

MRS MIDI III+

- Instrument for near-surface water content and porosity investigations.

Nuclear Magnetic Resonance



Geophysics

The Nuclear Magnetic Resonance Sounding (MRS resp. NMR, PMR or SNMR) method is an innovative, non-penetrating and cost-effective technique for groundwater exploration. Our **MRS MIDI III+** instrument provides information about the content of free pore water and the dominating pore-sizes up to a depth of 10 meters. The MRS measurement is performed in the earth's magnetic field. Laptop based operating software calculates: Larmor frequency, peak amplitude E_0 , phase and the transversal relaxation time T_2^* . The instrument also supports T_1 measurements. The Reference Noise Cancellation (RNC) technique is highly effective to suppress cultural noise that is often disturbing MRS measurements in densely populated areas. To investigate the vadose zone (up to 2 m depths) a pre-polarization field can be generated. This improves the S/N ration up to one order. If required, the Tx Transmitter can generate a wide variety of adiabatic pulses, which opens up further investigation possibilities. The instruments allows FID measurements with up to 7 Receiver Loops at the same time. All time series can be stored.

NMR MIDI III+

The system consists of:

- Base Unit with 8 channels
- Px Transmitter and Loop
- Tx Transmitter and Loop
- Rx Receivers and Loops
- Operating Software (W 7-10)

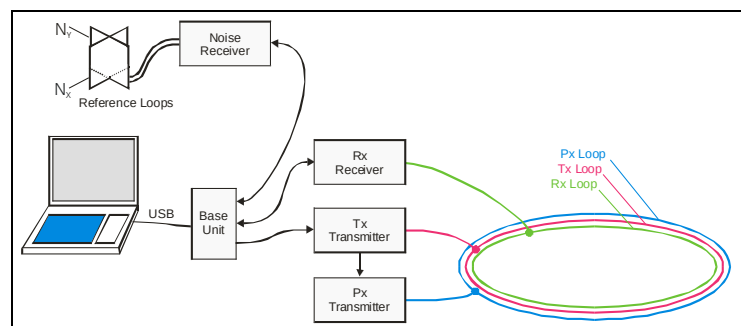


Fig. 1: MRS MIDI III+ simplified schematic diagram.

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BASIC MRS MEASURING SCHEMA

A Tx pulse excites the protons of the groundwater more or less perpendicular to the earth's magnetic field (fig. 2). Immediately after the current is suddenly cut off the induced field collapses, and the Protons precess back to their initial orientation. This FID can be recorded at a frequency of ~2 kHz (fig. 2, equ. 2). The precession (Larmor) frequency is directly proportional to the earth's field strength (equ. 1).

$$\omega_0 = \gamma_p B_0 \quad \gamma_p = 0.267 \cdot 10^9 \text{ Hz/T} \quad \text{Larmor frequency} \quad (1)$$

$$E(t) = E_0 \sin(\omega) e^{-\frac{t}{T_2^*}} \quad \text{Free induction decay} \quad (2)$$

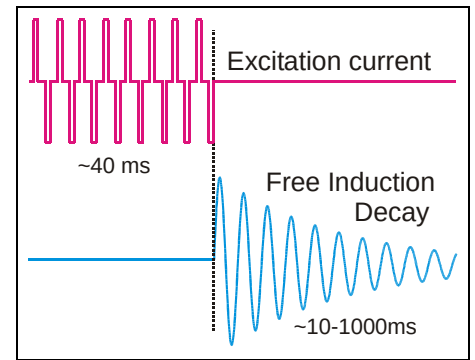


Fig. 2: Basic MRS measuring schema.

MRS SOUNDING

A SNMR sounding curve delivers two important parameters: E_0 (initial FID amplitude) and T_2^* (transversal relaxation time) as a function of the Q (pulse moment). Figure 3 shows the result of a sounding in Linum (near Berlin, Germany). E_0 depends on the water content of the soil and T_2^* depends on the radii distribution of the water-filled pores. Largest times (up to 1 sec) are observed only in wide pores, which are filled with fresh water. Small pores or dissolved salts with paramagnetic ions like chrome, iron, nickel or copper shorten the T_2^* time. This can be used to evaluate the water quality if the pore radii are known.

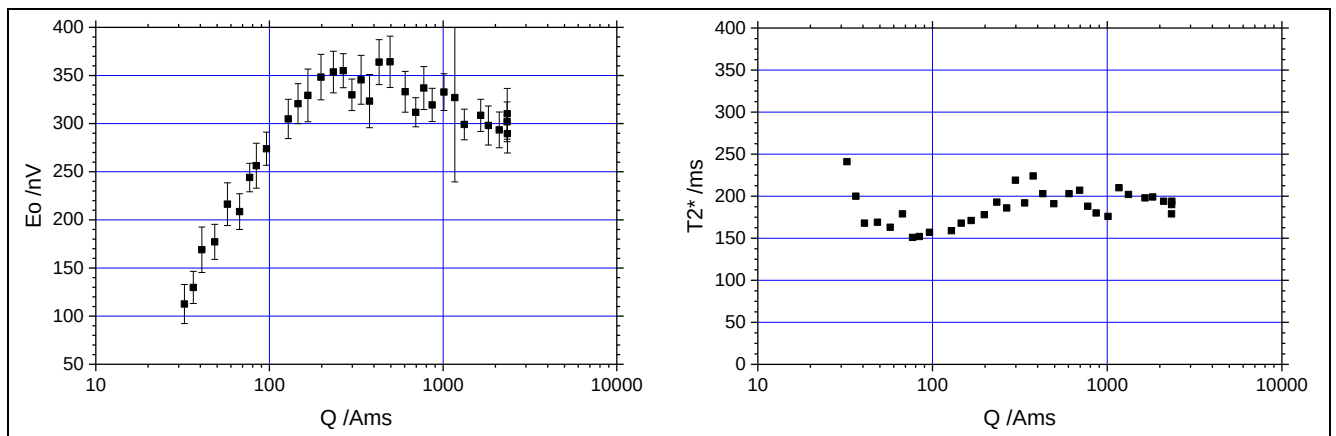


Fig. 3: Typical MRS sounding curve. Left: E_0 vs. Q , right: T_2^* vs. Q . Error bars indicates the RMS FID envelope misfit. Stacking: 16, Layout: Tx and Tx Loop (10 m x 10 m), Rx Loop: 12 turns. Linum, Germany.

OPERATING SOFTWARE

The operating software displays each FID immediately after its recording (fig. 4). Full time series can be stored for user specific processing. The software supports a selective stacking of the records. This increases the data quality even in case of low water content and/or high noise level. Additionally, the Reference Noise Cancellation technique is supported. The user can choose the parameters: sample rate, record length, numerical band pass filter, spike elimination level and excitation pulse strength Q . To estimate the NMR parameters the FID's envelope is calculated. Fitting this envelope allows the relevant NMR parameters to be derived.

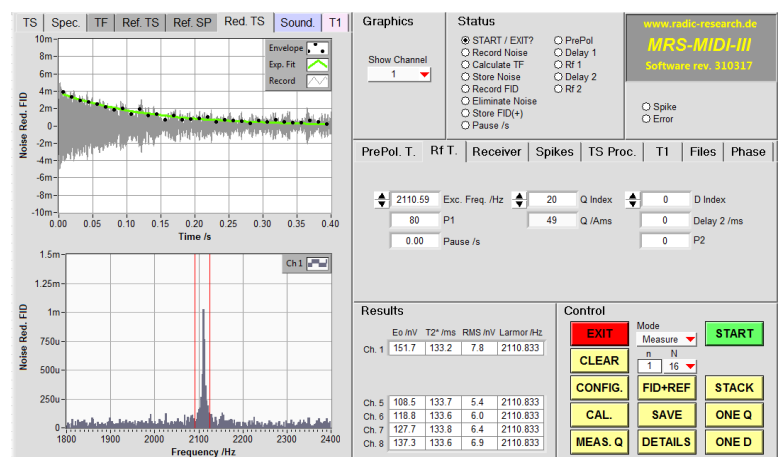


Fig. 4: Main screen of PC operating software. The screen shot shows the recorded FID Signal in frequency and time domain.

REFERENCE NOISE CANCELATION

In densely populated areas cultural noise can lower the signal-to-noise ratio. The Reference Noise Cancellation (RNC) technique effectively suppresses this noise as well as natural noise. For this two additional receiver channels, which record the noise before and during the NMR measurement, are used (fig. 5). A multivariate coherence analysis method is used to calculate the magnetic transfer function, which is needed to predict and eliminate the noise in the FID record.

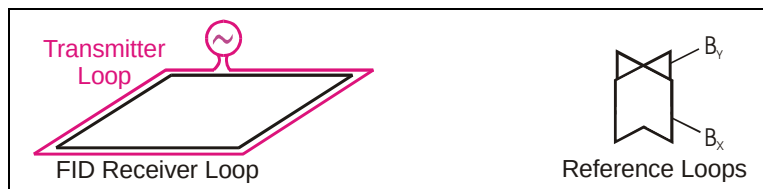


Fig. 5: MRS MIDI III+ setup for Reference Noise Cancellation (RNC).

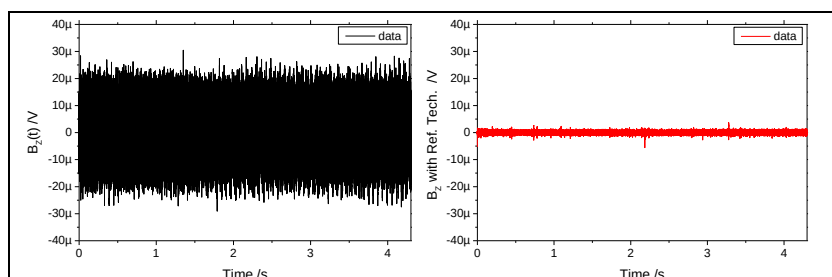


Fig. 6: Left: Standard record, right: record with RNC technique.

Figure 6 shows a typical noise record. Applying the RNC on this record the noise can be reduced by a factor of 20 (right). Different from conventional data stacking, the RNC technique does not appreciably consume additional time. This helps to reduce the stacking time and significantly forces the progress in MRS measurements.

MRS SOUNDING WITH PRE-POLARIZATION

Small loops ($\varnothing \sim 2$ m) are required to examine structures with very flat lying surfaces (e.g. vadose zone). The useful signals (FID) are, however, then often so small that they disappear below the noise floor. Pre-Polarization can correct this. To achieve this, a strong magnetic field (500 μ T) is produced for a few seconds by the Px transmitter in a Px loop. This magnetic field raises the nuclear magnetization of the groundwater. The directly following MRS measurement then prompts an up to one magnitude larger FID signal.

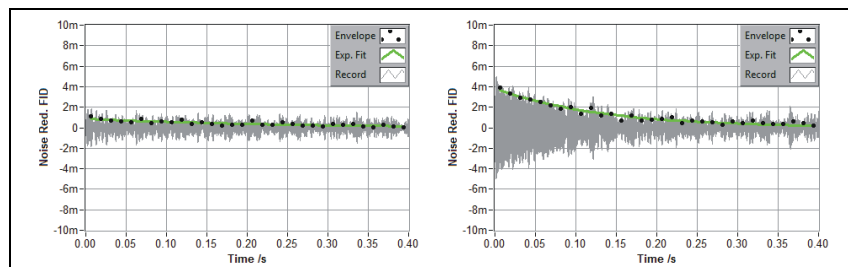


Fig. 7: FID record without (left) and with (right) pre-polarization.

MULTI-CHANNEL MEASUREMENT

The instrument and the software also support multi-channel MRS measurements. Measurements with up to 7 FID receiver loops at the same time are possible. Figure 8 shows one possible cable layout. This allows high-resolution 2-D investigations and improves the survey progress.

MRS MIDI III+

Technical Specifications

General

- Safe Operation: -5°C to $+40^{\circ}\text{C}$, 20-80% humidity (non condensing)

Base Unit

- 8 Channels
- 16-Bit AD Converter (USB)
- Sample Rate: 50 kHz / Channel

Px Transmitter (Pre-Polarization)

- Current in Px Loop: 20 A
- Power Supply: 2x 12 V (Car Battery)

Px Loop

- Diameter: 2 m
- Turns: 49
- Wire: 6 mm²

Tx Transmitter

- Max. Pulse Moment Q: 2 As
- Excitation Frequency: 1 - 3 kHz
- T_1 Measurement: 2-Pulse Technique
- Opt. Adiabatic Pulses
- Current Recording (Time Series)
- Weight: 8 kg
- Size: 28 cm x 23 cm x 30 cm
- Internal LiFePO₄ Battery: 48 V, 5.5 Ah

Tx Loop

- 10 m x 10 m, 1 turn (or other)

Rx Receiver

- Noise: 1 nV Hz^{-1/2}
- Band Pass Filter: 1 - 3 kHz
- Gain: ~ 30000
- Dead Time: ~ 2.5 ms
- Weight: 1 kg
- Size: 13 cm x 16 cm x 25 cm
- Power Supply: internal rechargeable battery for 24 h operation

Rx Loop

- 10 m x 10 m, 12 turns

Remote Reference Loop

- 90 cm x 90 cm, 130 turns

PC Software

- Windows 7-10
- PC Control of the whole system
- Time series recording, storing, displaying and stacking, Spike filter, Reference Noise Cancellation, FID Parameter: E_0 , T_2^* , T_1

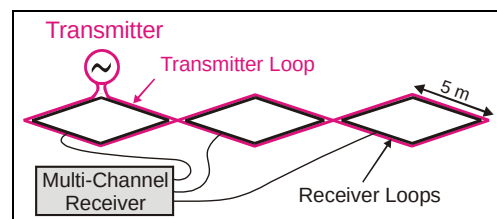


Fig. 8: Possible multi-channel layout.