RCS Histogram Analysis of Scaled Target Models for 77 GHz Radar Applications

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***Abstract*— This paper proposes an approach of obtaining radar cross section (RCS) histogram using a scaled-down target model to minimize the computational load and simulation time for electromagnetic (EM) simulation. First, we design scaled models and estimate their RCS histograms considering the frequency band, radar directions, and the system noise. Then, we compute cumulative distribution functions (CDFs) of the RCS data and examine Kolmogorov-Smirnov (KS) distances to verify proper relative scaling factors. The result demonstrates that the CDF distribution of a 7/10-scale model well describes that of the real-scale model with a KS distance of 0.07, and the simulation time is also reduced to 30.4%.**

Keywords- RCS histogram , FMCW radar, Classification

I. INTRODUCTION

Frequency modulated continuous wave (FMCW) radars are widely used in unmanned vehicles to estimate the range and velocity information of targets [1]. Recently, radar cross section (RCS) histograms obtained from the beat frequency data of the radar, have been used to classify types of targets because the RCS histograms exhibit target-specific characteristics according to the size, shapes, and materials [2-3]. The RCS histograms are usually be obtained by measurement, which requires a significant amount of human effort and time. A lot of effort has been made to obtain the RCS histograms using electromagnetic (EM) based analysis instead of the measurement; computational load and time however have posed problems for this approach. Thus there have been increased demands for a more sophisticated approach in the EM simulation to obtain the RCS histograms with a reduced computational load and resources.

In this paper, we propose an approach for obtaining RCS histograms using a scaled-down target model to minimize the computational load and time in EM simulation. The RCS data are estimated by varying the relative scaling factors of the targets from 0.1 to 0.9 using the FEKO EM simulator. More detailed features, such as system noise, environmental influence, and random motions effects, are added to the data. Using these data, the cumulative distribution functions (CDFs) are computed to compare RCS histograms obtained from the scaled-down target models with a real-scale model. To verify the proper scaling factors, the Kolmogorov-Smirnov (KS) distance is adopted to evaluate how the CDF distributions of the scaled models differ from that of the real-scale model. The results show that the RCS histogram with a scaling factor of 0.7 has a low KS distance of 0.07 compared to the real-scale model, and the simulation time is decreased from 2.3 hours to 0.7 hours with a reduced memory resource of 3.5 Gbytes.

II. RCS HISTOGRAM ANALYSIS

Fig. 1 shows a flow chart of the proposed approach to obtain RCS histograms based on a full-wave EM simulation. We examine various targets, such as a cube, a traffic sign, and a simplified human model, that are often confronted by FMCW radars in a real traffic situation. It is assumed that continuous waves are incident from all azimuth direction from $\phi = 0°$ to $\phi = 359°$ and the elevation angles from $\theta_{EL} = 0°$ to $\theta_{EL} = 3°$ at an internal of 1°. Since the FMCW radar used in our approach has a frequency range from 76.4 GHz to 76.6 GHz, the RCS data are simulated at three frequency points of 76.4 GHz, 76.5 GHz, and 76.6 GHz. To take into account the environmental effect and the noise figure of the FMCW system, a noise power of about −80 dBm is added to the RCS data. The CDF distribution is then calculated using these target RCS data, and this process is repeated by varying the relative scaling factor of targets from '0.1' to '1.0' at an internal of '0.1'. In the process, the KS distance is used to measure the similarity of CDF distributions between the scaled-down models and the real-scale model.

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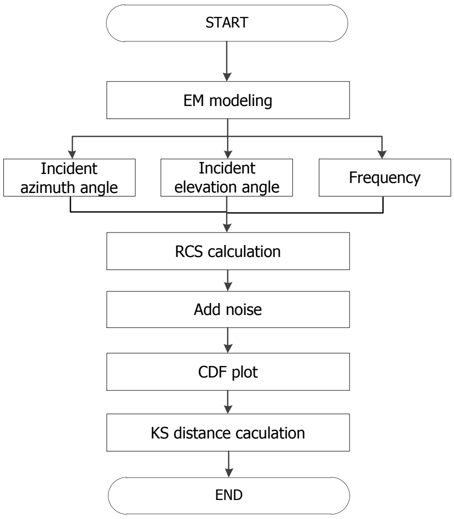

Figure 1. Flow chart of the procedure used to obtain the RCS histograms.

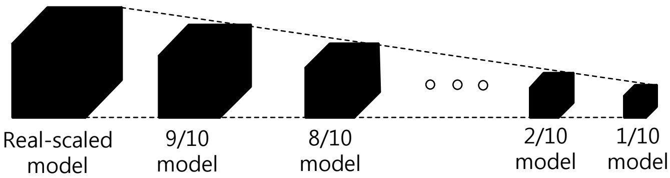

Figure 2. Scale models of targets.

Using the proposed approach, a proper scaling factor is investigated for a cube whose edge length is 75 cm, as shown in Fig. 2. Fig. 3 illustrates CDF distributions of real-scale, 7/10-scale, 4/10-scale, and 1/10-scale models, and their simulation times and KS distances are presented in Table 1. The simulation time of the real-scale model is 2.3 hours, and the time is reduced to 0.44% for the 1/10-scale model and 8.7% for the 4/10-scale model; however, their KS distances are significantly increased to 0.64 and 0.24, respectively. On the other hand, the 7/10-scale model shows a low KS distance of 0.07 with a simulation time of 0.7 hours with a reduced memory resource of 4 Gbyte.

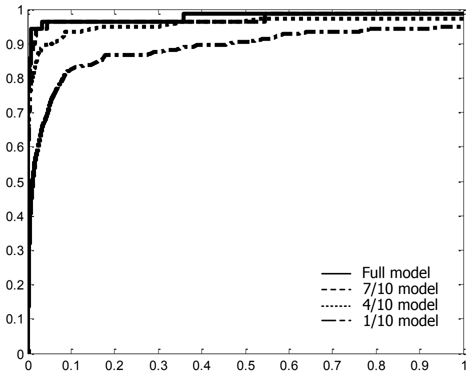

Figure 3. RCS CDFs according to the scaled models.

Table 1. Simulation time and the KS distances.

	1/10	4/10	7/10	Real-scale
Simulation time (hours)	0.01	0.2	0.7	2.3
KS distance	0.64	0.24	0.07	0

III. Conclusion

We have investigated the approach of obtaining RCS histograms using a scaled-down target model. We built scaled models for a cube and estimated their RCS data by considering the frequency band, radar directions, and the system noise. The CDF distributions were then obtained from the RCS data, and their KS distances were calculated to examine the proper relative scaling factor that minimizes both the simulation time and the KS distance. The result showed that the scaling factor of 0.7 well described the real-scale model with the KS distance of 0.07, and the simulation time was significantly reduced to 30.4%.

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