A Source Wavelet Deconvolution Approach to Improve the Spatial Resolution for Radar-based Breast Imaging System

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In microwave breast imaging, image reconstruction involves tomographic reconstruction, radar-based imaging, or some combination of both methods (J. F. Deprez, et al., PIER B, 42, 381-403, 2012). With radar-based techniques, similar basic processing steps, i.e., calibration and skin subtraction are taken to process the raw data prior to their deployment in Kirchhoff summation (image focusing). Usually, minimal consideration is given to improve the temporal resolution of the raw signals. However, the spatial resolution associated with the reconstructed image is a function of the temporal resolution of raw data. With simple breast phantoms, i.e., homogeneous breast volume with a single inclusion, an image with low spatial resolution may give a relatively accurate estimate of inclusion location, however lacks sensitivities to the changes in its size. With complicated breast phantoms, i.e., heterogeneous breast volume with multiple malignant and benign inclusions, low imaging resolution may blur malignant inclusions into adjacent features.

Inspired by seismic imaging data processing workflow, we propose the method of source wavelet deconvolution for pre-processing prior to Kirchhoff summation. The idea is to improve the temporal resolution of calibrated raw data by compressing the source wavelet. We also propose the method of picking the first break (arrival) of wave propagation for the purpose of locating the scatterer in the signal. Previously, the signals were integrated prior to Kirchhoff summation, which assumes that a local maximum indicates the round-trip distance between the antenna and the scatterer. In reality, this assumption is not always true due to the complexity of wave propagation (A. Ishimaru, 1997). In this sense, the proposed new processing workflow can be described as improved calibration, skin subtraction, deconvolution, and reconstruction.

We tested the proposed methods with both simulation and measured data collected from simple breast phantoms. To illustrate the benefits of the new workflow, Figs. 1(a) and 1(b) compare the point spread function of reconstructed images for spheres of various sizes. The dashed line shows actual target location. The obtained results indicate that the first break method can accurately determine the scatterer location in the signal. This prevents phase shift in deconvolution output. After source wavelet deconvolution, the sidelobes of the response in the image have been significantly reduced. The image not only indicates the correct location, however also reflects the size change of target.