Focused Microwave Therapy Study on Realistic Breast Phantoms

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Minimally invasive and non-invasive breast cancer therapies help preserve cosmetic appearance and reduce morbidity in patients compared to more aggressive surgery. Focused Microwave Therapy (FMT) is an innovative approach for hyperthermia and ablation through near-field electromagnetic beamforming employing phased array antennas. Accurate focusing of the microwave beam and localized heating requires predictive modeling, optimized microwave hardware, and, ideally, a feedback system to monitor temperature and tissue changes during heating. In this study, we report the modeling performance of a phased-array system designed for FMT of the human breast, which parallels a system we are currently building.

The system is comprised of a conformal array of microstrip patch antennas in a multi-ring setting, as shown in Figure. 1, operating at 915 MHz to focus CW microwave power deep into the breast immersed in coupling/cooling medium. Initially, time reversal beamforming algorithm is employed, where a virtual source is excited at the target location within the breast. Phase-conjugated fields are re-radiated from the antenna array to generate focus at the tumor location (Stang, John et al., IEEE Trans Biomed Eng. 2012; 59(9):2431-8). Microwave power deposition is derived based on conductivity and E-field distribution inside breast phantom. Power deposition values are then used to determine the temperature distribution using the Penne's bio-heat equation through CST Bio-EM coupled simulations considering the blood flow coefficient and basal metabolic rates. The beamforming algorithm is verified using realistic breast phantoms. [University of Wisconsin, Madison]

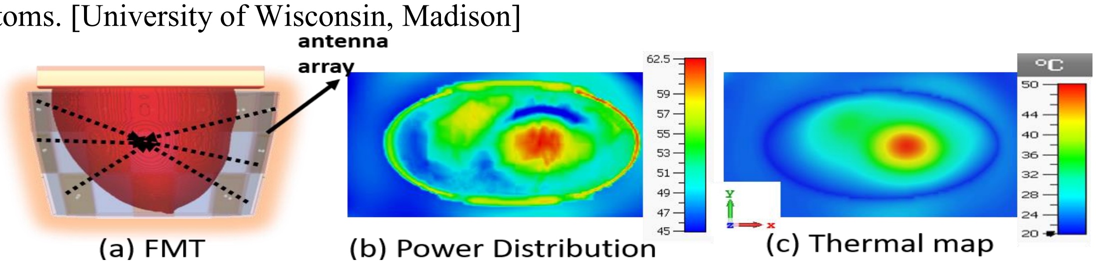

Figure 1. (a) Focused Microwave Therapy setup used to create focused beam in realistic human breast phantoms (b) Microwave power distribution (W/m^3) (c) Thermal map

Following the simulation process, the results for power and temperature distributions inside a dense breast model are depicted in Figure 1. (b) and (c). The results suggest that the current time-reversal method employing 32 element array (with a total power of 320W) can achieve suitable focusing with cm level focal spot sizes. The steady state temperature distribution exhibits preferential heating at the tumor location while maintaining healthy tissue around 37°C. The surrounding cooling medium maintains the skin temperature at 20°C.

As the invariance of Maxwell equations in lossy scenarios is broken, time reversal technique becomes inadequate. Additionally, limitations of peripheral heating and unwanted hotspots exist which can be mitigated by optimization techniques. Hence, once initial excitations are obtained from time reversal algorithm such that the main beam is focused at the target, non-linear optimization techniques using built-in optimizers in CST are used for enhanced accuracy in focal size and intensity. The beamforming ability after application of these optimization strategies are currently being evaluated and will be reported at the conference.