RCS Measurement and PO Simulation of a Scale Model Rocket

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1. Introduction

The simple RCS measurements are well-known as the near-field method to obtain the far-field RCS conversion [1], and the compact range method with the reflector [2] and the phase-hologram range [3] for the scaled sized model target. The authors have investigated the scale model measurement and the Method of Moment (MoM) simulation with the Multi Level Fast Multi-pole Method (MLFMM) [4]. In this paper, the scale model measurement method in an anechoic chamber with 4.4m long and the physical optics (PO) simulation are presented. The simulation methods are compared for simulating the RCS of the scale model rocket. The measurement environment is examined in detail to reduce the mutual coupling between the transmitting and receiving antennas. The measured and simulated RCS results are compared with the theoretical values of the scale model rocket.

2. Simulation Methods

Fig. 1 shows the photograph of the scale model rocket made of aluminium. The model consist of 3 parts; cone, cylinder and hemisphere. The longitudinal length of the model is 78cm. The joint part between the cylinder and the cone is covered by a copper tape in order to reduce the influence of the gap. The analysis frequency of 10GHz is employed and the longitudinal length is corresponding to 26λ. Table 1 shows simulation methods for electromagnetic analysis of RCS. The commercial simulator FEKO Suite 5.3 is used for the analysis. In the case of Method of Moment (MoM), the Multi Level Fast Multi-pole Method (MLFMM) is applied to reduce calculation memory and time. However, the calculations cannot reach to appropriate convergence (residuum is less than 0.003). And the calculate time is about 2 hours per a direction with the iteration of 500 times. In the case of Physical Optics (PO) simulation, even though it can be applied for a smooth surface, the requirement of memory size and the calculate time is very low. In the simulation of the model, the memory and the calculate time are 70 MB and less than 10 seconds, respectively.

Fig. 2 shows the simulated RCS results obtained by MLFMM and PO simulations. The simulated region is around the tip of the cone part. The RCS of the MLFMM results is about 5dB higher than that of PO simulation. Considering the insufficient convergence of MLFMM and the smooth surface of the model, PO simulation is employed as the analysis method.

3. Measurement Environment

Fig. 3(a) shows the configuration of the transmitting and the receiving antennas for the measurement of RCS. The separation length between the corner reflector antennas is 17cm. The reduction of mutual coupling between the transmitting and the receiving antenna is important in the measurement. The antennas are covered with the corned shape absorbers, and the absorber plate with 3cm thickness is arranged between the antennas. The received power P_r can be obtained by

$$P_r = P_t + G_{st} + G_{sr} - L_{space} - L_{abs} \, . \qquad (1)$$

Here, P_t is the transmitted power, G_{st} and G_{sr} are the antenna gain of the transmitting and receiving antennas in a direction to each other, L_{space} is the propagation loss, and L_{abs} is the loss of the absorbers. From this configuration, the mutual coupling of -90.8dBm is achieved. Fig. 3(b) and (c) show the environment of the turn table. The turn table can not be ignored as a reflection object under the measurement of such minute values and increases a noise level as show in Fig.3 (b). The reflection can be suppressed by placing absorbers in front of and on the turn table. The noise level of −75.8dBm is achieved and it is corresponding to a measurement condition of a circular disk of *r*=2cm.

Fig. 4 shows a RCS pattern of a circular disk of *r*=2cm. Because the difference between the peak and the noise level is 10dB, the reflection wave of the disk can be observed accurately.

Fig. 5 shows the relation of the received level P_r [dBm] and theoretical RCS [dBsm] of circular disks of *r*=2, 5 and 10cm. The received levels P_r are plotted as the triangles with reference of the left axis. The theoretical RCS values σ are obtained by Eq. (2) and are plotted as the squares with the reference of the right axis. Because the tendencies of received levels and theoretical RCS are same, the measured results are considered to be proper. The relation of σ and P_r at *r*=2cm, the following transform equation is obtained.

$$\sigma = P_r + 43 . \quad (3)$$

From the noise level of −75.8dBm, σ of over 32.8dBsm can be measured. And the equation is ensured by Friss's formula and cable losses.

4. Measured and Simulated Results of the Scale Model Rocket

Fig. 6 shows the RCS pattern of measured and PO simulation results the rocket model. And theoretical RCS values of tip (Eq.(4)), cylinder (Eq.(5)) and hemisphere (Eq.(6)) are also shown. In hemisphere RCS (radiation angle of 180º), measured and simulated results and theoretical values agree very well. And angular region of 110º to 250º, measured and simulated results agree very well. In cylinder RCS (radiation angle of 90º and 270º), the measured results are about 4.5dB less than the simulated results and theoretical value. It is due to that the measurement distance of 4.4m is not sufficient for the far field of the frequency of 10GHz and the model length of 26λ. In tip RCS (radiation angle of 0º), the differences among the measured and the simulated results and the theoretical value are observed. The measurement alignment and PO simulation of the tip are left as future challenges.

In order to compare the measured and simulated results in detail, both results from 0º to 50º and from 120º to 180º are shown in Fig.7 (a) and (b). In Fig.7 (a), from 0º to 20º, the cycle and peak level of the measured and the simulated results agree well. And from 30º to 50º, upper tendency of both results agree well. Fig.7 (b), the measured and simulated results agree very well.

5. Conclusions

Measured and simulated results of RCS characteristics of the scale model rocket are obtained and compared with the theoretical values. Important results are summarized in the following;

(1) For electromagnetic analysis of RCS of the rocket model, PO simulation is effective and the results agree with the measured results and theoretical values.
(2) Exact measurement of RCS over −32.8dBsm in an anechoic chamber is obtained.

References

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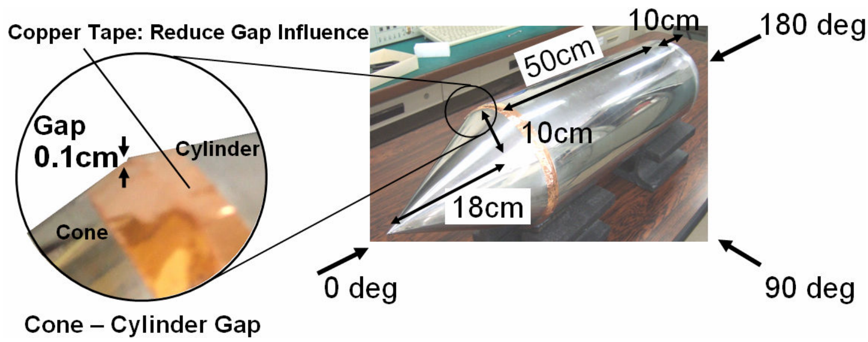


Fig.1 Scale Model Rocket

Table 1 Simulation Methods

	memory(/1direction)	time (/1direction)	usefulness
MoM (Method of Moment) with MLFMM	1.5GB	2hour	Maximum number of iterations are exceed without convergence.
PO (Physical Optics)	70MB	less than 10sec	Only smooth surface can be applied.

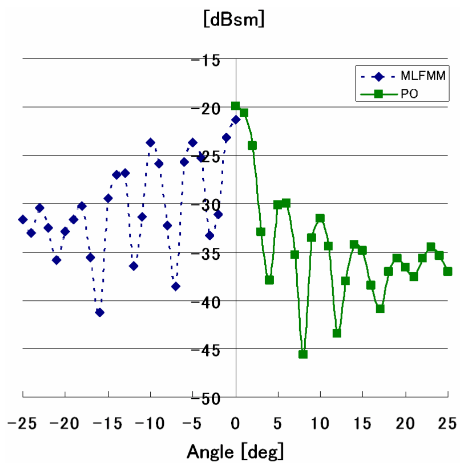
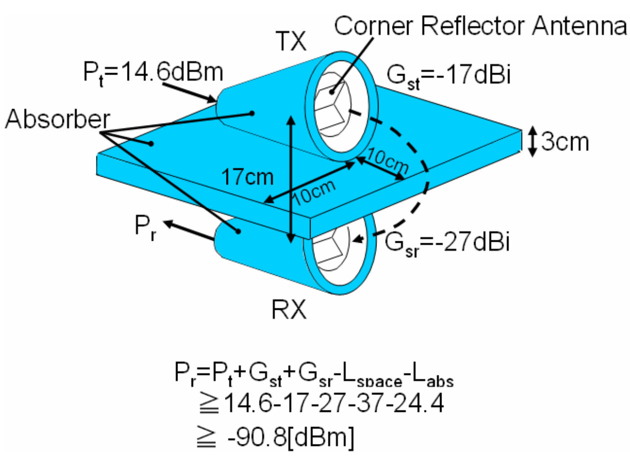
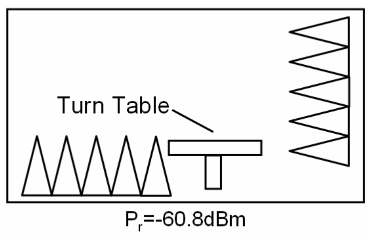


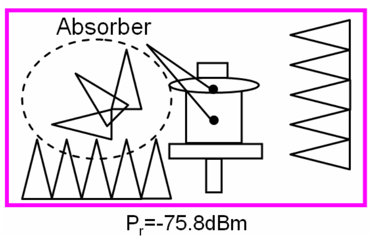
Fig.2 Compared with PO and MLFMM



(a) Transmit-Receive Antenna



(b) Without Absorber



(c) With Absorber

Fig.3 Measuring Equipments

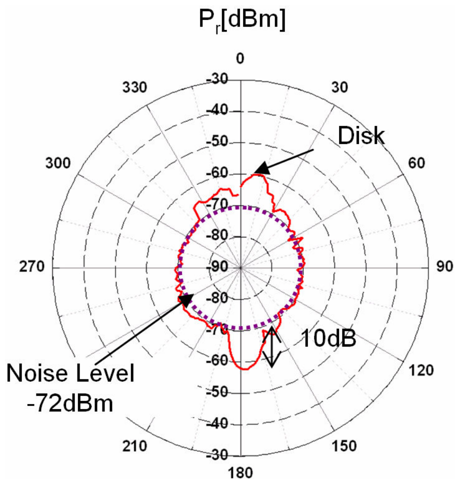


Fig.4 Disk Radiation Pattern(r=2cm)

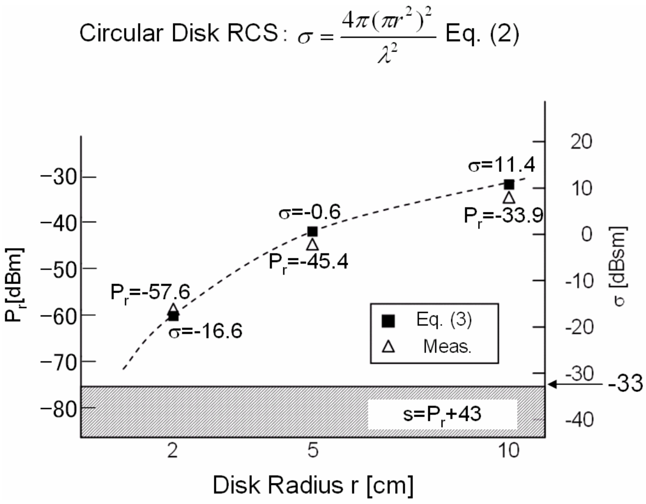


Fig.5 Relations of P_r and σ

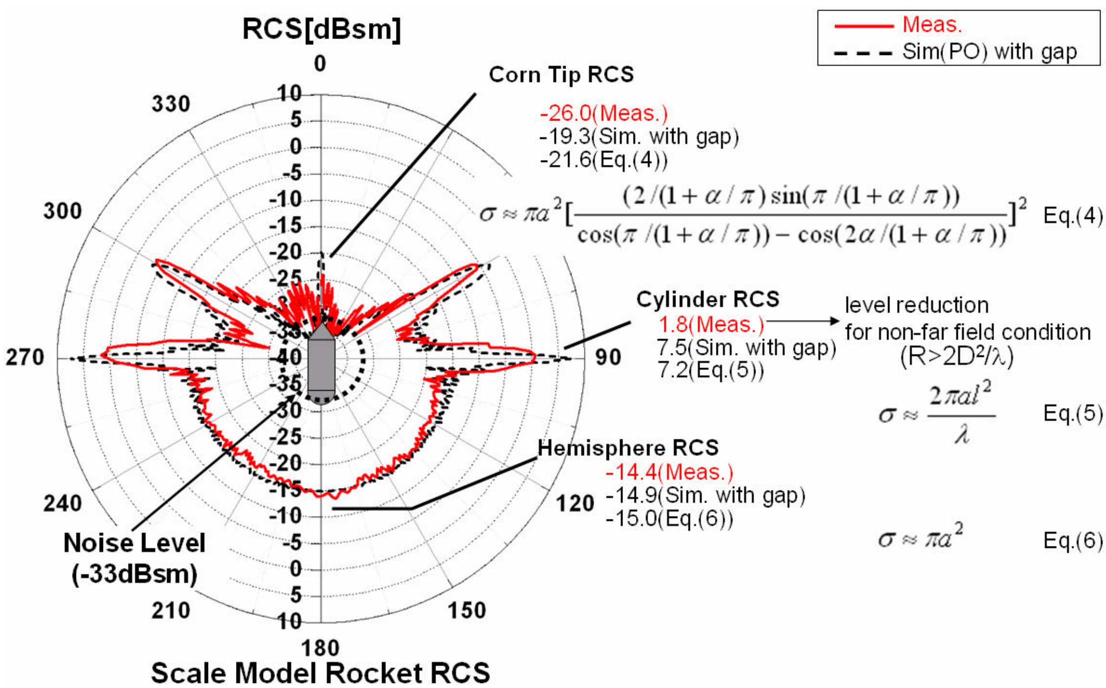
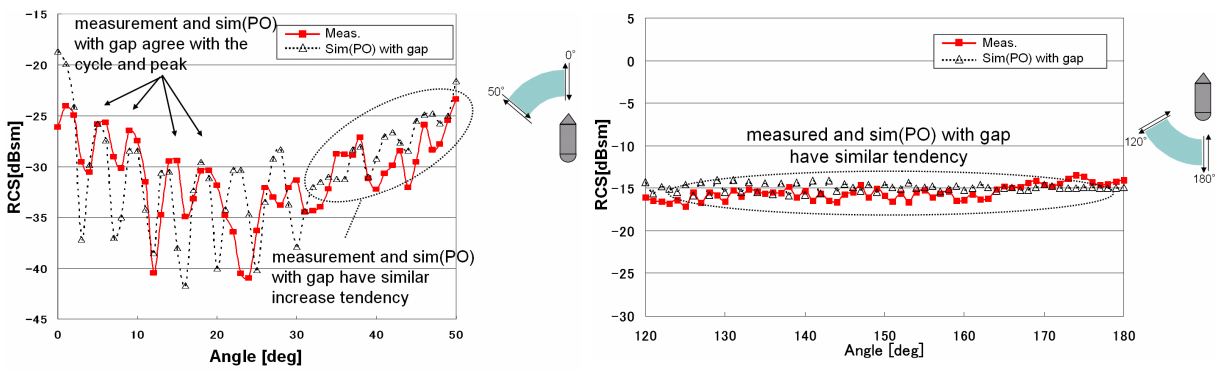


Fig.6 Comparing RCS Result



(a) 0-50deg

(b) 120-180deg

Fig.7 Comparing RCS Result