# Ultrasound-transparent RF coil design for improved MR thermometry of HIFU therapy

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## Introduction

An unobstructed acoustic path from the transducer to the target zone is a prerequisite for any MR guided HIFU procedure. For most MR-HIFU applications, e.g. the ablation of uterine fibroids or palliative treatment of bone metastasis, the ultrasound propagates into the patient through an acoustic window in the liquid-filled table top that contains the transducer [1, 2]. The RF coil solutions of these MR-HIFU platforms typically consist of a single loop coil element surrounding the acoustic window, combined with a multielement upper coil placed on top of the patient [1, 3]. A larger acoustic window is generally preferable since it facilitates faster patient positioning and also provides an improved transducer access to the target region, both of which aid in reducing the total treatment time. For MR-HIFU applications with off-axis targets such as liver or bone, a larger acoustic window is particularly important since both patient positioning and finding an acoustic path to the target can otherwise be very difficult. A larger acoustic window would typically require a larger bottom coil element, which in turn would significantly reduce the SNR and image quality. Here, a novel coil design is presented that enables placing RF coil elements in the acoustic window without interfering with the ultrasound propagation or causing MR thermometry artifacts due to the HIFU exposure of the coil element.

## Material and methods

The proposed window coil consists of one large element surrounding the acoustic window (28 × 28 cm) and one thin detunable center rod (⌀ =0.5 mm) placed across the middle of the acoustic window that can split the large element into two, thus allowing the window coil to be used as either a two- or single-element coil. The prototype coil solution also includes a multielement upper coil. The effect of the thin center rod on the ultrasound propagation was evaluated by measuring the acoustic field of the Philips Sonalleve uterine fibroid transducer with a hydrophone, with and without the center rod within the beam path. The MR thermometry performance of the coil was evaluated on a 3.0 T Philips Achieva MR scanner with the window coil in both single- and two-element mode. To compare the performance of both modes, gradient echo EPI images were acquired with parameters used in PRF-based thermometry of clinical MR-HIFU therapy (5 coronal slices, 1 transverse slice, TR = 29ms, TE = 20ms, resolution = 2.5×2.5×7mm$^3$, FOV 400×340, flip angle 20°, EPI factor = 9, temp. res.= 3.4s). The performance of the two-element mode of the coil for rapid high-resolution thermometry was evaluated using a SENSE factor of 2 to improve the spatial resolution to 1.8×1.8×7mm$^3$ and the temporal resolution to 2.7s, while keeping the other acquisition parameters the same. This sequence was also used for continuous MR thermometry of a HIFU sonication performed with the Sonalleve uterine fibroid MR-HIFU platform through the center coil rod.

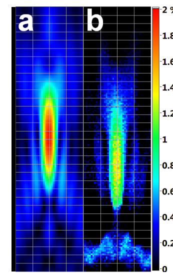


Figure 1: Pressure maps of the focal spot in the direction of the middle coil element (a) with the middle element in place, and (b) the relative difference to when no center rod element is used. Transducer is at the bottom. FOV: 8 × 32 mm, pixel: 0.2 × 0.2 mm.

## Results

Figure 1 shows only minimum disturbance of the pressure field in the presence of the coil rod. There is a 1.6% drop in pressure at the focal point due to the rod, although the focal spot shape remains unaffected. Figure 2 shows a 50% improved SNR in the region near the acoustic window when using the window coil in two-element mode as compared to single-element mode. The region in the immediate vicinity of the center rod element can be seen to have a very high localized signal. Figure 3 shows a good image quality for a SENSE factor of 2 with a 50% reduced SNR in the examined ROI due to the increased spatial resolution and image acceleration factor. Sonication through the center coil rod is in Fig. 4 seen not to create any distortion to the shape of the heated area, or to create any artifacts in the temperature image.

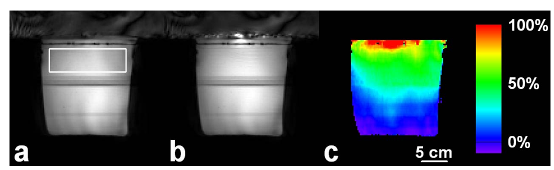


Figure 2: Transverse magnitude images of thermometry sequence with window coil in (a) single-element mode, and (b) two-element mode. The relative improvement in SNR when using the window coil in two-element mode (c) is also shown. The ROI from which the SNR is calculated is given as an overlay in (a). The dark horizontal lines in the magnitude images, (a) and (b), are due to partial saturation caused by the excitation of the coronal slices.

## Discussion/Conclusion

The window coil center rod was seen not to cause any significant disturbances to the acoustic field, and sonication through the coil rod did not produce any noticeable artifacts in the PRF-based temperature images. The use of such coil elements within the acoustic path was shown to increase the SNR, especially in the near field, and will thus decrease the temperature uncertainty. The area with substantially increased SNR for the prototype coil studied was seen to extend approximately 10 cm from the acoustic window, thus encompassing the near field and target region for most MR-HIFU applications. The improvement in temperature accuracy is particularly valuable in the near field where the temperature is monitored for safety reasons and smaller increases in temperature are expected. Moreover, the increased amount of coil elements also allows for imaging acceleration factors that would otherwise not be possible, which can either be used for increasing the temporal or spatial resolution, or gain a larger coverage. A larger amount of coil elements than the one used here can of course also be placed within the acoustic path, potentially allowing even higher acceleration factors. To our knowledge, the positioning of coil elements within the HIFU beam path without disturbing the acoustic field is here demonstrated for the first time. This novel coil design, which might prove useful for several different MR-HIFU applications, allows for considerably more freedom in the RF coil design for MR-HIFU. This should in turn allow for improved MR thermometry while also enabling the use of large acoustic windows for easier patient positioning and improved transducer access to the target region.

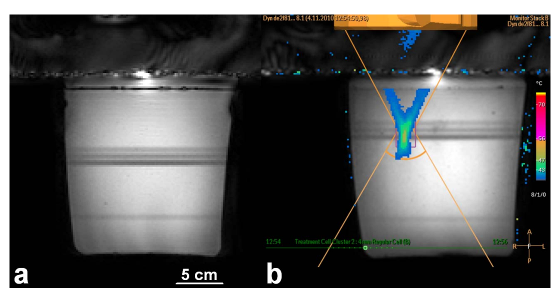


Figure 3: Transverse magnitude image of the high-resolution rapid thermometry sequence with a SENSE factor of 2 when no sonication is applied (a) and temperature map acquired with the same sequence during sonication through the middle coil element (b). The location of the middle coil element corresponds to the bright spot in the middle of the images.

## References

[1] Tempany et al. Radiology 2003; 226:897-905. [2] Gianfelice et al. Radiology 2008; 249:355-363. [3] Köhler et al. Med Phys 2009; 36(8):3521-3535.