Underwater Wireless Energy Transfer Using Resonant Coil Systems

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In this study, the response and performance of resonant two-coil wireless power transfer systems in salt water were investigated. The motivation for this study was to develop an efficient system for the transfer of energy from a primary power source to a secondary underwater power supply such as a battery, without using direct electrical connections. Power levels investigated under this study were on the order of several kilowatts (kW). While there is a considerable body of work on wireless power transfer in air for various commercial applications, such as the charging of electric vehicles or personal electronic devices, there is relatively little work focused on underwater applications. In order to assess possible differences which could affect system designs for underwater wireless power transfer, the operation of transmit and receive coil pairs in both air and salt water was compared. As expected, it was found that power losses due to the conductive salt water medium play an important role in the selection of coil design parameters, the resulting efficiency, and transfer distances which can be achieved.

In this study, several two-coil transfer systems were built and their performance was characterized in both air and in salt water. Circuit theory and Finite Element Method (FEM) electromagnetic simulation were used to design the coils, as well as to model their performance in order to compare with our in-laboratory measurements. Close agreement was found between the predictions of circuit theory and the FEM simulations. The measurements and the simulations were also found to be in good agreement for both the air and the salt water cases. The experiments and simulations both showed that underwater wireless energy transfer should be possible, at reasonable efficiencies, for distances on the order of 15 centimeters (cm), depending on transfer coil radius in general, and for frequencies in the 20-100 kilohertz (kHz) range. Energy transfer losses in salt water were seen to increase significantly for frequencies above 100 kHz.

Furthermore, the use of ferrite materials as magnetic shielding was investigated experimentally and with simulations to mitigate the additional energy losses due to proximity of metallic objects which can interact with the magnetic field of the coils to produce eddy currents. Other field shaping approaches such as the use of metamaterials for focusing and shielding will be investigated in future studies.

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