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Confocal Imaging for Breast Cancer Detection using UWB Antenna Array on Si

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1. Introduction

Confocal imaging using a UWB radar technique has shown the potential for detecting and locating breast cancer [1]. The reflected signals from the tumor were observed due to the contrast in the dielectric properties of normal and malignant tissues [2]. This is considered as an alternative technique to X-ray mammography, which is currently considered as the standard technique for breast cancer diagnosis.

In this paper, the confocal imaging technique was developed using UWB antenna array fabricated on a Si substrate. Two-dimensional cross-section images were reconstructed for the simulated structure of breast cancer using a dielectric target in the dielectric substrate.

2. Experimental

P-type (100) Si wafers with resistivity (ρ) of 79.6 Ω·cm were prepared as substrates, whose thicknesses were 260 μm. The surface of Si wafer was oxidized in H_2-O_2 at 1000ºC to form 0.3-μm-thick field SiO_2. 1.0-μm-thick aluminum was deposited on the SiO_2 layer by direct current magnetron sputtering and the antenna patterns were formed by electron beam lithography followed by wet etching. Bow-tie antennas were fabricated on the SiO_2 layer. The flare angle of a bow-tie antenna was 53°. The antenna length of a bow-tie antenna was 7.16 mm. 5 bow-tie antennas were fabricated on a chip. The distance between antennas was 10 mm.

Figure 1 shows a measurement set-up for UWB pulse radiation and receive measurement set-up by use of Gaussian monocycle pulse. It consists of Agilent 4902B serial bit error rate tester (BERT), Picosecond impulse forming networks, SHF 810 broadband amplifier (30 kHz - 40 GHz, +30 dB), Agilent 86100C sampling oscilloscope and a microwave probe station. Rectangular pulses were transformed to Gaussian monocycle pulse trains by use of two impulse forming networks. The 3dB bandwidth was 20 GHz. The center frequency was 15 GHz. Antenna array was consisted of 10 bow-tie antennas using 2 chips. S-parameter of bow-tie antennas were measured by a vector network analyzer HP8510C, 180° hybrid couplers (6-26.5 GHz) and signal-signal (SS) probes. 3 dielectric targets were prepared. The size of a dielectric targets were 15×13, 10×10, 7×6 mm^2. The permittivity and conductivity of the dielectric target and the substrate were measured by a vector network analyzer HP8510C, connecting Agilent 85070E dielectric probe kit. Each antenna was excited individually and the reflected signals from a target were received at other antennas.

3. Result and discussion

Figure 2(a) shows S-parameter of two adjacent bow-tie antennas. S_{11} was less than -10 dB in the frequency range above 7.6 GHz. Measurement results were in agreement with simulation results by 3-D field simulator of Ansoft HFSS ver. 8.5. Figure 2(b) shows antenna radiation pattern at 15 GHz for a bow-tie antenna by simulation. The half power beamwidth was 120°. Figures 3(a) and 3(b) show the permittivity and conductivity of a dielectric target and the substrate. The permittivity and conductivity of the target were 30 and 20 S/m at 15 GHz. The permittivity and conductivity of the substrate were 7 and 0.6 S/m at 15 GHz. The dielectric properties of the target and substrate were similar to that of normal and malignant tissues [2]. Figures 4(a), 4(b) and 4(c) show confocal images [3] of a dielectric target whose size was 15×13 mm^2 using 2, 4 and 10 antennas, respectively. The image of target became more clearly as the number of antennas increased. Figures 5(a), 5(b) and 5(c) show confocal images using 4 antennas for dielectric target sizes = 15×13, 10×10 and 7×6 mm^2, respectively. A dielectric targets of 10×10 mm^2 and 7×6 mm^2 could not be reconstructed clearly. Figures 6(a), 6(b) and 6(c) show confocal images using 10 antennas for dielectric target size = 15×13, 10×10 and 7×6 mm^2, respectively. The dielectric target for the size = 7×6 mm^2 was reconstructed.

4. Conclusion

Two-dimentional cross-section images of a dielectric targets embedded in the dielectric substrate were reconstructed by confocal imaging using bow-tie antenna array with Gaussian monocycle pulse whose center frequency was 15 GHz.

Acknowledgement

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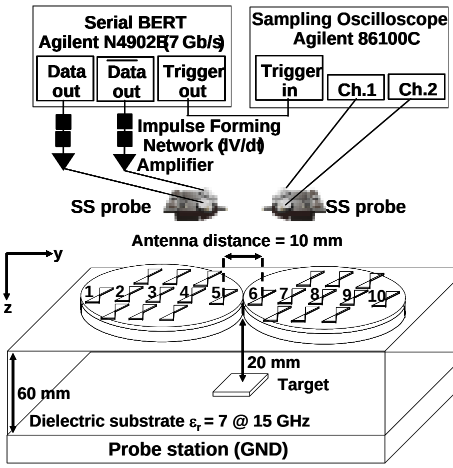

Fig. 1. Experimental set-up.

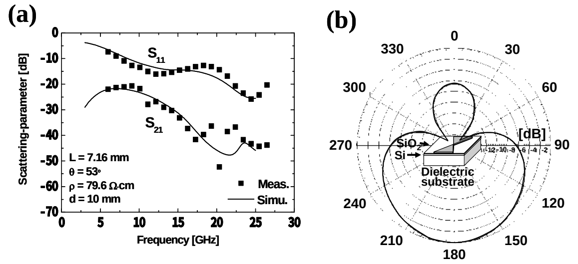

Fig. 2. Antenna characteristics. (a) S-parameter versus frequency. (b) Normalized directivity at 15 GHz.

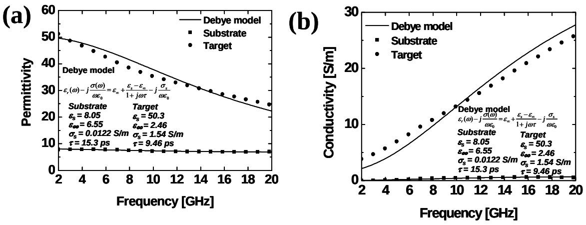

Fig. 3. Dielectric substrate characteristics. (a) Permittivity versus frequency. (b) Conductivity versus frequency.

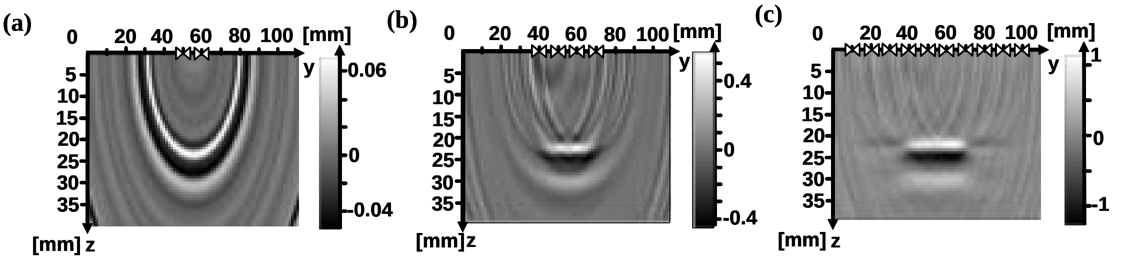

Fig. 4. Confocal images of a dielectric target for the size = 15 × 13 mm in the dielectric substrate by subtracted waveforms. (a) Image using 2 antennas (antenna #5,6). (b) Image using 4 antennas (antenna #4,5,6,7). (c) Image using 10 antennas (antenna # 1,2,3,4,5,6,7,8,9,10).

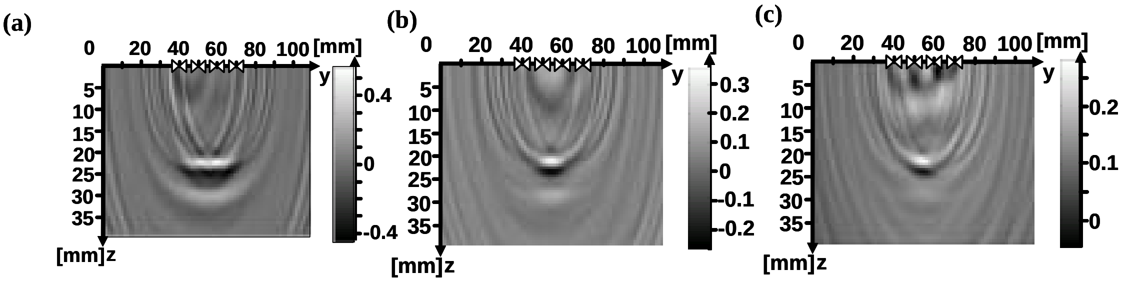

Fig. 5. Confocal images of a dielectric target in the dielectric substrate using 4 antennas (antenna #4,5,6,7). (a) Image of a dielectric target for the size = 15 × 13 mm. (b) Image of a dielectric target for the size = 10 × 10 mm. (c) Image of a dielectric target for the size = 7 × 6 mm.

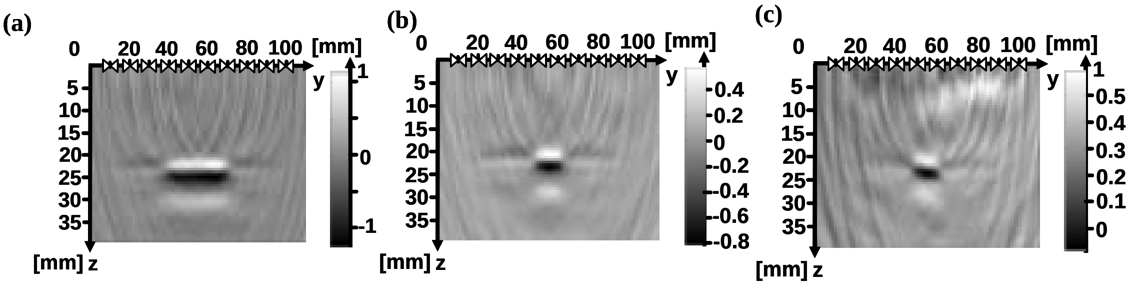

Fig. 6. Confocal images of a dielectric target in the dielectric substrate using 10 antennas (antenna #1,2,3,4,5,6,7,8,9,10). (a) Image of a dielectric target for the size = 15 × 13 mm. (b) Image of a dielectric target for the size = 10 × 10 mm. (c) Image of a dielectric target for the size = 7 × 6 mm.