Multifunctional Microwave Ablation Antennas and Algorithms for Combined Ablation and Monitoring

James F. Sawicki, Hung Luyen, Nader Behdad, and Susan C. Hagness
University of Wisconsin-Madison, Madison, WI, 53706

Microwave ablation (MWA) is a thermal therapy technique applied to cancerous tumors of organs like the liver, lung, and kidney, as well as to non-cancerous diseases like endometrial bleeding. In MWA, an interstitial antenna delivers electromagnetic energy directly to the diseased tissue site and causes a local temperature rise and rapid cell death. Real-time monitoring of the tissue coagulation zone is currently achieved using clinical imaging systems, such as magnetic resonance imaging (MRI), computed tomography (CT) or ultrasound, all of which pose technical or logistical challenges for this application.

We propose an interstitial microwave ablation antenna capable of simultaneously performing ablation and providing data for treatment monitoring. Microwave propagation does not undergo the strong scattering that ultrasound waves do when incident upon steam bubbles, does not expose the patient to ionizing radiation as in CT, and does not require expensive scanning equipment as in CT and MRI. The use of a MWA applicator for tumor detection (P. Wang, et al., IEEE Trans. Biomed. Engr., 56, 2634–2641, 2009) and ablation monitoring (P. Wang, et al., World Conf. Interv. Oncol., Beijing, China, 2009) has been proposed previously as a simple alternative to microwave tomography arrays. The approach reported by Wang et al. for tracking the growth of the ablation zone resulted in experimental errors of up to 25%. The goal of our work is to dramatically improve the accuracy of microwave-based monitoring over previously reported attempts.

Our system utilizes multi-frequency monitoring in order to take advantage of the dependence of sensing volume on frequency; lower frequency waves can penetrate further into tissue and provide information about the dielectric environment further from the antenna than higher frequency waves. The proposed sensing technique exploits changes in the broadband reflection coefficient of the antenna to determine the progress of ablation. The MWA antenna is designed to have multiple narrowband resonances whose movements are tracked over the duration of the heating. The spatial and temporal dependence of dielectric properties in liver tissue during ablation is incorporated in realistic electromagnetic simulations to test the behavior of the antenna and the performance of the algorithm. Results of a simulation study are confirmed with *ex vivo* tissue experiments.