Active bucking using a system on a chip Field PRogrammable Gate Array for geophysical investigations

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One of the difficulties that geophysicists encounter with geophysical equipment, particularly using frequency domain (FD) electromagnetic induction (EMI) techniques, is the ability to null the primary transmitted field well enough to distinguish the small secondary fields from low conductive materials like soils. Many frequency domain EMI sensors function by transmitting a strong primary field at a given frequency by exciting a current in a transmitter coil. A second transmitter coil, known as a bucking coil, is used to transmit a field opposing the primary field and thus null the primary field at a given location. A third coil, known as a receiver coil, is placed at the location where the primary field is nulled so that any fields that pass through the receiver coil are solely due to the secondary fields resulting from currents excited in surrounding conductive media. The transmitter and bucking coils can be connected electrically and counter wound in a figure eight pattern so that the current through both coils is the same. Another design is to find the exact geometric location and the necessary voltage in the bucking coil in a lab setting and then designing the system in such a way that the physical location of the transmitter and bucking coils do not move. Both configurations work well but are highly sensitive to the location of the bucking coil with respect to the transmitter coil. Any small movement of the transmitter or bucking coils will lead to a non-zero magnetic field passing through the receiver and result in a higher-than-expected signal to noise ratio.

In this presentation we show an active bucking system where the transmitter and the bucking coil are not connected electrically and the input voltage and phase are controlled independently by a Red Pitaya, a small electronics board which combines an ARM processor and an FPGA SoC. The Red Pitaya has a built-in signal generator, spectrum analyzer, and LCR meter. Additionally, the Red Pitaya is controlled using open-source software that is free and available to the public. At a given voltage amplitude and transmit frequency, the Red Pitaya is used to generate a voltage since wave which is amplified into a current. Additionally, band capacitors and operational amplifiers have been incorporated to achieve a desirable primary field. Using the inputs on the Red Pitaya, the receiver coil can sense the strength of the primary field and then we designed an algorithm to calculate the necessary voltage and phase in the bucking coil to cancel the primary field in the receiver coil. Unlike a geometric bucking system, our method does not require the location of the transmitter and bucking coils to be held constant. The intention is that this design will allow the sensor to be more rugged in the field, particularly when jarred. Additionally, this EMI sensor design uses commercially available electronics and open-source software. Therefore, it does not require specialized electronics engineers to design the bucking system. This allows for the systems to be built cheaper and easier to fix