Real-Time 3D Microwave Thermal Imaging of a Microwave Ablation Probe

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Radio Frequency (RF) and microwave probe ablation is currently used clinically for the treatment of a variety of cancers, such as prostate, pancreatic, breast, liver, and uterine. The most common ablation method employs the use of narrow gauge invasive coaxial probes that are excited with a low frequency, high power radio signal. These probes are typically guided into place using either ultrasound or MRI based monitoring systems that have either limited or no temperature monitoring capability. The treatment zone is therefore relatively uncontrolled and can only be verified with post-operative imaging. In order to improve outcomes, there is a clear clinical need for 1) better controlled heating zones, and 2) real-time, non-invasive monitoring of the heat deposition. In this work, we attempt to address the latter.

In previous work, we have demonstrated real-time 3D microwave imaging of differential temperature in simple breast phantoms with 2 cm spatial resolution, 0.5^{o}C temperature resolution, at 4 second refresh rates (M. Haynes, J. Stang, M. Moghaddam, *IEEE TBME,* 61(6), pp. 1787-1797, 2014). Here, we investigate the use of this system and method for the task of imaging the heat deposition of an invasive microwave ablation probe.

The imaging system consists of a 12-panelled cavity filled with a coupling fluid. Each panel has three antennas that operate at 915 MHz. Real-time imaging is accomplished with an HFSS model, pre-computed linear inverse scattering solution, Vector Network Analyzer, Labview, and solid-state switching matrix. The microwave ablation probe was designed and fabricated at the University of Wisconsin-Madison (L. Hung, G Fuqiang, S. C. Hagness, N. Behdad, *IEEE TBME,* 61(6), pp. 1702-1710, 2014). Its heating zone is optimized with a balun to work at 1.9 GHz in human soft tissue and is wrapped in a Teflon coating. In our experiments, the probe is inserted into gelatin or in vitro animal tissue targets and excited with a 40W, 1.9 GHz CW signal while scattered field measurements are taken at 915 MHz. We have increased the refresh rate from our previous results to under 0.5 seconds per volumetric image. We also compare L1-norm versus L2-norm cost functions and their effect on image quality.