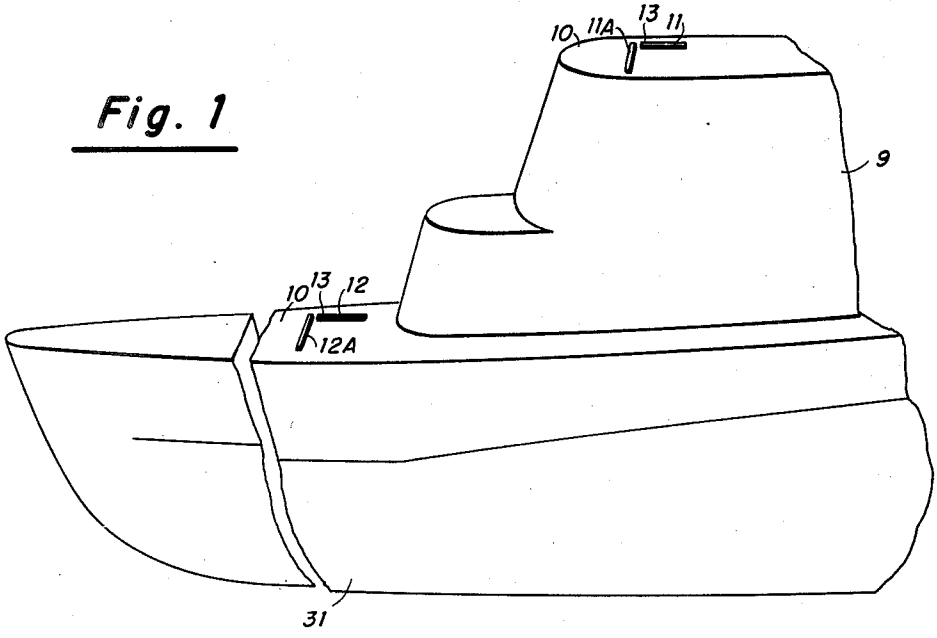
June 24, 1958 J. D. BROWDER 2,840,700

ELECTRODE VERY LOW FREQUENCY RADIO RECEIVING ANTENNA FOR SUBMARINES

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Fig. 1



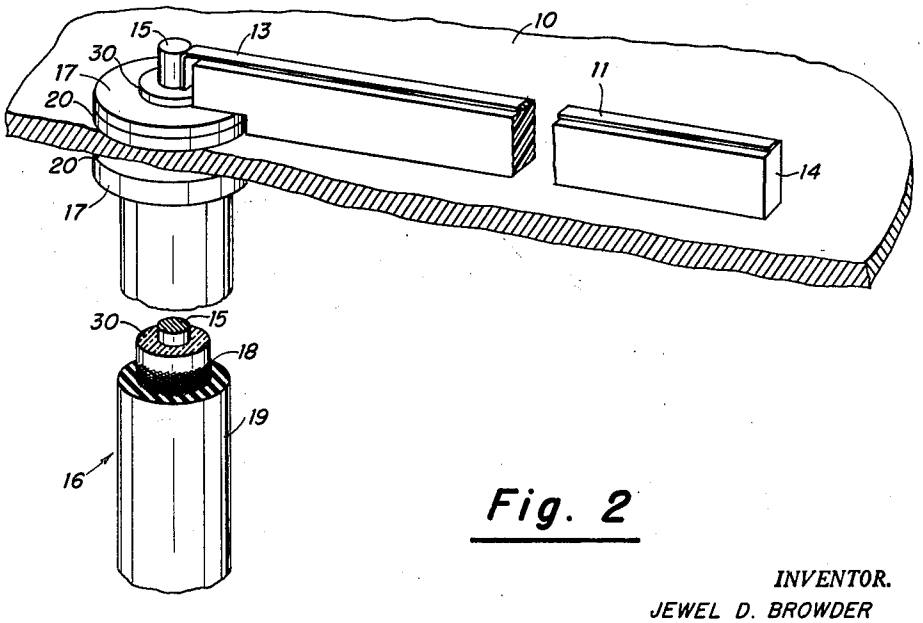


Fig. 2

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Fig. 4

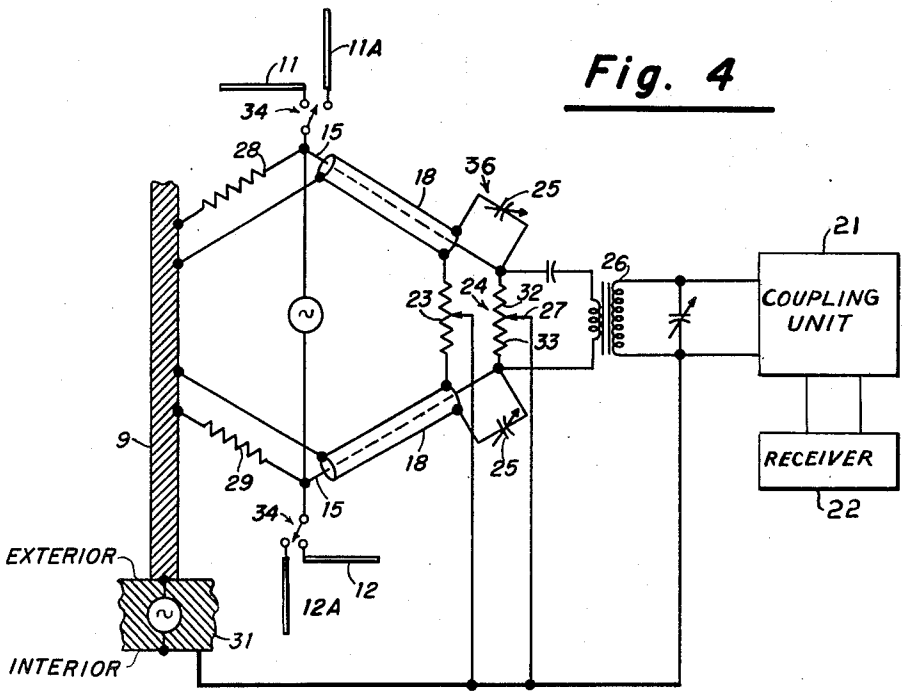
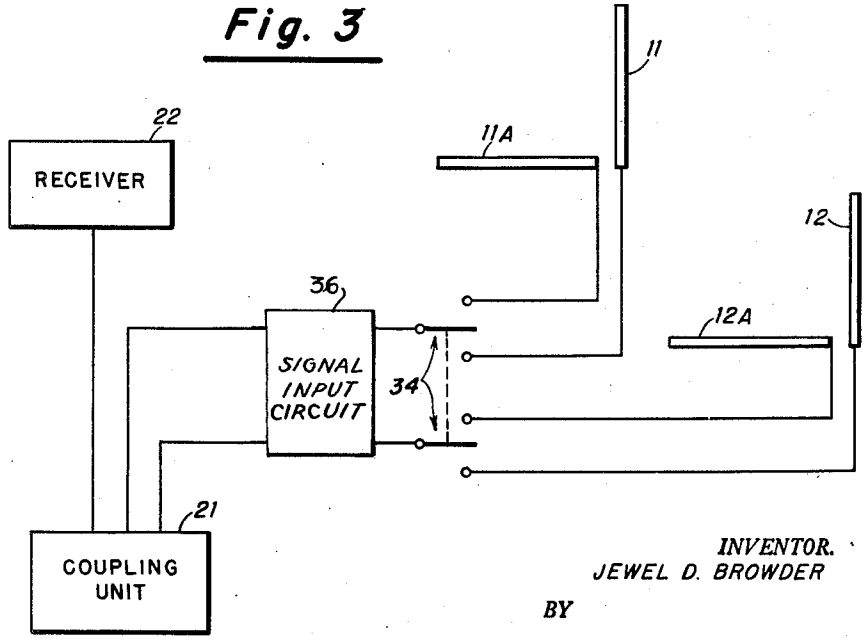


Fig. 3



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ELECTRODE VERY LOW FREQUENCY RADIO RECEIVING ANTENNA FOR SUBMARINES

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Application June 30, 1954, Serial No. 440,569

15 Claims. (Cl. 250—20)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to an electrode V. L. F. (very low frequency) radio receiving antenna for submarines and more particularly to an electrode radio receiving antenna for submarines which abstracts signal energy from the electric field of passing radio waves instead of the conventional method of abstracting energy from the magnetic field and in which at least one of the two requisite electrodes is permanently secured to the top surface of the fairwater of the submarine, the other electrode being a second permanently secured one or, in the alternative, may be the existing retractable whip antenna.

Heretofore fixed or rotatable loop receiving antennae have been employed. While the electrode radio receiving antenna of the present invention and the conventional loop receiving antenna perform equally as well with respect to signal-to-noise ratio, figure-of-eight directivity pattern and signal strength versus submarine depth, the electrode system of the present invention excels with respect to weight, simplicity, adaptability, dependability, installation costs, and maintenance costs.

The present invention employs in a submarine radio receiving system two electrodes, one of which may be the existing whip antenna, electrically connected in series to the input circuit of a radio receiver. The radio signals are received in the form of minute currents driven through the receiver's input circuit by the potential difference existing between the electrodes. Reception when the submarine is surfaced is a result of the distributed capacitance between the lower electrode and the surface of the fairwater whereas, when submerged the electrode receiving system operates by virtue of the horizontal electric field which produces a useful radio-signal potential difference between the two electrodes spaced a few feet apart.

The upper electrode may consist of the existing submarine retractable whip antenna or a long narrow metal strap type electrode mounted in an insulating support secured to the top surface of the fairwater. The former has the advantage that it may be extended upward toward the sea surface and thereby effect a higher received signal level, permitting reception at deeper submergence depths. Since the whip antenna cannot normally perform its usual functions when the base of the whip does not clear the surface of the sea, the whip antenna makes an effective upper electrode for the electrode receiving system during submergence when it otherwise is not in use. On the other hand, the latter type of upper electrode enables the electrode receiving system to be independent of the whip, and thus free the whip for preforming its normal functions at all times while the submarine is submerged at periscope depths. In the second arrangement the whip antenna can additionally be used when additional signal strength is necessary.

An object of the present invention is the provision of an improved system of receiving V. L. F. radio signals on board a submarine which is simple, light-weight, reliable, and economical.

Another object of the present invention is the provision of a submarine radio receiving antenna comparable to conventional loop antennae in signal-to-noise ratio, figure-of-eight directivity pattern and signal strength versus submarine depth characteristics.

Another object is the provision of a receiving antenna system which excels known systems with respect to weight, simplicity, adaptability, dependability, installation and maintenance costs.

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 when considered in connection with the accompanying drawings wherein:

Fig. 1 is a pictorial view showing the relationship of the electrodes on the fairwater and deck of the submarine;

Fig. 2 is a pictorial view of one of the electrodes mounted to the fairwater top;

Fig. 3 is a block diagram of the coupling unit and its interconnections; and

Fig. 4 is a schematic diagram showing the noise reduction circuit.

It has been shown that the total energy of a V. L. F. radio wave is equally divided between the electric and magnetic fields of the wave, both when the wave is propagating in space above the sea surface and within the sea water itself. In space above the sea surface where the direction of wave propagation is parallel with the earth's surface, the electric field is polarized almost vertically and the magnetic field horizontally at right angles with the direction of wave propagation. However, in sea water the direction of wave propagation is downward toward the earth's center and both the electric and magnetic fields are polarized almost horizontally or parallel with the earth's surface but displaced by 90 degrees in the horizontal plane, with the electric field parallel with the direction of wave propagation above the sea surface. Thus, in sea water the electrode receiving system of the present invention operates by virtue of the horizontal electric field which produces a useful radio signal potential difference between two electrodes separated by a few feet. When these electrodes are electrically joined together with insulated conductors which connect the input circuit of a radio receiver in series with the electrodes, radio signals are received in the form of minute currents driven through the receiver's input circuit by the potential difference existing between the electrodes.

The highest level of signal energy is just below the surface of the sea and as the radio wave propagates downwardly, it is attenuated in db per meter at the rate of $0.034\sqrt{f}$, where f is depth in feet, which amounts to approximately 1.25 db per foot for a 20 kc. wave. This means that a potential difference exists between two electrodes separated by a small distance in a vertical plane. A potential difference also exists between submerged electrodes located in a horizontal plane and separated by a few feet by virtue of the phase difference of the sinusoidally varying field between the two electrodes. Thus signals can be received from two electrodes located either in a vertical plane, horizontal plane, or any intermediate plane, the latter planes obviously having horizontal and vertical components of electrode displacements.

Through experimentation it was found that as one of the two electrodes is lengthened and oriented more or less parallel with the electric field of the radio waves to be received, the energy level of received signals is greatly increased. Referring now to the drawings, wherein like

reference characters designate like or corresponding parts throughout the several views, there is shown in Fig. 1 the preferred positions of arrangement of the upper electrodes **11** and **11A** mounted on the fairwater surface **10** and lower electrodes **12** and **12A** mounted on the main deck **10**. Because of the directivity pattern being a figure eight configuration, two sets of upper and lower electrodes, **11**, **11A**, **12**, and **12A**, are placed at right angles to each other with a pair of single pole double throw switching mechanism **34** conveniently placed such that the operator may easily switch from one set to the other in order to effect an omnidirectional reception pattern. Electrodes **11** and **12** will be hereinafter described in connection with the electrode receiving system, although it is obvious that electrodes **11A** and **12A** are similarly constructed and utilized. Due consideration must be given to the signal level, noise effects, and directivity pattern, influenced by such salient factors as impedance matching of the electrode and receiver input circuits, the most effective type of wiring of conductors through the pressure hull, and analyzing the various kinds of noise disturbances and effecting their maximum reduction. Corresponding ends of upper electrode **11** and lower electrode **12** are joined to the signal input circuit of the receiver, as illustrated by ends **13** which are the forward ends as shown in Fig. 1. These connections however may be reversed or even staggered without seriously affecting the performance of the electrode antenna. All four electrodes are more or less identical in construction.

As best shown in Fig. 2, the upper electrode **11**, preferably of stainless steel or other corrosion resistant material, is flush mounted on a linenized Micarta base **14**, insulating it from the fairwater top surface. The upper electrode **11** and its base **14** weigh approximately 15 pounds as compared to the approximate weight of one ton for a conventional loop receiving antenna including its retractable mechanism. End **13** of upper electrode **11** is joined to connecting coaxial cable **16** which protrudes through a brass bushing **17** mounted through a hole in the fairwater top surface **10**. The outer covering of coaxial cable **16** comprises a flexible copper shield **18** insulated from conductor **15** by insulation **30** and covered by external insulating jacket **19**. Bushing **17** comprises two threaded metallic members, such as brass, secured by use of shock-absorbing washers **20**. At bushing **17** the shield **18** is grounded to the metal of fairwater **10**. Electrical connection is made between the copper conductor **15** of coaxial cable **16** and the end **13** of electrode **11** bent at right angles to its axis. This connection is given a heavy coating of Glyptal or other waterproof compound to prevent corrosion.

Coupling unit **21**, shown in block diagram in Fig. 3, is for the purpose of providing an impedance match with electrodes **11** and **12**, signal input circuit **36**, and the antenna input circuit of conventional types of V. L. F. receivers **22**. To do this without losing signal strength, a vacuum tube amplifier may be used having a tuned input over the V. L. F. band. Power for the amplifier may be gotten from the power supply of the receiver **22** which is equipped with filters in the A. C. power lines which reduce additional noise from the power system.

Noise is a major problem in the practical operation of both the electrode receiving system of this invention and the conventional loop antenna receiving system. Noise disturbances fall into three major classifications, those that get into the receiver via the A. C. power system, those due to potential differences between the interior and exterior surfaces of the submarine hull, and those due to atmospherics and the submarine's underwater electrical potential. The first type has been generally eliminated or at least greatly reduced in amplitude by use of adequate filters in the power input leads of the receiver power supply.

Noise disturbances of the second type originate in other electrical equipments aboard the sub and are not only impressed on the power lines like those of the first type but also they produce potential differences between the interior and exterior surfaces of the hull as indicated diagrammatically by the generator in Fig. 4. Voltage and current waves thus propagate along the interior and exterior surfaces of the pressure hull. These are of little consequence in the conventional loop antenna receiving system as the signal input of this system is balanced to ground (hull). However, they present a problem which must be met in practicing the present invention.

In the electrode receiving system of the present invention the signal input circuit **36** must also be balanced to ground, which is effected by the potentiometer **24**, Fig. 4, connected in shunt with the signal input transformer **26**. The potentiometer **24** with its slide **27** comprises a portion of a balanced bridge, the remaining portions being established upon submergence of the submarine. In Fig. 4 is shown the equivalent circuit of the balanced bridge, where **28** and **29** represent the impedances between the upper electrode **11** and hull **31** and between the lower electrode **12** and hull **31**, respectively. These are the impedances of the sea water between the electrodes and hull, having magnitudes in the order of 1 to 3 ohms, while those of the other arms of the bridge, **32** and **33** of potentiometer **24**, are in the order of 1,000 ohms each. The balance effected by proper placement of the slide is not critical over the V. L. F. band and the bridge may be out of exact balance either way before the resistive components of the noise disturbances of the second type are audible. The capacitive components of the noise currents in noise of the second type, while not so great as the resistive components, are also damped out. Without the cable shields **18** a capacitance exists between the sea water and the conductor **15**. Change in speed and other conditions constantly change the amount of capacitance, causing noise disturbances in the receiver. By the use of shields **18**, this capacitance can be controlled. As shown in Fig. 4 these shields are grounded to the exterior surface of the hull **31** and are connected together at their inner ends by a variable potentiometer **23** whose slide wire is grounded to the interior of the hull. Since the coaxial cables are of unequal lengths, their capacitances between shield and inner conductor must be equalized or balanced. This is done by connecting variable condensers **25** between the conductors **15** and shields **18** of each cable **16** coupling unit **21**, shown in block diagram, couples the output of transformer **26** with the input of receiver **22**.

The third type of noise disturbances, i. e., those due to atmospherics and the submarine's underwater electrical potential (hereinafter referred to as UEP), are the most difficult to eliminate since they enter the receiver in the same manner as signals enter, i. e., by virtue of the potential difference between the electrodes or induced potentials on the conventional loop receiving antenna. This type of noise disturbance is divided into two subgroups, namely, atmospheric or static, and water noise or noise due to variations caused by water turbulence which, in turn, is governed by the motion of the submarine. These noises usually become barely audible in both the electrode and loop antenna systems at relatively low speeds of a submerged submarine. While the elimination of this type of noise is not found in the apparatus of the present invention, it is desired to point out that the electrode receiving system of the present invention is able to cope with the situation with ability equal to that of conventional loop systems.

While the electrode system has been described as utilizing two upper electrodes and two lower electrodes, each at right angles to the other, an obvious modification would be to employ rotatable antennas. A further modification would be the utilization of the submarine's whip antenna as the upper electrode or used together with the upper electrode for greater signal reception.

Both lower electrodes **12** and **12A** are flush mounted

with deck surface 10 so as to offer little or no obstruction to normal traffic on the deck. To further clear the deck electrode 12A which functions electrically with upper electrode 11A may be installed on the side apron of the deck superstructure, below the elevation of deck surface 10 but parallel to upper electrode 11A. To completely clear the deck another alternative is to combine both lower electrodes into a single electrode of smaller physical dimensions, mounted on the side apron below the deck surface and with the upper electrodes only so connected with one single pole double throw switch 34 that the lower combined electrode serves as a common electrode with each of the upper electrodes 11 ad 11A. This alternative should yield a slightly reduced received signal strength but still retain the omnidirectional pattern.

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. Apparatus for receiving very-low-frequency signals from the electric field of passing radio waves comprising a first upper electrode, a first lower electrode, a second upper electrode substantially at right angles to said first electrode, and a second lower electrode substantially at right angles to said first lower electrode, an input circuit connecting one upper and one lower electrode to a receiver, and switching means for alternately connecting the first upper and lower electrodes and second upper and lower electrodes to said input circuit.

2. Apparatus for receiving very-low-frequency signals from the electric field of passing radio waves comprising a first long narrow upper electrode; a first lower electrode, a second long narrow upper electrode substantially at right angles to said first electrode, both said upper electrodes secured to the fair-water surface of a submarine, and a second lower electrode substantially at right angles to said first lower electrode, both said lower electrodes secured to the surface of the main deck of said submarine, an input circuit connecting one upper and one lower electrode to a receiver, and switching means for alternately connecting the first upper and lower electrodes and second upper and lower electrodes to said input circuit.

3. Apparatus for receiving very-low-frequency signals from the electric field of passing radio waves comprising a first upper electrode, a first lower electrode, a second upper electrode substantially at right angles to said first electrode, and a second lower electrode substantially at right angles to said first lower electrode, said first upper electrode placed substantially parallel to and spaced above said first lower electrode, said second upper electrode placed substantially parallel to and spaced above said second lower electrode, an input circuit connecting one upper and one lower electrode to a receiver, and switching means for alternately connecting the first upper and lower electrodes and second upper and lower electrodes to said input circuit.

4. Apparatus for receiving very-low-frequency signals from the electric field of passing radio waves comprising a first upper electrode, a first lower electrode, a second upper electrode substantially at right angles to said first electrode, and a second lower electrode substantially at right angles to said first lower electrode, said electrodes being mounted on the outer surface of the hull of a vessel, a receiver, an input circuit connected to said receiver, and switching means for alternately connecting the first upper and lower electrodes and second upper and lower electrodes to said circuit, said circuit comprising a plurality of adjustable impedance means having connection to the inner surface of the hull of said vessel for reducing noise voltage between said outer and inner surfaces.

5. Apparatus as in claim 4 wherein said impedance means comprises first and second impedance branches connected in parallel.

6. Apparatus as in claim 5 wherein said first branch comprises potentiometer means having a slide connected to said inner surface.

7. Apparatus as in claim 5 wherein said second branch comprises adjustable condenser means.

8. Apparatus as in claim 7 wherein said second branch further comprises potentiometer means connected in series with said condenser means, said potentiometer means having a slide connected to said inner surface.

9. Apparatus as in claim 5 wherein said second branch comprises conductors connected to said electrodes, said conductors having insulation and shields thereover, said shields being connected to said outer surface, a plurality of adjustable condenser means connected to each of said shields and one of said conductors, and potentiometer means connected to said shields and having a slide connected to said inner surface.

10. Apparatus for receiving very-low-frequency signals from the electric field of passing radio waves comprising a first upper electrode, a first lower electrode, a second upper electrode substantially at right angles to said first electrode, and a second lower electrode substantially at right angles to said first lower electrode, said electrodes being mounted on the outer surface of the hull of a vessel, a receiver, an input circuit connected to said receiver, and switching means for alternately connecting the first upper and lower electrodes and second upper and lower electrodes to said circuit, said circuit comprising first and second impedance branches connected in parallel, said branches each having a potentiometer with a movable slide connected to the inner surface of the hull of said vessel for reducing noise voltage between said outer and inner surfaces.

11. Apparatus for receiving very-low-frequency signals from the electric field of passing radio waves comprising a first upper electrode, a first lower electrode, a second upper electrode substantially at right angles to said first electrode, and a second lower electrode substantially at right angles to said first lower electrode, said electrodes being mounted on the outer surface of the hull of a vessel, conductors connected to a receiver, said conductors having insulation and shields thereover, said shields being connected to said outer surface, switching means for alternately connecting the first upper and lower electrodes and second upper and lower electrodes to said conductors, and first and second adjustable impedance means connected to said conductors and the inner surface of said hull for reducing noise voltage between said outer and inner surfaces.

12. Apparatus as in claim 11 wherein said first impedance means comprises potentiometer means having a slide connected to said inner surface.

13. Apparatus as in claim 11 wherein said second impedance means comprises potentiometer means having a slide connected to said inner surface.

14. Apparatus for receiving very-low-frequency signals from the electric field of passing radio waves comprising upper and lower electrodes mounted on the outer surface of the hull of a vessel, conductors connected to said electrodes, said conductors having insulation and shields thereover, said shields being connected to said outer surface, a receiver connected to said conductors, first potentiometer means connected to said conductors and having a slide connected to the inner surface of the hull of said vessel, adjustable condenser means connected between each of said shields and one of said conductors, and second potentiometer means connected to said shields and having a slide connected to said inner surface, whereby adjustment of said condenser means and said slides reduces noise voltage between said outer and inner surfaces.

15. Apparatus for receiving very-low-frequency signals from the electric field of passing radio waves comprising

upper and lower electrodes mounted on the outer surface of the hull of a vessel, a receiver, and input circuit means comprising an impedance branch connected in parallel to said receiver, said branch having conductors with insulation and shields thereover connected to said electrodes, said shields being connected to said outer surface, adjustable condenser means connected to each of said shields and one of said conductors, and potentiometer means connected to said shields, said potentiometer means having a slide connected to the inner surface of the hull of said vessel, whereby adjustment of said capacitor means and said slide reduces noise voltage between said outer and inner surfaces.

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