Microwave Detection of Breast Cancer via Contrast-Enhanced Differential Imaging in Three Dimensions

Jacob D. Shea, Panagiotis Kosmas, Barry D. Van Veen, and Susan C. Hagness
Department of Electrical and Computer Engineering
University of Wisconsin, Madison, WI 53706
shea@cae.wisc.edu, hagness@engr.wisc.edu

The application of microwave tomography to medical imaging of the breast has been an active topic of research in recent years. A microwave antenna array surrounding the breast volume measures the scattered electromagnetic waves for each transmit-receive pair of antennas. The measured data is used to construct an estimate of the unknown dielectric profile of the breast interior by solving a system of equations that relates the unknown profile to the received scattered fields.

Recent studies of normal and malignant ex-vivo breast tissues (Lazebnik et al, Phys. Med. Biol., 52: 2637-2656, 2007, and Lazebnik et al, Phys. Med. Biol., 52:6093-6115, 2007) revealed a considerable (as large as 10:1) dielectric contrast at microwave frequencies between normal fatty and glandular tissue in the breast, but only a small (at most 10%) contrast at microwave frequencies between normal and malignant fibroglandular tissues. We recently developed and applied a three-dimensional inverse scattering algorithm to scattered signals computed from numerical breast phantoms that incorporated the recent dielectric properties data (Winters et al, IEEE Trans. Med. Imaging, in press, 2008). Our results illustrated the implications of the latest dielectric properties data. Despite being blurred by the limited resolution of the microwaves, the images accurately portrayed the patient's normal tissue density. However, a 1-cm-diameter malignant inclusion located in an area of normal fibroglandular tissue could not be discerned by visual inspection of the resulting images.

This fundamental challenge to the detection of tumors by microwave illumination can be addressed in part through the use of comparative information. Preferential uptake of a contrast agent could allow differential detection using pre- and post-contrast images. Here, we explore the impact of air-filled microbubbles as a contrast agent on tomographic microwave breast imaging. We assume a change in dielectric properties based on recent findings (Lazebnik et al, URSI General Assembly, Chicago, IL 2008) and apply the contrast exclusively to the malignant tissue. In this way we assess the applicability of microwave tomography to contrast-enhanced detection of malignant inclusions. We test four realistic numerical breast phantoms spanning the full range of density classifications of normal fibroglandular tissue distribution. The resulting differential images show that the contrast agent allows the inclusion to be detected and localized. In addition, the relative density of the breast phantom does not appear to affect the ability of the method to detect the contrast. Instead, these preliminary results show a larger tumor differential for the higher density phantoms. While there are many practical challenges to the concept of contrast imaging, our results to date demonstrate a baseline feasiblity of robust tumor detection though the use of contrast agents and microwave imaging systems.