A STEADY-STATE APPROACH TO SURFACE NUCLEAR MAGNETIC RESONANCE

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The signal-to-noise ratio remains a major challenge in surface nuclear magnetic resonance (NMR), where low-amplitude NMR signals are measured in areas with high ambient noise such as near urban areas or infrastructure. While significant advances have been made in signal processing, transmit schemes, and technology, noise remains a critical issue, often requiring large numbers of stacks to extract useful information. This approach is time-consuming and can limit the number of sites measured per day, reducing the regional mapping capabilities of surface NMR.

Recent advances in transmitter and modelling capabilities have allowed for a greater variety of transmit schemes such as a steady-state protocol. This transmitter sequence provides an orders-of-magnitude improvement compared to standard free-induction decay measurements (FID), providing high-fidelity groundwater measurements at high-speeds in areas previously inaccessible to surface NMR due to noise.

The steady-state approach uses a pulse train of identical pulses separated by a constant repetition time. In contrast to FID sequences, which require several seconds per stack and potentially hours to acquire a full sounding at one site, the close separation between transmit pulses in the steady-state scheme eliminates the wait time between subsequent observations. By varying the current between sequences—similar to an FID—as well as the transmit pulse length and repetition time, a sounding can be performed at a fraction of the time of FID measurements with a similar or improved signal-to-noise ratio.

We have acquired well over 100 sites with the steady-state sequence, acquiring up to 16 sites in a single day using the Apsu instrument developed by the HydroGeophysics Group (HGG). We have developed an associated processing workflow to produce inverted models of water content, T2*, and T2 with depth at each. Results are consistent with FID measurements and nearby water table depths/aquifer tests where available.

Here we present the background of the steady-state approach and discuss the modular processing workflow. We then show a selection of examples of data and associated models from a variety of noise conditions in Denmark.