3-D RADAR IMAGING BY A PASSIVE ELECTRIC FIELD SENSOR

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Abstract: Optical electric field sensor was used for 3-D imaging by a bistatic radar configuration. Radar signal scattered by a target was used for image reconstruction. We could image a metal plate set in a free space by this technique. Advantage of a small passive sensor will be useful for estimation of location of the scattering targets.
Key words: Optical electric field sensor, Bistatic radar, 3-D imaging, Diffraction stacking, Pulse compression, SAR

1. Introduction

Radar remote sensing will be useful for estimation of the locations of the scattering objects for EMC. Although radar is an active imaging technique, we can find many similarities for passive radio source imaging techniques used in EMC.

For example, in order to understand EM environment in a small area, we have to understand the scattering mechanisms of the surrounding environment. In these situations, we do not have enough space to use a high resolution radar antenna due to the limited space size. However, if we can use synthetic aperture radar (SAR) for imaging, the problem can be solved. In this report, we propose a bistatic radar configuration for SAR imaging. In this radar system, we use a passive optical electric field sensor as a receiver. It has some advantages as a electric field sensor, and suitable for configuration of a radar system.

2. Imaging Radar System

2.1 Electric Field Sensor

The optical electric field sensor has been developed last 10 years, and now some commercial sensors are available as shown in Figure 1[1]. The optical electric field sensor modulates amplitude of optical signal through a modulator by electric field applied by electrodes attached to the modulator. The sensor is passive and electrically completely isolated. It has metal parts only for the electrodes and antenna elements attached to the electrodes. The advantage of this passive and electrically isolated sensors have been used in various applications including indoor electric field distribution measurement and remote television satellite systems. We have tested this sensor for a receiver of a radar system[2].

There are two significant advantages of this sensor as a receiver of radar systems. Due to the small metal part configuration, the sensor does not disturb the field around the sensor by itself. It must be suitable for array operation and bistatic operation, where incident field from a transmitter immerses antennas. The second advantage is the small size of the sensor. The main body of the modulator is less than 1cm^2 and it does need any power supply. This small size is suitable for scanning the receiver in a small space.

Figure 2 shows the field sensitivity of the sensor which we used for the experiment.

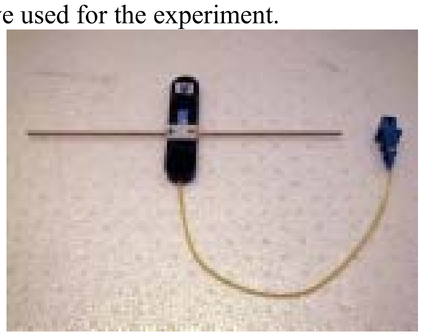


Figure 1 Electric Field Sensor

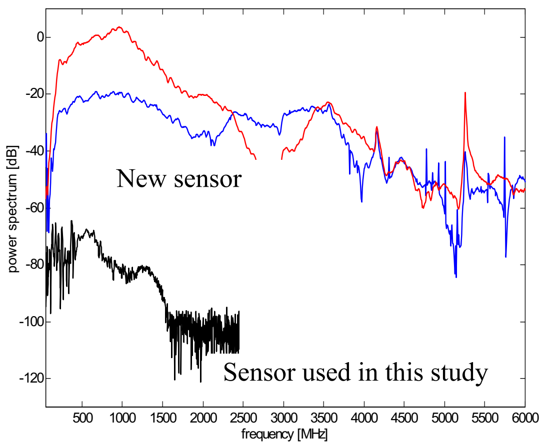


Figure2 Field sensitivity of the Electric Field Sensor

2.2 Bistatic radar

Figure 3 shows a system block diagram of the prototype system, which we propose as a bistatic SAR system. A commercial optical electric field sensor (Tokin OEFS-1) shown in Figure 1 was used as a receiver. It is equipped with a dipole antenna. The dipole length is 30cm. A double-ridged horn antenna (ETS Model 3106) was used as a transmitting antenna. A vector network analyzer (HP8753E) was used for a transmitter/receiver, and the system was operated as a stepped frequency radar system. Due to the frequency response of the optical electric field sensor, we used 3MHz – 2.4GHz for the measurement. We used 30cm dipole antenna element, which was attached to the modulator of the sensor. The nominal frequency bandwidth of the optical electric field sensor is 300kHz-1GHz and the sensitivity of the electric field with this dipole antenna is 70-120dBμV/m .

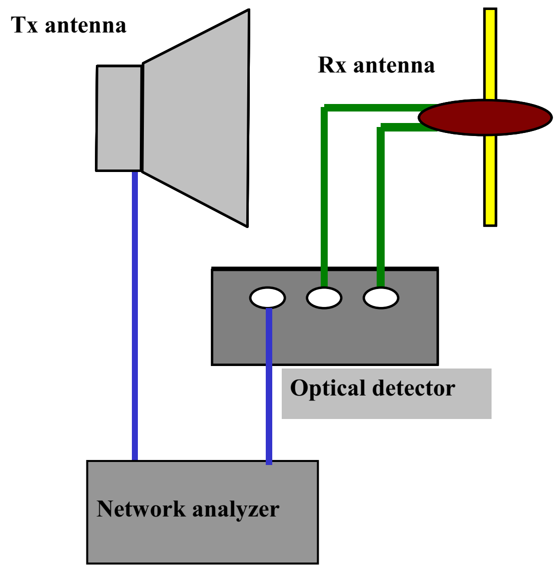


Figure 3 Bistatic radar configuration

2.3 Antenna Layout

The transmitting antenna was fixed for illuminating an incident field to the radar target and the receiving antenna, namely, electric field sensor was scanned by using an antenna positioner. It can scan the antenna in the area of 1.5m in vertical and 20m in horizontal directions at the accuracy of 1mm. Figure 4 shows the set up of the transmitting and receiving antennas in an anechoic chamber. The distance from the transmitter antenna to the radar target is 3m and the distance to the scanning plane of the receiver antenna is 2.5m. The receiving antenna is placed between the transmitting antenna and the radar targets. Therefore, the receiving antenna will be illuminated by a strong incident field. However, since the antenna uses metallic part only for the antenna element, the scattering from the receiving antenna is small. If we had a coaxial line for feeding the receiving antenna, the scattered field would be almost the same as the radar signal to be measured.

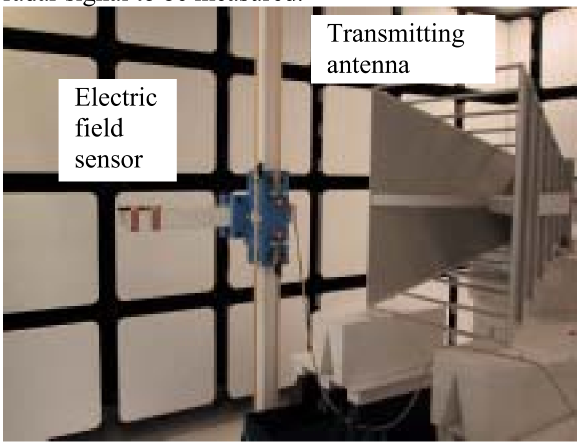


Figure 4 Transmitting and receiving antennas

3. Experiment

Experiment to test the bistattic radar system was conducted in an anechoic chamber. A metallic disc having a diameter of 360mm was used as a radar target. The data was acquired at the 50mm step in both horizontal and vertical directions. Figure 5 shows the radar target with the receiving antenna mounted on an antenna positioner.

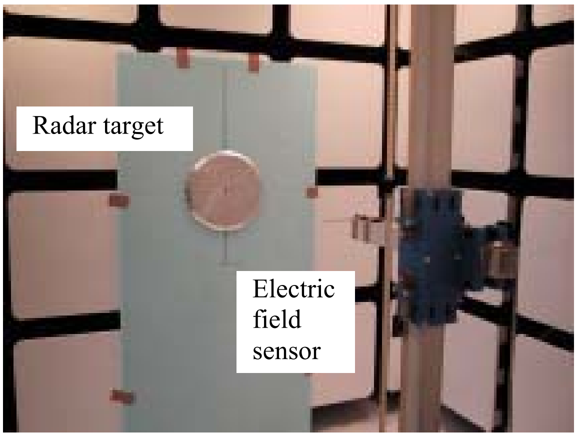
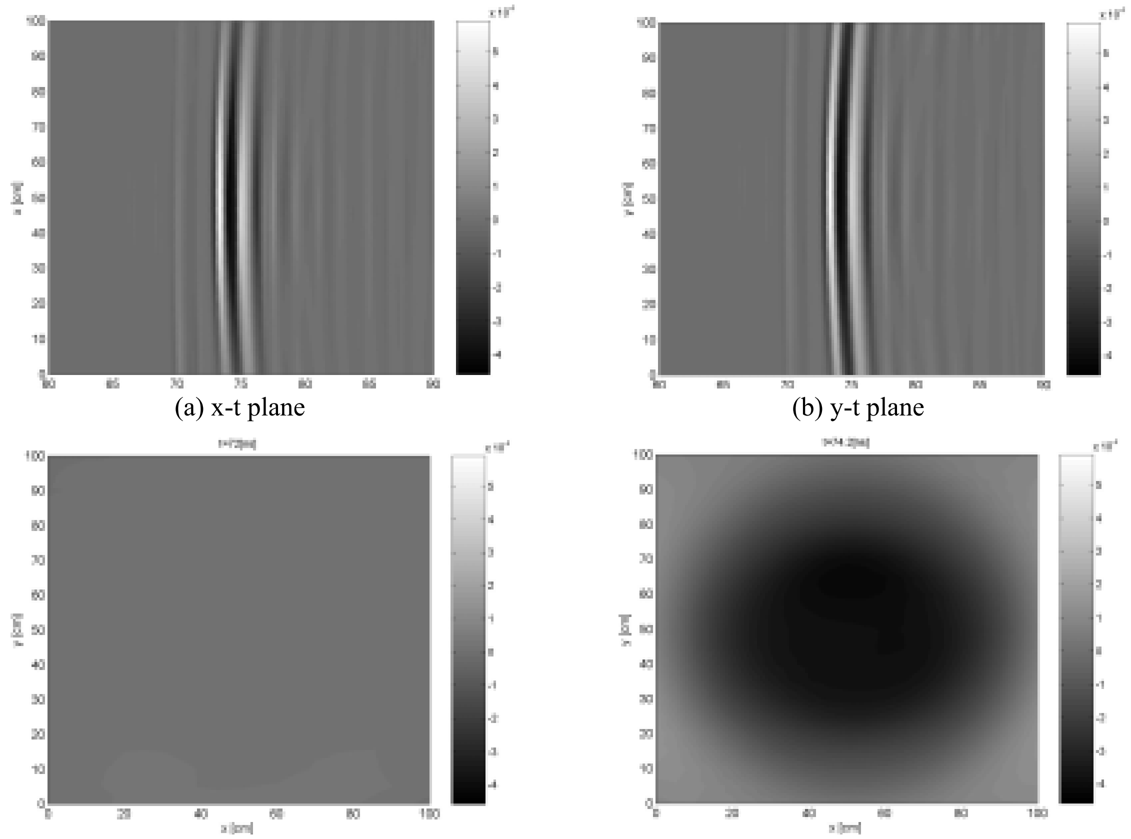


Figure 5 Metal disc for radar target

In this experiment, we can measure the incident field from the transmitter by setting no targets. By subtracting the recorded signal from the measured scattered signal from targets, only the scattered targets from the targets can be obtained. Figure 5 shows the scattered signal. We can find that the raw scattered wave from the targets is spread in the much wider region than the target itself, and we have to use signal processing for target image reconstruction.



(a) x-t plane (b) y-t plane

(c) x-y plane (t=72ns) (d) x-y plane (t=74.2ns)

Figure 5 Raw radar scattered signal in time-domain.

4. 3-D Image Reconstruction

We use a synthetic aperture radar processing to reconstruct the target image. Several signal processing techniques for SAR is known. In order to use the advantage of bistatic arrangement of antennas, we use the diffraction stacking algorithm for image reconstruction. The diffraction stacking is calculated in the time-domain, and although it is a time consuming algorithm, it is very flexible for the positions of the antennas.

The time domain signal was processed by diffraction stacking as follows:

$$P(x',y',z') = \iint f(\tau, x_r, y_r, z_r) dx_r dy_r \qquad (1)$$

where

$$\tau = \frac{\sqrt{(x_t - x')^2 + (y_t - y')^2 + z_t^{\ 2}} + \sqrt{(x_r - x')^2 + (y_r - y')^2 + z_r^{\ 2}}}{v} \qquad (2)$$

is the travel time along a path from the transmitter to the receiver reflected from the imaging point.

Figure 6 shows the reconstructed 3-D image of the metal disc target.

5. Discussion

We can find the shape of the target in Figure 6. The position and the size of the target is clear in the reconstructed image. The exact location and the size of the disc is also shown by solid circle in the figures. However, we can also find some fringes appearing at the edge of the disc. We think these artifacts were caused by the limitation of the range resolution of the radar system. The range resolution of the radar system is determined by the frequency bandwidth of the system. Figure 2 shows the field sensitivity of the receiver, and we can find that it works up to 1GHz, and it limits the range resolution about 1ns or 30cm. In Figure 2, the sensitivity of the new sensor, which we are testing now is also shown, and it will improve the resolution.

6. Conclusion

A bistatic radar system for imaging 3-D radar targets was developed and evaluated the system by experiments. This system uses a optical electric field sensor as a receiver, and its features such as passive, small sensors made the system quite unique.

A metal disc was successfully imaged by diffraction stacking algorithm, which is one kinds of SAR signal processing. We think this kind of technique will be useful for understanding electromagnetic scattering in a small space.

Acknowledgement

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References

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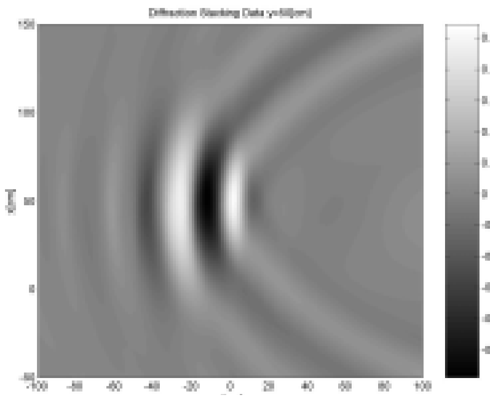
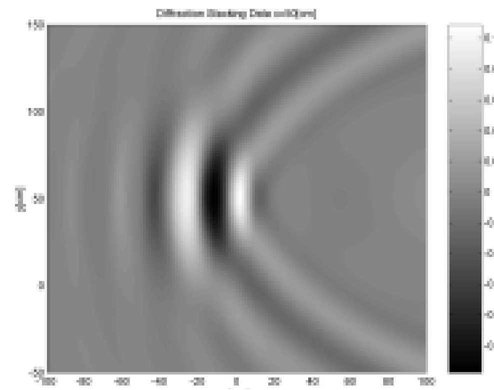
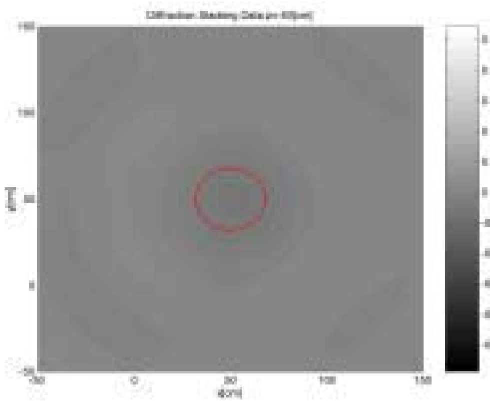


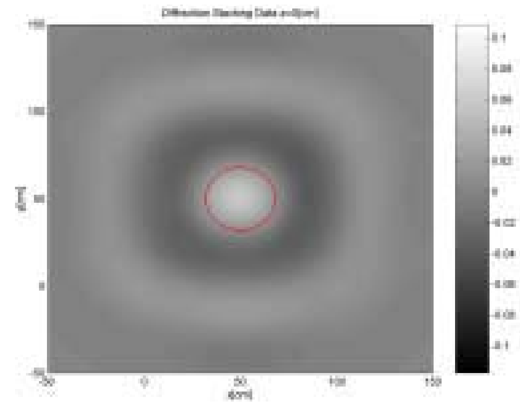
(a) x-z plane



(b) y-z plane



(c) x-y plane (z=-50cm)



(d) x-y plane (z=0cm)

Figure 6 3-D reconstructed image of a metal disc