Confocal imaging by turning antennas with CMOS integrated circuits for breast cancer detection

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Abstract - **Confocal imaging for breast cancer detection by turning an antenna array with CMOS integrated circuits is presented. The detection system consists of 65 nm technology CMOS integrated circuits such as a Gaussian monocycle pulse (GMP) generation circuits, antenna array switching (SW) matrix circuits, equivalent-time sampling circuits, and a 4x4 flat antenna array. By turning the array antennas, reference signals can be obtained to extract the tumor response from the received signals. An alignment method is employed to compensate the phase shift caused by the jitter of the system. Using the detection system and turning antenna method, successful detection of a 1-cm tumor target is demonstrated.**

Index Terms — **Breast cancer, ultra-wideband, confocal imaging, CMOS.**

1. Introduction

Early detection for breast cancer can help the patient to get a proper treatment promptly. Conventionally, the X-ray mammography is employed as a screening method. However, this technology has a drawback such as ionizing radiation, which limits frequent examinations [1]. As a complementary method, the microwave imaging method has attracted wide research interests in breast cancer detection. This technology is based on the facts that the dielectric properties of the cancer and normal breast tissues have a significant difference [2]-[3]. A number of prototype detection systems have been developed such as multi-static radar-based system, mono-static detection system which use the ultra-wideband (UWB) microwave [4]-[5]. A tomography system using a single frequency microwave was also developed which reconstructed the dielectric distribution of the breast tissue [6]. However, those systems have large footprints and use off-the-shelf equipment.

In this paper, a radar-based breast cancer detection system using 65 nm technology CMOS integrated circuits and a 4x4 flat antenna array is developed and confocal imaging is presented. All the signals are digitalized and saved in a laptop computer without using any off-the-shelf equipment.

2. Experiment

This system is composed of signal generation circuits which transmit Gaussian monocycle pulses, antenna switching matrix circuits, sampling circuits and a 4×4 antenna array [7]-[11]. The detection experiment is conducted by turning a 4x4 antenna array. By averaging the signals obtained from different angles, reference signals can be calculated. Since a jitter exists in the system and received signals have phase shifts in the time axis, an alignment method based on the squared error is used to compensate the signals before averaging. By subtracting the reference signals from the original received signals, the tumor response can be extracted. Then the confocal imaging algorithm is applied to the subtracted signals and successful detection of a 1-cm tumor target is achieved.

The detection system is connected to the 4x4 antenna array via the switching matrix circuits as shown in Fig. 1. The antenna array is placed on the surface of one of rubber substrates which have similar permittivity to that of breast adipose. A 1-cm target which is made of bacon is buried in the other rubber substrate. The experiment is carried out by turning antenna array with respect to the target every 10 degree from 0 degree to 350 degree using a 1-mm thick rubber sheet protractor. During the detection, the signal which is transmitted from a transmitting antenna (Tx) and received at a detecting antenna (Rx) is sampled 16 times and saved to improve the resolution [11].

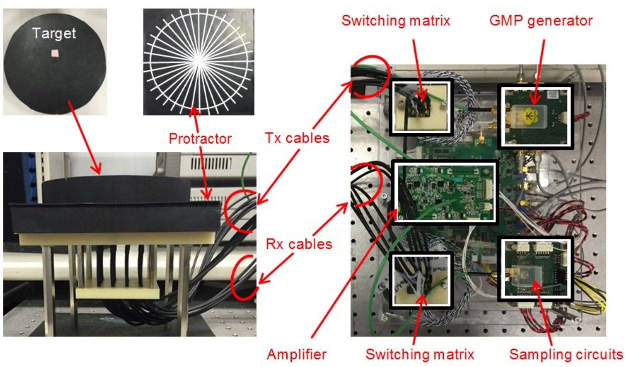

Fig. 1. Experiment setup and breast phantom.

3. Signal processing and imaging results

Figure 2 shows the measurement data from Tx3-Rx7 at 36 different angles. As we can see, these signals have offsets with each other. In order to get a reference signal, an alignment process is applied. Let the signal measured at 0 degree as the baseline, and adjust the other signals. The goal is to find the best offset time which let the summation of the squared errors between the base signal and other signals be the minimum. The aligned signals are shown in Fig. 3.

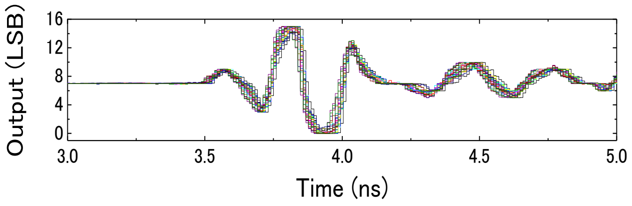

Fig. 2. Measured signals from antenna pair Tx3-Rx7 at 36 different angles.

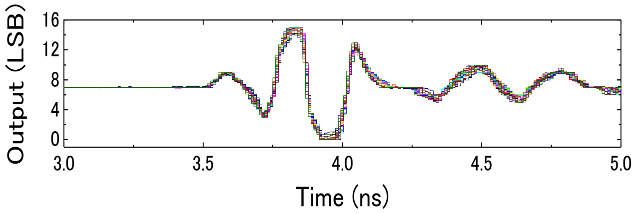

Fig. 3. The aligned signals from antenna pair Tx3-Rx7.

After alignment the 36 signals are averaged so that a reference signal is obtained. Subtracting the reference signal from the original received signal, the target response can be extracted. Figure 4 shows the signal from 0 degree, the corresponding reference signal and the subtracted signal. The maker is the theoretical reflection time from the target.

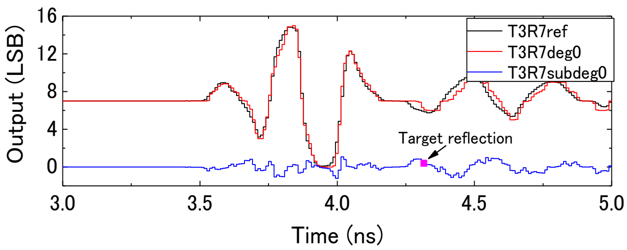

Fig. 4. Received and reference signals at 0 degree and the subtracted signal.

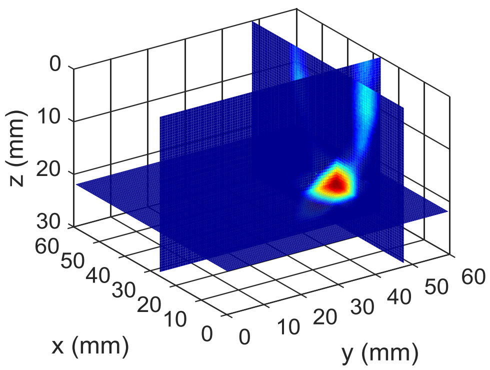

Fig. 5. Confocal imaging result.

Finally, the confocal imaging algorithm is applied to the subtracted signals to recognize the position of the target [1]. Figure 5 shows the confocal imaging result. The estimated position is x=27, y=48, z=22 mm, compared with the actual position x=28, y=46, z=26 mm.

4. Conclusion

The breast cancer detection by turning the antenna array was conducted using the CMOS integrated circuits detection system. A signal alignment method was employed to obtain a reference signal from the raw received signals. After subtracting the reference signal from the original received signal, the tumor response was extracted. By use of the subtraction signals, the confocal imaging was carried out to reconstruct the breast image. The target position was detected successfully from the imaging result, demonstrating the feasibility of the turning antenna array for breast cancer detection.

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