Near-field microprobes : NMR and MRI applications

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The principle of NMR is based on the detection of the magnetization originating from the spin of atomic nuclei such as ^{13}C, ^{31}P and ^{1}H. The sample is placed in a static magnetic field, which polarizes the ensemble of spins and it is excited by radiofrequency pulses (wavelength about one meter), that tilt the axis of the magnetization. When the magnetization returns to equilibrium, it generates an electromagnetic field which is classically detected by a receiving antenna (coil with a tuning/matching circuit) [1,2].

In this contribution, we propose the use of a micrometer-sized probe positioned in the vicinity of the object of interest, at a distance well shorter than the wavelength of the radiated NMR signal [3]. Our microprobe presents innovative characteristics (i) a capacitive coupling (electric field component) and (ii) reduced dimensions for an accurate positioning, which ensure the detection of NMR signal from the sample. We demonstrate that the NMR signal can be described by $E(x,z) = A(k_z^{max})\, e^{i\frac{z}{L}}\, e^{-\frac{x}{L}}$+Propagative Term, which is expected for evanescent waves.

Figure 1 presents the experimental setup where the receiving antenna is immersed in water in the center of a cylindrical container of 4 mm in height. The microprobe is a 100 μm in diameter microcoaxial cable with an active part of 1.5 mm in length. It detects the signal from each voxels of the sample excited by the radiofrequency pulses [4].

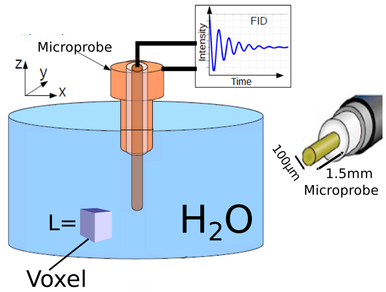

FIGURE 1 – Microprobe immersed in a cynlindical water container

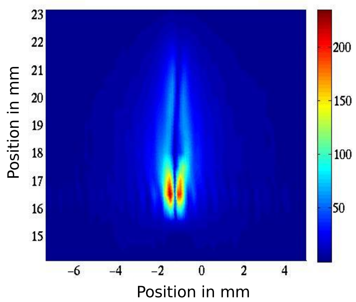

FIGURE 2 – ^{1}H NMR image in the xz plane measured with the microprobe.

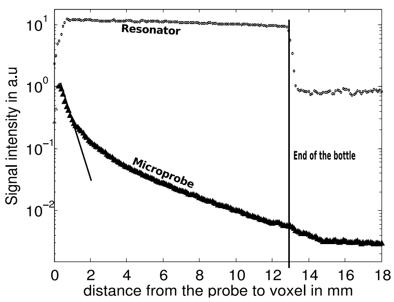

FIGURE 3 – Profile curves of the ^{1}H NMR signal using the resonator and the microprobe.

Figure 2 shows a ^{1}H NMR image in the xz plane measured with the microprobe. The collected NMR signal is more intense in the vicinity of the microprobe (center of the image) and decreases exponentially with the distance, in agreement with near field theory. The localized detection is evidenced from the comparison of the profile curves (see Figure 3) between "resonator" and "microprobe". In the case of the microprobe, 90% of the signal is detected within 1.3 mm. The analysis of the decay profiles, using microprobe, from samples of various sizes allows us to demonstrate that we collect mainly evanescent NMR signal.

The spectral and spatial resolutions will be discussed in terms of the modifications of the geometry of the microprobe. The first application of the microprobe to NMR imaging in a biological system (cherry tomato) is also presented (Figure 4).

[1] A. Abragam « Principles of Nuclear Magnetism » Oxford University Press, 1961. [2] D. I. Hoult and B. Bhakar « NMR signal reception : Virtual photons and coherent spontaneous emission » Concepts in Magnetic Resonance, Volume 9, Issue 5, pages 277–297, 1997. [3] Daniel Courjon and Claudine Bainier « Le champ proche optique : théorie et applications » Springer, 2001. [4] Patent : 04GR1290 CNRS/UM2/MicroElectronics.

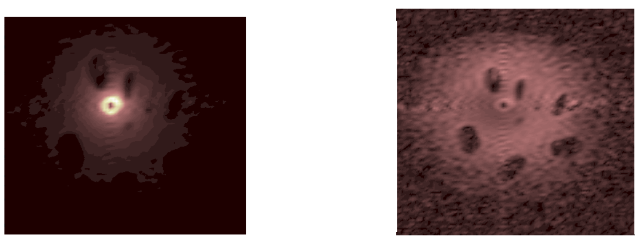

FIGURE 4 – NMR Image of a cherry tomato using the microprobe (left : raw image, right : processed image).