# Energy Harvesting towards autonomous MRI detection

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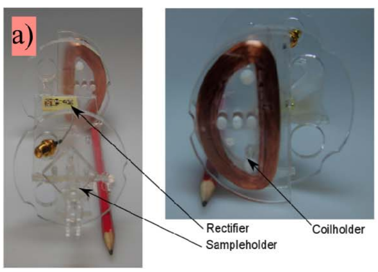
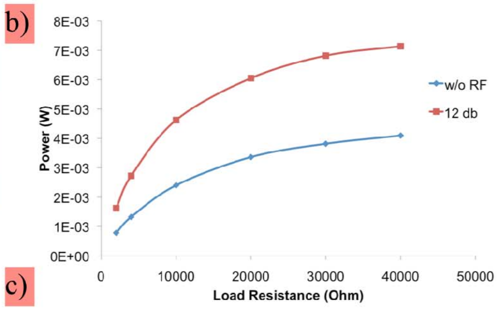
**Introduction:** At present, the signal from magnetic resonance is recorded by one or several receive coils inside an MR imaging system and transferred via coaxial cables from the magnet to the receiver usually located some distance away from the magnet. Signal deterioration by cables has to be minimized, therefore, double-shielded high-quality coaxial cables with low damping factors are used preferably. Using large numbers of coils in a receive array, the overall size and possible crosstalk of the corresponding larger number of cables increase and need to be accounted for. An alternative solution is described in [1][2], where a completely wireless MR system was suggested, leading to a careful decoupling of these interactions. The power supply necessary for such a system was not addressed in that work leading to the idea that we present here. We will use a small coil in the vicinity of the MR sensitive volume to take energy out of gradient and RF-fields, that are always present for image encoding. The harvested power from these pulses needs to be rectified and also be stored for use at some later time period, here to drive a special low-power preamplifier during the acquisition period. Thus, the energy harvester that we present here is a first step towards a future completely autonomous energy-self-sufficient MR system.

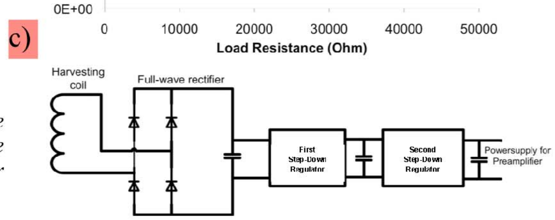
**Methods:** A first prototype of the harvesting coil was built from insulated copper wire (thickness = 0.1 mm, 5000 turns) and was wound on a PMMA holder with dimensions 71 mm x 35 mm x 10 mm. Resistance of the coil gave $R$ = 230 Ω. Dimensions were chosen to fit smoothly inside a commercial Bruker AVANCE III MRI spectrometer (see figure 1a). The harvesting coil was placed 8 cm away from the magnetic isocenter. Next to the harvesting coil, a diode rectifier (to convert AC signals into DC signals) built from Avago HSMS-2822 Schottky diodes [3] was installed on PCB (Printed Circuit Board). This circuit also included a smoothing capacitance, and was connected to an SMB connector plug allowing for external power measurements. Electric power generated by gradient and RF pulses was measured with a hand-held multimeter, or by energy dissipation in external resistors. MRI experiments were performed on a Bruker AVANCE III MRI spectrometer (400 MHz) using standard imaging sequences and coil configurations.



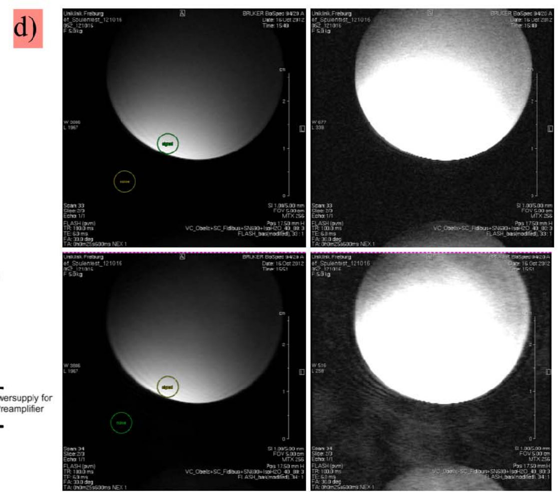

*a) Left: Overview of the sample holder, front and end caps have 72 mm diameter and fit perfectly inside the bore of the scanner. Right: Backside of the sample holder with coil on coil holder attached by screws (5000 windings).*




*b) Power curve of harvesting coil with RF power and without RF power for varying load resistances. Measured during standard Flash sequence*




*c) Electronic circuit for regulating the voltage output of the harvester. We use two step-down converters to get down to the preamplifier supply voltage of 0.5V.*




*d) Comparison between driving the preamplifier with our harvesting coil and with a normal power supply. Upper row with power supply. Lower row with our harvester*

In a first test a commercial linear resonator was used for transmission, while a Bruker surface coil was used to record MR signals from a phantom of ionized water. Additionally we used a preamplifier [4], which was solely powered from our harvesting coil.

**Results:** During the time period of a gradient echo pulse sequence harvested power was measured with varying load resistance. A maximum power of 7 mW with an optimal load resistance of 40 kΩ (see figure 1b) could be recorded. A comparison of the signal intensity of images from the water phantom with and without the harvesting coil driving the preamplifier (see figure 1d), shows that only negligible disturbances could be observed when doing so. We calculated SNR values for both cases for a slice thickness of 1 mm. This gave a value of 61 for driving the preamplifier with a normal power supply and 56 when using power from our harvesting coil.

**Discussion and Conclusions:** It was shown that energy harvesting during an MR experiment with a harvesting coil located inside the magnet bore is possible with only minor disturbance to the imaging setup. Furthermore, a preamplifier could be driven without external power supply. Improvement of the coil and the rectifier are in progress, in order to achieve even higher output and lower noise from the harvesting coil and power regulation electronics.

**References:** [1] O. Heid et al., Proc. Intl. Soc. Mag. Reson. Med. 17 (2009) 4809. [2] S. Martius et. al., Proc. Intl. Soc. Mag. Reson. Med. 17 (2009) 2934. [3] Avago Technologies, San José, CA, USA. [4] E. Fischer et. al., Proc. Intl. Soc. Mag. Reson. Med. 19 (2011) 1862.