Simplifying MR-guided focused ultrasound experiments by using the water bath as an intrinsic high mode dielectric resonator.

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Target audience: researchers involved in the area of MR-monitored thermal therapies such as high intensity focused ultrasound

Purpose: to introduce a new setup for integrated MR/ultrasound (1-3) in which the water bath required for the ultrasonic irradiation forms a high modal structure dielectric resonator, removing the need for a separate RF coil.

Methods. The dimensions of the water bath required for a TE_{012} mode resonance were determined at 7 T from (4), and verified using EM simulations. The magnetic field is shown in Figure 1(a). An ultrasound transducer operating at 1.5 MHz was waterproofed and placed at the bottom of the water bath, as shown in Figure 1(b). A small pick-up coil is placed outside the water bath and interfaces with the scanner. Gradient echo images were acquired with a TR/TE of 20 ms/ 5 ms, slice thickness 2 mm, in-plane spatial resolution 1 x 1 mm.

Results. Figure 1(c) shows a gradient echo image acquired through the centre of the water bath. The dark outline of the ultrasound transducer is clearly seen. As expected from the magnetic field profile of the TE_{012} mode within the water bath the highest signal intensity occurs at the top central part of the water bath, corresponding to the focal point of the transducer. In Figure 1(d) an orange is placed at the focal point, showing high MR signal.

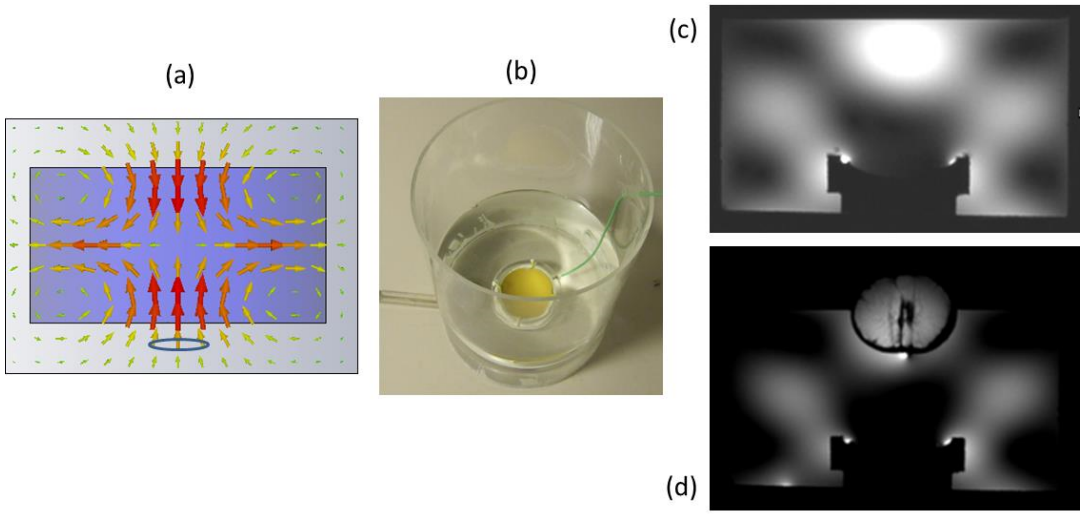

Figure 1 . (a) Electromagnetic simulation of the TE_{012} mode through the centre of a water bath, showing high values at the top and bottom of the water bath. (b) Experimental setup using a single element focussed transducer placed at the bottom of the water bath. A small pickup loop at the bottom and outside of the bath transmits the RF pulse and detects the MR signal. (c) and (d) gradient echo images showing maximum MR sensitivity at the focus of the transducer.

Discussion. By designing the dimensions of the water bath required to couple the energy of a high intensity focused ultrasound transducer into the tissue to be irradiated, it is possible to use the TE012 mode of the bath to image the sample. This removes the requirement to have a separate MRI coil which either has a very low filling factor (body coil) or can interfere with the set-up (localized surface coil). The TE012 mode is very appropriate since the intensity maximum lies at the top of the cylinder, exactly where the sonicated sample lies. Although the experiments were performed at 7 Tesla, the dimensions of the water bath which would be required at 3 Tesla fit well with current sizes of integrated water boluses in the MR table.

Conclusion. A new principle of MR signal detection, specifically targeted towards MR-guided HIFU, has been introduced. This approach needs no RF coil, using a natural resonance mode of the high permittivity water bath, reducing the complexity of an integrated MR/ultrasound setup.

References. 1. V.Rieke and K.Butts, J.Magn.Reson.Imag. 27, 376, 2008. 2. J.W.Wijlemans et al. Canc.Imag. 12, 387, 2012. 3.K.Hynynen, J.Magn.Reson.Imag. 34, 482, 2011. 4. A.G.Webb, J.Magn.Reson. 216, 107, 2012.