Polarimetric Scattering by A Finite Dihedral Corner Reflector

Ryoichi Sato [1]*, Kei Hayashi [2], Yoshio Yamaguchi [3] and Hiroyoshi Yamada [3]

[1] Faculty of Education and Human Sciences, Niigata University
8050, 2-no-cho, Ikarashi, Niigata, 950-2181 Japan
E-mail: sator@ed.niigata-u.ac.jp
[2] Graduate School of Science and Technology, Niigata University
8050, 2-no-cho, Ikarashi, Niigata, 950-2181 Japan
[3] Department of Information Engineering, Niigata University
8050, 2-no-cho, Ikarashi, Niigata, 950-2181 Japan

1 Introduction

In the field of microwave remote sensing, polarimetric synthetic aperture radar (POLSAR) image analysis is one of the most significant and effective imaging techniques since scattering matrix obtained by POLSAR system may provide us detailed three dimensional high resolution target information [1],[2]. It has been reported in Ref.[3] that three-component scattering model, which is based on simple physical scattering mechanism by surface scattering, double-bounce scattering and volume scattering, is successfully applied to decompose mixed scattering components in measured POLSAR data. This technique is very effective to POLSAR decomposition analysis especially for natural distributed target area. Also, four-component scattering model, which consists of the above three scattering components and additional circular polarization contribution, has recently been proposed in Ref.[4] to realize more accurate POLSAR decomposition analysis in urban distributed area.

For precise urban environment monitoring and classification, it is also significant to understand the polarimetric scattering features from some specific artificial targets in urban area [5]. One of the typical and basic artificial targets in urban area is a dihedral corner reflector structure, which is often observed between building wall and road surface. The local dihedral structure may become a dominant source for double-bounce scattering phenomenon with strong back scattering return.

So far, some analytical investigations on scattering by a finite dihedral structure have been reported [6],[7]. However, in the references, even though the examination of back scattered return power or monostatic radar cross section (RCS) for each HH-, HV- and VV-component from the basic target was done, no consideration on the phase difference feature between co- (HH- and VV-) or cross- (HV-) polarizations has been made for their derived solutions.

Taking into account the above, in this paper, to investigate the polarization phase feature, polarimetric scattering analysis for a finite dihedral corner reflector is carried out by using the Finite-Difference Time-Domain (FDTD) method [8]. Especially, the phase difference characteristics between

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co-polarized scattering elements are investigated for angular variation. It is found from the detailed examination that even though the received return power becomes small with aspect angle increase, a quasi double-bounce scattering region, in which the polarimetric phase behavior of the co-polarization ratio is as similar as that for general double-bounce scattering by an infinite PEC dihedral, is observed for the relatively large aspect angle.

2 FDTD analysis for a finite dihedral corner reflector

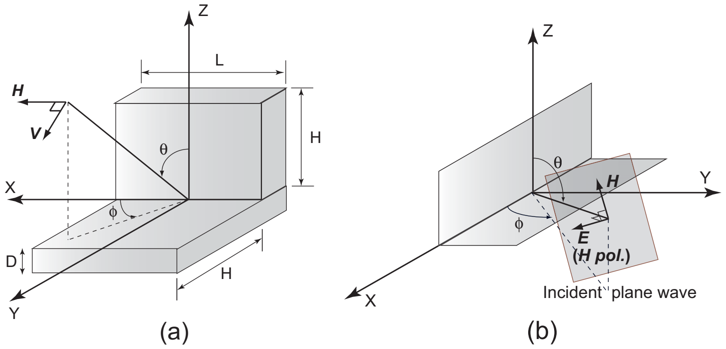

Figure 1: Geometry of the problem (θ: look angle, ϕ: aspect angle) (a) A finite dihedral corner reflector (b) Incident plane wave and polarization

As depicted in Figure 1, we will consider polarimetric scattering problem when horizontal (H) or vertical (V) linear polarized plane wave impinges on a finite dihedral corner reflector. The definition of H or V polarization and the incident plane wave are shown in Fig.1(a) and (b), respectively.

In this paper, the Finite-Difference Time-Domain (FDTD) method [8], which is widely utilized in the field of electromagnetic wave analysis and antenna development, is employed to obtain the scattering matrix for the finite dihedral reflector. By using this method, one can easily realize modeling the finite reflector target with many edges and obtain the angular scattering feature for entire look and aspect angles. Also, material's feature of the target can be taken into account in the analysis. As an incident plane wave pulse, a lowpass Gaussian pulse is utilized. The fundamental parameters of the FDTD simulation used here are shown in Table 1. By appropriately processing the far zone scattered fields derived by the FDTD analysis, the scattering matrix, which is effective to find out the particular polarimetric feature for the considering target, can be obtained.

3 Numerical results and discussion

To obtain the scattering matrix and find out particular polarimetric scattering characteristics for the finite corner reflector, the FDTD simulations have been extensively executed for L-band, *i.e.* for 1.2 GHz frequency band.

Let us consider the polarimetric characteristics for angular variation. First, Figure 2 shows the mono-

Table 1: Parameters in FDTD simulation

Analytical region	350×350×350 cells
Cubic cell size $\Delta (= \Delta x = \Delta y = \Delta z)$	0.01 m
Time step Δt	1.925×10^{-11} s
Incident pulse	Lowpass Gaussian pulse
Absorbing boundary condition	Mur 2nd
Relative permittivity of dielectric material	$\varepsilon_r = 4.0 - j0.1$

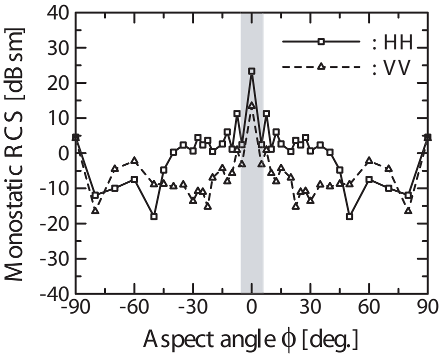

Figure 2: Monostatic RCS from a dielectric dihedral for aspect angle ϕ variation ($\theta = \theta_i = 45^o$, $\varepsilon_r = 4.0 + i0.1$).

static RCS from the finite dielectric dihedral for aspect angle ϕ change. Here, the look angle θ is not critical parameter for this geometry, so it is constant as $\theta = \theta_0 = 45^o$ in the simulation. Each dimension size of the dihedral target is L=8.8λ (2.10 m), H=5.9λ (1.42 m) and D=2.5λ (0.60 m) to the wavelength of 1.25 GHz frequency, where the corresponding aperture size is over 8λ. When $|\phi|$ is smaller than 5^o, the strong RCS values for both HH and VV polarizations can be observed, even though there is the attenuation of the reflected power due to the wave transmission through the dielectric target. Therefore, this aspect-angular region, $|\phi| < 5^o$, may be regarded as the double-bounce scattering region. While, for $|\phi| > 5^o$, the outstanding returned power attenuation can be seen for both polarizations. This is due to the fact that for such large angular region, the double-bounce backscattering contribution from the dihedral can hardly be made.

For more detailed polarimetric evaluation, let us next discuss the aspect-angular dependency of the co-polarization ratio. Figure 3 shows the co-polarization ratio of the finite dielectric reflector for the aspect angle change. It is observed in Fig.3 (a) that the amplitude of the co-polarization ratio is close to about 0.5 in the double-bounce scattering region as $|\phi| < 5^o$. When the aspect angle is within $\pm 20^o$, it seems that the amplitude still retains about 0.5, but varies with small oscillation.

For the phase behavior in Fig.3(b), even though it again undergoes small oscillation change, the phase difference between the co-polarizations seems to keep roughly constant, about 180^o, when $|\phi|$ is smaller than 20^o. For the oblique aspect-incident case within $|\phi| < 20^o$, the similar polarization signature by co-polarization channel to that for $\phi = 0^o$ can be obtained. Therefore, we shall call this angular region a quasi double-bounce scattering region.

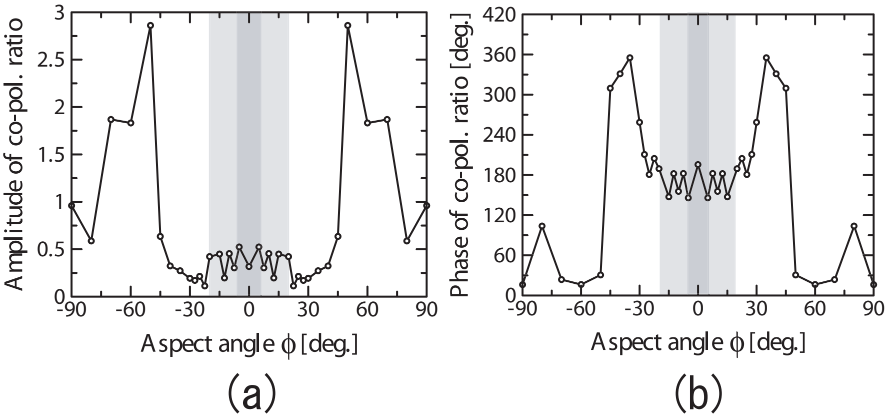

Figure 3: Co-polarization ratio from a dielectric dihedral for aspect angle ϕ variation ($\theta = \theta_i = 45^o$, $\varepsilon_r = 4.0 + i0.1$). (a)Amplitude (b)Phase

It may be concluded from these discussions that for the finite dihedral model, the double-bounce scattering characteristics can be observed for the co-polarized scattering matrix elements when the aspect angle is within not only the double-bounce scattering region ($0^o < |\phi| < 5^o$) and but also the quasi double-bounce scattering region ($5^o < |\phi| < 20^o$).

In addition to the general double-bounce scattering, taking into account the polarimetric characteristic of the quasi double-bounce scattering complementarily, it may be possible to precisely classify the buildings with dihedral structures in man-made area even when the building-aspect angle to radar line of sight is relatively large, but within the quasi double-bounce scattering angular region. Therefore, as a future development, by considering the phase feature of the quasi double-bounce scattering, the accuracy improvement of the decomposition method based on three- or four-component scattering model for acquired POLSAR data will be discussed.

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