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Improvement in Radar Imaging by UWB Antenna Attached to an Optical Electric Field Sensor

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1. Introduction

Humanitarian demining is a very urgent and important task for many countries and many techniques are proposed for its solution [1]. We have developed a bistatic GPR system using an Optical Electric Field Sensor (OEFS) as a receiver for landmine detection [2]. This system has two unique features, one is that it is a bistatic radar and the other one is to use a OEFS as a receiver. Therefore, it is our expectation that this system will be used for stand-off detection. In this system, reflections from a buried target are received by the receiver when it scans over the target. Then, radar image is constructed by migration in time domain. In order to improve the resolution of a radar image, receiving antenna with wide frequency bandwidth is required. In this paper, we propose a small Vivaldi antenna that has wide frequency bandwidth and evaluate a radar image obtained with the small Vivaldi antenna.

2. Optical Electric Field Sensor

Fig.1 shows the configuration of our system.Fig.2 shows an OEFS (NEC TOKIN) and Fig.3 shows its inner structure. The OEFS is a balanced type sensor with a capacitive impedance, and consists of two electrodes and an optical waveguide which branches off at each end. Optical signal is modulated due to the interferometric effect caused by the voltage between two electrodes, which is induced by the outer E-field. Then modulated signal is demodulated by the optical detector into electric signal for analysis with a vector network analyzer.

There are two advantages of the OEFS as a receiver in GPR system. First, the OEFS does not disturb the E-field around the sensor by itself because it does not need coaxial cable and consists of nonmetallic parts except two electrodes. Second, the size of the OEFS is small enough, its size is 1cm $\times$ 1cm $\times$ 10cm. These advantages make the antenna scanning in bistatic operation more flexible.

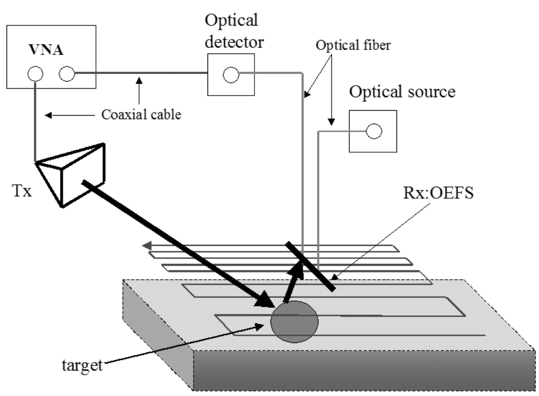


Figure 1: Configuration of the bistatic GPR system for landmine detection

ISBN: 978-4-88552-223-9 C3055©IEICE

Figure 2: Optical Electric Field Sensor (OEFS)

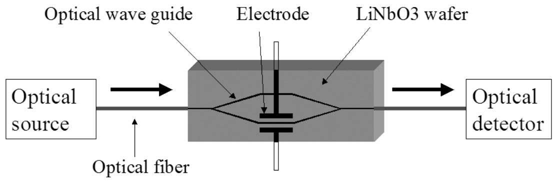


Figure 3: Inner structure of an Optical Electric Field Sensor

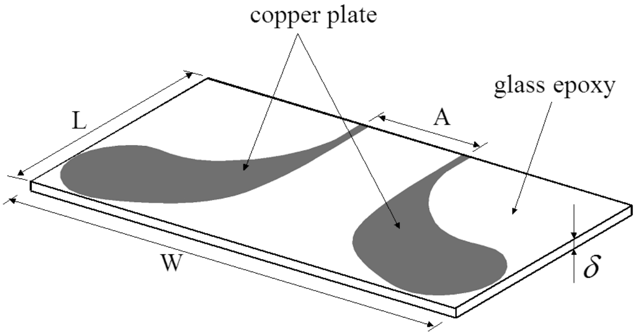


Figure 4: Scheme of small Vivaldi antenna

Table 1: Dimensions of the small Vivaldi antenna

L	71.5 mm
W	125 mm
δ	1.5 mm
A	30 mm

3. Small Vivaldi antenna

3. 1 Antenna design

We propose a small Vivaldi antenna attached to the electrodes of the OEFS for better receiving characteristic. Its scheme and dimensions are presented in Fig.4 and Table.1, respectively. The proposed antenna is fabricated on a glass epoxy substrate with a thickness of 1.5mm, and the separation between two conductors is 30mm to match with two electrodes. Exponential curve and elliptical curve are used to form the outline of the conductors to remove a discontinuity point. Furthermore, the dimensions have been optimized focusing on frequency characteristic and effect to the E-field around the antenna using numerical simulation. As a result, it is confirmed that the small Vivladi antenna has wide bandwidth and less disturbance to the E-field by the antenna [3].

3. 2 Receiving characteristic measurement

Return loss and S_{21} measurements were carried out in an anechoic chamber, to estimate receiving characteristics of antennas. A frequency range of 64MHz-6.464GHz was used in the measurements with vector network analyzer (Agilent E5071-B). Transmitting antenna is dual rided horn antenna (ETS Model 3164-03), and its return loss is shown in Fig.5. In S_{21} measurement, OEFS without any antenna element and OEFS with the small Vivaldi antenna are used as a receiver, respectively. Antenna coupling is measured when the separation between transmitting antenna and receiving antenna is 2m. The received voltage is shown in Fig.6.

In Fig.6, the dashed line shows received voltage of the OEFS, and solid line shows received voltage of the OEFS with the small Vivaldi antenna. Notice that received voltage is higher except dominant frequency of the OEFS and frequency characteristic is flat from 1.5GHz to 5.5GHz, when the small Vivaldi antenna is attached to the OEFS. It shows a significant advantage of the small Vivaldi antenna. Due to the frequency response of the OEFS, we have used a frequency range of 300MHz-4.3GHz to construct radar images. However, the bandwidth can be broadened to a range of 300MHz-5.5GHz with the proposed small Vivaldi antenna. Furthermore, with the small Vivaldi antenna, center frequency can be higher compared to the OEFS without any antenna element. Therefore, it is possible to improve the range and the azimuth resolution of a radar image using the small Vivaldi antenna.

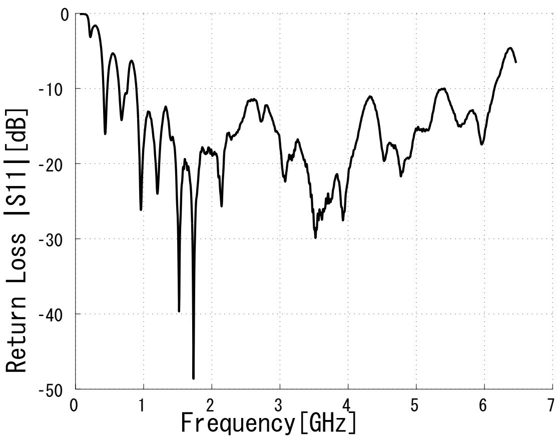


Figure 5: Return loss

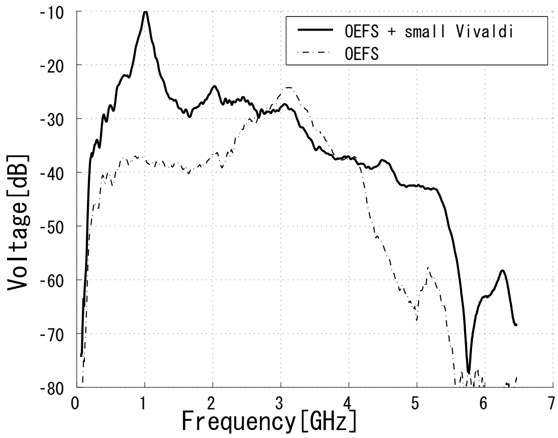


Figure 6: Received characteristic

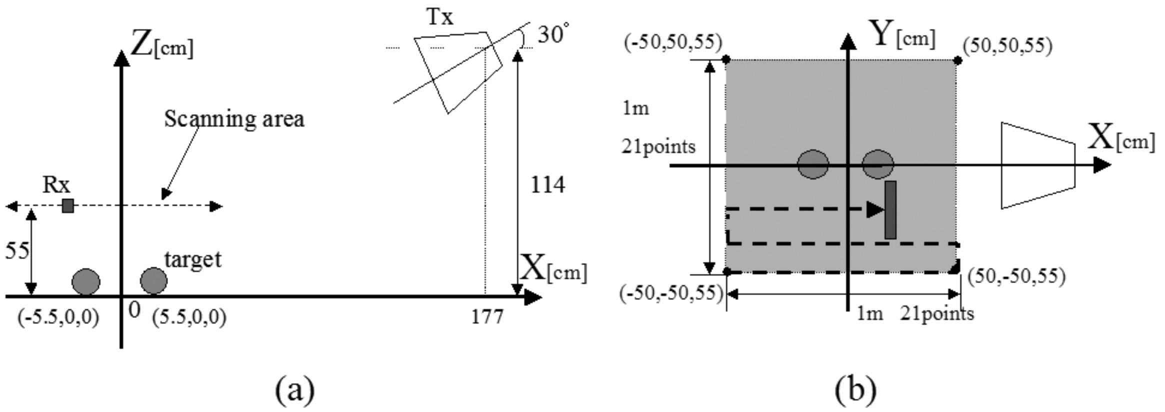


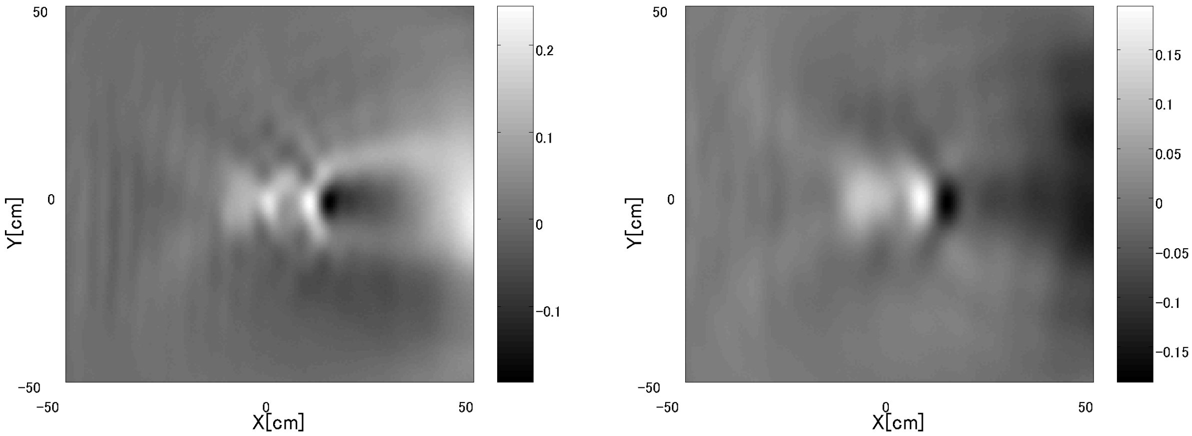
Figure 7: Configuration of the measurement, (a)side view and (b)top view

4. Resolution in radar image

In order to evaluate resolution of radar image with the small Vivaldi antenna, we carried out measurement in an anechoic chamber. Here, we discuss only the range resolution, due to the limitation of space. Fig.7 shows the antenna and target configuration. Scanning area is 1m $\times$ 1m, and the increment of the scanning is 5cm. Two metallic spheres whose diameter is 10cm are used as targets, and the separation between them is 11cm in range direction. For comparison, OEFS without antenna element and OEFS with the small Vivaldi antenna are used as a receiver, respectively.

The signal is acquired in frequency domain. After pulse compression, the signal is transformed to time domain with IFFT. In time domain, the radar image is constructed using diffraction stacking method of migration. The radar images are shown in Fig.8(a)(b). Furthermore, traces along Y=0 in Fig.8 are plotted in Fig.9.

In Fig.8(a), we can see two points with high amplitudes which correspond to the targets. On the other hand, in Fig.8(b), we can see the reflection from the target at (x,y,z)=(5.5,0,0), however the reflection from another target at (x,y,z)=(-5.5,0,0) is weak and ambiguous. The same phenomena can be observed in Fig.9. As the result shown here, the range resolution of radar image is improved because of the wider bandwidth of the proposed small Vivaldi antenna.



(a) (b)

Figure 8: Radar image for (a)OEFS+small Vivaldi and (b)OEFS are used as receiver.

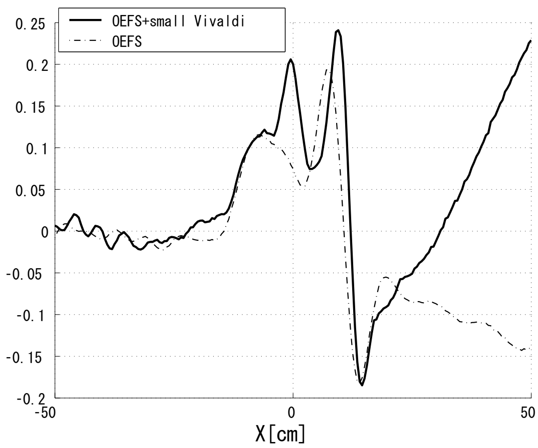


Figure 9: Traces along Y=0 in Fig.8

5. Conclusion

We proposed and evaluated a small Vivaldi antenna as antenna element attached to the OEFS, which is the receiver of bistatic GPR system for landmine detection. Laboratory measurement showed its advantage, receiving characteristic and range resolution. Frequency range could be broadened with the small Vivaldi antenna, thus range resolution in radar image could be improved. We believe that the small Vivaldi antenna attached to the OEFS can be applied to varied applications which require UWB technique, such as Through Wall Radar.

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