



Evaluation of a Portable Microwave Imaging System for Soft Tissue and Early Tumor Detection

Nesreen Alsbou+, Imad Ali*

+Department of Engineering and Physics, University of Central Oklahoma, Edmond, OK

*Department of Radiation Oncology, University of Oklahoma Health Sciences Center, Oklahoma City, OK



Introduction: Microwave imaging has emerged as a promising technique for a range of clinical applications, including cancer detection and screening, as well as the diagnosis of conditions such as atherosclerosis, cardiopulmonary edema, bone deterioration, and leukemia. Compared with conventional imaging modalities like computed tomography (CT) and magnetic resonance imaging (MRI), microwave imaging offers a more affordable, portable, and non-ionizing alternative. Unlike X-ray-based techniques that rely on high-energy ionizing radiation, microwave imaging employs low-energy photons, significantly reducing potential biological risks. In addition, microwave imaging provides strong contrast between malignant tumors and surrounding healthy tissue due to its heightened sensitivity to regions with elevated water content. This contrast advantage makes microwave imaging particularly suitable for early cancer detection.

Motivation: The purpose of this study is to evaluate a multi-antenna microwave imaging system capable of producing high-resolution three-dimensional images of different phantom models representing abdominal, thoracic, and brain tissues.

Methods: A microwave imaging system incorporating multiple antennas arranged in a circular configuration around the phantom targets was developed. This setup enabled the acquisition of both two-dimensional and three-dimensional microwave images of phantom models simulating various anatomical regions with differing tissue densities. The phantoms were constructed from soft-tissue-equivalent materials to assess the system sensitivity, linearity, and image uniformity. During data acquisition, the antennas rotated around the phantoms in 5° angular steps over a full 360° rotation, generating 2D axial images. To reconstruct 3D volumes, the phantoms were translated in 2 mm increments along the axial direction. Image performance metrics including spatial resolution, contrast resolution, linearity, and uniformity were evaluated as functions of antenna number, operating frequency, and distance between the antennas and phantom.

Results: The developed microwave scanner successfully generated both 2D and 3D images of multiple phantom models (Fig. 1a–b). The reconstructed images exhibited distinct contrast among different tissue types, including lung, breast, adipose tissue, muscle, liver, and bone (Fig. 1c). Image uniformity was assessed using a homogeneous water phantom. Overall image quality was influenced by several factors, such as microwave frequency, the number of antennas, and their spatial positioning relative to the phantoms. Higher operating frequencies and a greater antenna count resulted in improved spatial resolution. Conversely, increasing the distance between the antennas and the phantom led to image degradation due to air attenuation. Additionally, the microwave signal response demonstrated a linear decline with increasing water volume within the field of view (Fig. 1d).

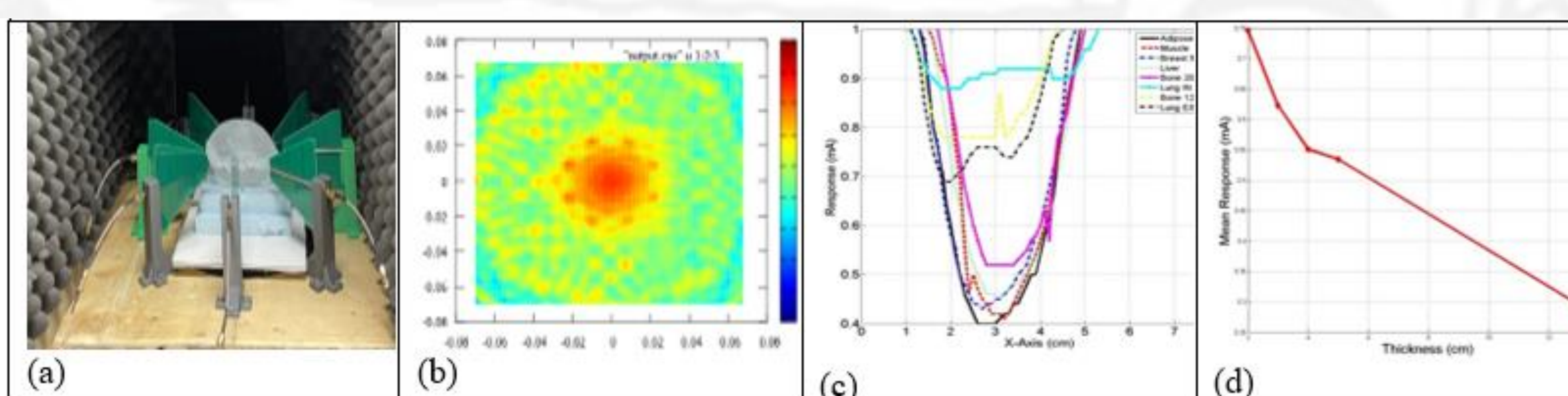


Figure 1: (a) Microwave imaging system experimental setup with multiple antennas. (b) Trans-axial 2D-microwave images for a 1cm lesion inserted a solid water homogenous phantom. (c) Intensity of the microwave signal as a function of different phantom plugs that represent lung, breast, muscle, adipose tissues. (d) Microwave intensity variations as a function of water volume in the field of view.

Conclusion: : A portable microwave imaging scanner was designed and systematically evaluated using a variety of tissue-equivalent phantoms. Although microwave imaging presents an emerging technology, the results indicate strong potential for future clinical applications in imaging and radiotherapy.