

# Optimization of a four-coil array arrangement for brain therapy by MR-guided transcranial focused ultrasounds

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## Introduction

A particularly critical issue for brain therapy with transcranial high-power focused ultrasound (HIFU) is to optimize the accuracy and rapidity of the temperature follow-up during the heating. MRI is a well-suited candidate for temperature monitoring since it offers several parameters such as the proton resonance frequency shift. Up-to-now, temperature scans were achieved using the standard body coil of the MR scanner in order to accommodate the large sized HIFU system and the stereotactic frame surrounding the patient head. However, the limited signal-to-noise ratio (SNR) with the body coil sets a severe constraint onto the quality of the temperature measurement. The aim of this study was to evaluate the improvement in SNR provided by a surface-coil-array alternative, in a 1.5T MR scanner equipped with a new HIFU prototype. Evaluation was done by reproducing the constraints of the HIFU environment with a head phantom and pairs of surface coils of different size available from the MR manufacturer.

## Material and methods

An MR-compatible HIFU prototype made of 512 transducers was constructed and installed in a 1.5T Achieva scanner (Philips, Netherland). A hollow plastic head phantom was placed in the head holder of the dedicated HIFU bed via the stereotactic frame (Figure 1). The head was filled with 0.3% saline water, to achieve almost the same RF loading effect than a human head, and with 2.5 ml of Dotarem (0.35mmol/L), to approach the T1 of white matter. To propagate ultrasounds, a latex membrane was fixed in front of the transducers and filled with water. Two shells of silicone of 1 cm thickness each were interposed between the membrane and the head phantom in order to absorb ultrasounds and protect the phantom during the shots. Five two-element Sense Flex (Philips, Netherland) were involved for the study in addition to the body coil: one Flex-L (20 cm circular elements), two Flex-M (14 cm x 17 cm elliptical elements) and two Flex-S (11 cm circular elements). For each one, the two elements were diametrically opposed either onto the parietal areas of the head phantom (pairs referred as L<sub>P</sub>, M<sub>P</sub>, S<sub>P</sub>) or onto the frontal and occipital areas (L<sub>FO</sub>, M<sub>FO</sub>, S<sub>FO</sub>) (Figure 1). Twelve coil-array configurations were compared. A spoiled gradient-echo EPI sequence was used, with axial slices to control the focal point and with coronal slices to control the signal at the top of the head (table 1).

The SNR was evaluated for each coil configuration and compared to the SNR delivered by the body coil. With Sense Flex scans, the SNR values were derived by applying the sum and difference method [1] to the successive images extracted from a dynamic acquisition series. With the body coil, the SNR was calculated by a mean in the signal of magnitude image and one in the noise of the same image.

In addition to standard thermal noise measurements, the systematic noise arising during HIFU shots (duration 15s, 100ms ON and 200ms OFF) was estimated at different levels of applied power (125Wac, 500Wac, 1000Wac or 2000Wac).

## Results and Discussion

The combination of two Flex-S coils led to the optimal SNR for both large and small ROIs into the transverse slice with a factor of 6 compared to the body coil (Figure 2(a), 2(b)). Flex-S coils were the only ones capable to ensure good coupling with the head in spite of space limitation due to the membrane, the frame and the head holder. The combination of one Flex-M<sub>FO</sub> coil and one Flex-S<sub>P</sub> coil gave the maximal SNR for the large ROI in the coronal slice. The SNR was also maximized into the small ROI, in spite of the marked hyposignal in this area, about 30 % below the signal into the large ROI (Figure 2 (c), 2(d)). The body coil gave the lowest but most homogeneous SNR for any configuration.

To pass the barrier of the skull and heat the brain, the intensity of the HIFU has to be higher than 2000Wac. The body coil and the surface coil arrays are sensitive to the systematic noise arising during a 2000Wac shot as shown in figure 3. However, the use of Flex coils does not entirely damage the phase images. In fact, a variation inferior to 2 radians was observed between two images chosen before and after the shot which corresponds to 0.05°C [2]. It is weak enough not to perturb the temperature mapping.

In conclusion, this study has emphasized the huge potential of using a dual Flex-coil arrangement to improve image quality and temperature sensitivity in HIFU therapy monitored by MRI. In addition, a better SNR will allow a good compromise between temperature sensitivity and faster acquisition times. Further improvement is possible by designing dedicated coil arrays that would incorporate a larger number of coil elements, close shape fitting for a best accommodation of the space restriction with HIFU, and integrated EMI filters within the coil architecture to reject any interference of the HIFU shots with the MR signal.

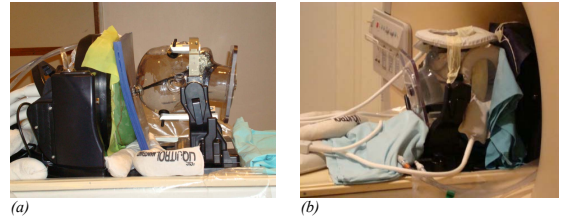
## References

[1] Dietrich *et al.* JMRI, 2007;26:375–385, [2] Quesson B *et al.* JMRI, 2000;12:525–533

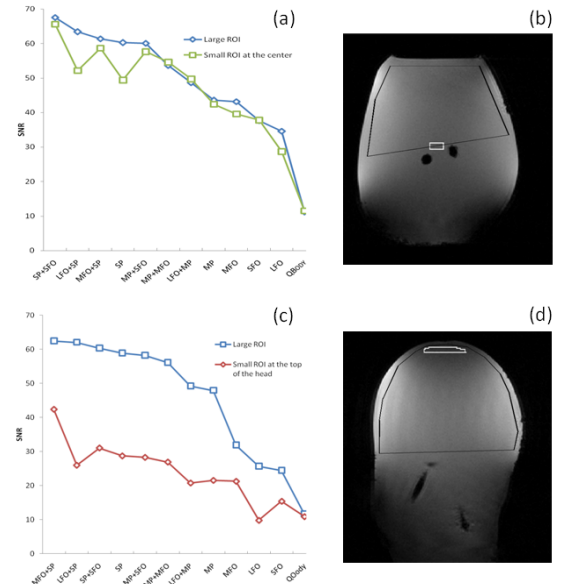
**Table 1:** MRI parameters

TE/TR	30ms/220ms
$\alpha$	55°
EPI factor	7
Spatial resolution	1×1×3 mm <sup>3</sup>
Temporal resolution /image	~2.12s

**Figure 1:** Experimental set-up without coils (a), with Flex coils (b) in the MRI environment.



**Figure 2:** SNR for each configuration of coils for (a) an axial slice with 2 ROIs, the larger one in black and the small one in white (b), and in (c) a coronal slice with 2 ROIs too (d).



**Figure 3:** Magnitude and phase images during a 20V shot with (a) the 2 pairs of Flex-S, and (b) the body coil.

