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Tumor Detection in a Multilayer Breast Structure

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1. Introduction

Ultra-wideband (UWB) is a carrierless short range communications technology which transmits the information in the form of very short pulses [1]. UWB microwave imaging technology is very attractive for the early breast cancer detection since it can provide both the necessary imaging resolution and the adequate penetration depth in the breast [2-4]. The early detection of the breast tumor is very significant for the longest survival and greatest patient comfort. The physical basis for microwave imaging lies in the significant contrast in the electrical properties between the normal breast tissue and the tumor at microwave frequencies [5]. The planar breast model is a typical model adopted in many related researches. It is assumed to approach the naturally flattened breast. In such model, the patient is oriented in a supine position in the planar configuration [2,6].

In this study, the multi- layers, which include the skin, the subcutaneous breast fat, the glandular tissue and the chest wall, are involved in the planar model in the tumor determination process. The way to recognize the thickness of the subcutaneous breast fat is developed. The confocal algorithm is employed in the imaging process for distinguishing the breast tumor [5]. Based on the correct determination of the fat thickness, the accurate location of the tumor can be ensured because of adopting correct velocities of microwaves during propagating in the different breast organisms. The error of several millimetres can be avoided by taking this consideration.

2. Tumor Detection

2.1 Structure Description

The planar structure configuration with the dimension of 100 mm horizontal span and 90 mm depth shown in Fig.1 (a) is used in this study. The top surface of the structure is the 2 mm thick skin; under the skin is the 23 mm thick subcutaneous breast fat. Below is the 40 mm thick glandular breast tissue. The underneath is the 25 mm thick chest wall. In this structure, the tumor is assumed to be embedded in the glandular breast tissue at the position of (55, 50). The principle of using electromagnetic microwave in the breast cancer detection is based on the large contrast of the dielectric constant and conductivity between the breast tumor and other breast organisms. The tumor has $\varepsilon_r = 50$ and $\sigma = 4$ S/m, while the fat has $\varepsilon_r = 9$ and $\sigma = 0.4$ S/m, and the glandular tissue has $\varepsilon_r = 11$- 14 and $\sigma = 0.4$ - 0.5 S/m for various persons, respectively [2]. The large difference offers the possibility to distinguish the tumor, which is embedded in the breast organisms.

2.2 Determine the Thickness of the Breast Fat

In this study, the input is a Gaussian monocycle impulse given by

$$e(t) = -\sqrt{e}\left(\frac{2\pi}{\tau}\right)(t - T_c)\, e^{-\frac{1}{2}\left(\frac{2\pi(t-T_c)}{\tau}\right)^2} . \qquad (1)$$

Where, $\tau = 1/f_0$ is the impulse width parameter, f_0 is the center frequency, T_c represents the time asynchronism. Here, 6 GHz is adopted as center frequency; the frequency domain shows a bandwidth of around 10 GHz is spanned in this impulse.

To determine the thickness of the subcutaneous fat, the waveform difference between the signals detected in the case of structure shown in Fig.1(a) and in the case in which the subcutaneous

ISBN: 978-4-88552-223-9 C3055©IEICE

fat is assumed instead of the glandular tissue. First, as a reference, we treat the whole breast organism is the subcutaneous fat between the skin and the chest wall. In the numerical simulation by the finite difference time domain method (FDTD), the impulse is emitted from the emitter designed at the proper location and collected by 6 detectors distributed on the surface skin. The detected backscattered waveforms can be used as the reference for the thickness determination. Then, the same process is carried out for the case in which the glandular tissue is taken into account. The difference between these two cases can be observed by subtract one waveform from the other corresponding one. Figure 2 shows the subtracted waveforms resulted from the backscattered signals detected from different sites. The results show the obvious time response when the microwaves meet the interface between the fat and the glandular tissue (interface 1), as well as the interface between the glandular tissue and the chest wall (interface 2). The time response agrees very well with the assumed case. These waveforms are used to generate the image by the confocal algorithm. The reconstructed image in Fig.1(b) shows the clear interface 1 at y = 25 mm and the interface 2 at y = 65 mm which agrees very well with the assumed situation. In the study, 3 emitters and 6 detectors as arranged in the Fig.1(a) are used to give a good image.

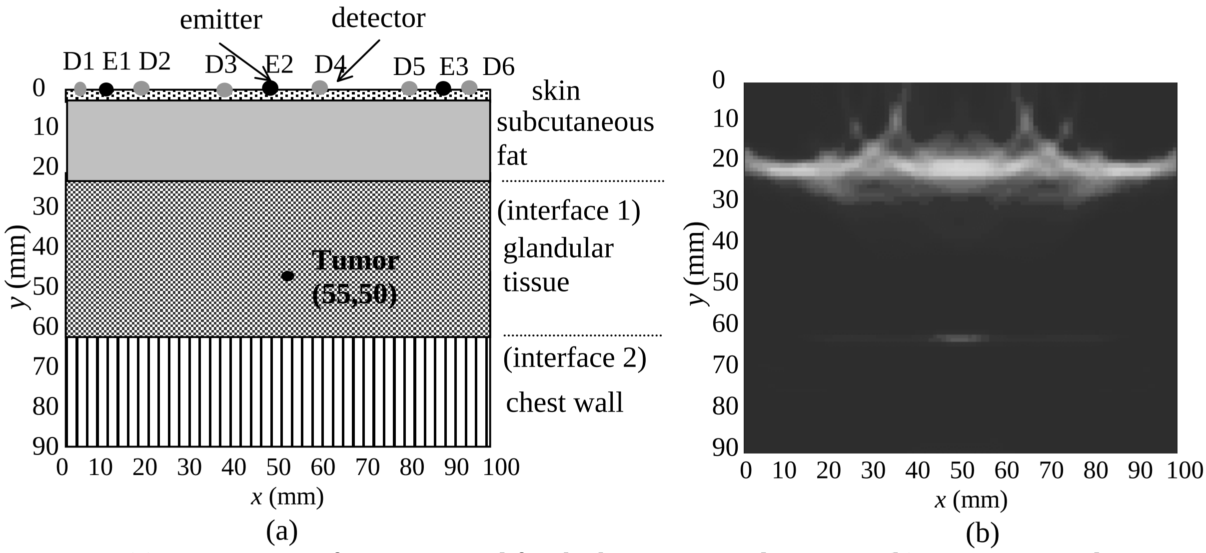

Fig. 1 (a): Structure configuration used for the breast tumor detection; (b): Reconstructed image from the electromagnetic microwave detection shows the multi-layered structure clearly.

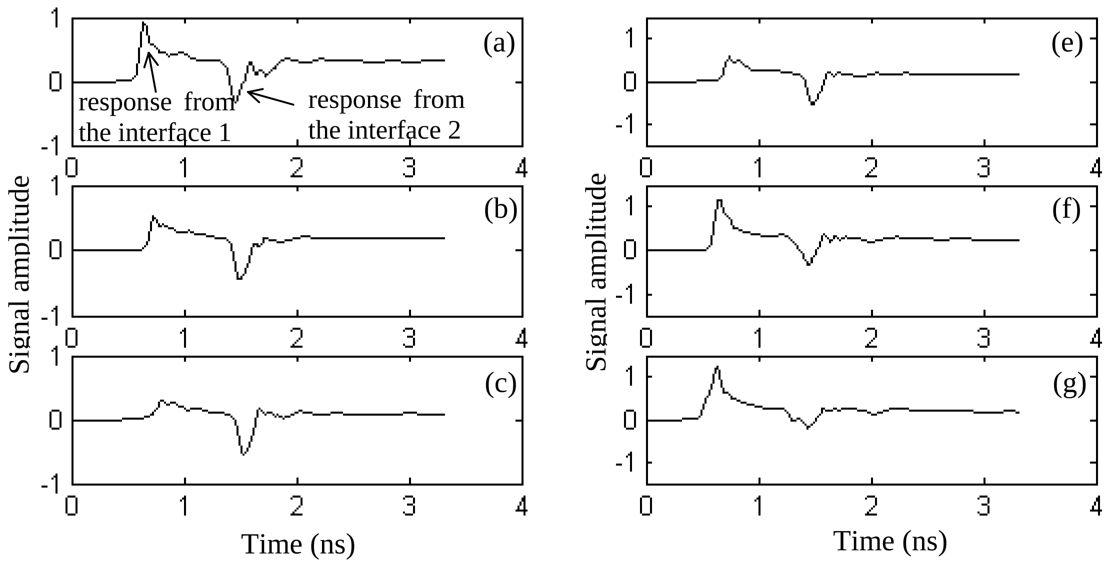

Fig. 2: Subtracted waveforms resulted from the backscattered signals detected from different sites. Left of the figure: signal emitted from the center emitter E2 and detected (a) at D3, (b) at D2, and (c) at D1, respectively; Right of the figure: signal emitted from the side emitter E1 and detected from (e) at D3, (f) at D2, and (g) at D1, respectively.

2.3 Signal Processing

The final purpose of the study is to detect the location and the size of the tumor embedded in the breast as shown in the Fig.1(a). In the detection, as a reference, the backscattered waveform for the case in which there is no tumor in the mode is firstly received. Then carry out the same detection process for the case in which the tumor is embedded in the assumed location. The difference waveform between these two cases can be obtained by simply subtracting one detected waveform from that of the other case. The image reconstruction can be achieved by the confocal method with series subtracted waveforms as partially shown in the Fig. 3, where also give the information of the scattering clutter due to the existence of the tumor.

To form the image, the processed signals are synthetically focused at all points in the breast. To execute this image formation, the distance of the microwave propagation from the emitter to a specific point as well as the distance reflected back to the detector need to be converted to the time response. In this step, it is very important to adopt the correct microwave speeds in the breast fat and glandular tissue, respectively. Fig.4 gives the flow chart of correct adoption of the microwave velocity in the confocal algorithm for the image reconstruction. Our study shows that it may cause 5 mm deviation from the correct location if without this consideration. In this connection, the way to determine the thickness of the breast fat is significant.

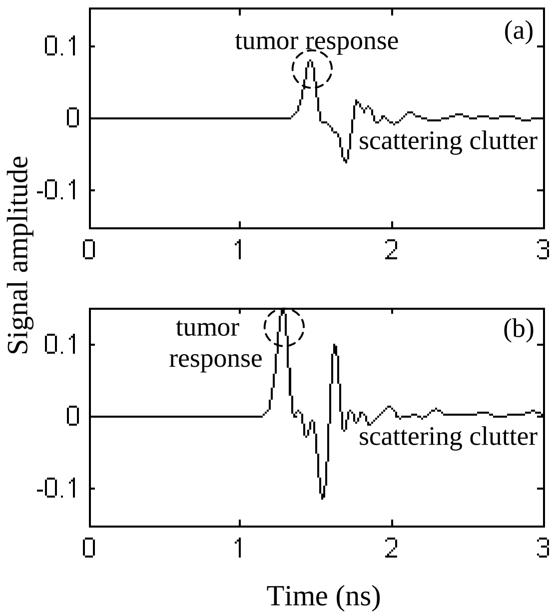

Fig.3 Subtracted waveforms used for the imaging process. Here the signal is emitted from the center emitter E2 and detected (a) at D2 and (b) at D3, respectively.

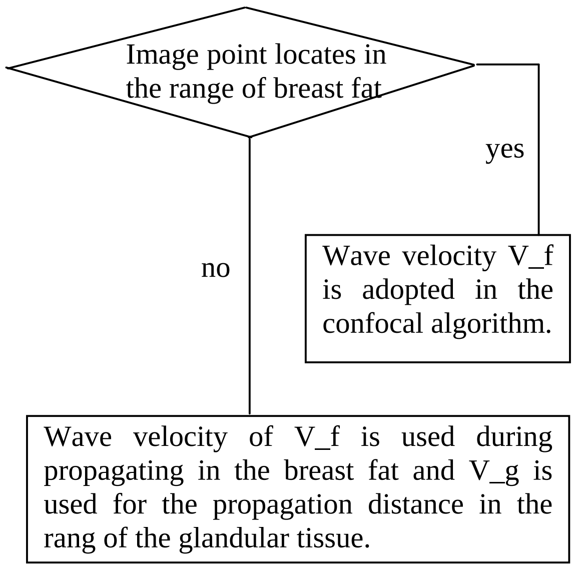

Fig.4 Flow chart of correctly adoption of the microwave velocity in the confocal algorithm for the image reconstruction.

2.4 Tumor Image and Discussion

Fig. 5 shows the reconstructed images for the multilayer breast structure with the tumor diameter size of (a)10 mm and (b) 6 mm located at the position of (55,50). In the imaging process, 3 emitters and 6 detectors as arranged in the Fig.1(a) are employed in the confocal method. The reappearance of the tumor in the image agrees very well with the assumed tumor both in the location and in the size.

The more detailed and complicated properties of breast organisms will be taken into consideration in our future research. However, it can be forecasted that the effects from the material complexity could be overcome in the tumor detection by introducing suitable process skills. The former researches on inhomogeneous breast tissue, and on the noised breast tissue verified this prediction [2, 4].

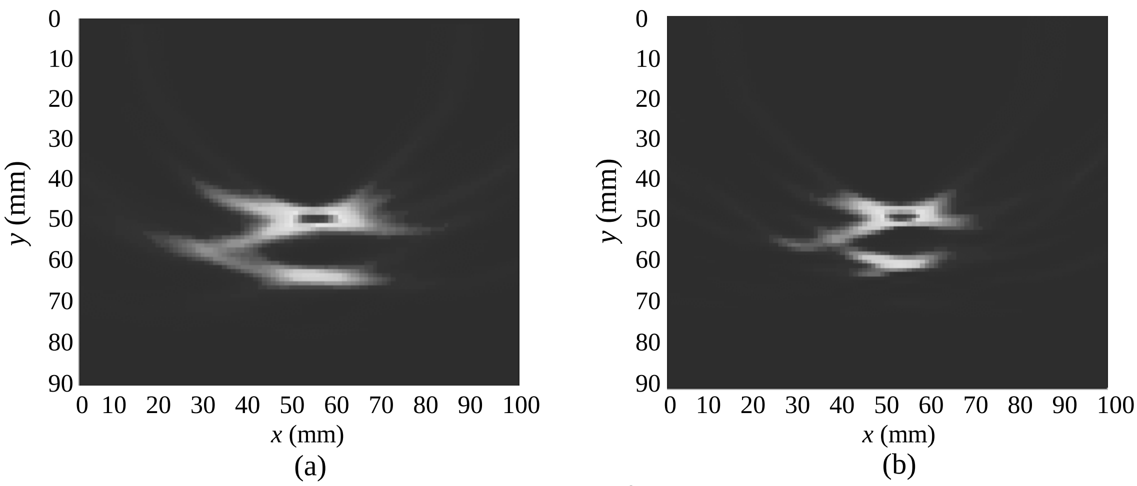

Fig. 5: Reconstructed images with the tumor size of (a)10 mm and (b) 6 mm located at (55,50).

3. Conclusion

A multilayer breast structure includes the skin, the subcutaneous fat and the glandular tissue is established in the study of breast tumor detection. It is essential to determine the thickness of the fat accurately for the breast imaging reconstruction process. The interface between the fat and the glandular tissue as well as the interface between the glandular tissue and the chest wall can be distinguished clearly by using the subtracted waveforms detected in the two cases of with and without the existence of the glandular tissue layer in the structure of Fig.1(a). By introducing the judgement function to distinguish the position of the imaged points in the breast, the microwave speed in the different breast organisms can be adopted correctly in the confocal algorithm. This treatment ensures the display of the correct tumor information in the resulted image.

Acknowledgments

The authors wish to thank the support from “Creation of Innovation Centers for Advanced Interdisciplinary Research Areas” based on the Special Coordination Funds for Promoting Science and Technology from the Ministry of Education, Culture, Sports, Science, and Technology of Japan.

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