Accuracy Investigation of Monostatic and Bistatic RCS Measurement by Near-field Far-field Transformation with Planar Scanning

Shuntaro Ohmi[1], Toru Uno[1], Takuji Arima[1], and Takao Fujii[2]
[1]Faculty of Engineering, TOKYO UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, NAKAMACHI 2-24-16, KOGANEI-SHI, TOKYO, 184-8588, JAPAN
[2]FUJITSU SYSTEM INTEGRATION LABORATORIES LTD., KAMIKODANAKA 4-5-6, NAKAHARA-KU, KAWASAKI-SHI, 211-8588, JAPAN

Abstract – **Radar cross section (RCS) is one of the important characteristics in EM engineering. In order to measure the RCS, near-field far-field (NF-FF) transformation technique is often used. The NF-FF transformation method based on fast multipole method (FMM) is well known as a one of effective method. However, in order to obtain quite accurate result, the method needs all of near fields which surrounds the whole of the targets. On the other hand, it is very difficult to measure all of near fields due to limitation of measurement equipment set up. Therefore, the size of using near field area is limited in real measurement situation of RCS measurement case. In this paper, the accuracy of NF-FF is investigated by changing the size of using near fields area. In this paper, only near fields which are in front of the target is used. The near fields are measured by planar scanning.**

Index Terms **— Near-field Far-field Transformation, Radar Cross Section (RCS), Fast Multipole Method (FMM)**

I. INTRODUCTION

The radar cross section (RCS) measurement is important for the target's characterization for both monostatic and bistatic case in EM engineering. It is meaningful information about how well the target detected by radar systems. It is well-known that huge measurement equipment is needed for the direct RCS measurements of large targets (e.g. aircrafts). The usage of near-field far-field (NF-FF) transformation techniques is a powerful approach to overcome the problem.

An NF-FF transformation technique is proposed in [1] which is based on fast multipole method (FMM) and it was used for measurement of antenna radiation pattern. The method has some advantages for antenna radiation pattern measurements. High accuracy result can be obtained by using all of near fields which surrounds the whole of the targets in radiation pattern measurement with the method. In this research, we apply the technique to RCS measurement by simply replacing the antenna to a target scatterer. However, it is very difficult to measure all of near fields due to limitation of measurement equipment. Therefore, the size of using area of near field is limited in real RCS measurement situation.

In this paper, the accuracy of NF-FF is investigated by changing the size of using near fields area in bistatic RCS measurement. Furthermore, the accuracy of monocratic RCS measurement by using the method is indicated. In this paper, only near field which is in front of the target is used. The near fields are measured by planar scanning.

II. TRANSFORMATION TECHNIQUE

In this section, the NF-FF transformation technique is introduced, briefly. The probe's output voltage is represented as spatially weighted integral of electric field by a target. So probe's output voltage are represented using Dyadic Green's Function, current distribution in the target and probe's weighting function as follows,

$$\begin{aligned} U(\boldsymbol{r}_M) &= \iiint_{V_{probe}} \boldsymbol{w}(\boldsymbol{r}-\boldsymbol{r}_M)\cdot \iiint_{V_{target}} \bar{\boldsymbol{G}}(\boldsymbol{r},\boldsymbol{r}')\cdot \boldsymbol{J}(\boldsymbol{r}')\,dv'\,dv \\ &= -\mathrm{j}\frac{\omega\mu}{4\pi}\oiint T_L(\hat{k},\hat{r}_M)\tilde{\boldsymbol{w}}^*(\hat{k})\cdot(\bar{\boldsymbol{I}}-\hat{k}\hat{k})\cdot\tilde{\boldsymbol{J}}(\hat{k})\,d\hat{k}^2. \end{aligned} \quad (1)$$

FMM like procedure was used to derive the lower part of (1) and $T_L(\hat{k},\hat{r}_M)$ denotes the FMM translation operator. $\tilde{\boldsymbol{J}}(\hat{k})$ denotes Fourier transform of $\boldsymbol{J}(\boldsymbol{r}')$ and $\tilde{\boldsymbol{w}}^*(\hat{k})$ that of $\boldsymbol{w}(\boldsymbol{r}-\boldsymbol{r}_M)$ (* denotes complex conjugation). Here, $\tilde{\boldsymbol{w}}^*(\hat{k})$ corresponds to probe's radiation pattern of $\hat{k}$ direction and antenna factor. $\tilde{\boldsymbol{J}}(\hat{k})$ correspond to target's far-field and can be regarded as a plane wave propagating in $\hat{k}$ direction. So (1) means that the probe's output voltage is determined by superimposing the individual plane waves weighted with $\tilde{\boldsymbol{w}}^*(\hat{k})$. To predict far-field value, we solve (1) for $\tilde{\boldsymbol{J}}(\hat{k})$ numerically from measured probe's output voltage.

III. MEASUREMENT SETUP

Our target for RCS measurement is a dihedral corner reflector (see Fig. 1) at 5GHz. The probe's output voltage near the target is measured by planar scanning depicted in Fig. 1. Because of the limitation of our measurement equipment, the planar scanning area is limited to 30cm. Sampling interval is set as 2cm (λ/3). The incident wave from transmitting antenna is assumed to be plane wave because it is needed condition for RCS measurement.

Fig. 2 is a picture of the measurement setup in our anechoic chamber. Our probe antenna is a dipole antenna and is set on X-Y scanner. The scanner moves the probe horizontally and performs planar scanning. Our transmitting antenna is a ridged horn antenna and is fixed on an arm which rotates on vertically plane. The arm and transmitting antenna are rotated to change the incident angle.

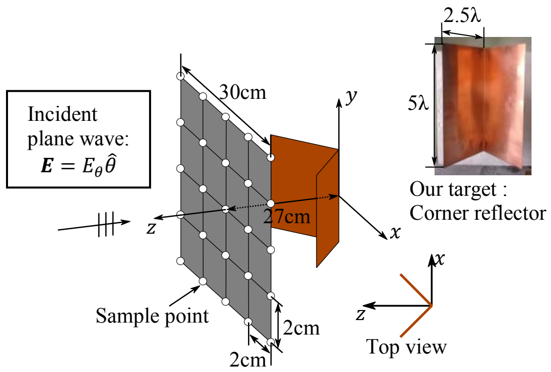

Fig. 1. Planar scanning of a corner reflector

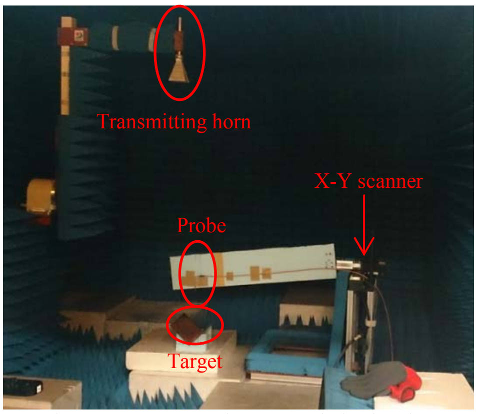

Fig. 2. Measurement in our anechoic chamber

IV. MEASUREMENT RESULT

Fig. 3 shows the measured bistatic RCS of y-z plane when the incident wave is –z directed. The horizontal axis indicates the angle from z axis. The reference value is calculated from FDTD simulation using the equivalent electric and magnetic current on the surface enclosing the target [2]. Fig. 3 shows the measured bistatic RCS and simulated one. The scanning areas of measured result are 30cmx30cm and 14cmx14cm. From results, the accuracy is improved by increasing the size of scanning area. In addition to measurement result, 90cmx90cm scanning plane is simulated by FDTD method to investigate the accuracy of the method. The sampling interval, distance between the target and scanning plane are same as measurement setup. The difference from the measurement is that the electric field is calculated directly instead of measurement of a probe. As you can see in the figure, good agreement of the transformed result with the reference value is obtained in wider region along with the expansion of scanning plane.

Fig. 4 shows the measured monostatic RCS of y-z plane. Similar setup is used as previous measurement. The horizontal axis indicates the angle from z axis and reference is FDTD simulated value like Fig. 3. In this figure, a good agreement between measured data and reference value is obtained in a region from 0° to 7°. Therefore, the method can be applied to monostatic RCS measurement near center angle with planar scanning.

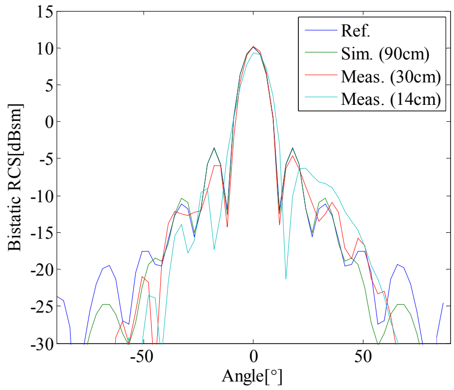

Fig. 3. Measured bistatic RCS

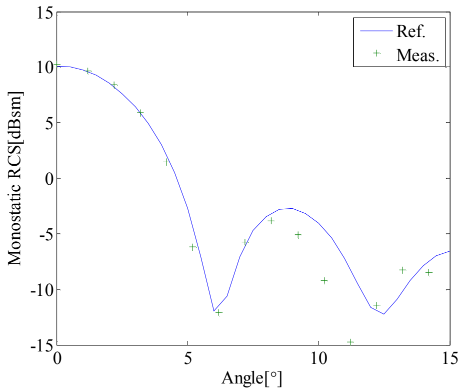

Fig. 4. Measured monostatic RCS

V. CONCLUSION

In this paper, we measured monostatic and bistatic RCS of a corner reflector by planar scanning. The measurement was done near region of the target and we use a near-field far-field transformation technique based on FMM. The measured data shows good agreement with reference value in some region and the region could be expanded by enlarging the near-field scan area.

REFERENCES

[1] C. H. Schmidt, M. M. Leibfritz and T. F. Eibert, "Fully probe-corrected near-field far-field transformation employing plane wave expansion and diagonal translation operators," *IEEE Trans. Antennas Propagat.*, vol. 56, no. 3, pp. 737-746, Mar. 2008.

[2] T. Uno, *Finite difference time domain method for electromagnetic field and antennas.* (Japanese), CORONA PUBLISHING CO., LTD: Tokyo, Japan, 1998.