On the Achievable Resolution from Microwave Tomography

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Microwave tomography (MWT) is an electromagnetic imaging modality that is actively being investigated for different biomedical and industrial non-destructive testing applications. In MWT, the quantitative dielectric profile of the object of interest (OI) is to be found from scattered microwave data collected outside the object. This is achieved by processing the scattered data using an appropriate inversion algorithm, which effectively solves the associated electromagnetic inverse scattering problem. The achievable image resolution from an MWT system is governed by several parameters including those of the OI itself. For example, experimental separation resolution levels ranging from one-thirtieth to one-eighth of a wavelength have been reported from an MWT system, depending on the object being imaged (Gilmore, *et. al.*, *IEEE AWPL*, 2009). Similar resolution studies can also be found in (S. Semenov, *et. al.*, *IEEE MTT*, 2000) and (T. Cui, *et. al.*, *IEEE TAP*, 2004) and in their references.

In this presentation, we first review a mathematical framework that has been recently proposed for analyzing the achievable resolution from MWT (N. Bayat and P. Mojabi, *Submitted*). This framework attempts to perform more accurate resolution analysis by taking into account the nonlinearity of the MWT problem, which is due to the multiple scattering events within the OI. The analysis is performed at the last iteration of two state-of-the-art nonlinear inverse scattering algorithms; namely multiplicative regularized Gauss-Newton and contrast source inversion algorithms. It makes use of the dimension of the subspace in which the final reconstructed profile lies, as well as the spatial frequency content of this subspace. Similar to (N. Bayat and P. Mojabi, *Submitted*), the role of the signal-to-noise ratio of the measured data, the frequency of operation, multiple frequencies of operation, number of transceivers, and the focused incident field distribution in the achievable resolution will be discussed. In addition, within the same mathematical framework, we investigate how the achievable resolution is affected by the MWT system's boundary condition (often governed by the choice of the MWT system enclosure and the utilized background medium), the geometrical arrangement of the transceivers, the use of the transverse electric and transverse magnetic polarizations, and the use of priori information.

The above parameters mainly deal with the information content of the measured data. On the other hand, the effectiveness of the utilized inversion algorithm on achieving a high resolution depends on how well it can extract and use this information. The fundamental question to be answered is whether a given inversion algorithm has extracted all the information from the measured scattered data, and used it effectively for profile reconstruction. The answer is not straightforward due to the presence of so-called modeling error (*i.e.*, the discrepancy between the actual system and the model used in the utilized inversion algorithm) in addition to the (often-unknown) measurement noise. Finally, synthetic and experimental imaging results will be presented to demonstrate the effects of the aforementioned contributing factors on the achievable image resolution and accuracy. Based on all of these considerations, some recommendations for MWT system development, which will be dependent on the general properties of the object to be imaged and the required resolution level, will be presented.