Microwave Breast Imaging: A New Mammography?

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Abstract

The sensitivity of screening X-ray mammography is significantly degraded by high breast density – a fairly common physiological phenomenon that also increases breast cancer risk. MRI is safer and more sensitive, but is less specific, much more expensive, and contraindicated for some patients. These concerns underscore the critical need for an affordable, non-ionizing, three-dimensional quantitative imaging modality for evaluating breast density as part of a patient's individualized risk assessment, screening women who are at higher risk for cancer, and monitoring changes in breast tissue in response to prevention and treatment protocols. Microwave imaging is a viable emerging technology for addressing this need.

The interest of engineers and clinicians alike over the past several decades has been captivated by the possibility of using of non-ionizing microwave-frequency electromagnetic waves to sense or image the dielectric properties of human tissue. Tissue dielectric properties are influenced by endogenous polar molecules, and as a result, convey useful clinical information about water content, protein content and hydration, angiogenesis, blood flow alterations such as ischemia and infarction, and temperature changes. Tissue dielectric properties can also be influenced by exogenous molecules, such as tumor-targeting nanoparticles, introduced as contrast agents.

This keynote presentation will highlight two classes of microwave measurement techniques for the estimation of breast tissue dielectric properties. Localized measurement techniques use a single sensor and treat the tissue in the sensing volume as a spatially homogeneous "material under test." Extracting the average dielectric properties of the local tissue from the measured data is relatively straightforward as the inverse problem is well-posed. This class of techniques typically requires the sensor to be in contact with the tissue and is particularly well suited for ex vivo characterization of small specimens. These techniques have been used in a large-scale dielectric spectroscopy study of breast tissue specimens obtained from reduction and cancer surgeries, and a study of the influence of candidate contrast agents on the dielectric properties of subcutaneous tumors in mice. Non-localized measurement techniques designed for full breast imaging use a large number of remote sensors (e.g. antennas) to transmit low-power microwave signals into the breast and measure the scattered fields. The inverse problem that must be solved to reconstruct the dielectric properties distribution throughout the breast is highly ill-posed. Consequently the solution is extremely sensitive to the quality of the measured data. Recent progress towards addressing this inherent instrumentation challenge will be highlighted. This presentation will also showcase microwave breast imaging studies conducted using breast phantoms as well as human subjects, and identify promising directions to be pursued in order to fulfill the potential of microwave imaging for breast health and disease management.