Accuracy Investigation of 2-D Near-Field Far-Field Transformation for RCS Measurement Using 2.5-D Targets

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***Abstract* - Near-field far-field transformation (NFFFT) is one of the solution methods for reducing the long-range requirement of RCS measurement. We proposed a NFFFT technique that utilizes the two-dimensional (2-D) plane-wave expansion. Comparing to the other techniques, this has advantage of near-field (NF) measurement flexibility. However, the applicability to variously shaped targets has not necessarily been clarified. This paper investigates the accuracy of this technique numerically using complex structure.**

***Index Terms* — radar cross section (RCS), near-field far-field transformation, fast multipole method (FMM)**

1. Introduction

Radar cross section (RCS) is an important information for radar systems that indicates the radar detectability of the target under test (TUT).
Near-field far-field transformation (NFFFT) is a powerful solution to reduce the long-range requirement for RCS measurement of large targets. Until now, many NFFFT techniques have been proposed using only monostatic NF measurement. These techniques are classified into the so-called "image-based" method because the reflectivity approximation on the target based on the high frequency EM field approximation were used [1]–[3]. The method in [1] reconstructs the reflectivity image by utilizing inverse synthetic aperture radar (ISAR) technique. The other methods in [2], [3] are calculates target's RCS without physical image reconstruction. A new technique in [4] is one of these methods, but it takes the unique approach based on an inverse problem. In this method, the far-field (FF) RCS is predicted by iteratively solving an integral equation between the RCS of the target and the receiving voltage measured in the near-field (NF). This method has high flexibility for location and polarization of measurement antenna. Based on this method, we modified the original 3-D integral equation and transformation formula to 2-D ones in order to effectively predict the RCS of large and long targets [5]. It has been shown numerically and experimentally that our 2-D formula can reduce both the measurement and computational costs.

However, the investigation of prediction accuracy was not necessarily adequate. In this paper, we will check the accuracy of our method using more complex targets such as a tilted metal plate or a long corner reflector.

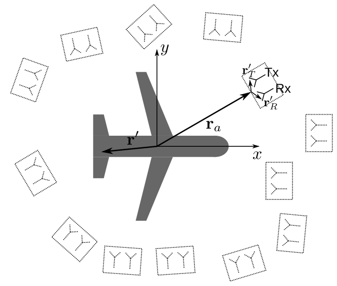

Fig. 1. The considered NF measurement geometry. $\mathbf{r}_a$ .is the measurement location and $\mathbf{r}'$ is the point on the target. $\mathbf{r}_{R/T}$.is the point on the Tx/Rx antennas.

2. Transformation Method

Fig. 1 shows the NF measurement geometry. The transmitting/receiving (Tx/Rx) antennas are located at $\mathbf{r}_a$ on xy plane. Using the reflectivity approximation which approximate the current density on the target as

$$\mathbf{J}(\mathbf{r}') \approx \overline{\mathbf{s}}(\mathbf{r}') \cdot \mathbf{E}_i(\mathbf{r}'), \tag{1}$$

the output voltage U of Rx antenna is represented as follows

$$\begin{aligned} U(\mathbf{r}_a) = U_i \iint_{S'_R} \iint_{S'} \iint_{S'_T} \mathbf{w}_R(\mathbf{r}'_R) \cdot \overline{\mathbf{G}}(\mathbf{r}_a + \mathbf{r}'_R, \mathbf{r}') \\ \cdot \overline{\mathbf{s}}(\mathbf{r}') \cdot \overline{\mathbf{G}}(\mathbf{r}', \mathbf{r}_a + \mathbf{r}'_T) \cdot \mathbf{w}_T(\mathbf{r}'_T) d\mathbf{r}'^2_T d\mathbf{r}'^2 d\mathbf{r}'^2_R, \end{aligned} \tag{2}$$

where $\mathbf{w}_{R/T}$ are the spatial weighting functions of the Rx/Tx antennas and $\overline{\mathbf{s}}$ is the reflectivity matrix. U_i is the input voltage of Tx antenna and S' and $S'_{R/T}$ are the area of TUT and Rx/Tx antennas.Approximating 3-D Green's function to 2-D one and using plane-wave expansion [5], (2) can be transformed to

$$\begin{aligned} U(\mathbf{r}_a) = -U_i \frac{k^2 Z_F^2}{4^2 \pi^2} \sqrt{\frac{k}{4\pi r_a^3}} e^{j\frac{\pi}{4}} \int_0^{2\pi} T_N(\beta, k\mathbf{r}_a) \\ \times \tilde{\mathbf{W}}_R(\mathbf{k}) \cdot \overline{\mathbf{S}}(\mathbf{k}) \cdot \tilde{\mathbf{W}}_T(\mathbf{k}) d\beta \end{aligned} \tag{3}$$

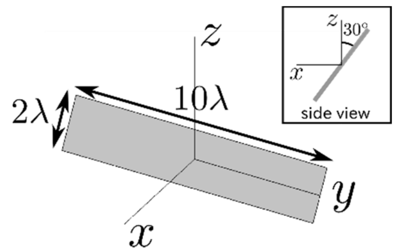

Fig. 3 The model of tilted PEC plate. Frequency is set to 3 GHz.

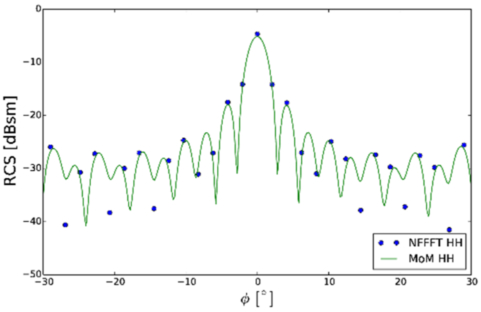

Fig. 4 The transformed results of tilted PEC plate.

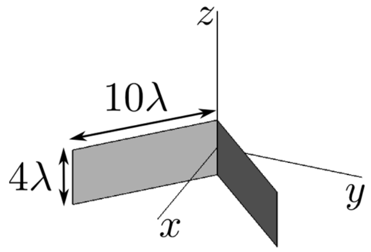

Fig.5 The model of dihedral corner reflector. Frequency is set to 6 GHz.

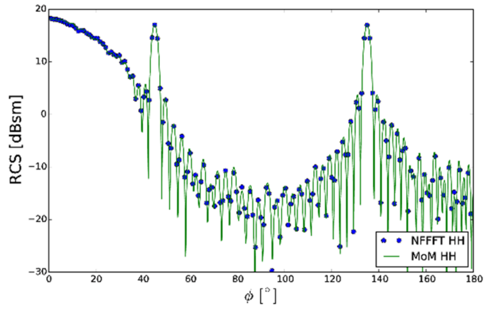

Fig.5 The model of dihedral corner reflector. Frequency is set to 6 GHz.

where $\tilde{\mathbf{w}}_{R/T}$ is the directivity of Rx/Tx antennas and $\bar{\mathbf{S}}$ is the 2×2 monostatic scattering matrix which includes the RCS information of all polarization channels (HH, HV, VH, and HH). The NFFFT technique calculates RCS by solving the matrix equation derived from (3).

3. Numerical Tests

In this section, accuracy of the above NFFFT technique is tested by method of moments (MoM) simulation for some targets.

(1) Tilted Plate

First, the technique is applied to a tilted perfect electric conductor (PEC) plate shown in Fig. 2. The plate is rotated 30° from yz plane and the main reflection direction (the front of the plate) deviates from xy plane where the NF measurement is done. The NF measurement is done on a circular line on xy plane at 1° interval. The Tx antenna is assumed to be horizontal polarized Herzian dipole. Rx antenna is also assumed to be Herzian dipole which measured 3-components of electric field at Tx antenna's location.

Fig. 3 shows the transformed results. The reference value is directly calculated value obtained from MoM simulation. It is found that the transformed value shows good agreement with reference. It should be noted, however, the calculated values are the RCS pattern of tilted plate, not the normal plate laid on yz plane. So the no information of front RCS of the plate is included in the results in Fig. 3. References

Number citations consecutively in square brackets [1]-[5]. Punctuation follows the bracket. Refer simply to the reference number, as in [2], [3]. Use "Ref. [4]" or Reference [4]" at the beginning of a sentence: "Reference [4] was the first …"

Give all authors' names; use "et al." if there are six authors or more. Papers that have not been published, even if they have been submitted for publication, should be cited as "unpublished" [6]. Papers that have been accepted for publication should be cited as "in press" [7]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

(2) Corner Reflector

Next, the numerical test of the PEC dihedral corner reflector is done. The TUT is shown in Fig. 4. In this case, also, the NF measurement is done on a circular line whose radius is 160λ. The measurement spacing and Tx/Rx antennas setup are same as the previous case.

Fig. 5 shows the transformed results. It has often pointed out that the reflectivity approximattion (1) would be failed for such structures due to the multiple scattering. However, the transformed results indicates good agreement with reference. The reason is not clear, we guess that the contribution of multiple reflecting is included in the reflectivity image out of the target as obtained in [6].

4. Conclusion

In this paper, the NFFFT technique using 2-D plane wave expansion is tested for some complex targets. It has been shown numerically that our method is sufficiently accurate.

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