A Preclinical Focused Microwave Thermal Therapy System with Integrated Real-Time Feedback and Monitoring

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In the current standard-of-care treatments for breast cancer (surgery, chemotherapy, hormonal therapy, and radiation therapy), there remains a need for the reduction of local recurrence, harmful side-effects, and cosmetic harm. Toward that end, a preclinical microwave thermal therapy system has been developed for the targeted treatment of breast cancer cells using focused microwaves as an adjuvant to radiation, chemotherapy, and high intensity focused ultrasound (HIFU).

A hemispherical array of antennas operating at 915 MHz is used to focus continuous-wave (CW) microwave energy transcutaneously into the pendent breast suspended in a coupling medium. Prior imaging studies are used to ascertain the material properties of the breast tissue, and this data is incorporated into a multiphysics model. Time-reversal techniques are employed to find a solution for the relative amplitude and phase for each antenna array element for focusing at a given location; this solution is also used to precondition a weighted inverse solver that can optimize treatment planning for ablation at the tumor location while minimizing the thermal dose elsewhere in the breast. A set of custom-designed RF modules, each with built-in RF feedback circuitry and digital control, is then used to deliver up to 1 kW of microwave power (CW) to the hemispherical antenna array. Using this array, the microwave therapy system is able to achieve focal spots with a full width at half maximum (FWHM) size on the order of 2 cm anywhere within the breast.

In addition, there is a clinical need for real-time monitoring of subcutaneous heat deposition. We investigate the use of microwave imaging for this. We expect the dielectric constant of water to change by a few percent over the expected range of therapeutic temperatures. Because the change is small, differential imaging methods are tested. The scattered field data for imaging is collected in the same antenna geometry and at the same frequency as the therapeutic array to test the feasibility of integrating the two systems. The ultimate goal of this feature is to use the differential images for real-time feedback of heat deposition.