

# Dimension Estimation of Polygonal Dielectric Targets From Surface Reflection RCS

Asuka Kisumi, Hiroshi Shirai

Graduate School of Science and Engineering

Chuo University, Tokyo, 112-8551 Japan

Email: a.kisumi1@shirai.elect.chuo-u.ac.jp, shirai@m.ieice.org

**Abstract**—A method has been proposed here to estimate the facet's size of polygonal dielectric targets using the specular reflected RCS. This algorithm has been tested to estimate the size of dielectric cuboids from the measurement data. Good accuracy has been found and the validity of our method is confirmed.

## I. INTRODUCTION

While present radar technology can be utilized for obtaining the size of, the distant from, and the speed of a target, it is still difficult to recognize the target's shape. And new technology to evaluate the target's shape has been sought [1]–[3].

A simple method has been proposed here to estimate the dimension of polygonal dielectric targets. The formulation is based on the high frequency assumption that the target is large compared with the wavelength. It has been found from our scattering analysis by metal/dielectric polygonal objects that the specular reflected RCS peaks and nulls have some important information of a reflected facet size, and a reconstruction algorithm of cylindrical metal objects has been tested for polygonal and smooth cylinders [4]–[6]. This reconstruction algorithm is now extended for dielectric objects which have an additional unknown parameter of the dielectric constant  $\epsilon_r$ .

In the present study, we shall analyze the facet's size of dielectric cuboids on the assumption that the dielectric constant  $\epsilon_r$  is given first. Time gating technique is also introduced to select the surface reflection of the target, and the validity of our estimation has been confirmed by applying it to measurement data.

## II. ESTIMATION FORMULA

Our dimension estimation formula is based on the assumption that the back scattering at the vicinity of the specular reflection direction can be derived from geometrical optical rays. Since the detail derivation may be found elsewhere [4]–[7], let us summarize briefly the procedure for estimating the facet sizes of dielectric polygonal targets.

The back scattering response from one of the dielectric surface  $S$  of a large cylindrical target is now considered as in Fig. 1. When the incident plane wave illuminates the flat surface  $S$  of width  $a$  and axial length  $b$  from the normal direction, the monostatic RCS  $\sigma$  may be given as [7]

$$\sigma = \frac{[kab\Gamma_s(\theta = \pi/2)]^2}{\pi}, \quad (1)$$

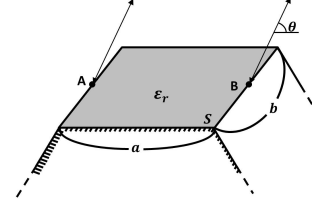


Fig. 1. Back scattering response from edges A and B.

where  $k$  is the free space wave number and  $\Gamma_s(\theta)$  denotes the plane wave reflection coefficient of the electric field at the dielectric half space where the relative dielectric constant is  $\epsilon_r$ .  $\Gamma_s(\pi/2)$  may be written as

$$\Gamma_s\left(\frac{\pi}{2}\right) = \frac{1 - \sqrt{\epsilon_r}}{1 + \sqrt{\epsilon_r}}. \quad (2)$$

The specular reflected RCS is excited by the surface current on  $S$  in-phase, so that it becomes strong and gives us typically a local maxima in the angular variation as shown in Fig. 2.

The nulls of the RCS are caused by the out-of-phase interaction between the edge diffracted waves of the surface edges A and B. Assuming the angular rotation is made in the transversal plane normal to edge line (ridge) A and B, the nearest null which occurs at  $\Delta\theta$  from the specular reflected RCS peak can be approximately given as [4]

$$ka \sin \Delta\theta = \pi. \quad (3)$$

Accordingly, if one measured the null distance  $2\Delta\theta$  between before and after the specular reflection peak RCS, the width  $a$  can be estimated from Eq. (3), then the axial length  $b$  may be determined subsequently from Eq. (1) as

$$a = \frac{\pi}{k \sin \Delta\theta}, \quad b = \frac{\sqrt{\pi\sigma}}{ka\Gamma_s(\pi/2)} \quad (4)$$

## III. ESTIMATION RESULTS AND DISCUSSION

Figure 3 shows the monostatic RCS of a dielectric rubber cuboid (100.0 mm×100.0 mm×100.0 mm,  $\epsilon_r = 7 - j0.1$ ). Measurement is made in an anechoic chamber at 24 GHz. One observes that four distinctive peaks which correspond to the specular reflections from the cuboid's surfaces. As a typical estimation results, measured data around  $-90^\circ$  are utilized here. Table I shows the estimated dimension. Case

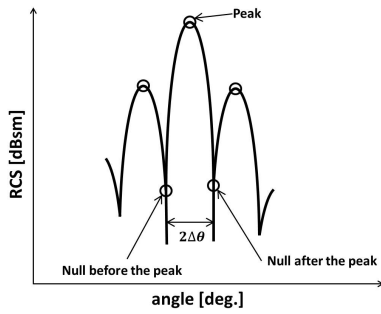


Fig. 2. RCS peak and its nulls from a flat facet.

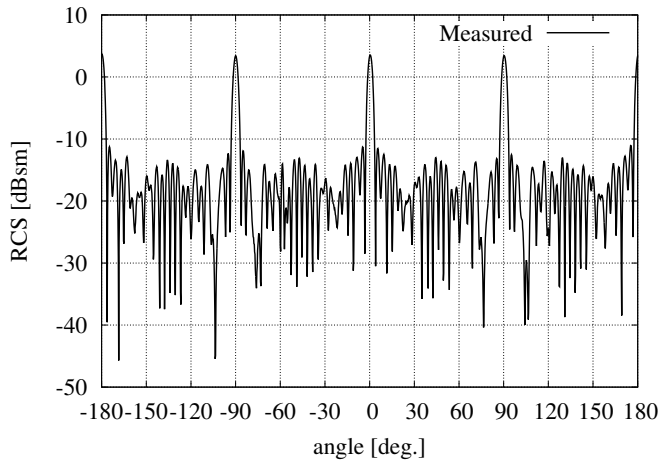


Fig. 3. Monostatic RCS of a dielectric cuboid at 24 GHz.

A is for a dielectric cuboid of 100.0 mm×100.0 mm×100.0 mm and case B is for 80.0 mm×80.0 mm×80.0 mm. While the width  $a$  is estimated within 5% error, the estimation of the axial length  $b$  is not good as that of the width  $a$ . As one may notices from Eq. (4) that the axial length  $b$  inherits the accumulated errors of the width  $a$ , the measured RCS  $\sigma$ , and the reflection coefficient  $\Gamma_s$ . Accordingly, error of the axial length  $b$  becomes generally large. Since the measured RCS is obtained from a finite size of a dielectric body, the RCS peak value contains the internal multiple reflection effect. Accordingly, one needs to isolate the *surface* reflection coefficient  $\Gamma_s$ . This may be possible by using time domain gating technique. Measured RCS data in the frequency domain (18~26 GHz) are transformed into the time domain via Fourier transform and the time gating window selects the early reflected signal from the dielectric surface. Then the gated signal is transformed back to the frequency domain to get the corresponding RCS return at a desired frequency. Dotted line in Fig. 4 shows the results obtained by the time gating. One observes the difference at the peak RCS and null locations. The estimated dimensions are also listed in Table I for cases A and B. Good improvement of the estimation has been shown by these examples.

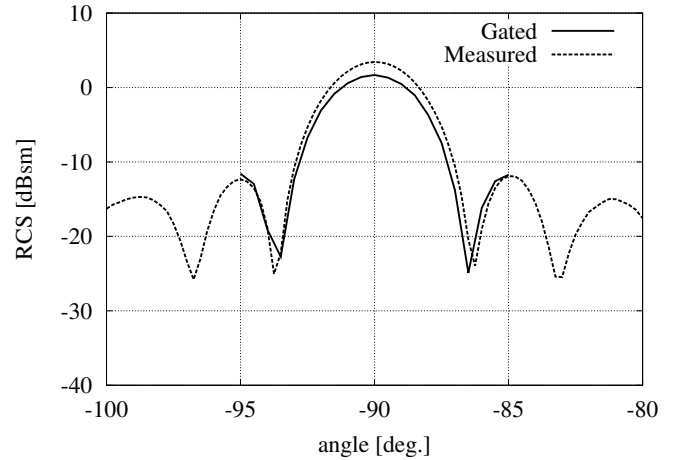


Fig. 4. RCS variation near  $\theta = -90^\circ$  at 24 GHz.

TABLE I  
ESTIMATED DIMENSION OF THE DIELECTRIC SURFACE.

	$a$ [mm] (error)	$b$ [mm] (error)
Case A	100.0	100.0
Measured	95.5 (-4.5%)	121.3 (21.3%)
Gated	102.3 (2.3%)	92.6 (-7.4%)
Case B	80.0	80.0
Measured	77.5 (-3.1%)	92.3 (15.4%)
Gated	79.6 (-0.5%)	78.3 (-2.1%)

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