# Multi-frequency trans-admittance scanner

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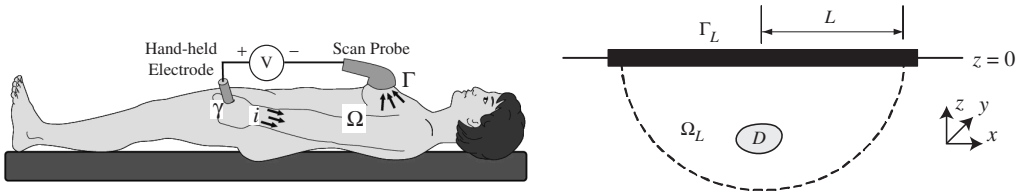
## ABSTRACT

A commercial breast cancer detection system called T-Scan produces trans-admittance images (Neumann data) of breast tissues using a scan probe with a planar array of electrodes. The detection of a lesion in TAS is based on the difference between the trans-admittance data of the presence of anomaly and the absence of anomaly. However, the trans-admittance data of the absence of anomaly is not available in practice. To deal with this problem, we developed a multi-frequency trans-admittance scanner (TAS) for probing anomalies underneath a planar array of 320 electrodes from the frequency difference of the trans-admittance data. We present the mathematical analysis and numerical experiments showing the feasibility of multi-frequency lesion detection. Using the developed TAS system and saline phantoms, we conducted frequency-difference experiments.

## INTRODUCTION

Bioimpedance techniques such as electrical impedance tomography (EIT) have been suggested as a diagnostic tool for breast cancer detection. This is based on experimental findings showing that there exists a high contrast in the complex conductivity between cancerous and normal tissues (Surowiec et al.1988; Jossinet and Schmitt 1999; Silva et al.2000; Hartov et al.2005). For example, Kerner et al.(2002) used circular arrays of electrodes around the breast and produced cross-sectional conductivity images using an EIT image reconstruction technique. Cherepenin et al.(2001 and 2002) adopted a planar array of 256 electrodes placed on the breast and sequentially injected currents between chosen pairs of electrodes and measured the induced voltage data on other electrodes. Using this kind of boundary measurements, they reconstructed three-dimensional EIT images of the breast called electrical impedance mammograms. There are also several investigations for the usefulness of a planar array of electrodes in EIT imaging of the breast (Larson-Wiseman 1998; Mueller et al.1999; Kao et al.2003). All of these approaches are to find lesions from cross-sectional EIT images. In this case, cancerous lesions within the breast should appear in the reconstructed EIT images. However, the reconstruction map from the boundary measurements to the geometry of a lesion inside the breast is highly nonlinear. Furthermore, the sensitivity of the boundary measurement to the inhomogeneity within the breast is very low. Therefore, the cross-sectional conductivity and/or permittivity imaging of the breast may suffer from its relatively low spatial resolution. On the other hand, there has been a different approach where feature extraction of lesions inside the breast is emphasized instead of the cross-sectional imaging. Figure 1(a) shows a configuration for breast cancer detection based on this kind of approach. A patient holds a reference electrode with one hand through which a constant voltage is applied. A scan probe is placed on the breast and it is equipped with a planar




(a) (b)

Figure 1. (a) Voltage is applied between the hand-held electrode and the planar array of electrodes in the scan probe. Exit currents through the scan probe are measured to provide trans-admittance data. (b) Simplified model of the breast region with a cancerous lesion $D$ under the scan probe.

array of electrodes kept at the ground potential. The voltage difference produces current flows from the hand-held electrode to each grounded electrode of the probe through the breast. By measuring exit currents from all electrodes of the scan probe, we can obtain a trans-admittance map and extract some information on the complex conductivity distribution within the breast region under the probe. Basically, it has the same architecture as the early frontal plane impedance camera suggested by Henderson and Webster (1978).

Based on this configuration, a commercial system called T-Scan has been introduced for adjunctive clinical uses with X-ray mammography (Assenheimer et al.2001). Use of T-Scan is to decrease equivocal findings and thereby reduce unnecessary biopsies. However, the diagnostic information from the currently available T-Scan system lacks a sophisticated reconstruction method of finding lesions even though there were some clever works and observations in processing the trans-admittance data (Assenheimer et al.2001; Scholz 2002). Lately, Seo et al.(2004) and Ammari et al.(2004) studied this measurement configuration and developed a mathematical framework to analyze the trans-admittance data. Based on the framework, they derived a direct relation between lesions and trans-admittance data and suggested a non-iterative algorithm to extract core features of lesions. A major drawback of the previous TAS-method is that the detection method requires the knowledge of the difference between the trans-admittance data of the presence of anomaly and the absence of anomaly, while the trans-admittance data of the absence of anomaly is not available in practice. Since the background conductivity of breast is not homogeneous, we can not compute the TAS-data numerically. To deal with these problem, we develop multi-frequency TAS which uses the frequency difference of the trans-admittance data for the lesion detection. We describe the development of a multi-frequency trans-admittance scanner (TAS) that captures trans-admittance maps under the scan probe with 320 planar array of electrodes. We first provide the mathematical theory which relates between the frequency difference of the trans-admittance data and the presence of the lesion. We also carry out numerical experiments to test feasibility of lesion detection from multi-frequency TAS. Using the developed TAS system and saline phantoms, we conducted frequency-difference experiments. Analyzing experimental results, future improvements in the lesion estimation algorithm are suggested.