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E-5-2

Microwave Imaging via Beamforming for Early Breast Cancer Detection with Adaptive Antenna Array

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1. Introduction

Recently, the mortality rate due to breast cancer has been increasing among women of middle age. The final goal of our study is to develop a mobile device system for detecting early stage breast cancer. UWB microwave imaging technique has been developed for detecting malignant tumors [1]. Due to the large contrast of the dielectric constant of tumor to that of breast tissue (Fig. 1), a small tumor could be detected [1,2].

In this work, performance of microwave imaging via space-time beamforming algorithm (MISTB) [3] with a compact adaptive antenna array is studied for a mobile device system.

2. Results and discussions

Figure 2 represents the two-dimensional model of a breast structure used for FDTD simulation. The breast is constructed of 2 mm thick skin layer, normal breast tissue, and chest wall. Malignant tumor is located at (60, 40) in x-y coordinate. As a source of clutter noise, glandular breast tissue is embedded. 5 antennas (N1-N5) are placed on the skin whose space is 1 cm. When N1 transmits microwave then N2-N5 antennas receive the wave propagated through the breast. The same operation is repeated changing the transmitting antenna from N2 to N5. The propagation of microwave is calculated by FDTD simulation. Here the dielectric relaxation of Fig. 1 is considered.

Figure 3 is the signal intensity as a function of elapsed time. In this case, Gaussian monocycle pulse is transmitted from antenna N1. Its center frequency was 6 GHz. The same calculation was done when no tumor and glandular tissue exist. The subtracted waveform between them is also represented in Fig. 3. These received signals are processed with MIST beamforming algorithm (Fig. 4). Each signal was shifted by the amount of round trip time from transmitted antenna to the receiving antenna at the searching point, so as to match each phase at the focal point. After fast Fourier transformation (FFT), an empirical weighting factor was multiplied to compensate the propagation loss in breast. All of signals are combined, and come back to time domain by inverse FFT. Then energy intensity is calculated with time window function, and re-constructed image of breast was obtained. For comparison, ordinary confocal imaging algorithm (CMI) with time delay and sum procedure were also used.

When the dielectric property of the breast was uniform, MIST beamforming and CMI could detect a small tumor. When there is clutter noise, the performance degrades. Figure 5 is reconstructed images of the breast with glandular tissue in which the tumor diameter is 3 mm. CMI failed to detect the tumor, but MISTB succeeded in the detection of tumor at the exact potion. It is remarkable that the clutter noise is eliminated dramatically in the MISTB image compared to that of CMI image. This is due to the noise filtering as depicted in Fig. 4. The maximum energy that appears around tumor is represented in Fig. 6. CMI could detect 4 mm tumor. MISTB image has stronger intensity compared to CMI image.

4. Conclusions

The feasibility of MIST beamforming technique (MISTB) with adaptive antenna array for early breast cancer detection is studied. It is shown that MISTB eliminates clutter noise efficiently and could detect 3 mm tumor in breast with glandular tissue.

Acknowledgement

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Reference

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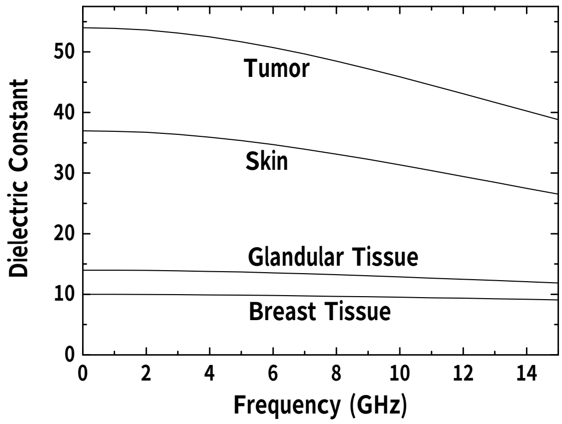

Fig. 1 Dielectric relaxation property of breast tissue, glandular tissue, skin, and tumor. This result is obtained by fitting experimental data with Debye model.

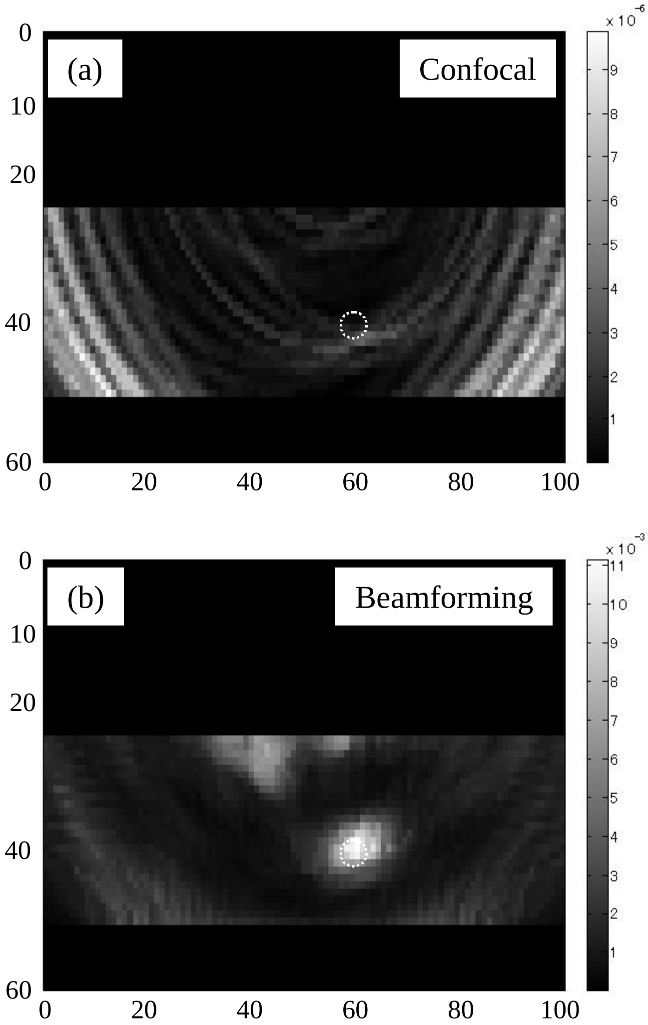

Fig. 5. Reconstructed images of breast phantom with glandular tissue by using received signals. Tumor diameter is 3 mm. Its position is marked by circle symbol. (a) Confocal algorithm. (b) MIST beamforming algorithm.

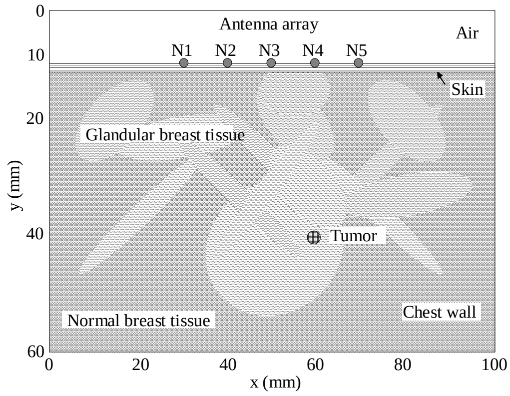

Fig. 2 Two-dimensional model of breast structure. Dielectric relaxation of skin, breast tissue, glandular tissue, chest wall, and tumor are considered in FDTD calculation

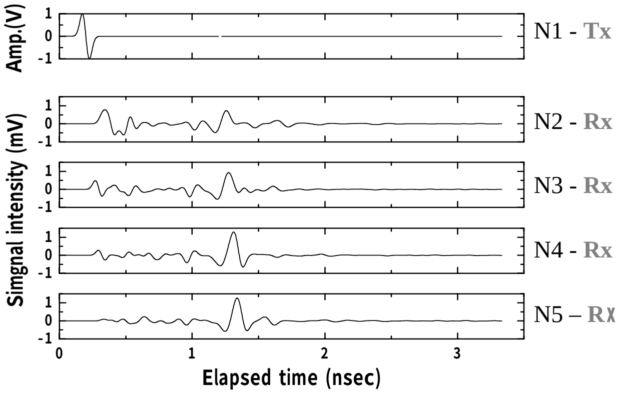

Fig. 3. Signal intensity as a function of elapsed time. Top figure shows transmitted Gaussian monocycle pulse from N1 and the following figures show the subtracted signals between with tumor and without tumor at Rx-N2, N3, N4, and N5.

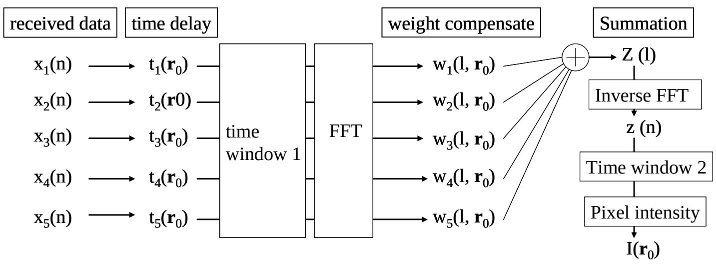

Fig. 4. Block diagram of digital signal processing by MIST beamforming algorithm in frequency domain [2]. In our calculation a simple empirical weighting factor w_i is used.

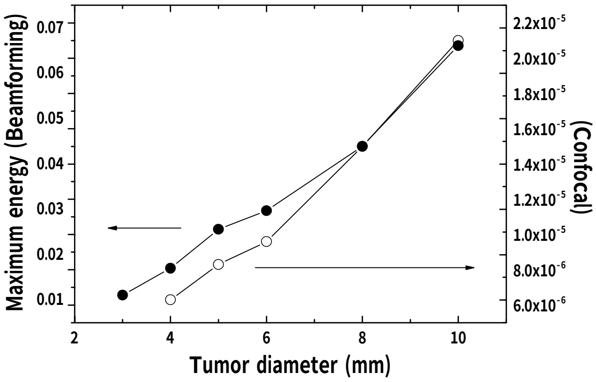

Fig. 6. Maximum energy of pixel appears around tumor in re-constructed image via beamforming or confocal algorithm. Tumor diameter is changed from 3 to 10 mm.