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Development of an Underwater Electric Field Modem

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Abstract

One of the major advantages of underwater acoustic communication is the extended ranges attainable using a high bit-rate acoustic modem, that results from the low attenuation of underwater acoustic energy. The effectiveness of propagation of acoustic signals between a source and receiver is inevitably accompanied by the unwanted effects of multipath, reverberation and ambient noise. Consequently, these factors require intense signal processing to account for the acoustic propagation effects in the transmitted data. Conversely, electromagnetic signals transmitted in the ocean are heavily attenuated by the conducting medium of seawater with attenuation increasing with frequency. This limited range in propagation implies multipath and reverberation are also minimized, unlike in acoustics. Therefore, an underwater electromagnetic modem could potentially have a simpler, cost-efficient design, with the trade-off in range of propagation. Multiple pairs of electromagnetic modems could simultaneously exchange data without causing interference with neighboring modems. This potentially could lead to increased network throughput.

An experiment was conducted that measured the magnitude of the frequency response between two vertical dipoles in seawater whose centers were at a depth of 10 m. One dipole was used as the transmitter and the other as the receiver, and a swept sine with frequency ranging from 50 Hz to 20 kHz was transmitted. The separation between the dipoles ranged from 1 m to 20 m in increments of 1 m. A generally good agreement is found at each range step and frequency between the measured values and a theoretical model giving errors typically less than 1 dB. However, at the short ranges of 1 and 2 m the errors are higher and are likely attributed to perturbations in separation being a significant fraction of separation. The theoretical model used for comparison is a simplified model giving the electric field of extended dipoles in a homogeneous medium, hence ignoring boundary effects. Furthermore, a measurement of electric field noise obtained at the receive dipole will be presented to provide an indication of spectrum content and order of magnitude of ambient electric field noise.

In order to investigate the benefits of electric field communications Defence Research & Development Canada – Atlantic Research Centre has been developing an underwater electric field modem in a project referred to as Low Complexity Access Network (LCAN). The modem utilizes a pair of platinum electrodes for transmit and another pair for receive. Alternating currents are generated between the transmit electrodes, and through conduction-current signalling in seawater, another modem measures the voltage between the receive electrodes. The received voltage, and therefore signal to noise ratio, depends linearly on the current transmitted, electrode separation of the transmitter, and electrode separation of the receiver. Moreover, the signal attenuates approximately as the cube of the distance between transmitter and receiver. The modem being developed contains an onboard battery pack and an amplifier board for transmit and receive.

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Another board, for modem processing, interfaces with amplifiers and provides the required signal processing. Using a 2 kHz carrier, the modem implements Differential Phase Shift Keying, IQ modulation, both Hamming error correction and convolutional coding. The current state of the underwater electric field modem will be presented.