RF Modeling of a Prototype Phased Array Applicator Designed for Thermal Therapy in the Breast

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Abstract

Thermal therapy kills tumor cells with the cytotoxic effects of heat. Thermal therapy simultaneously sensitizes otherwise resistant cells to the effects of radiation therapy, which motivates the use of thermal therapy as an adjuvant to radiation therapy. Thermal therapy techniques are also employed in heat-mediated drug delivery, where the contents of encapsulated drugs are released within a tumor volume once the threshold temperature is exceeded.

In a collaborative effort between Michigan State University and Duke University Medical Center, prototype Radio Frequency (RF) phased array applicators are being designed and characterized for thermal therapy in the breast. This effort, which models RF fields with the finite element method, incorporates the boundary conditions imposed by the walls of the treatment room, the geometry of the prototype RF array, and a 3-D description of patient anatomy. The room is, as a first approximation, a Faraday cage so all RF radiation outside of the room is ignored. The RF phased array prototype is intended for regional heating and therefore operates in the frequency range of 130-160MHz. In this numerical model, a description of the breast anatomy is extracted from Computed Tomography (CT) or Magnetic Resonance (MR) scans, and this information is combined with the material properties of normal and tumor tissue for finite element calculations. The geometrical and material descriptions are entered into FEMLAB, which defines the finite element mesh for all numerical simulations of the prototype RF applicator. After the mesh is defined, finite element results are computed for each antenna and then superposed. Results of simulated power depositions in a 3-D breast model containing a tumor and normal tissue will be presented for a 4-channel RF array prototype. In the breast model, the penetration depth will be evaluated for both single-channel and phased array configurations. Ultimately, the power depositions computed from the RF model will be combined with thermal modeling, and the results of the numerical modeling effort will impact future array designs and treatment strategies.