Profiling the temperature dependent frequency of an open-magnet for outdoor applications

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Profiling the temperature dependent frequency of an open-magnet for outdoor applications

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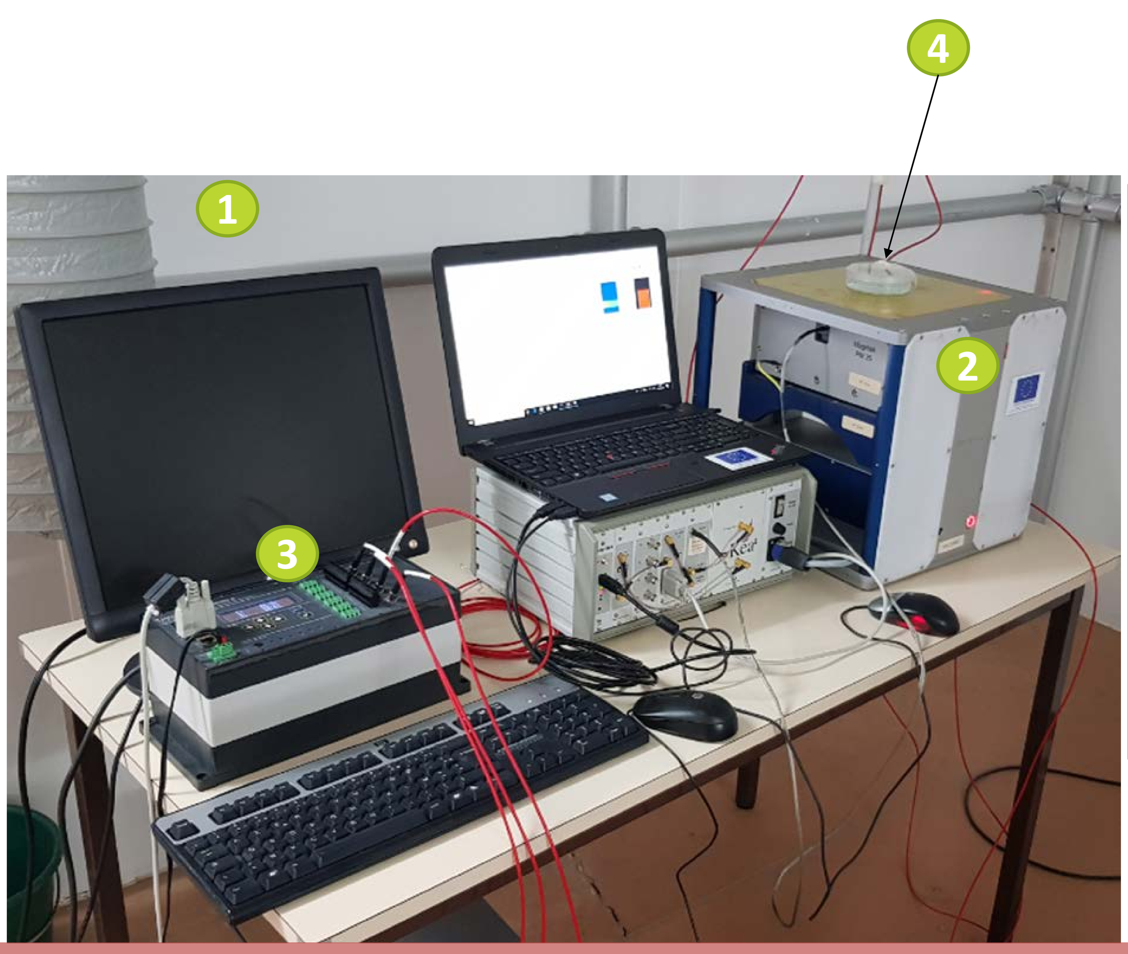
The open geometry of the single-sided NMR-MOUSE® (Magritek®, Aachen, Germany) sensor results in a powerful spectrometer to characterize arbitrarily sized samples. This inhomogeneous magnet is designed in such a way that it generates a highly flat sensitive slice, i.e. the measurement volume, at a given distance (25 mm for the PM25 system) parallel to the scanner surface [1]. It is well known that low field magnets have a strong dependence between the magnetic field and the magnet temperature. For the MOUSE® it leads to a dependence between the magnet temperature and the position of the sensitive volume [2].

As our aim is to use this portable device *in situ* to study plants in their living environment, we anticipate daily temperature variation of the magnet. This study aimed at characterizing the relationship between changes in the magnet temperature and the position of the measurement volume.

Materials

1. Climate room with temperature regulation between 10°C and 25°C
2. MOUSE® with Kea spectrometer (Magritek®, Aachen, Germany)
3. Fiber optic temperature sensors (LumaSHIELD®, Lumasens Tech, France)
4. Sample = 1-cm height dopped-water in a Petri dish



Experimental set-up :

- Two temperature cycles were used : 10 to 25 °C and 25 to 10°C
- Sample profiles were acquired from 6mm to 0 of the magnet surface, 8min/profile, 2min gap with the slice thickness of 50 µm
- Room, sample, and magnet temperature were logged each 2 min

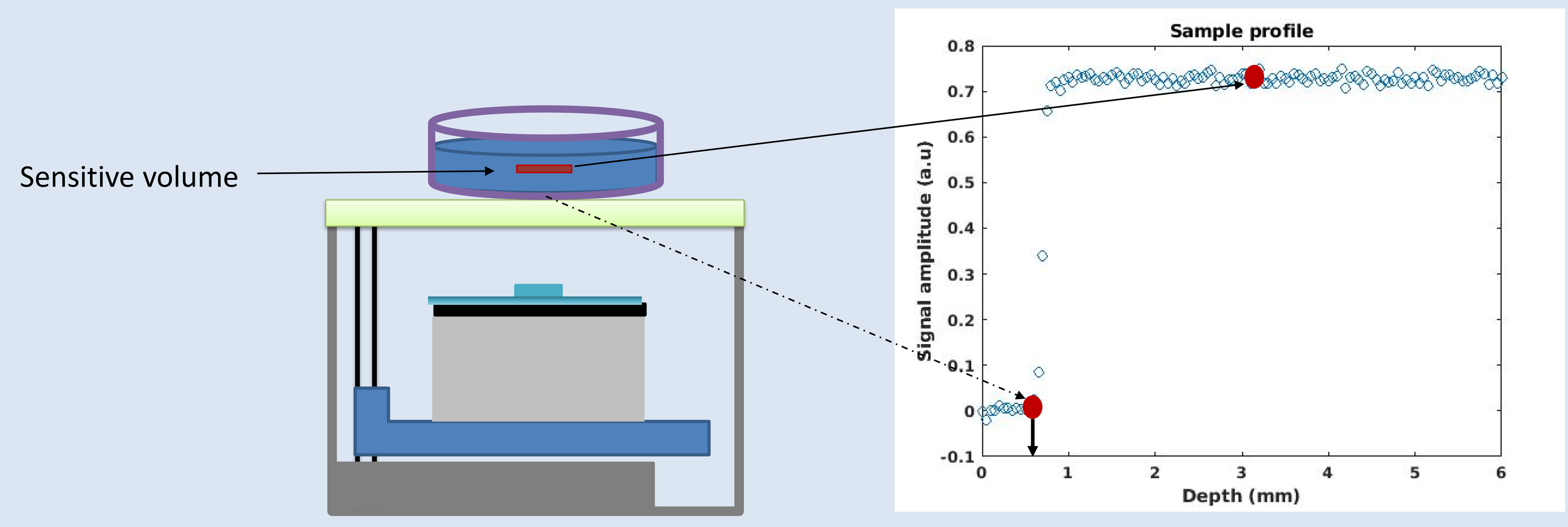
Methods

Principle

Magnet temperature change → Change in B_0 → Shift in the position of the sensitive volume

How ?

Continuous acquisition of sample profile during room temperature change and following-up of the depth corresponding to the position of water-dish interface (where signal vanish)



Results

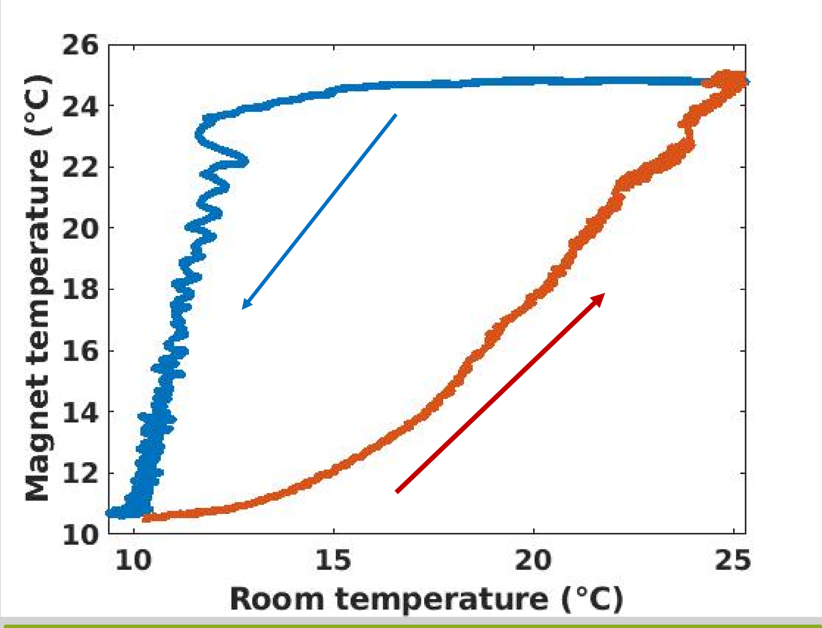


Figure 1: Evolution of the magnet temperature in function of the room temperature during the cooling (blue) and the warming cycle (red).

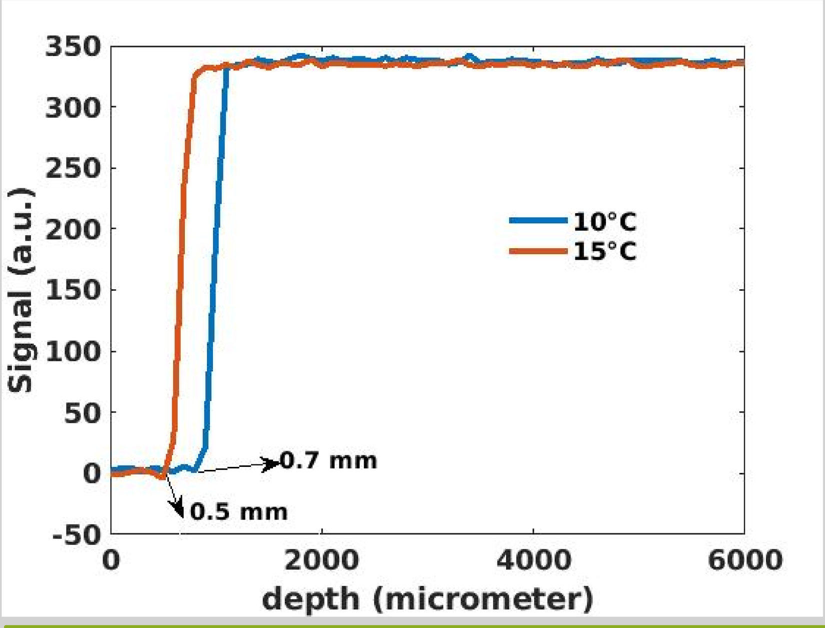


Figure 2 : Sample profiles recorded after 2 hours of magnet temperature stabilisation at 10°C (blue) and 15°C (red). A shift of 200µm is observed.

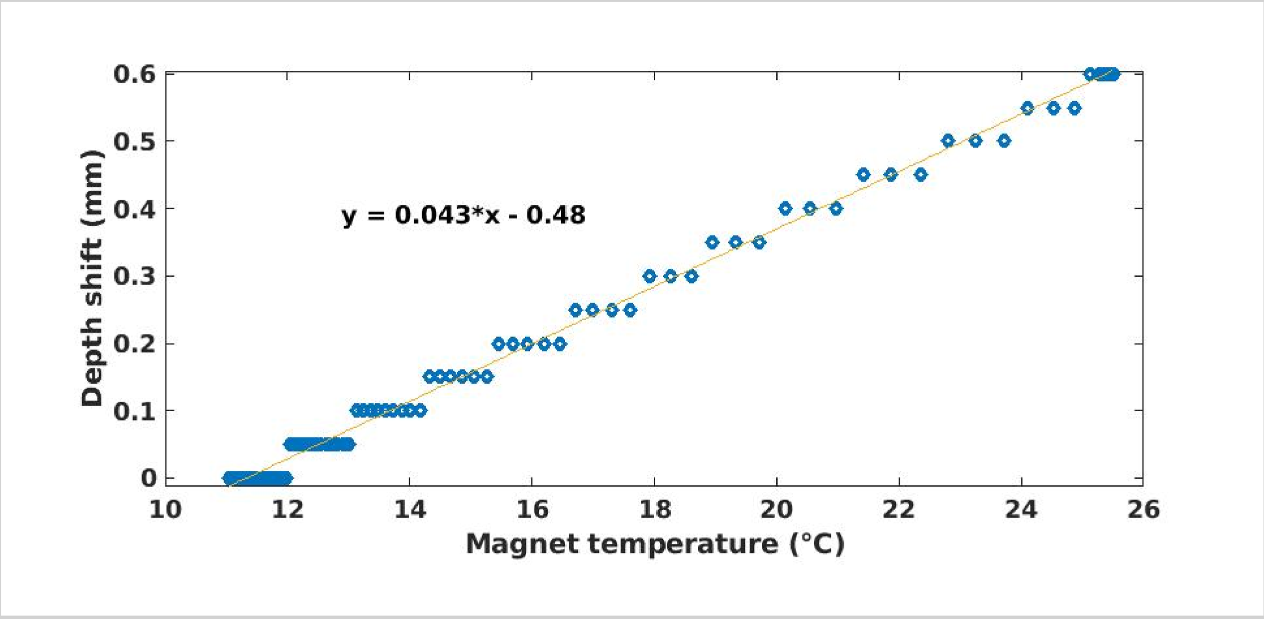


Figure 4 : The resulting shift of the position of the measurement slice corresponding to the edge of the sample.

Magnet insulation

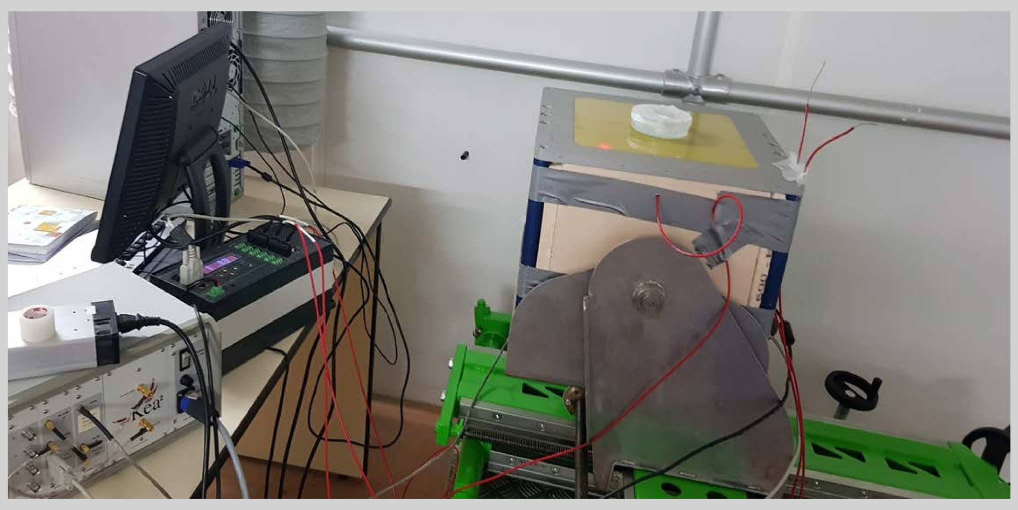


Figure 5 : identical experimental setup as in figure 1 except that the magnet is insulated with a 4-cm extruded polystyrene plate

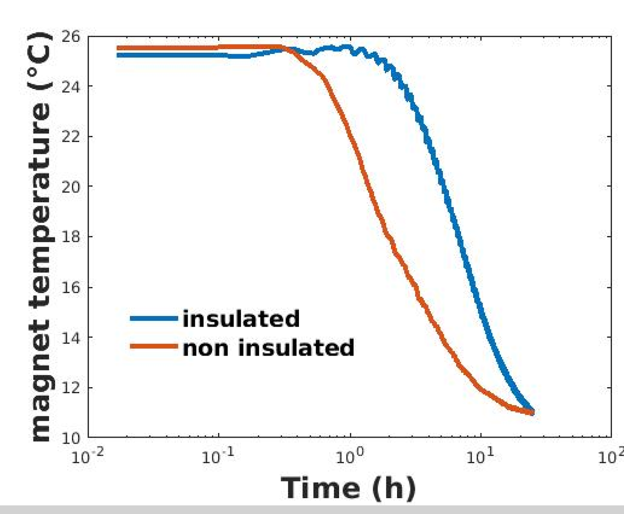


Figure 5 : The evolution of magnet temperature with (blue) and without (red) insulation during the cooling cycle. The insulation resulted in a slower magnet cooling.

The evolution of the magnet temperature during the two temperature cycles shows a magnet inertia pattern which is more pronounced during the cooling cycle (Figure 1 blue). The magnet temperature decreased only by 2°C (from 25 to 23°C) during the room temperature variation from 25 to 12°C. Afterward, the decrease is more rapid to reach the room temperature. The observed hysteresis may be explained by the active (rapid) cooling process of the climate room as opposed to the passive warming. Figure 2 shows a shift of 200 µm in the position of the measurement volume even for a 5°C difference in the magnet temperature. In agreement with the literature (2), both temperature cycles resulted in a linear variation of the position of the sensitive volume in function of the magnet temperature with a slope of ~50 µm/°C, i.e., the resolution of our measurement protocol (Figure 3). Tacking this step further, a magnet insulation (Figure 4) was tested for solving the problem of the use of NMR-MOUSE® under evolving external temperature conditions. The insulation resulted in a marked delay in the magnet temperature decrease (Figure 5).

Discussion and Conclusions

The relationship between the temperature of the MOUSE® magnet and the position of the sensitive volume is characterized in the range of 10 to 25°C. Either an increase or a decrease in magnet temperature results in a ~50 µm/°C shift in the position of the measurement volume. This linear relationship may be used in a development of an automatic method for repositioning the magnet according to its inline temperature logging. This study also shows some magnet "inertia", i.e., a delay for the magnet to reach the room temperature. This "inertia" shows that even for relatively long experiments (< 3h), magnet insulation may be used as a simple solution of the problem of using the MOUSE® under different environmental temperatures.

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(1) [1] J. Perlo, et al. J. Magn. Reson. 176 (2005).
(2) R. LU et al. CJME. 26 (2013)