Abstract

This thesis is a reconciliation between multiple bodies of work with one common objective which is to “identify the support” under unfavourable environment with main focus on DOA estimation and EIT application. The term “support” is commonly used in the compressed sensing and sparse signal recovery communities which essentially means the “active parameters” in a system of linear equations. It is important to note that a technique that is used to identify a set of active support under unfavourable environment should have a robust characteristic. Although with one common theme shared among the works done within this thesis, this thesis can be divided into two major parts based on the applications’ environment.

The first part is the support identification under a process expressible by Fredholm integral equation of the first kind. For this problem, a research topic which is known as “Electrical impedance tomography (EIT),” is chosen as a representative application for a collection of problems expressible by the Fredholm integral equation of the first kind. The Physics of EIT can be explained by Maxwell's equations under Quasi-Static environment. Under such a scenario, the energy dissipated from the source is spread throughout the region (domain) in a non-linear fashion, which leads to low signal-to-noise-ratio (SNR) and support ambiguity issues. Multiple real-life applications fall under this type of problem such as medical and geophysical subsurface imaging, deconvolution, and image deblurring.

The EIT is an imaging technique which estimates internal impedance distribution of a “subject under test (SUT)” that sometimes called “medium” based on data collected from the medium's boundary. The “tomographic reconstruction” or “the process of estimating the medium's internal impedance distribution" can be accomplished through solving a mathematical problem known as an “inverse problem.” Due to Quasi-Static nature of this modality, the image reconstruction of the EIT is known to be one of the most severely ill-posed inverse problems. The image reconstruction problem in EIT will be analyzed from two different perspectives. Firstly, this problem will be analyzed through the lens of a discrete ill-posed inverse problem from an applied Mathematics community perspective. Secondly, this problem will be re-analyzed through the lens of array signal processing/beamforming framework from the signal processing community perspective. While exploring the EIT image reconstruction techniques, we also observed that although the EIT system can be implemented economically, the implementation process is not completely straightforward. Therefore, we had also implemented an EIT prototyping system to experiment with different data format. A robust, economical, and uncomplicated implementation framework was developed with the hope that it will be beneficial for those who are interested in image reconstruction task without the access to a full functioning commercialized EIT system.

The second part is the support identification under α-stable distributed noise, which is not uncommon in the real-life scenario. In this case, the additive noise is a cause of the issue as opposed to the previous case where the environment itself is the issue. Additionally, several improvements of a beamforming technique called MUSIC-like algorithm will be explored under both Gaussian and α-stable distributed noise. The signal model used in this part is based on the solution of a wave function impinging on sensor array located at different locations. The main focus of this part is performance improvement of the beamforming framework for DOA estimation under different noise scenarios. Three different approaches for estimating a relaxation parameter (an essential parameter used in the MUSIC-like

algorithm) are presented. By experimenting with different approaches, an adaptive framework for relaxation parameter was observed to have potential for further investigation. Hence, the performance improvement of the MUSIC-like algorithm was further explored through the directional adaptive framework under both Gaussian and α-stable distributed noise. It was also compared with the conventional MUSIC algorithm coupled pre-conditioned covariance matrix.