Improving the sNMR signal-to-noise ratio using cost-effective EM shielding

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Surface Nuclear Magnetic Resonance (sNMR) is a geophysical method suited for hydrogeologists, due to its unique ability to **directly sound groundwater**. Nevertheless, its **use is highly limited in urbanized areas** due to the ubiquitous ambient electromagnetic (EM) noise that perturbs the signal originating from the groundwater response to the sNMR excitation.
In this study, we investigate the efficiency of a cost-effective shielding made of cattle fences to **reduce the noise impact** on sNMR measurements. We conducted measurements in different environments that are characterized by a large EM noise. Those field experiments showed that using such methods can **remove up to 80% of the noise**.

1. sNMR

In geophysics, surface Nuclear Magnetic Resonance is unique in the way it directly probes groundwater. The NMR signal is produced by the interaction of the protons (H^+ - contained in the water molecules) with electromagnetic fields. On-site, we install an antenna that acts both as a transmitter and a receiver (in most cases) whose size is directly proportional to the depth of investigation. The experiment is described physically as follow (see **Fig. 1**):

0. At rest, the spins of the protons are aligned with the Earth's magnetic field.
1. We inject a pulse at the Larmor frequency of the water that creates a strong magnetic field. The spins align with the created magnetic field.
2. The injection of current in the transmitter antenna stops. The spins return progressively to their equilibrium state. This change in orientation creates a small magnetic field that can be recorded via the receiver antenna.
3. Equilibrium is reached and the spins are aligned back with the Earth's magnetic field.

As one can imagine, the created signal is very weak, implying the use of sNMR in urban environments challenging.

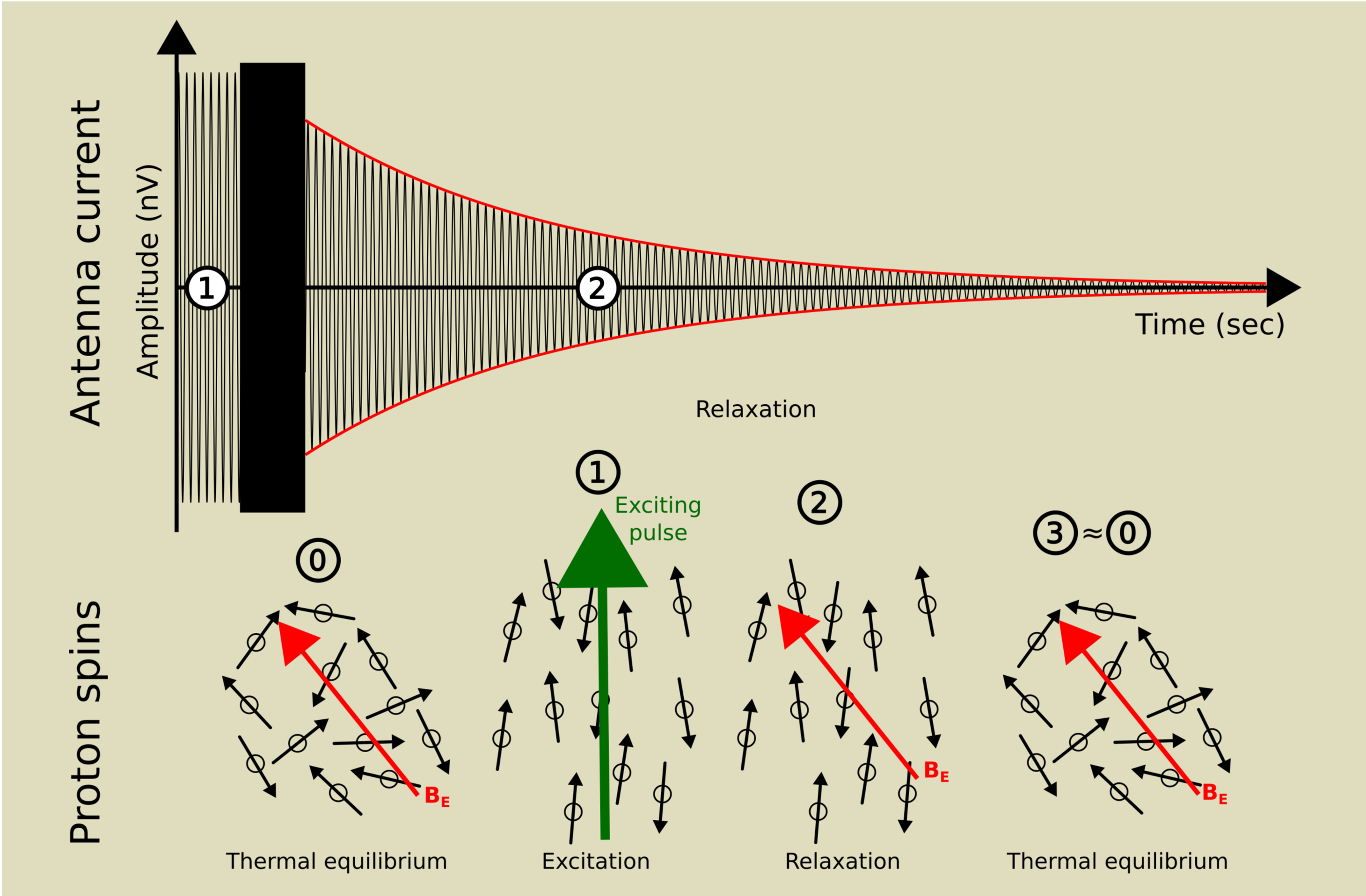

Figure 1: Illustration of the NMR acquisition principle. The upper part presents the idealized raw signal and the lower part presents the physical phenomenon that produces the signal.

Figure 2: Pictures of different tested filtering dispositions. (A) Dome built above the antenna loop. (B) ERT line on the test site with the Orval Abbey in the background. (C) Tunnel built above the cable of the antenna loop.

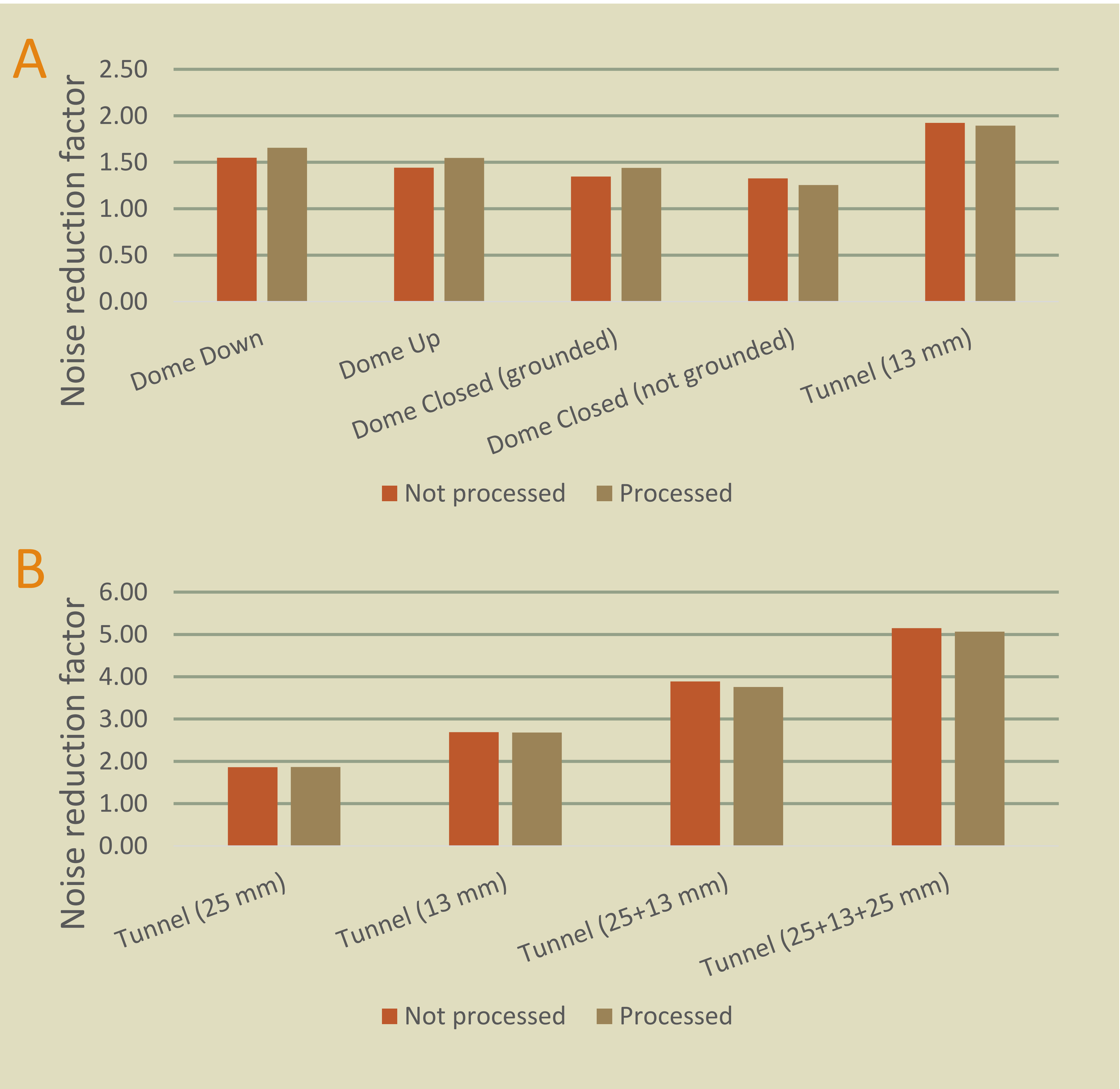

Figure 3: Results of the experiments. (A) Different configurations and (B) Multiple layers on the tunnel configuration.

2. EM shielding

On the Orval Abbey grounds, we tested multiple configurations to filter the noise (**Fig. 2**):

- A dome covering the full antenna loop
  - In the air, touching and not touching the ground
  - On the ground
- A tunnel above the cable constituting the antenna loop
  - 13 mm/25 mm grids
  - Combinations of grids

The results (**Fig. 3**) show that using a tunnel is more efficient that any configuration of domes. This is explained by the difficulty to build a correctly closed dome. On the other hand, shaping a tunnel above the receiver loop is straightforward.
Combining multiple grids on a tunnel filter achieved the best results with a reduction up to 5 times of the ambient noise measured in the loop.
No data was acquired on this site due to the high noise level from an underground high voltage power line close-by.

Conclusion – Filtering EM noise with simple cattle grids seems **possible and efficient**. More **experiments are required** to assess the impact on the NMR signal. We are conducting experiments on a **new test site to explore this impact**.

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