Screen Printed HIFU Compatible Receive Coil

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Target Audience: MR Engineering, RF coils, HIFU designers and clinicians.

Introduction: We present a screen-printed surface coil compatible with MR guided High Intensity Focused Ultrasound (HIFU) therapy. MR guided HIFU is a therapy technique used to ablate tissue or activate heat sensitive medication inside a patient's body with acoustic energy (Fig.1) [1].

A surface coil is most sensitive to tissue close to the coil, so placing it between the transducer and the patient would give the highest signal to noise ratio (SNR). To treat the entire target, the transducer is moved in the water bath, which would pass acoustic energy directly through different parts of the coil. However, ultrasonic energy easily scatters and attenuates in the thick fiberglass reinforced boards, solder, and porcelain capacitors commonly used in coil construction. As a result, body or non-fitting coils are currently being used during therapy. This limits the SNR for accurate temperature estimation and resolution compared to what could be achieved using surface coils. We created a surface coil using ultra-flexible materials that allows it to be placed in the beam path of an ultrasonic transducer while adding negligible attenuation and signal distortion.

Methods and Results: I. *Processing-* We printed coil components - specifically conductors and capacitors - on a 75 µm thick polyethylene terephthalate (PET) film by screen-printing Creative Materials 118-09A/B and Creative Materials 116-20 inks layer by layer as described in [2].

II. Materials Testing- To understand the performance of the printed components we immersed printed capacitors in water between an ultrasonic transducer and hydrophone. Acoustic power was transmitted through capacitors on substrates and recorded by the hydrophone over an area of 20x20 mm^2 in 2 mm increments (Fig. 1). Figures 2a and 2b show that common coil conductors and capacitors significantly attenuate and scatter the beam compared to printed components.

To examine the effects of water on coil lifetime, we immerse several test coils into a deionized water bath and measured quality factor (Q) periodically over the course of 24 hours (Fig. 3a). Printed coils without encapsulation showed degradation after a few minutes whereas printed coils laminated with a second sheet of PET and sealed with Delo Katiobond LP612 maintained an adequate Q for 10 hours.

III. Imaging- SNR and heating behavior in were performed on a 3T clinical scanner (GE Healthcare Waukesha, WI) equipped with an InSightec HIFU transducer in the patient table. A single channel 8.7 cm diameter receive coil resonant at 127 MHz (Fig. 4a) was fabricated.

Attenuation and scattering of acoustic energy was tested by placing a printed coil and a coil made from 1 mm thick PCB with soldered capacitors between an InSightec gel phantom and the HIFU transducer (Fig. 4b). The transducer was focused 11 cm into the phantom and applied acoustic power of 10.8 W for 20 seconds. Temperature increase was calculated according to [1] with gradient echo scans (FA 30^o, TR 25.432 ms, TE 12/12.853 ms, and 3 mm slice thickness). Figures 3b and 3c show the printed coil retaining 79% of the acoustic signal intensity without significant beam spreading compared to 32% for the conventional surface coil. A phantom was scanned using the printed coil and body coil without ultrasonic heating to compare SNR. Figure 4c shows that the printed surface coil outperformed the body coil up to an 8 cm depth. The SNR and penetration would improve using coil arrays.

Conclusions and Outlook: Our printed coils showed high SNR at the surface of the phantom and did not significantly interfere with the HIFU system's ability to operate. Through the use of a barrier layer the coils withstood the mechanical and environmental stresses present in HIFU. Using this technique, an array of printed coils could be created to increase field of view and penetration in addition to enabling multi-coil parallel imaging techniques [3-4].

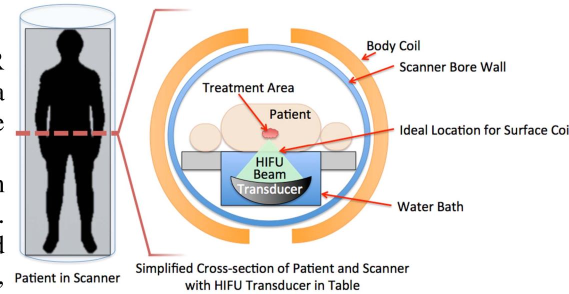

Fig 1: Schematic of patient in HIFU capable scanner along with cross-section. Ultrasonic transducer is in water bath below patient's body.

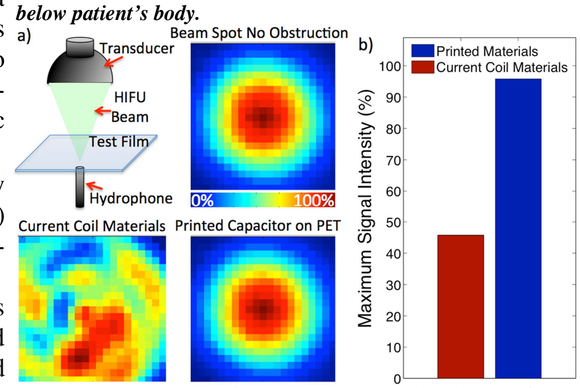

Fig 2: (a) Setup and acoustic power distribution from transducer as seen by a hydrophone over a 20x20 mm^2 area. (b) Maximum signal intensity of ultrasonic signal transmitted through printed and conventional coil materials.

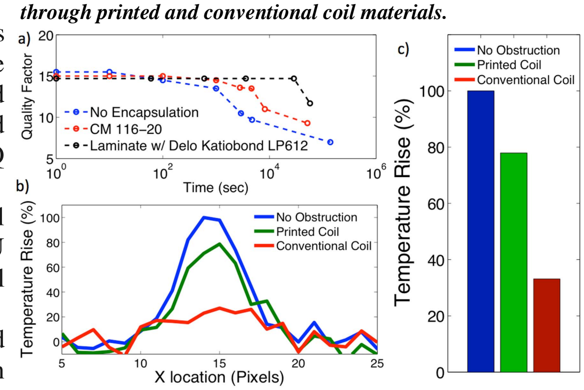

Fig 3: (a) Quality factor of printed coils over time when exposed to deionized water. (b) Beam profile from scans of heating area through printed and conventional surface coil. (c) Maximum temperature rise through printed and conventional coil.

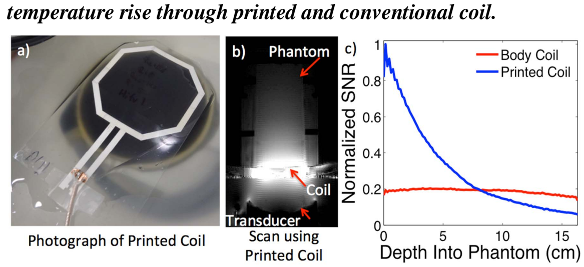

Fig 4: (a) Picture of printed HIFU compatible coil. (b) Sagittal scan of InSightec heating phantom using printed coil. (c) SNR vs. depth into phantom for printed and body coils.

[1] V.Rieke and K. Butts-Pauly Jorn. Magn Reson Imaging (2008) Feb;27(2):376-90. **[2]** J. Corea et. al, ISMRM 2012. **[3]** P. Roemer et al., MRM. 16, 192 (1990). **[4]** KP Pruessmann et al., MRM 42, 952 (1999). **[5]** E. Minalga et al ISMRM 2012. **[6]** R. Watkins et al., ISMRM 2014.