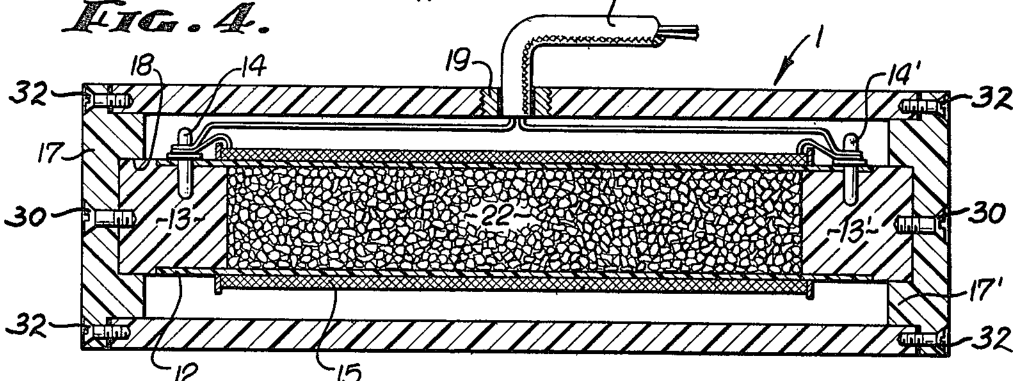


FIG. 4.



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UNDERWATER COMMUNICATIONS SYSTEM

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Continuation-in-part of application Ser. No. 555,516, June 6, 1966. This application Nov. 13, 1968, Ser. No. 775,450

Int. Cl. H04b *13/00, 5/00;* **H01q** *1/04*

U.S. Cl. 340—4 **5 Claims**

ABSTRACT OF THE DISCLOSURE

A directional underwater communications system for transmitting and receiving intelligence by the use of a magnetic field of varying audio frequencies, the system being operable through aqueous media without the use of radio, supersonic and carrier frequencies. A transmitting coil is wound on a non-magnetic cylindrical form circumjacent an elongated ferrite core which has multiple ferrite portions separated from each other by non-magnetic material, or is comprised of small-grained ferrite particles retained with the cylindrical form. The transmitting coil provides a magnetic field containing frequencies within the audio spectrum. A remote receiving element including a coil similar to the transmitting coil and having a similar ferrite core with its axis aligned with the axis of the transmitting coil, responds to the transmitted magnetic field and an amplifier connected to the receiving coil increases the amplitude of the received magnetic field. The output of the receiving amplifier is connected to a transducer which converts the magnetic field to intelligence within the audio spectrum corresponding to the frequencies being transmitted.

This application is a continuation-in-part of my copending application Ser. No. 555,516 filed June 6, 1966 and now abandoned.

Prior means for transmitting and receiving intelligence in the form of sounds or frequencies within the normal audio frequency range, which did not require wire connections between the transmitting and receiving apparatus, necessitated the use of auxiliary frequencies such as radio frequencies, generally referred to as carrier frequencies which were modulated by the audio frequencies. It is well known that radio or carrier signals are subject to many forms of distortion, blocking and other forms of interference, whether accidental or deliberate, since these types of signals when disseminated are readily located and identified by direction-finding means. Such high frequency signals or waves cannot be readily transmitted within bodies of water, are deflected, distorted and absorbed by buildings, shielding, etc., cannot be used for transmission or secret communication and are easily intercepted. The system of the present invention distinguishes from these prior devices and systems in that it is extremely simple, exhibits directional characteristics and operates solely with audio frequencies as normally defined within the range of 20 to 20,000 cycles per second, although this range may be somewhat widened at the lower as well as the upper end.

The equipment is lightweight, extremely compact and portable. It operates extremely well in an aqueous medium, although operation in gaseous, and between gaseous and aqueous media is also possible. Gaseous media as used herein may include the atmosphere. It is at most only slightly affected by interposed sheets of metal or other shielding arrangements. The system and devices of the present invention have great utility in communicating with submarines, in maintaining contact and following

craft equipped with the system of the present invention and in maintaining communication between any two objects, persons, vehicles or ships irrespective of the medium in which they exist or are moving.

In its simplest embodiment, the directional system for transmitting and receiving intelligence at audio frequencies comprises a transmitting element composed of an elongated ferrite core provided with an encircling coil winding, the coil winding being associated with a source of electrical current oscillations within a range of audio frequencies, such as for example the current produced by a transducer, such as a microphone associated with an amplifier. The system also includes a remote receiving element including an elongated ferrite core provided with an encircling coil winding, said core and coil being in axial alignment with the transmitting element. The transducer means associated with the coil of the receiving element is used for converting electrical oscillations, radiated by the transmitting element in the form of a magnetic field comprising a range of audio frequencies, into audible sound as through a speaker. As previously indicated, the system is capable of being used over long distances and through various media and is directional. Communication distances may be increased by increasing the level of the radiated magnetic field or by increasing the sensitivity of the receiving amplifier. Details of construction and other characteristics and conditions which produce optimum operation will be described hereinafter. At all events, the system does not employ radio, supersonic or carrier frequencies nor modulated carrier signals, and is therefore free from the disadvantages incident to high frequencies used in connection therewith.

It is therefore an object of my invention to provide a system for transmitting and receiving intelligence in the form of audio frequencies comprising a varying magnetic field, to provide a communication system that is directional and to provide transmission and reception of audio intelligence that is not subject to interference or jamming, whether deliberate or accidental.

A further object of the present invention is to disclose and provide transmitting and receiving elements composed essentially of an elongated core containing ferrite material, which is composed of segmentary portions. Each portion is separated from others by non-magnetic separator means or, alternatively, the core may consist of granular particles retained within a non-magnetic cylindrical container, each core being provided with an encircling coil winding associated with a transducer.

Other objects and advantages will become apparent from the following detailed description. For purposes of illustration and explanation, reference will be had to the appended drawings in which:

FIG. 1 is a diagrammatic representation of a system including transmitting and receiving elements suspended in a body of water, such as ocean water;

FIG. 2 is a perspective view of a typical transmitting element or receiving element;

FIG. 3 is a longitudinal sectional view taken along plane III—III of FIG. 2 showing details of one form of the core in accordance with the invention; and

FIG. 4 is a longitudinal sectional view taken along plane III—III of FIG. 2 showing details of another form of the core in accordance with the invention.

FIG. 1 illustrates a transmitting element **1** and a remotely located receiving element **1'**, these elements being shown suspended in a body of water by cables **20** and **20'**. The respective amplifiers **2** and **2'** are shown positioned above water level (as aboard ship) while the transmitting and receiving elements are suspended at any desired depth, but it is to be understood that the sound transducing means such as speakers, microphones or recording devices may be included with the amplifiers and all these components may be located on submerged vessels or may be used above the water surface or above ground level.

Amplifiers **2** and **2'** are generally solid state amplifiers containing their own power sources but may also be vacuum tube amplifiers, The transmitting amplifier **2** may, for instance, be combined with microphone **3** or some other source of audio frequency intelligence in a single unitary structure. The output of microphone **3** is connected to the input of amplifier **2**. Likewise, receiving amplifier **2'** may, for instance, be combined with speaker **4** or some suitable reproducing transducer in a single unitary structure. The output of amplifier **2** is connected by means of cable **20** to the coil of transmitting element **1**. The coil of the remotely located receiving element **1'** is connected by cable **20'** to the input of amplifier **2'**, whose output is connected to speaker **4**. It is to be understood that the output of amplifier **2'** may be associated with a tape recorder instead of the speaker **4**.

The transmitting and receiving elements may be of similar structure and FIG. 2 illustrates the external configuration of transmitting element such as **1**. FIG. 3 illustrates the transmitting element which contains an elongated ferrite core **11** comprised of ferrite core portions of **11***a*, **11***b*, **11***c*, **11***d* and **11***e*. Core portion **11***a* is separated from core portion **11***b* by means of non-magnetic member **21***a*, core portion **11***b* is separated from core portion **11***c* by means of non-magnetic member **21***b*. Core portion **11***c* is separated from core portion **11***d* by means of non-magnetic member **21***c*. Core portion **11***d* is separated from core portion **11***e* by means of non-magnetic member **21***d*. The non-magnetic members may be of a hard plastic or a metal which has no magnetic properties. The ferrite core may also be comprised of finely divided particles, such as granular particles of the material used in ferrite core **11** and is shown in FIG. 4 at **22**. The transmitting element contains an elongated cylindrical ferrite core such as core **11** or core **22** within a non-magnetic and preferably non-metallic tube **12**, made of any desired hard material such as nylon, for example. Ends of tube **12** extend beyond the ends of cores **11** or **22**, and plugs **13** and **13'** (made of molded nylon or other suitable dielectric) provided with inner reduced end portions seal the ends of the tube and hold the core in position within the tube. These plugs are particularly useful to retain the granular particles of core **22**. Terminal posts **14** and **14'** may extend through the end portions of the tube **12** into the plugs and lock the plugs into position.

A coil winding **15** is carried by the exterior of tube **12**; usually three or four ordinary lap wound layers of insulated copper wire are found to be adequate. Ends of the coil are preferably soldered to terminal posts **14** and **14'**. The ends of transmission cable **20** are similarly soldered to posts **14** and **14'**.

Cores **11** or **22** and corresponding coil **15** are enclosed in a housing comprising outer tube **16** and end caps **17** and **17'**, preferably of a reinforced plastic composition. Molded nylon having a modulus of elasticity of 0.03 to 0.045 p.s.i. has been used for plugs **13** and end caps **17**. The end caps are firmly attached to the housing tube by suitable attachment means such as screws **30**. The end caps are preferably recessed, as at **18**, to receive the outer ends of the plugs and are also retained in place and sealed by attachment members **32**. A water and pressure-tight fitting **19** is provided for cable **20**. The outer housing tube may also carry additional fittings for suitably suspending and controlling the angular or directional position of the element when suspended in the ocean or other body of water or for positioning its axis accurately when on land.

Optimum operation of the system of the present invention is attained by observing the following:

(1) The use of an elongated ferrite core formed by cylindrically-shaped, segmentary portions of ferrite material separated by non-magnetic separator means or by using finely divided particles of the ferrite material.

(2) The coil wound around each ferrite core is of sufficient number of turns so that its mid-frequency impedance matches the impedance of the communication medium such as water or air. Likewise, the amplifier is so designed as to match the impedance of the coil. This impedance match provides optimum power transfer between the amplifier and the element, and between the element and the communication medium.

(3) Both receiver and transmitter cores and their coils should be in sealed insulated housings for underwater use; the cylindrical exterior of the receiving element is preferably provided with non-magnetic shielding. The transmission lines **20** and **20'** connecting the transmitting and receiving elements with their respective amplifiers should be shielded.

In one exemplary form of the system of this invention, each of the transmitting and receiving elements included a ferrite core 22.56" long and 0.625" in diameter. This core material was obtained from Indiana General Corp. of Keansburg, N.J. (identified by Code 6F504Q1). A polyamid dielectric (nylon) tube with a wall thickness of 0.040" was slipped over the core. Four layers or laps of #18 insulated copper wire were wound around the tube, forming 1522 turns. The cores utilized were of the types hereinabove described and illustrated in FIG. 3 at **11**, and in FIG. 4 at **22**. In the case of core **22** the core material **11** was broken up into very small finely divided particles approximately 200 mesh, although it will be understood that particles differing fairly widely from this exemplary size may be used.

Tests of the above described transmitting and receiving devices showed their ability to transmit and receive signals at source frequencies of from about 60 c.p.s. to about 15,000 c.p.s. However, it is pointed out that even wider ranges of frequencies can be used, such as from 20 c.p.s. to 20,000 c.p.s. For test purposes, a Hewlett-Packard audio oscillator connected to amplifier **2** input was used in conjunction with oscilloscopes at the outputs of amplifiers **2** and **2'**. High impedance voltmeters were connected in parallel with the oscilloscopes. The oscilloscopes were used to monitor the waveforms and virtually to assure that no distortion was present in the transmitter and receiver devices. The voltmeters were used to measure the level of the signal being transmitted and received. The tests were made using air as a communication medium and also water as a communication medium by suspending elements **1** and **1'** in water.

It is notable that transmission and reception were not impaired by interposing grounded metal plates between the separated transmitting and receiving elements. When the transmitting and receiving elements were suspended in a body of water, reception was actually improved. It has been observed that good results are obtained when the receiving element is provided with a non-magnetic metal shield. However both transmitting and receiving elements may be retained in a non-magnetic sealed container having water and pressure-proof cable connections for use in bodies of water.

The devices of the present invention have been used in ranges up to 400 feet by increasing the transmitting power, the range may be very substantially increased. When tested at 60 feet, with intervening ferromagnetic material interposed between axially aligned receiving and transmitting elements, it has been found that reception is virtually unaffected by the intervening material. However, axial alignment of the elements is critical. It has been found that reception is virtually lost in the event that the difference in alignment exceeds about 5°. With the transmitter or receiver element under water and the other element out of the water, or with one in an air raid shelter covered with a ⅛" lead shield and the other in water or in air, excellent results have been obtained indicating that transmission of intelligence with the system of the present invention may be through virtually any medium.

Highly directional characteristics were established in the short-range tests wherein the longitudinal axes of elements **1** and **1'** were aligned and the elements were spaced 60 feet apart. In the aligned condition with an output voltage across amplifier **2'** of 3 volts, and without changing the output of amplifier **2**, the axis of element **1'** was angularly displaced 5°, and it was observed that the output voltage of amplifier **2'** was decreased to 0.375 volt. As will be understood, this constitutes an 87.5% drop from the original reading of 3 volts.

It may accordingly be concluded that the core structures in accordance with the present invention contributed to the concentration of magnetic flux at the axes of the cores. It thus appears that the amplitudes of the magnetic fields transmitted and received tend to be proportional to the axial alignment of the transmitting and receiving elements, it being understood that the word proportional is not limited to a linear relationship between the decrease of the magnetic fields and the angular displacement between the axes of the elements.

Other tests wherein either element **1** or **1'** was encased in an iron pipe while being connected to its respective amplifier and with a signal applied to the input of amplifier **2**, the output voltmeter connected across the output of amplifier **2'** was reduced to zero, thereby tending to establish that the field generated by the transmitting device as radiated from the transmitting element was basically magnetic. It is realized that all fields have electric as well as magnetic components; however, the magnitude of the electric component in accordance with the present invention is so small that for all intents and purposes it may be stated that the field is basically magnetic.

This clearly demonstrates the unusual character of the system and the phenomena obtained in accordance with the system, in that the system is highly directional, has very good range, employs low power, is incapable of being intercepted or distorted by obstructions, shielding and the like; and, surprisingly, the system operates with even greater effectiveness under water than in air.

The system of the present invention has a large number of uses. It permits the transmission of intelligence in the audio frequency range by simply speaking into a transmitter and having the receiver hear the voice virtually without distortion, and with knowledge that the information is being received without being intercepted by a third party. The compact and simple character of the elements and their relatively light weight and low power consumption, permit the system to be employed on vehicles, submarines, boats, military outposts, control centers, in industry, in tracking a vehicle, individual or device equipped with a transmitter, and for many other purposes.

I claim:

1. An underwater communications system for transmitting and receiving audio frequency intelligence utilizing radiated magnetic fields varying in accordance with the audio frequency intelligence, comprising:
   a transmitting means, comprising an audio frequency source, a first amplifying means fed by said source and a first coil connected to the output of said first amplifying means and wound about a first non-magnetic elongated hollow form containing segmentary portions of ferrite material for radiating within the water medium magnetic fields corresponding to the frequencies of the source; and
   a receiving means, comprising a second coil wound about a second non-magnetic elongated hollow form containing segmentary portions of ferrite material, said second coil being responsive to said magnetic fields, and a second amplifying means fed by said second coil for amplifying the audio frequencies of said magnetic fields and for energizing a transducer connected to the output of said second amplifying means in accordance with the frequencies and variations of the transmitted audio frequency intelligence.

2. The apparatus as set forth in claim **1**, wherein the segmentary portions of ferrite material constitute a plural member of cylindrically-shaped ferrite portions, and including non-magnetic separator members between successive portions.

3. The apparatus as set forth in claim **1**, wherein the segmentary portions of ferrite material constitute finely divided particles of ferrite material.

4. The apparatus as set forth in claim **1**, wherein the amplitude of a magnetic field transmitted and received is proportional to the axial alignment of the first coil with respect to the second coil, thereby providing directional communications characteristics between the transmitting and receiving means.

5. The apparatus as set forth in claim **1**, **2**, **3** or **4**, wherein the first and second hollow forms are encased in a waterproof and pressureproof case made of non-magnetic material and provided with water and pressureproof cable connection means.

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RICHARD A. FARLEY, Primary Examiner

U.S. Cl. X.R.

179—82; 325—28; 343—719, 787