# Superconducting-magnetoresistive sensor: Reaching the femtotesla at 77 K


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## Habilitation à diriger des Recherches


In order to measure extremely weak magnetic fields, such as those produced by the neuronal activity during cognitive tasks in the brain, we have proposed and realized a femtotesla ($10^{-15}$T) sensor based on the association of spin electronics and superconductivity which offers an alternative in thin film technology and at 77K to the most sensitive devices which are low-$T_C$ SQUIDs (Superconducting Quantum Interference Devices).

The principle of these mixed sensors is to combine an efficient flux-to-field transformer, realized by a large superconducting loop containing a constriction, and a magnetoresistive sensor with very good sensitivity (GMR or TMR). Field levels of few fT/√Hz in the thermal noise have been reached at liquid nitrogen temperature, which is comparable to performances of SQUIDs in liquid helium. Performances are nevertheless reduced in the low frequency (below 1kHz) range due to 1/f noise present because of the small volume of the magnetoresistive element. Cancellation techniques based on switching on and off the sensor to reference points have been developed and already allow reducing the low frequency noise of more than one order of magnitude, leading to sensitivity in field of 0.1pT/√Hz at 1Hz.

First measurements of the magnetic component of the cardiac signal (few pT/√Hz at 1Hz) have been acquired with mixed sensors. The very low thermal noise level has also allowed realizing nuclear quadrupolar resonance measurements on nitrogen compounds, which is a non invasive detection technique for solid explosives. We have also achieved first proton Low-Field Nuclear Magnetic Resonance experiments with such sensors, which has led to develop and build a Magnetic Resonance Imaging setup to realize 3D images at low field (<20mT), which is of great interest for low cost and portable equipment development.


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