Resolution Analysis of a Radio Frequency Tomography System

Vittorio Picco*, Tadahiro Negishi, and Danilo Erricolo
University of Illinois at Chicago,
Department of Electrical and Computer Engineering
851 South Morgan Street, Chicago, IL 60607, USA

In this work, we analyze the resolution performance of a Radio Frequency (RF) Tomography system developed at the University of Illinois at Chicago, by commenting on results obtained from both simulations and measurements. RF Tomography (see L. Lo Monte *et al.*, "Radio Frequency Tomography for Tunnel Detection," *IEEE Trans. Geoscience and Remote Sensing*, Vol. 48, No. 3, Mar. 2010, pp. 1128-1137) promises to be a very attractive imaging technology because it is narrowband, it makes use of distributed inexpensive sensors and offers sub-wavelength resolution. Some crucial applications include underground exploration, medical imaging, search and rescue, archeology, and thru-wall imaging, thanks to a very flexible forward model. All these different application share the search of a target by reconstructing images through information measured by the sensors. The resolution achievable through a system of this kind can affect the estimation of the size and the location of the target, and it is therefore one of the main criteria used to judge the overall performance of the system.

Usually, the resolution of an electromagnetic imaging system is linked to the wavelength of the signal used to probe the target, or to its bandwidth. Depending on the particular technology, the achievable resolution is linked to physical phenomena such as diffraction (e.g. the Rayleigh criterion in optics), or to more abstract considerations such as an analysis of the Radon transform (e.g. back-projection operators). However, there are no known explicit theoretical limits to the resolution achievable by a MIMO tomography system operating at a single frequency.

Obtaining an image with RF Tomography involves three main steps: collecting the scattered electric field data, using a forward model to compute a discretized linear operator that links the field to the target, and finally using an inversion algorithm to invert such operator to obtain an image of the target. In a tomographic application all of these steps will affect the final resolution of the system.

In this work we show that sub-wavelength resolution in the order of $\lambda/20$ is achievable in simulations and $\lambda/10$ can be obtained in laboratory experiments under favorable conditions. We show how these figures are affected by the number of sensors used, and how they can change significantly depending on the reconstruction algorithm used. We do not attempt to derive an analytical expression for the resolution, which remains an open question for further research.