RCS Estimation of a Scale Model Rocket

#Tan Watanabe, Hiroshi Okada, Naobumi Michishita and Yoshihide Yamada
Electrical and Electronic Engineering, National Defense Academy
1-10-20 Hashirimizu, Yokosuka, 239-8686 Japan, e-mail: g48003@nda.ac.jp

1. Introduction

Owing to rapid increases of computational abilities in electromagnetic simulators and processing abilities of personal computers, RCS simulations become easy. Many examples of RCS simulations and comparing with measured results were reported [1] and [2]. Authors also had been investigating accurate measurement method and convenient simulation method [3]. Previously, the methods of achieving accuracy were not made clear.

In this paper, the procedure of achieving accurate measurement is explained using examples of anechoic chamber. As a RCS target, a simple rocket structure composed of fundamental RCS components such as tip, cylinder and hemisphere parts is employed. As for simulation method, PO and MoM simulation results and computer roads are compared. As examples of accurate small RCS simulations, FEKO and WIPL-D simulation results are compared with measured results.

2. Measurement method

For measurement of RCS, a small anechoic chamber shown in Fig.1 is employed. The measured RCS value corresponds to the received power (P_r) from the target. In this case, coupling power (C_1) from the transmitter antenna and the reflected power (C_2) from the pedestal of the target become interferences. And C_1 and C_2 determine the lowest measurement level of RCS. The received power (P_r) from the target of RCS value σ is given by the next equation.

$$P_r = \frac{P_t G_t G_r \lambda_0^2}{(4\pi)^3 R^4}\sigma \qquad (1)$$

The experimental target is shown in Fig.2. The target is composed of fundamental RCS components such as tip, cylinder and hemisphere. The theoretical σ of the target is summarized in Table.1. σ of the tip becomes -21.6 dBsm. So, minimum received power is requested less than -30 dBsm of σ. The power relations measuring σ = -30 dBsm is calculated from Eq.(1) and shown in table.2. Here, transmitter power (P_t) is 14.6dBm. Antenna gains of G_t and G_r are 14.75 dBi. The measurement frequency is 10 GHz. And the distance (R) between the transmitter antenna and the target is 4.4 m. Then, the received power (P_r) from the σ = -30 dBsm becomes -75.1 dBm. So, P_r - P_t becomes -89.7 dB. As a conclusion, interference level C_1 and C_2 must be lower than -90 dB.

In order to achieve small C_1 value, the transmit antenna and receive antenna are covered by an absorbing sheet as shown in Fig.3. Moreover an absorbing sheet is inserted between two antennas. By this structure C_1 of -90 dB is achieved. As for low C_2 value, the pedestal of the target is covered by absorbing materials. C_2 value of -93.4 dB is ensured. As for the reference of RCS measurement, σ of circular discs are measured. The results are shown in Fig.4. The white circles express measured results. The black squares express theoretical values of Eq.(1). It is recognized that the minimum measured σ of -30 dBsm can be achieved.

3. Simulation method

Recently, abilities of personal computers and electromagnetic simulators have been improved rapidly. So, RCS calculations become possible by personal computers. Typical simulation methods applicable to RCS calculation are shown in Table.3. The PO method is very simple. However, this is approximation method. The MoM method can produce very accurate results. However, the very small mesh configuration of the target surface requires huge memory capacity and long calculation times. In order to reduce memory capacity, two schemes are proposed. One is the Multi Level Fast Multi-pole Method (MLFMM) that can lighten the matrix solving procedure. MLFMM can reduce memory capacity about 1/100 of the fundamental MoM. The other is employing high order function in expressing current on the mesh. In this case, large mesh size is acceptable. So, computer loads are surprisingly reduced.

In Table.4, simulation conditions are summarized. First of all, PO needs only a small computational resource. As typical examples of MoM simulations, famous simulators such as FEKO and WIPL-D are employed. In the case of WIPL-D, almost optimized simulation parameters are achieved. Especially, the revolutionary symmetric condition reduces calculation time effectively. In the case of FEKO, we could not optimize calculation conditions. The symmetric condition is not applied. And the uniform mesh size of $\lambda/8$ is used. So, by optimizing mesh sizes and simulation set up conditions, calculation time will be sufficiently reduced.

4. Comparing of measured and simulated results

An example of measured result and PO result is shown in Fig.5. The tip and the hemisphere directions correspond to 0 degree and 180 degrees, respectively. In the angular region greater than 40 degrees, measured and PO results agree very well. At 90 degrees, because of the insufficient far field condition, measured level becomes lower. And the beam width becomes broad. In the angular region, less than 40 degrees, differences appear between the measured and PO results. In this region, more accurate MoM calculations are requested.

Comparing of measured and MoM results are shown in Fig. 6(a) and (b), calculated results of WIPL-D and MLFMM agree very well. In the comparing of measured and calculated results, periodicity and levels of all lobes agree rather well. So accuracies of methods are ensured. As for measurement levels, about -40 dBm values seem correctly measured.

5. Conclusions

In order to achieve very small RCS measurement and calculations, measurement environmental condition tuning and accurate MoM simulations are conducted, respectively. Important technical results are as follows.

(1) As for measurement tuning, coupling between the transmit antenna and the receive antenna is suppressed lowest than -90 dB.

(2) Back scatterings around the target pedestal are suppressed lower than -93.4 dB.

(3) Typical MoM simulation tools such as MLFMM of FEKO and WIPL-D are employed for low RCS calculations.

(4) Calculated and measured results agree very well.

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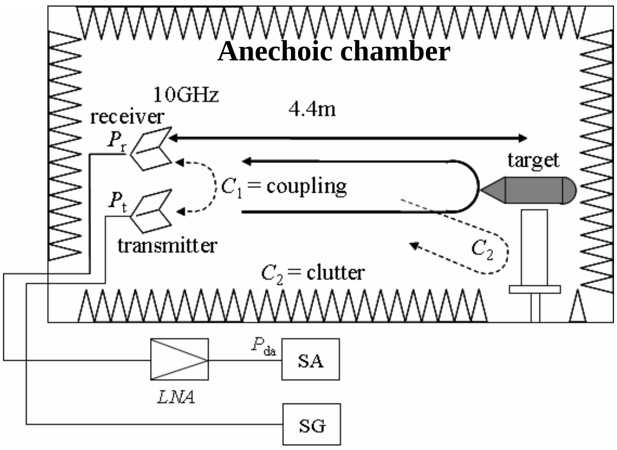


Fig.1 The measurement system

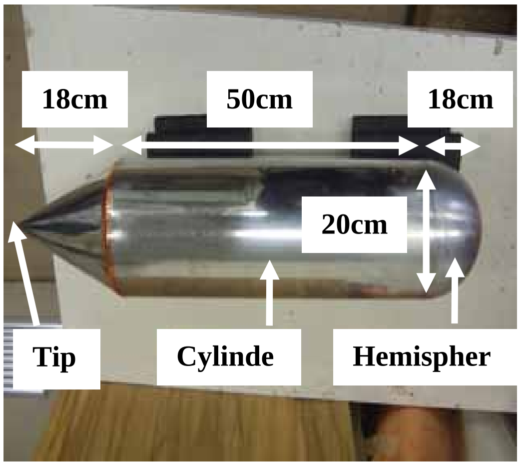


Fig.2 Configuration of a scale model rocket

Table.1 Theoretical RCS values of a scale model rocket

Polarization	Tip	Cylinder	Hemisphere
Vertical(dBsm)	-21.6	7.2	-15
Horizontal(dBsm)	-21.6	7.2	-15

Table.2 Required levels of interferences

σ (dBsm)	P_t (dB)	P_r (dB)	P_r -P_t (dB)	C_1 (dB)	C_2 (dB)
-30	+14.6	-75.1	-89.7	Less than -90	

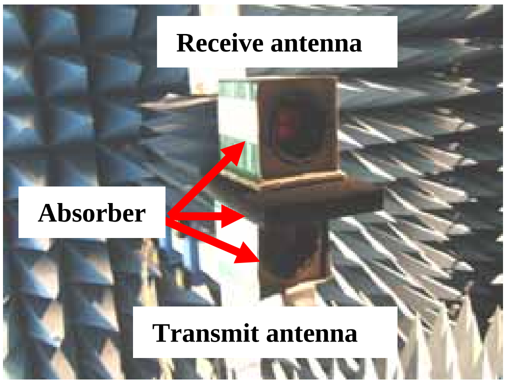


Fig.3 Antenna set up of reduced coupling

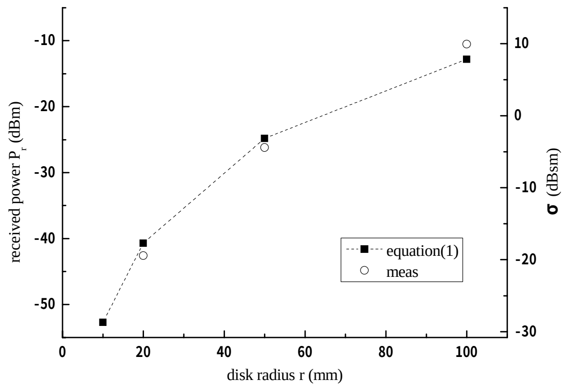


Fig.4 Measurement calibrations by circular disks

Table.3 Simulation methods

<table>
<tr><th>Simulation method</th><th>Simulation tool</th><th>Base function</th><th>Figure of meshes</th><th>Feature</th></tr>
<tr><td>PO</td><td>FEKO</td><td></td><td rowspan="2">Triangle</td><td>Current on the object surface is directly expressed by the incoming electric field.</td></tr>
<tr><td rowspan="2">MoM</td><td>FEKO (MLFMM)</td><td>RWG function</td><td rowspan="2">Currents on the small mesh segments of the object surface and incoming electrical fields are related by a matrix equation form.</td></tr>
<tr><td>WIPL-D</td><td>High order function</td><td>Quadrangle</td></tr>
</table>

Table.4 Summaries of simulation conditions

Simulation method		PO	MoM	
Simulation tool		FEKO	FEKO(MLFMM)	WIPL-D
Computing machine	SPEC	CPU Xeon 3 GHz/ Memory 16 GB RAM		
	OS	Window XP 64bit Edition		
Frequency (GHz)		10 GHz		
Cell size		0.1λ	0.13λ	0.38λ~1.85λ
The total number of meshes		132,278	101,926	1,540
The total number of unknowns			152,889	11,736
Total time (sec)		476	14,831	1,096
Memory (MByte)		50	1,302	1,088

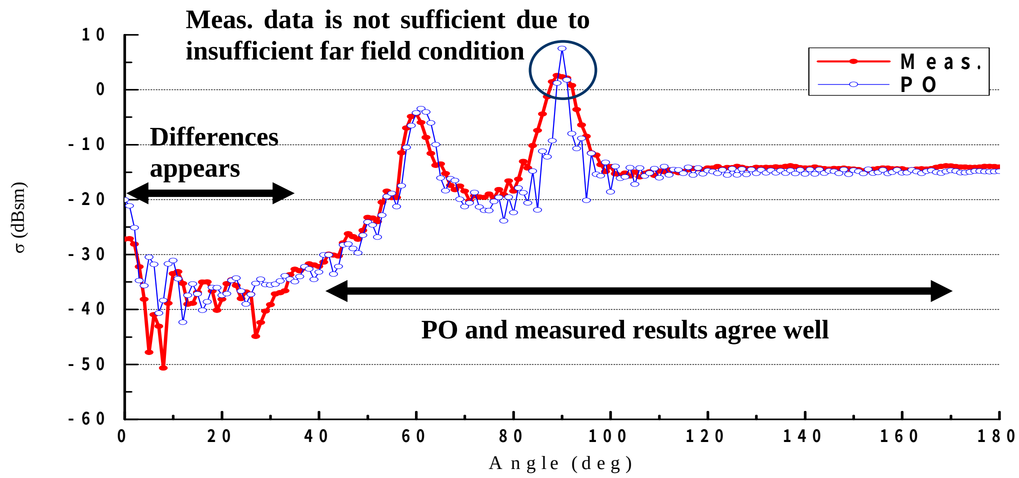
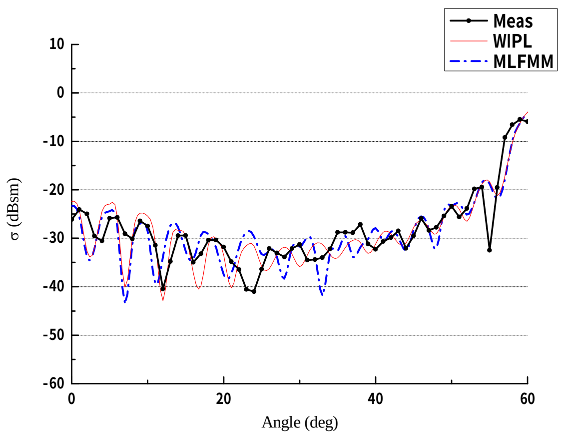
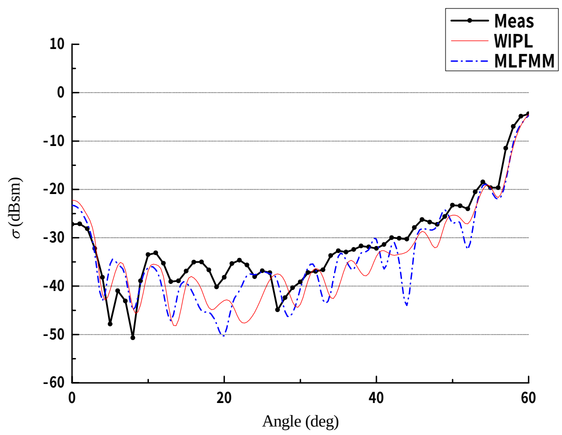


Fig.5 Measured and PO simulated results (vertical polarization)



(a) Horizontal polarization



(b) Vertical polarization

Fig.6 Measured and MoM simulated results