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Microwave Breast Imaging by the Filtered Forward-Backward Time-Stepping Method

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***Abstract*—In this paper, an inverse scattering technique referred to as the filtered forward-backward time-stepping method is applied to microwave imaging for breast cancer detection. A two-dimensional numerical breast phantom (derived from MR images) with high contrast between fat and fibroglandular tissues, and low contrast between fibroglandular and tumor tissues are used to assess the efficacy of the proposed method.**

I. Introduction

Breast cancer is the leading cause of death from cancer among women. To reduce the breast cancer mortality rate, it is recommended for women to have annual breast screening. At present, X-ray mammography is regarded as the most effective examination modality in mass screening. However, it is less effective for detecting a tumor in a dense breast. A complementary and alternative modality has been looking for to overcome its shortcoming [1].

Over the last two decades, a number of researchers have been working on the early detection of breast cancer by microwave imaging. The microwave breast imaging techniques are classified into two approaches: one is based on the principle of radar and another is based on inverse scattering. The former images spatial distribution of the scattering intensity due to abnormalities, while the latter images spatial distribution of dielectric properties of a region of interest. The radar-based techniques get an image quickly, but only the location and size of the abnormality can be found from the image [2]-[5]. The inverse scattering-based techniques require a long processing time to get an image, but the dielectric properties of the abnormality can be obtained as well as its location and size [6]-[10]. Therefore, the imaging based on the inverse scattering techniques has a potential for tissue characterization.

Both the frequency-domain and time-domain inverse scattering techniques have been applied to the microwave breast imaging. Although the use of frequency diversity does not increase information content about a target object, it reduces ill-conditioning of the reconstruction process, so that a solution algorithm with multifrequency data becomes more stable than the use of monochromatic data [11]. We have proposed an inversion technique referred to as Forward-Backward Time-Stepping (FBTS) algorithm [12] and applied it to breast cancer detection in two-dimensional (2-D) and three-dimensional (3-D) cases [13, 14].

Recently, the permittivity and conductivity of fibroglandular breast tissue is shown to be much higher than previously imagined [15]. This makes microwave imaging of a dense breast more challenging.

In this paper, the filtered FBTS technique [16] which has been shown to be more robust to noise is applied to the cancer detection of a dense breast with high-contrast between fat and fibroglandular tissues, and low-contrast between fibroglandular and tumor tissues.

II. Inverse Scattering Techniques

We consider inverse scattering problem where the electrical property distributions within a target object are estimated from scattering time domain data. The object is surrounded by an array of antennas. Each antenna takes turns to transmit a microwave pulse while the rest of antennas collect scattered signals. Then, a set of transmitter/receiver data for multiple antenna combination is obtained.

A. FBTS Inversion Algorithm

In the FBTS technique, the measured scattering dataset is compared to an equivalent simulation in which the same set of scattering data is computed for assumed electrical property distributions within the target object. Reconstruction procedure of FBTS minimizes iteratively the following cost functional:

$$Q(\mathbf{p}) = \int_0^T \sum_{m=1}^{M} \sum_{n=1}^{N} K_{mn}(t) \left| \mathbf{v}_m(\mathbf{p}; \mathbf{r}_n, t) - \tilde{\mathbf{v}}_m(\mathbf{r}_n, t) \right|^2 dt \qquad (1)$$

where $\tilde{\mathbf{v}}_m(\mathbf{r}_n, t)$ and $\mathbf{v}_m(\mathbf{p}; \mathbf{r}_n, t)$ are the measured electromagnetic fields in time domain at the receiver position $\mathbf{r}_n$ due to a transmitter m and the corresponding calculated electromagnetic fields for an assumed set of electric parameters $\mathbf{p}$, respectively. The set of parameters $\mathbf{p}$ consists of the relative permittivity ε_r and the conductivity σ .The factor $K_{mn}(t)$ is a nonnegative weighting function which takes a