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UWB Imaging for Early Breast Cancer Detection by Confocal Algorithm

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1. Introduction

Ultra-wide band imaging techniques for breast cancer detection is recently developed based on the obvious contrast in the electromagnetic properties of malignant tumor related to normal fatty breast tissue, which is approximately 5:1 in the relative dielectric constant and 10:1 in the conductivity at microwave frequencies [1]. The detection for tumor can be performed by analyzing the reflection and scattering behaviors of electromagnetic microwaves during propagating in the breast. Encouraging results have demonstrate the feasibility of the UWB microwave imaging scheme in the detection of the early breast cancer of diameter smaller than 10 mm within the depth of 50 mm under the breast skin [2, 3].

This paper examines the possibility of tumor detection and localization for an assumed 4 mm tumor assumed in the breast by using the principle of confocal microwave imaging technique. The finite difference time domain method is applied in simulating the microwave propagation in the breast.

2. Tumor Detection

Figure 1 is the geometry configuration of the planar breast structure used in this study. The breast structure has the dimension of 100 mm horizontal span and 70 mm depth. Such planar breast model is assumed to approach the naturally flattened breast when the patient is oriented in a supine position. The top surface of the structure is the 2 mm thick skin; under the skin is the 48 mm thick fatty breast tissue. The underneath is the 20 mm thick chest wall. In the structure, a 4 mm tumor is assumed embedded in the breast tissue. Three emitters and four detectors are arranged on the breast surface as shown in Fig. 1. The emitter-detector system has the feature of the synthetic aperture radar system. The whole span of the emitter-detector array is 60 mm width with equal interval space of 10 mm between the emitter and detector.

The tumor has $\varepsilon_r = 50$ and $\sigma = 4$ S/m, while the fat breast tissue has $\varepsilon_r = 9$ and $\sigma = 0.4$ S/m, and the glandular tissue has $\varepsilon_r = 11\text{-}14$ and $\sigma = 0.4\text{-}0.5$ S/m for various persons, respectively [2]. Since the contrast between the glandular tissue and the fatty breast tissue is very small, it is reasonable to treat the glandular tissue as the noises added to the fatty breast tissue.

In the detection, a Gaussian monocycle impulse with the center frequency of 6 GHz is radiated from one emitter at one time and detected by 4 detectors. Figure 2 shows the examined signals emitted from E3 and detected at D1, D2, D3 and D4, respectively. With the wave propagation, the signal amplitude is largely decreased due to the radial spreading of the impulse energy and the path loss in the lossy breast tissue. Signals detected by D3 and D4 look similar in the current scale because the early time responses are mainly direct waves of the incident impulse and reflections from the skin which are symmetric for D3 and D4 related to E3. Since the backscattering signal from tumor is quite small as hidden in the late time wave responses, the tumor information can be obtained by comparing the detected signals examined for the tumor-contained case and the tumor-free case, the latter is treated as the calibration waveform. To obtain the calibration waveform and approach the real application, the tumor is arranged randomly located in a limited range from 20 to 40, and 40 to 80 in the x and y directions, respectively. By averaging the detected waveforms resulted from similar detections, the tumor response can be eliminated to approach the tumor-free case. The feasibility of this extraction method was verified in our prior work [4]. This idea can be performed in the actual detection by randomly moving the emitter-detector array of the apparatus to multiple positions.

After the signal process of subtraction, integration and compensation [5], the signals as partially shown in Fig. 3 can be used for the image reconstruction by the confocal algorithm. The gray region of the figure marks the time response for the assumed tumor with the solid line, and the dashed line gives the time response for the tumor-free case at the same time domain. In the confocal method, the distance from the emitter to a specific point and reflected back to the detector is converted to the time response. All contributions identified from the signal amplitude are summed and its squared value is synthetically focused to the pixel value at the specific points to reconstruct the breast image. The resulted images show correctly the tumor information in the Fig.4 (a) and the tumor free case in the Fig.4 (b).

2. Summary

The breast cancer detection is performed with consideration of a planar breast structure involving the skin, fatty tissue, tumor, glandular tissue and chest wall. By suitable processing for the examined backscattering signals, an assumed 4 mm tumor in the breast can be detected accurately by the array of 3 emitters and 4 detectors with the synthetic aperture of 60 mm.

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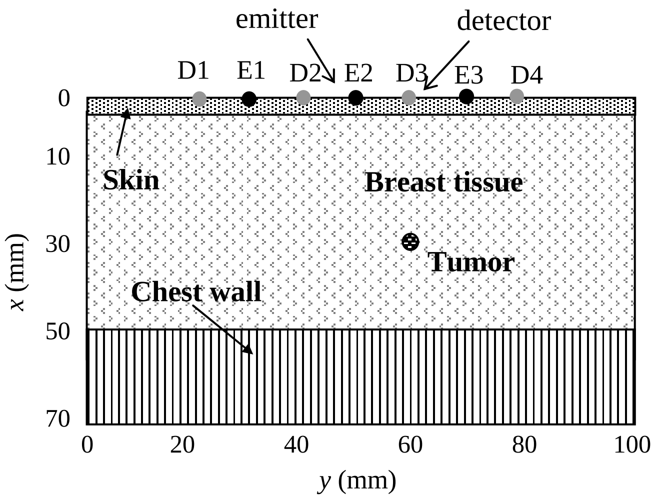

Fig.1 Geometry configuration of the planar breast structure for a supine position used in the simulation.

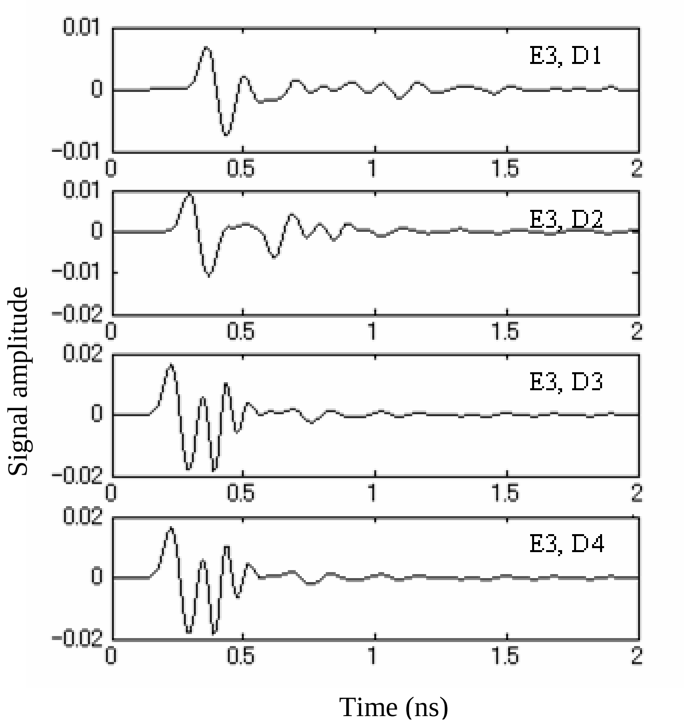

Fig.2 Detected signals emitted from E3 and detected at D1, D2, D3 and D4, respectively. The early time responses are direct waves of the incident impulse and reflections from the skin, the late time responses contains the backscattering from tumor, which is hidden in the signal.

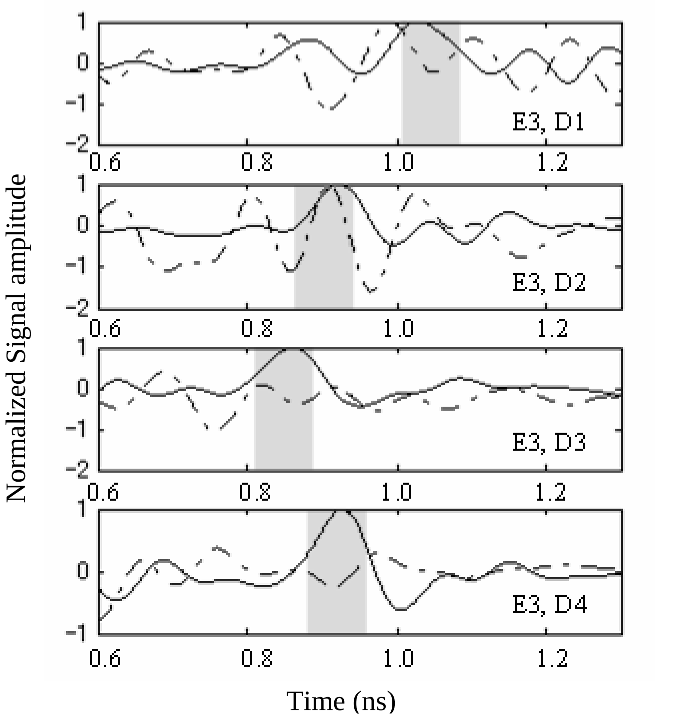

Fig.3 Processed signals employed in the image reconstruction with the confocal algorithms. The gray region marks the time response for a 4 mm tumor located at (30, 60) in the breast for the solid line. The dashed line gives the time response for the tumor free case.

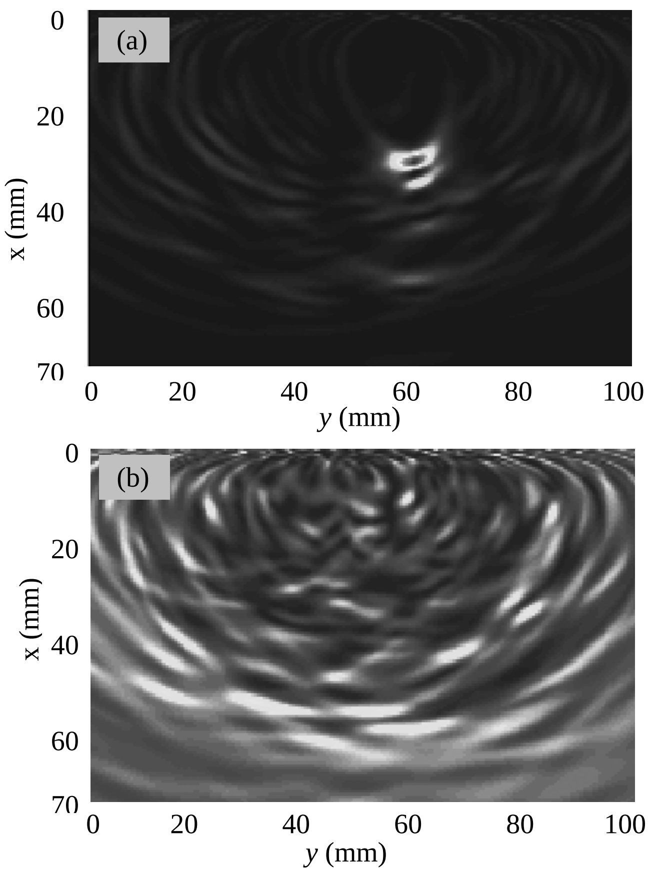

Fig.4 Reconstructed images of the breast for the cases of (a) an assumed 4 mm tumor with its center located at (30, 60) in the breast, and (b) tumor free.