Ultra-Sensitive Electric-Field Sensor for Underwater Object Detection

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***Abstract*—In certain situations such as the detection of underwater objects, knowing the magnetic field component (H-field) of extremely low-frequency (ELF) propagating electromagnetic (EM) waves is of scientific importance. Perturbations to the H-field in sea water can assist in the detection of underwater objects. An ELF wave is so low in frequency that its electric field component is quasi-electrostatic. Measuring the H-field component of an EM wave can be difficult, but the ratio E/H of the electric to magnetic field components of the wave is a known constant determined solely by the permittivity and permeability of the medium (E/H = 377 volts –per-amp in free space). Thus measuring the E-field component of an ELF wave provides and indirect measurement of the H-field component. The latter can be used to detect underwater ferromagnetic (e.g., steel) objects.**

In the frequency range of interest (0.01 Hz to 1 Hz), the electric field component of the wave is quasistatic and behaves essentially like a DC electric field over the time and distance scales of interest. Thus the E-field can be measured using known techniques for electrostatic measurement, such as field mills and the like. One important constraint of our application, however, is the very low sensor sensitivity (about 1 mV/m) that is required.

This paper describes an ultrasensitive E-field sensor under development that combines known technologies optimized and fine tuned to work together to facilitate very low sensitivity at an acceptable signal-to-noise ratio. The core components of the sensor include a) multi-blade, dual-rotor electric field mill; b) very-high-speed DC brushless motor; c) very-low-noise current-to-voltage converter; d) very-narrow-band analog filter; e) high-resolution, high-speed analog-to-digital converter, and f) post detection synchronous signal processing. The basic operation of each component of the sensor will be reviewed, and the way in which they are combined to achieve high field sensitivity measurements will be discussed.