Experimental UWB Microwave Imaging of Anatomically Realistic Breast Phantoms: Investigations of a Breast Surface Identification Algorithm

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Ultrawideband (UWB) microwave radar imaging is a promising new method for detecting early-stage breast cancer. Low-power microwaves are transmitted into the breast using an array of antennas which in turn measure the scattered microwave signals. We process the scattered signals using the following sequence of four algorithms: breast surface identification, average dielectric properties estimation, skin-artifact removal, and imaging. The breast surface identification (BSID) algorithm has been previously validated with backscatter data computed from realistic 3D numerical breast phantoms. Our initial experimental work with UWB microwave imaging was conducted on a first-generation planar phantom, composed of synthetic materials which mimicked the expected contrast between the dielectric properties of normal and malignant breast tissue (X. Li *et al.*, IEEE Trans. Microwave Theory Tech., 52, 1856-1865, 2004). Due to the simplified geometry of this phantom, the BSID step was not necessary. The main contribution of the current work is the experimental investigation of a BSID algorithm using a second-generation, anatomically realistic breast phantom.

The breast phantom is composed of two different tissue-mimicking (TM) materials (M. Lazebnik *et al.*, Phys. Med. Biol., 50, 4245-4258, 2005): a 1.5-mm-thick layer of TM skin and a homogeneous interior of TM fat. The realistic shape of the phantom is formed by a polyethylene mold (E. L. Madsen *et al.*, J. Clin. Ultrasound, 10, 67-75, 1982). The phantom is mounted on a rotating platform and immersed in a coupling medium. Experimental backscatter data is acquired from the phantom using a synthetic cylindrical antenna array. A single miniaturized UWB horn antenna (Tera-X, LLC) is positioned at 40 spatial locations around the phantom (5 vertical positions for each of 8 rotations of the phantom). At each position, the S11 is recorded by a vector network analyzer (Agilent Technologies E8364 PNA) operating in swept-frequency mode (201 frequencies, 1-11 GHz) and converted to a time-domain backscatter waveform for BSID processing.

The accuracy of the resulting estimated breast surface is determined by comparing it to a benchmark, which is obtained by forming a cast of the phantom from hydraulic cement and using a computer numeric control (CNC) desktop milling machine to scan its surface. Comparison of the maximum spatial mismatch between the estimated and benchmark surfaces inside and outside the array aperture indicates excellent agreement between the two surfaces.