STUDY OF CORRELATION COEFFICIENTS OF THE RECEIVER PAIR IN MICROWAVE TOMOGRAPHY

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***Abstract* - In microwave tomography, it is necessary to increase the amount of diverse observation data for accurate image reconstruction of the dielectric properties of the imaging area. The multi-polarization method has been proposed as a suitable technique for the acquisition of a variety of observations data. While the effectiveness of employing multi-polarization to reconstruct images has been confirmed, the physical considerations related to image reconstruction have not been investigated. In this paper, an analysis of the correlation coefficient of the received data of adjacent antennas was performed to interpret the imaging results. Numerical simulation results demonstrated that multi -polarization can reconstruct images better compared to single polarizations owing to its low correlation coefficient.**

***Index Terms* — Microwave tomography, Inverse scattering, Distorted Born iterative method, Breast cancer, Correlation coefficient.**

1. Introduction

Recently, studies on the early detection of breast cancer by microwave imaging (MWI) have attracted considerable interest among researchers [1]. In microwave tomography, it is necessary to obtain diverse observation data in order to achieve accurate image reconstruction. The amount of observation data can be increased by increasing the number of antennas; however, the antennas must be arranged at a certain distance from each other. Thus, the scale of the apparatus increased and the computational cost becomes substantial. Furthermore, the signal to noise ratio (SNR) is degraded by this method, which creates difficulties in the correct reconstruction of the image.

To overcome the problem, the multiple-polarization method has been examined. In [2], the impact of polarization was evaluated with a shielded array of patch antennas using truncated singular-value decomposition (TSVD) analysis. Although the effectiveness of employing multi-polarization to reconstruct images has been demonstrated, the physical considerations related to antenna arrangement to achieve sufficient image reconstruction have not yet been investigated.

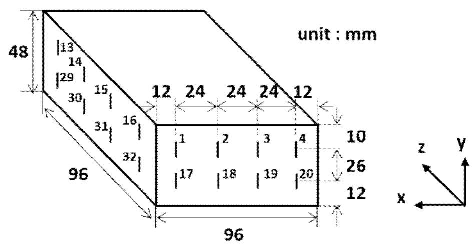
In this paper, we consider the effectiveness of multi - polarization method for breast cancer detection using a compact sized imaging sensor. The Distorted Born Iterative Method (DBIM), described in [3] is used to reconstruct the image. We clarify the impact of multi-polarization in terms of physical considerations using the analysis of the correlation coefficient of the received data from adjacent antennas for a different antenna arrangement [4].

2. Numerical Simulation

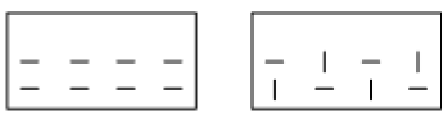
(1) Simulation model

Fig. 1 shows the aperture of the imaging sensor with dimensions 96×96×48 mm (width×length×height). The imaging region is discretized into 1183 voxels to obtain 8-mm resolution. A dipole with length of 20 mm is used for the antennas, and they arrange in a 4×2 configuration on each of the four side panels of the sensor. Fig. 1(a) shows the position of the antenna. The lines in Fig.1 represent the polarization direction of the antenna, where the y-axis indicates vertical polarization, and the x- or z-axis horizontal polarization. The antenna arrangements for each side are identical. In this study, we investigated three different configurations as shown in Fig. 1, to examine the effectiveness of polarization in breast cancer detection. Fig. 1(a) illustrates the vertical polarization, Fig. 1(b) the horizontal polarization, and Fig. 1(c) vertical and horizontal polarization.

We assume that the imaging sensor is constructed from resin, which has properties similar those of adipose (fatty) tissue. Antennas are buried in the resin. The simple breast model shown in Fig. 2 consists of adipose tissues, fibro-glandular tissues, and a tumor. The breast model is a hemisphere with a radius of 48 mm, and the tumor has a

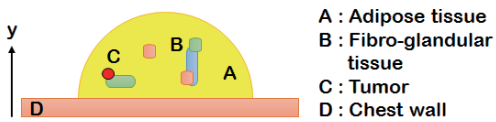


(a) Vertical polarization

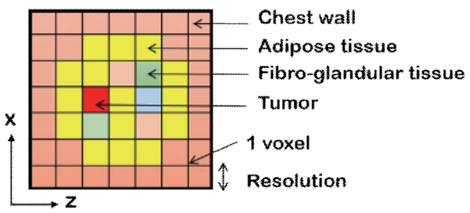


(b) Horizontal polarization (c) Multi polarization

Figure 1. Imaging sensor with various polarizations



(a) Configuration of breast model



(b) Allocation of dielectric properties
Figure 2. A simple breast model

Table 1. Dielectric properties of breast model.

	Relative permittivity, ε_r	Conductivity, σ
Background	8	0.15
Chest wall	57	2
Adipose Tissue	7	0.4
Fibro-glandular Tissue	25-10	1-2.2
Tumor	52	4

radius of 4 mm. The chest wall under the breast was also modeled. 10% of the volume ratio of the breast is occupied by fibro-glandular tissues. We characterized the dielectric properties of the breast model in each voxel, as shown in Table 1.

(2) Correlation Coefficient of Adjacent Antennas

In this section, we investigate the impact of multi-polarization by the analysis of the correlation coefficient of the received data between adjacent antennas in our imaging sensor. A correlation coefficient is a coefficient that provides a quantitative measure of the correlation and dependence between two or more observation data sets. In this study, we use an average correlation coefficient to evaluate the whole correlation coefficients. It is defined by,

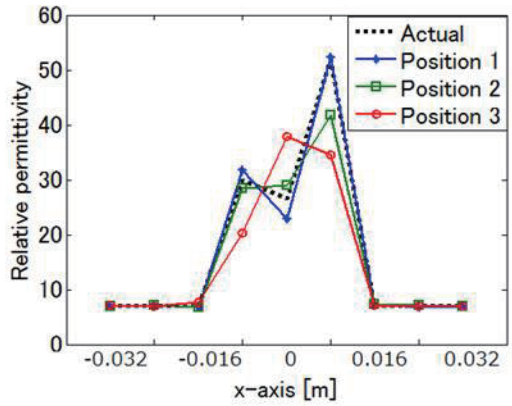
$$\rho = \frac{1}{N}\sum_{t=1}^{N}\left| \frac{\sum_{\substack{n=1\\ t\neq n}}^{N/2} X_{t,2n-1}X^{*}_{t,2n}}{\sqrt{\sum_{\substack{n=1\\ t\neq n}}^{N/2} X_{t,2n-1}X^{*}_{t,2n-1}}\sqrt{\sum_{\substack{n=1\\ t\neq n}}^{N/2} X_{t,2n}X^{*}_{t,2n}}} \right| \quad (1)$$

Here, N is total number of antennas, t is the number of the transmitting antenna. Since we are dealing with a correlation of adjacent elements, it is necessary to remove the transmission antenna. Therefore, we assume $n \neq t$.

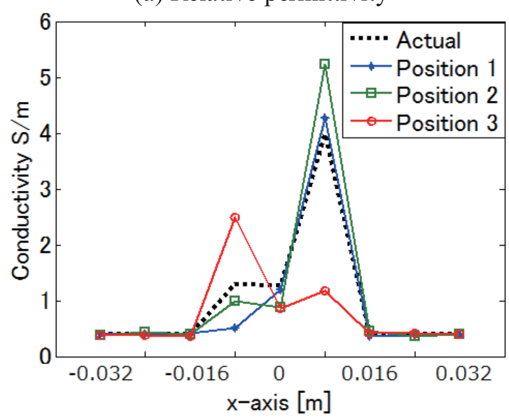
First, we examined the positions of the antennas shown in Fig. 1(a), with the upper antenna at y=38 mm and the lower antenna at y=12 mm (Position 1). Table 2 summarizes the correlation coefficients for different polarization. At this position and for Model 1, we observed that single polarizations achieve correlation coefficient close to 1, and the correlation coefficient of the multi-polarization is 0.1860, relatively low compared with the single polarizations. Next, we changed the positions of the the upper and lower antenna to y=35 mm and y=13mm (Position 2), and finally the position of the upper and lower antenna to 37mm and 16mm

Table 2. The average correlation coefficient for different positions of the antennas.

	Position of antenna (upper, lower) mm	VP	HP	MP
1	38, 12	0.9132	0.6537	0.1860
2	35, 13	0.9328	0.7144	0.1986
3	37, 16	0.9367	0.6668	0.2046



(a) Relative permittivity



(b) Conductivity

Figure.3. Dielectric property distributions of Model 1 in the cross section between different positions of the antenna obtained using multi- polarization.

(Position 3). Fig. 3(a), (b) shows the setting and reconstruction values of the dielectric properties of the voxel that has the tumor in the x-axis direction when positions of the antennas change. These results demonstrate that the position with low correlation coefficients reconstruct the dielectric properties sufficiently.

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