RCS Characteristic of Electromagnetic Gradient Surfaces due to Polarization for normal incidence

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Abstract

In this paper, RCS reduction characteristics of Electromagnetic Gradient Surface (EGS) due to polarization of incident wave are studied. We make a comparison of RCS characteristic between perpendicular polarization and parallel polarization of normal incident wave. RCS characteristic has been verified from the simulation and the measurement.

Keywords : Electromagnetic Gradient Surface RCS Reflection phase Polarization

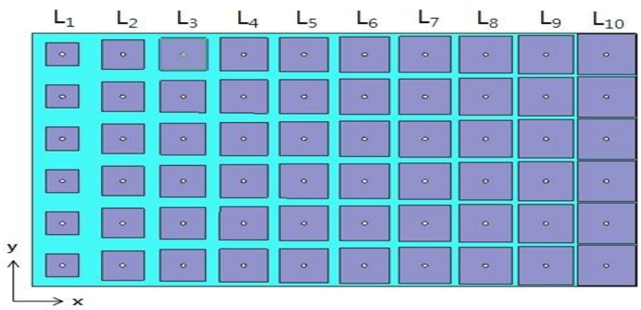
1. Introduction

The research and various techniques of the radar absorbing materials (RAMs) have been widely performed in the past [1-6]. Among these, some materials [3-5] have represented reduciotn of the Radar Cross Section (RCS) at boresight for demonstrating their performances. In [2], Electromagnetic gradient surfaces (EGS) showed that it can change reflected direction of incident plane wave. Moreover, it is shown that EGS can reduce and control RCS values by adjusting reflected angle. However, we are still anxious to know what relation between RCS characteristic and polarization of normal incident wave.

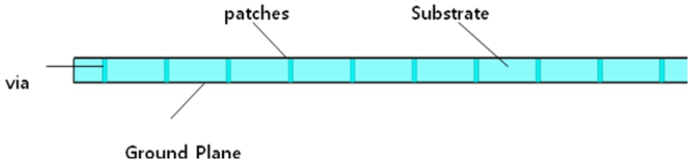
In this paper, we show RCS reduction characteristics of EGS due to polarization of incident wave. RCS characteristics between perpendicular polarization and parallel polarization of normal incident wave are compared and analysed. All simulations are in this work are carried out using the commercial software MWS of CST and a design examples are demonstrated.

2. Theory of Design

The EGS has lattices with different lengths in order to generate different reflection phase. The configuration of the EGS is depicted in Fig. 1. On the top layer, metallic patches with six rows that contain nine cells with different size in each row are patterned. Electrical vias at the center of each patch are connected to the ground plane through a dielectric substrate. By tuning the length of $L_{1\text{-}10}$ unit cell, the reflection phase gradient with the unit cell index can be designed to be linear from $\pi/1.5$ to $-\pi/1.5$ with $\pi/6$ step.



(a)



(b)

Figure 1: Configuration of the EGS : (a) Top view, (b) Side view

The electric field of the incident and reflected waves on EGS can be expressed using the reflection coefficient of the EGS, $\Gamma = |\Gamma| e^{j\phi}$, as follows [2]:

$$\overrightarrow{E^i} = \hat{y} \cdot E_0 e^{jk_z^i z} \quad (1)$$

$$\overrightarrow{E^r} = \hat{y} \cdot E_0 |\Gamma| e^{-jk_z^r z + j\phi} \quad (2)$$

where E_0 denotes the magnitude of electric fields, k_z^i is the free-space wave number of the incident wave, and ϕ is the reflection phase of each cell for the y-polarized incident wave. Time-harmonic variation is represented by e^{jwt}

Since the reflection phase gradient on the surface is linear along the x-axis, ϕ can be expressed using a gradient coefficient, m, as following Eq. (3).

$$\phi = mx = \frac{\Delta\phi}{\Delta x} x \quad (3)$$

Thus the total reflected wave becomes

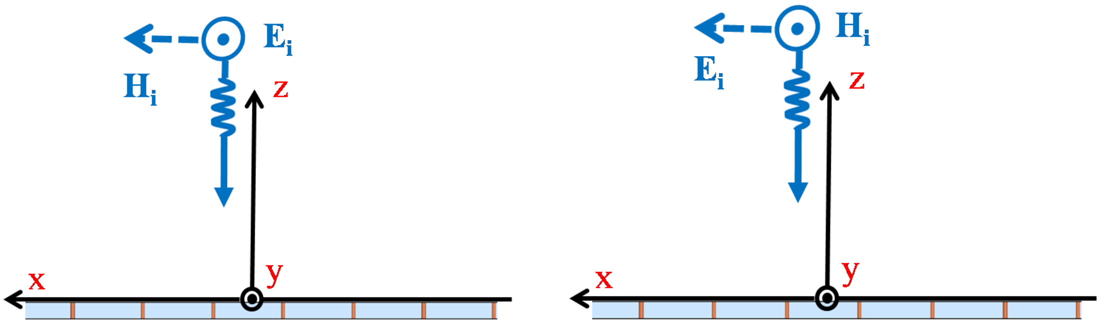
$$\begin{aligned} \overrightarrow{E^r} &= \hat{y} \cdot E_0 |\Gamma| e^{-j(k_z^r - \frac{\Delta\phi}{\Delta x} x)} \\ &= \hat{y} \cdot E_r e^{-j(k \cdot r)} \end{aligned} \quad (4)$$

where k is a wave vector. A linear phase gradient $\Delta\phi / \Delta x$ will reflect a normally incident microwave beam to an angle θ that depends on the magnitude of the gradient.

$$\theta = \sin^{-1}\left(\frac{\lambda}{2\pi} \cdot \frac{\Delta\phi}{\Delta x}\right) \quad (5)$$

3. Simulated and Experimental Results

Perpendicular and parallel polarization of normal incident wave are shown in Fig. 2. Reflection phase due to polarization of normal incident wave is depicted in Fig. 3 and it can be seen that values of reflection phase of perpendicular and parallel polarization of normal incident wave are very similar to each other and values of reflection phase are not affected by polarization.



(a) (b)

Figure 2: Polarization of normal incident wave: (a) Perpendicular Polarization, (b) Parallel Polarization

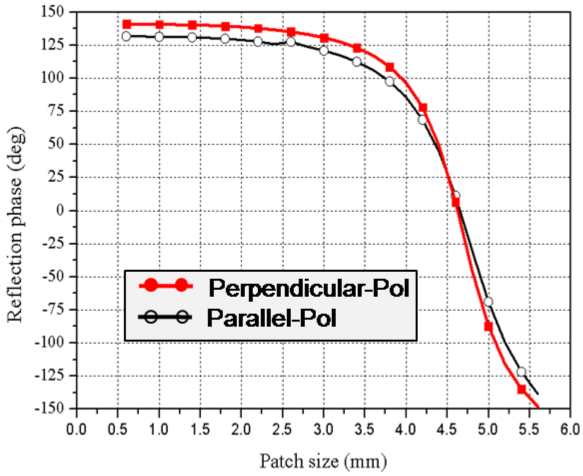


Figure 3: Reflection phase due to polarization of normal incident wave

Levels of RCS reduction due to each polarization at bore sight are shown in Fig. 4 and Table 1. Fig.4 shows that a vertical cut for a constant incidence angle due to reflected angle of 0° and it can be seen that reflection pattern of perpendicular polarization of incident wave is similar with the results of parallel polarization of incident wave. Moreover, Table 1 shows that RCS of the EGS due to each polarization is compared with RCS of PEC at boresigth each values of RCS reduction due to polarization at boresight is similar to each other as there is only 2 dB difference of RCS value between perpendicular polarization and parallel polarization.

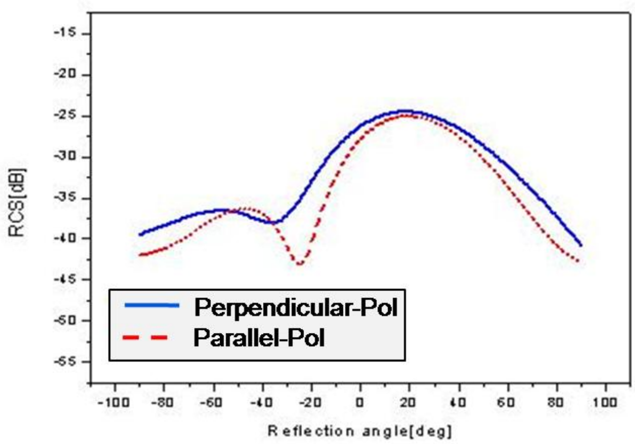


Figure 4: RCS due to polarization of normal incident wave (inc = 0 deg)

Table 1: RCS reduction due to reflection angle

Polarization	RCS reduction at boresight (dB)
Perpendicular	14.02
Parallel Polarization	16.41

3. Conclusion

In this paper, RCS reduction characteristics of EGS due to polarization of incident wave are investigated and discussed. RCS characteristics between perpendicular polarization and parallel polarization of normal incident wave are compared and analysed and each values of RCS reduction due to polarization at boresight is similar to each other. It can be said that EGS can be used for various circumstance.

References

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