# Comparison of improved breast magnetic resonance guided focused ultrasound system with improved radio frequency phased array coils.

Emilee Minalga[1], Robb Merrill[1], Dennis L Parker[1], Allison Payne[1], and J. Rock Hadley[1]
[1]*UCAIR, University of Utah, Salt Lake City, UT, United States*

**Introduction:** High signal to noise ratio (SNR) is critical in magnetic resonance guided focused ultrasound (MRgFUS) for accurate tissue characterization and faster, more accurate temperature measurements. Yet, the system requirements include transducer location, body anatomy, and use of an acoustic coupling medium make engineering coils in the MRgFUS environment challenging. This work modified a previously designed and constructed breast-specific MRgFUS system to improve performance for imaging and treating the breast. A specific goal was to increase SNR in the breast for improved spatial and temporal resolution, temperature measurement, and tissue characterization for MRgFUS breast treatments.

**Methods:** **Construction:** Two FUS breast systems with phased-array decoupled ladder coils[2] wrapped around the treatment cylinder and one large loop around the chest wall were simulated and built with the characteristics given in Table 1:

| TABLE 1 | Version 1[1] | Version 2 |
|---|---|---|
| **Total channels** | 11 | 8 |
| **# of ladder channels** | 10 | 6 |
| **Ladder channel dimensions** | W=4 cm; H=11 cm | W=5 cm; H=9 cm |
| **Treatment cylinder dimensions** | D=18 cm; H=13 cm | D=14 cm; H=12cm |
| **Chest loop diameter** | D=17 cm | D=17 cm |
| **Coil around transducer opening?** | No | Yes: W=16cm H=14cm |

Compared to version 1 (v1), version 2 (v2) had a smaller tank radius allowing the RF coils to be placed nearer to the breast volume. Because of the reduced circumference, fewer coil channels were used to maintain a similar surface area per channel to avoid any unnecessary increase in the signal sensitivity at the water surface near the coil. (**Figure1**). Having fewer channels allowed reduced image reconstruction time and reduces data file size. Channels were decoupled from neighboring coils using capacitive decoupling and preamp decoupling[3]. Each coil had active and passive detuning. **Phantom Studies:** Experiments were performed in a TIM Trio 3T MRI scanner (Siemens, Erlangen, Germany). For SNR comparisons (**Figure 3**) a 3D gradient-echo sequence was used with (1.5 mm)$^3$ isotropic spatial resolution, TR/TE = 50/4.2 ms, flip angle = 25$^o$. Noise correlation values were also calculated (**Figure 4**).

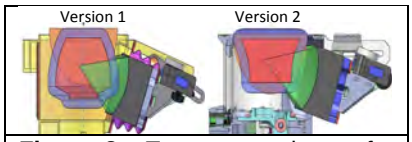


**Figure 2.** Treatment volumes for v1 (left) and v2 (right). Pink volume is treatment volume achieved with mechanical steering, purple volume is additional volume achieved with electronic steering.

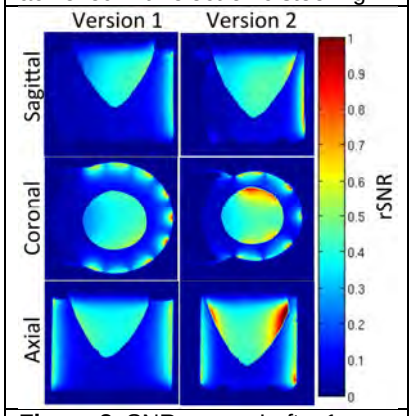


**Figure 3.** SNR scans. Left: v1. Right: v2. Top: Sagittal. Middle: Coronal. Bottom: Transverse..

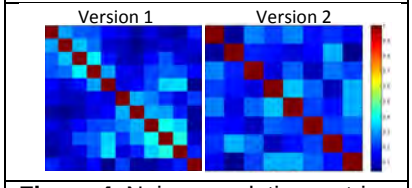


**Figure 4.** Noise correlation matrix. Left: v1. Right: v2.

**Results & Discussion:** The treatment volumes (mechanical + electrical range displayed in Figure 2) were 1422 cm$^3$ and 1001 cm$^3$ for v1 and v2, respectively. Compared to the v1 coil, the v2 coil had an increase in SNR of 13% in the center of the breast, 61% at the skin surface by the cylinder side wall, 45% at the skin surface near the transducer opening and 45% at the chest wall (**Figure 3**). The neighboring coils of the v1 and v2 were decoupled sufficiently from each other with the highest off-diagonal correlation values being 0.4154 and 0.3358, respectively. The treatment volume for v2, although smaller, more closely fit the anatomy of the breast with an increased treatable volume at the chest wall. In addition, the v2 system was designed with the preamps positioned around the bottom circumference of the tank, shielded from water with a 3D printed housing. This new configuration improved the stability and robustness of the entire system. The breast-tensioning device is integrated into the system and controlled with an external gear mechanism. The transducer is positioned 1cm closer to the chest wall for improved patient treatment volume, and the overall maximum diameter of the device has been reduced by 15 cm.

**Conclusions**: Directly integrating RF coil design into MRgFUS systems can improve all aspects of therapy including treatment planning, monitoring and assessment. The v2 MRgFUS breast coil array has increased the SNR compared to the v1 coil over the entire breast volume with the most gains in the SNR starved regions such as the transducer opening and the chest wall. The use of this coil in MRgFUS breast treatments will provide greater temperature measurement accuracy that will aid in providing safer more efficacious treatments for patients.

**Acknowledgments:** The funding was provided by the FUS Foundation, the Mark H Huntsman chair, and NIH R01 CA 172787.

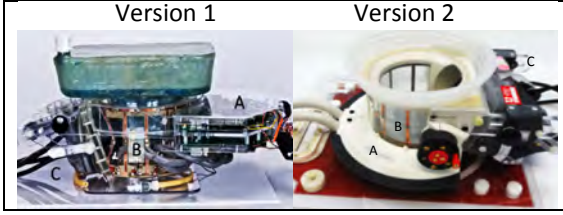


**Figure 1.** RF coils mounted on the MRgFUS treatment cylinders. Right: ***V1***: An 11-channel MRgFUS system with fiberglass breast phantom placed in the system. Left: ***V2***: An 8-channel MRgFUS system.

References:[1.] Minalga et al. Magn Reson Med. 2013 Jan;69(1):295-302. [2.] A EW et al. Journal of Magnetic Resonance; 1986. p 156-161. [3.] Roemer et al. Magn Reson Med 1990;16(2):192-225.