DESIGN AND EVALUATION OF RF COILS FOR MAGNETIC RESONANCE GUIDED HIGH INTENSITY FOCUSED ULTRASOUND

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Introduction: The purpose of this work was to design and construct an MRI radio frequency (RF) coil with better performance for imaging the breast than a single loop chest coil. The specific goal was to increase SNR in the breast for improved temperature measurement, cancer verification, and tissue characterization for MR guided high intensity focused ultra-sound (MRgHIFU).

Methods: **Simulations** were performed to assess the SNR performance of several coil designs for breast HIFU. **Construction:** From the results of the simulations, a 10-channel cylindrical ladder coil with a loop at the chest was chosen (**Figure 1**) for its relatively high SNR, ease of implementation, and reduced image reconstruction time. The coil was easier to implement by having relatively small number of channels and the capacitive decoupling of adjacent loops. Channels were decoupled from neighboring coils using capacitive decoupling and preamp decoupling. Each coil had active and passive detuning. **Phantom Studies:** For SNR comparisons, a gradient-echo sequence was used with (1 mm)^3 isotropic spatial resolution, TR 50 ms, TE 4.12 ms, and flip angle 25^o. Inverse g-factor maps were calculated and the g-max value was found for a 2x2 reduction factor. **Human Studies:** With IRB approved informed consent, 1 female volunteer has been imaged in the breast coil. Anatomy images are shown here were proton density gradient echoes with (1 mm)^3 isotropic spatial resolution, TR 50 ms, TE 4.12 ms, and flip angle 25^o. **Ex Vivo Heating:** MRgHIFU experiments were performed with a MR compatible 256-element phased array HIFU system (IGT, Inc.). An ex vivo porcine muscle sample was heated with 10 acoustic watts for 30s. Temperature maps were acquired using a phase difference calculation at 1.5x1.5x3mm and was acquired every 3.2 s. The standard deviation of each non-heating point in the volume through time was calculated and the map is displayed. These tests were performed to determine the spatial resolution that is achievable while retaining accurate temperature maps to assess the coils' functionality in temperature imaging.

Results: The neighboring coils of the HIFU coil decoupled sufficiently from each other where the lowest nearest neighbor noise correlation being 0.303, median 0.474, and highest value was 0.554. The 11-channel cylindrical coil compared to the single loop chest coil had 2.4 times the SNR in the center of the breast and 4.5 times more SNR at the skin of the breast (**Figures 2 and 3**). The g-max value for 2x2 reduction factor was 2.2451 (**Figure 4**). The anatomy images were better with the HIFU coil compared to the chest coil (**Figure 5**). The temperature curves were less corrupted by noise for the HIFU coil compared to the chest coil (**Figure 6**). The mean standard deviation through time for the chest coil was 0.8025 and for the HIFU coil was 0.3156 (**Figure 7**).

Discussion: The breast ladder coil gave much better SNR than the single chest loop. This increase translates directly to higher resolution both spatially and temporally. The g-factor maps and values show that a reduction factor of 2x2 can be achieved while maintaining a higher SNR than the chest coil. The temperature maps for the breast ladder coil have less noise as indicated by the lower standard deviations in the volume through time. The temperature curve appears to follow known heating and cooling curves. The spatial resolution can be increased and this will allow for more precise heating of the tumors and add to patient safety and treatment efficacy.

Conclusions: Limitations that have come up include the amount of reconstruction time for a multi-channel coil increases. Due to the need for temperature maps every few seconds; reducing image reconstruction time becomes a factor to consider. The size of HIFU tank can also be reduced to reduce water volume and the resulting noise contribution to the images. Further testing will be completed to more fully characterize the impact of this coil on HIFU treatments.

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References

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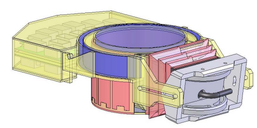


Figure 1. The 11-channel HIFU cylindrical ladder coil.

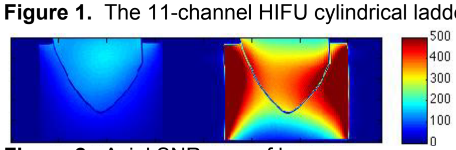
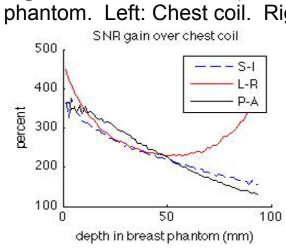


Figure 2. Axial SNR map of homogeneous phantom. Left: Chest coil. Right: HIFU coil



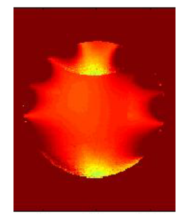


Figure 3. Line plots of percent SNR increase of the HIFU coil over the chest coil taken through the SNR maps. The blue line is taken from superior to inferior. The red line was taken from left to right. The black line was taken from posterior to inferior.

Figure 4. Inverse g-factor maps of 2x2 reduction factor in coronal plane. Gmax is equal to 2.2451.

Figure 5. Anatomy image of a breast. Left: chest only. Right: HIFU coil.

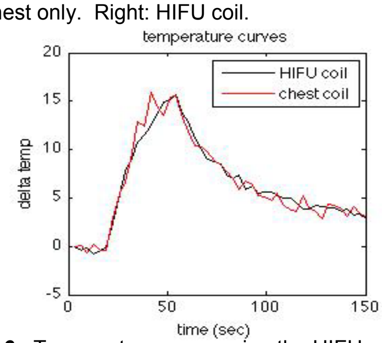


Figure 6. Temperature curve using the HIFU coil (black line) and a chest coil (red line).

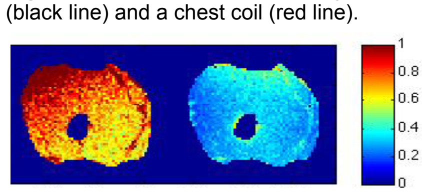


Figure 7. Standard deviation plots through time of non-heating region of sample. Left: Chest coil only. Right: HIFU coil8.