Leibniz Institute for Applied Geophysics

Contrary and unexplained – Experimental field data of Surface-NuclearMagnetic-Resonance using grounded dipoles

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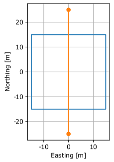
Surface NMR measurements are sensitive to water content and relaxation time variations in the subsurface and mostly used in combination with geoelectrics or electromagnetics. Common usecases are given if salt and fresh-water or variable clay content are observed.

water content		**soil moisture**		**saltwater - freshwater - clay discrimination**
relaxation times	→	**porosity**	→	**salt water intrusion**
(resistivity)		**hydraulic conductivity**		**coast aquifer characterization**

SIRIUS B The project "Simple and rapid imaging of groundwater using magnetic resonance and grounded bipoles (SIRIUS B)" is an experimental project funded by the Volkswagen Foundation to investigate the applicability of dipoles instead of coils for the excitation and detection of NMR signals. This could reduce the effort in the field and thus increase the measurement progress and allow for more complex 2D setups.

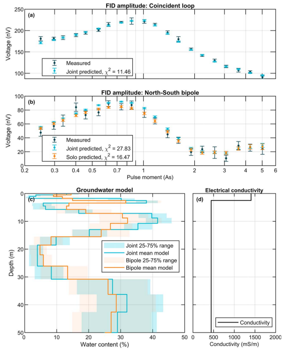
The Spot (Coast)

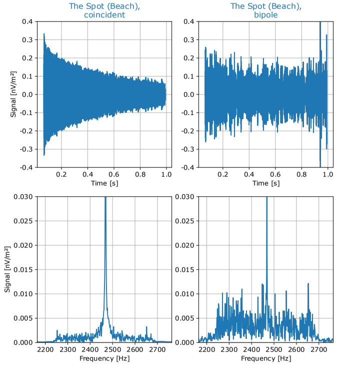
The first successful measurements using grounded bipoles were conducted on the west coast of Australia near Perth.
Davis et. al, 2019: First Measurements of Surface NMR Signals in a grounded Bipole, Geophysical Research Letter (https://doi.org/10.1029/2019GL084342)



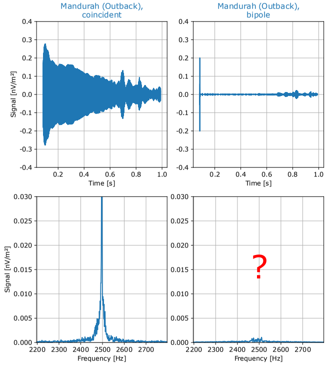
We used the unmodified GMR Surface NMR equipment for the test measurements.

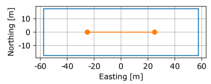
Monte-Carlo inversion of Bipole and combined Bipole and Loop data in comparison for a local conductivity model. Figure from Davis et al. (2019).





Mandurah (Outback)





The second unsuccessful measurements using grounded bipoles were conducted in the Outback in the west coast of Australia near Perth. A clear NMR signal in the coincident loop could not be found in the bipole.

Buried electrodes with salt water are used for receiving NMR Signals (right). Measurement layout for Bipole wires and receiver loop (top).

Eletrodes were above the water table, suspected high contact resistance, resistive subsurface.

NMR Signal

NMR Excitation → **Magnetization** → **Magnetic Field at larmor frequency** → loop receiver **Induced Voltage in receiver coil**

NMR excitation due to hydrogen nuclei absorbing energy at the larmor frequency

Ensemble of nuclear spins precessing at the larmor frequency causing a macroscopic magnetization

bipole receiver ↓ **Corresponding electric field** → **Electric potential** → **Voltage due to potential difference in receiver bipole?**

$$V_R(t) = -\frac{1}{c}\frac{d\Phi_R}{dt}$$

$$\Phi_R(t) = \int_{S_R} \mathbf{B}(\mathbf{r},t)\hat{\mathbf{n}}dA = \int_{C_R} \mathbf{A}(\mathbf{r},t)d\mathbf{l}$$

$$V(t) = -\int d^3\mathbf{r}\int_0^\infty dt'\mathbf{B}_R(\mathbf{r},t')\frac{\partial\mathbf{M}}{\partial t}(\mathbf{r},t-t')$$

measured voltage

volume integration

Virtual magnetic field caused by passing a unit current through the receiver loop

temporal variation of spin magnetization with the receiver field

Experiments and parameters tested at the field site Schillerslage without detecting a signal with bipoles

Resistivity:

resistive, freshwater

Layouts:

In-loop dipole, out-of-loop dipole, symmetrical, asymetrical, NS, EW

Electrode types:

electrodes, direct push rods (>2m), Ag-AgCl non-polarizing electrodes

Acknowlegments

We like to express our gratitude towards A. Davis and the CSIRO for the opportunity to conduct these experimental measurements. Data are available from the CSIRO Data Access Portal (Davis 2019).

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