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A Radar-based Breast Cancer Detection Using CMOS Integrated Circuits with A Cross-shaped Dome Antenna Array

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Abstract

Breast cancer imaging is performed by use of a radar-based ultra-wide-band CMOS integrated circuits with 16 cross-shaped dome array antennas for a hemispherical breast phantom. The CMOS detection system with 65 nm technology transmits Gaussian monocycle pulses, receives scattered signals followed by track-and-hold, equivalent time sampling and analog-to-digital conversion. The dome array antennas are rotated and selected by CMOS switching matrix. A breast cancer phantom target in the silicone-based breast phantom was successfully detected by confocal imaging.

1. Introduction

The most commonly used technology for early breast cancer screening is X–ray mammography. However, this method has a drawback of ionizing radiation, resulting in the limitation of frequent monitoring. For the purpose of screening without non-ionizing radiation, some complementary methods were developed, such as electrical impedance tomography (EIT) [1] and microwave imaging. The microwave imaging is based on the facts that the dielectric properties of the cancer tissue and normal breast tissue are different [2]. There are mainly two ways for the imaging of the cancer, the microwave tomography [3] and confocal imaging [4]. Confocal imaging prototype systems were developed [4-5]. However, these systems are composed of vector network analyzers with a bed cabinet, resulting in being installed at a hospital.

In this study, CMOS integrated circuits were developed to get rid of off-the-shelf equipment for portable use and a cross-shaped dome antenna array was developed for use in a spine position.

2. Cross-shaped dome antenna

A cross-shaped dome antenna array with 16 antenna elements is employed to conduct the target detection experiment as shown in Fig. 1. The dome array rotates on the surface of a hemispherical breast phantom. The array antennas are consolidated into the dome shell to fit a woman breast.

The detection system is composed of the signal generation part, the switching (SW) matrix part, the receiving and sampling part and the control board [6-11]. A photograph of the entire system with the dome antenna is shown in Fig. 2.

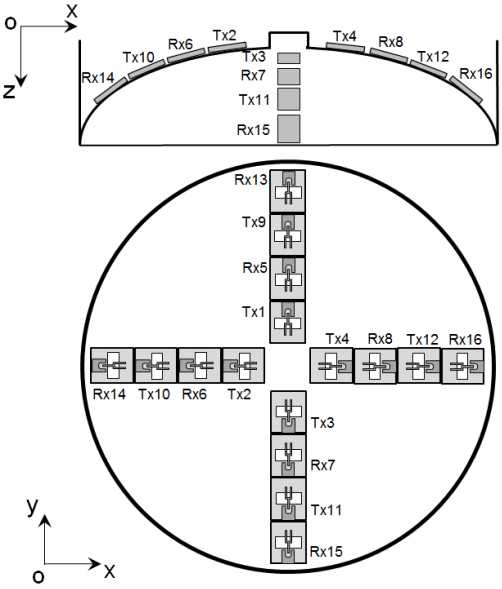

Fig. 1. Side and top views of a cross-shaped dome antenna array.

A hemispherical silicone breast prosthesis is fabricated as the breast phantom. A 1-cm-diameter aluminum ball is inserted into the breast phantom as a target. Glycerin is smeared on the surface of the silicone breast phantom and the dome antenna is pressed on the phantom to exclude air. A tubular spirit level is employed to guarantee the dome is horizontal. During the experiment, the input signal is transmitted to the transmitting antenna (Tx) through the SW matrix and the reflected signals are captured by the receiving antennas (Rx). The SW matrix can select which Tx and Rx to be used, thus various combinations of signals can be obtained. The received signals are then digitalized by the sampling module. Figure 3 shows the signal emitted from the Tx1 and received by Rx5 in analog and digitalized forms. The digitalized signal is reversed due to the inverter circuits. The digital signal is stored into the memory of a computer and calculated off-line to reconstruct the breast image by confocal imaging algorithm.

3. Imaging results

In order to extract the target reflection from the received signals, the experiment is conducted at different angles by rotating the dome antenna.

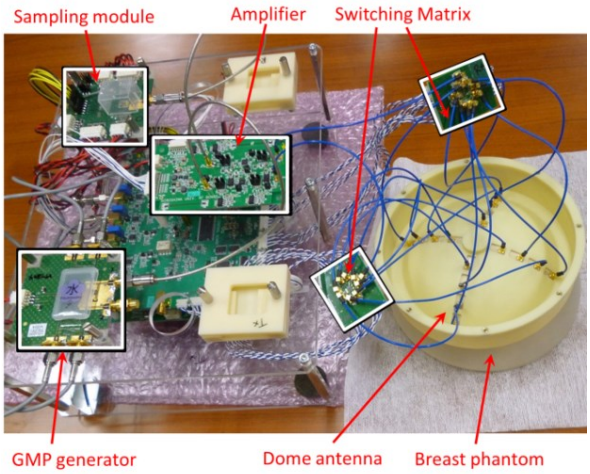

Fig. 2. Photograph of CMOS detection system and a dome antenna array.

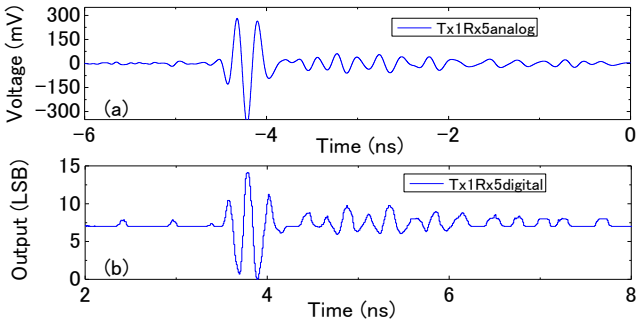

Fig. 3. Received signals from the antenna pair Tx1-Rx5. (a) Analog signal. (b) Digital signal.

The relative position between antennas is not changed but the relative distance to the target is changed. Consequently, the amplitude and shape of the direct surface waves remain similar and the signals from the target have shifts in the time axis. By averaging the signals obtained from different angles, the amplitude of deterministic direct wave is enhanced and the reflections from the target are decreased so that the reference signal is obtained. By subtracting the reference signal from the original one, the target response can be obtained. Figure 4 shows the signals from the antenna pair Tx11-Rx15, the reference signal and the subtracted signal.

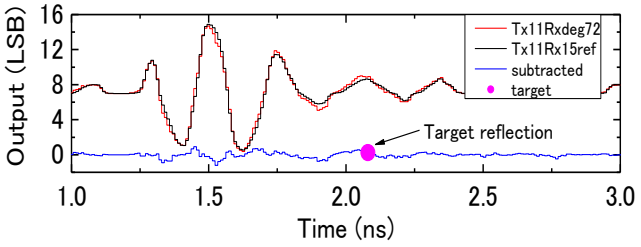

Fig. 4. The waveforms of the received signal by the antenna pair Tx11-Rx15 at the degree of 72, the reference signal and the subtracted signal.

The confocal imaging result is shown in the Fig. 5. The target is buried at (80, 55, 25) mm in the x-y-z coordinates. The estimated position is (79, 57, 26).

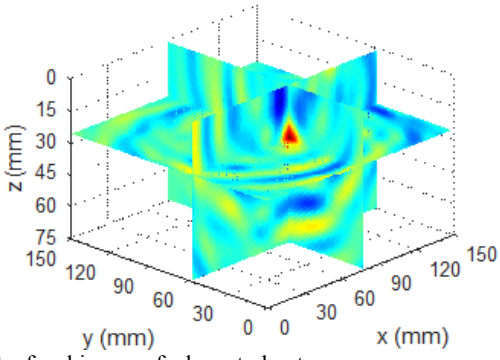

Fig.5. Confocal image of a breast phantom.

4. Conclusion

A cross-shaped dome antenna array is developed to conduct the breast cancer detection experiment. The successful detection of the target demonstrates the feasibility of the dome antenna array and the CMOS system for breast cancer detection.

Acknowledgement

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