URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Comparison of Microwave Breast Hyperthermia Applicators with FORA Dipole: Circular, Linear and Cross Arrays

Gulsah Yildiz*[1], Iman Farhat[2], Lourdes Farrugia[2], Tuba Yilmaz[1], Ibrahim Akduman[1], and Charles V. Sammut[2]

(1) Istanbul Technical University, Istanbul, Turkey: gulsahyildiz@itu.edu.tr, tubayilmaz@itu.edu.tr, akduman@itu.edu.tr

(2) University of Malta, Msida, Malta; e-mail: imanfarhat@um.edu.mt, lourdes.farrugia@um.edu.mt, charles.v.sammut@um.edu.mt

In microwave hyperthermia (MH) breast cancer therapy, electromagnetic waves are optimized to focus energy on the tumors and elevate the temperature above its normal levels with minimal disturbance to the healthy tissue. The efficacy of the therapy remains within the modelling parameters of MH applicator and the antenna excitation parameter selection. This study utilizes the fractal octagonal ring antenna (FORA) elements at 2.45 GHz for breast tumor hyperthermia application. FORA element was considered due to its adaptability to different array configurations. Two types of antennas were investigated, the FORA dipole antenna and FORA connected array. FORA dipole were obtained using two FORA elements on either side of the excitation port yielding a dipole antenna. The FORA connected array consists of connected dipoles in the latitude direction of the array and capacitively coupled via inter-digital capacitors in the longitudinal direction. Despite the fact that the dipole array is made of numbers of individual dipole antennas, the number of antennas in the connected array can be extended by including extra array elements in the latitude or longitude. The FORA dipole is an narrow band while the FORA connected is wideband. Both dipole antenna array and connected array geometries were analyzed thoroughly. To derive the field distributions, simulations of microwave hyperthermia system using various FORA array designs and a fat phantom are performed in COMSOL Multiphysics. For ease of comparison, fat phantom was chosen. The antennae excitation phases and magnitudes were optimized using the global particle swarm algorithm to selectively increase the specific absorption rate (SAR) at the two-dimensional target region while minimizing hot spots in other regions within the breast. SAR distributions, obtained inside the phantom, were analyzed for each proposed MH applicator design. The dipole FORA arrays were comparatively assessed for three different geometric designs and two different layer options: circular, linear, cross array and one- and two-layers. The 16-antenna dipole array performance was superior for all three one-layer applicator designs, and no distinct difference was found between 16-antenna circular, linear, or cross arrays. Two-layer dipole arrays have better performance in the deep tissue targets than one-layer arrays. The performance of the connected array was compared for 11- and 13-latitudinal antennas and 3-, 5-, and 6-longitudinal antennas (or layers), where the largest number of antennas to be examined had $11 \times 6 = 66$ antennas. With a higher number of layers, connected array exceeds the performance of the dipole arrays in the superficial regions, while they are comparable for deep regions of the breast. The 16-antenna FORA dipole array with two-layers was then implemented with a realistic breast phantom and the SAR optimization was performed in three-dimensions. The distance between the layers was optimized for each target region for a better focusing performance.

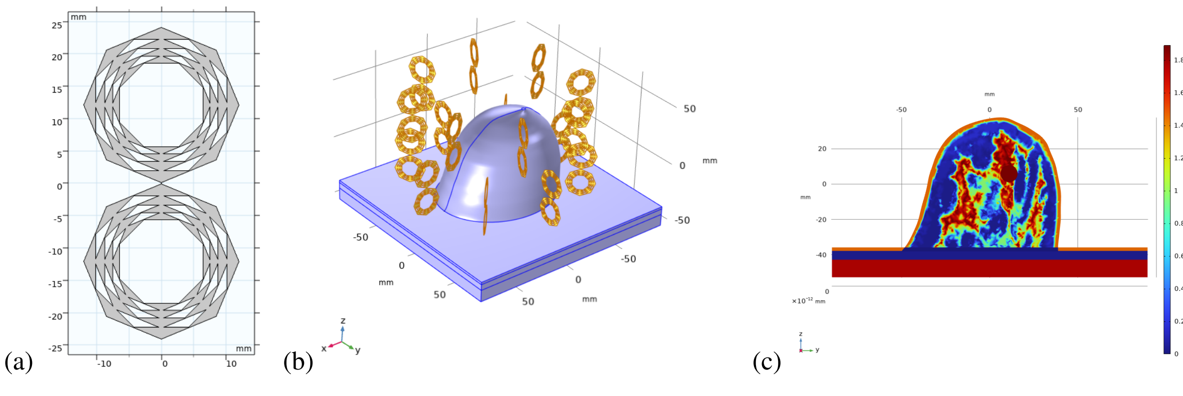

Figure 1. (**a**) FORA dipole antenna geometry, (**b**)Hyperthermia applicator system with the breast model, (**c**) The electrical conductivity (S/m) distribution of the breast model with tumor inclusion. The axes are in mm.