RCS characteristics of the Electromagnetic Gradient Surfaces

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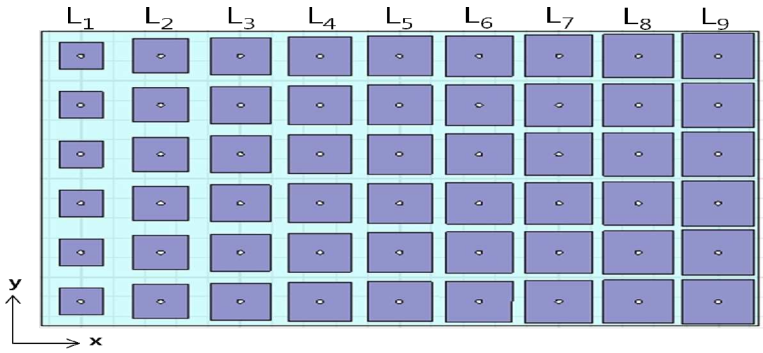
1. Introduction

The research and various techniques of the radar absorbing materials (RAMs) have been widely performed in the past [1-5]. 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 by redirecting it along 21.6°,

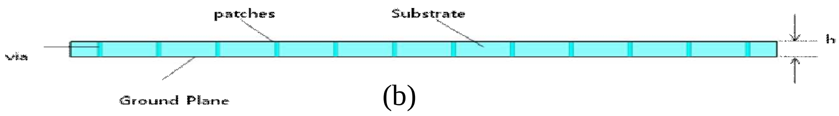
In this paper, we show RCS reduction characteristics of EGS. RCS reduction can be obtained by redirecting the incident plane wave. Levels of RCS reduction are compared and analysed with each different reflection angle. All simulations are in this work are carried out using the commercial software Ansoft HFSS and a design examples are demonstrated.

2. Theory of reflection angle

The EGS has lattices with different lengths in order to generate different reflection phase for y-polarized wave. 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 $L_{1\text{-}9}$ 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. The reflection phase diagram of each cell with length $L_{1\text{-}9}$ is depicted in Fig. 2.



(a)



(b)

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

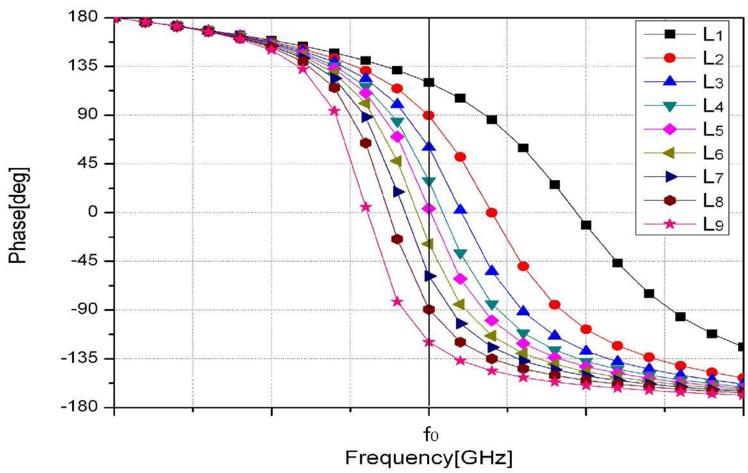


Figure 2: Reflection phase of each cell with length L_{1-9}

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]:

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

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

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).

$$\phi = mx = \frac{\Delta\phi}{\Delta x} x \tag{3}$$

Thus the total reflected wave becomes

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

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

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

where $\Delta\phi = \pi / 6$, $\Delta x = \lambda / 6$, and λ is a free-space waevelength. Thus the reflection angle of the y-polarized wave is obtained as follows:

$$\theta = 30^\circ \tag{6}$$

3. Simulation Results

The EGS structure was designed on the substrate FR-4 with a thickness of 1.6mm and a dielectric constant of 4.9. The radius of the via is 0.2mm. The EGS structure has been simulated in the commercial software Ansoft HFSS.

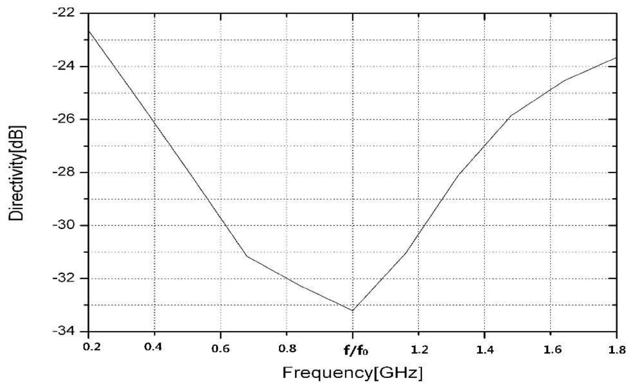
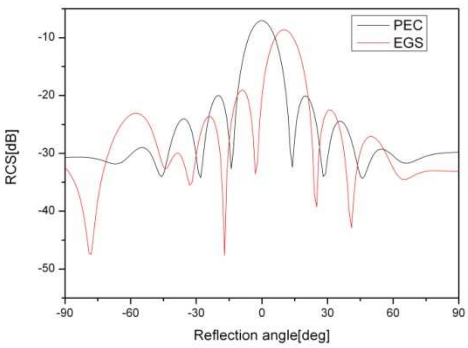
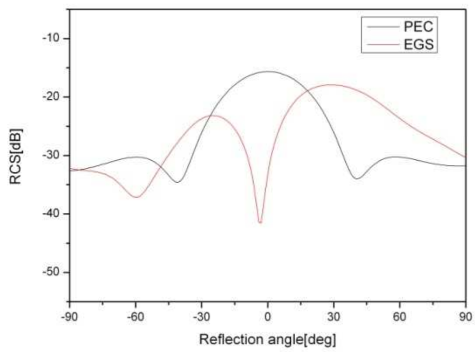


Figure 3 : Directivity of the scattered field vs frequency at boresight direction

In Fig.3, the directivity of the scattered field at boresight(theta = 0° and phi = 0°) is presented with changing the frequency for a normal incident wave. The minimum value has been obtained at f_o and the scattered field in the normal direction has been considerably reduced.



(a)



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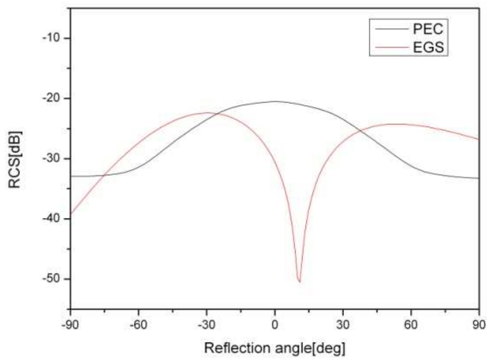

(c)

Figure 4: RCS with three types of reflection angle (inc = 0 deg) :
(a) 11.53° (b) 30° (c) 56°

Table 1: RCS reduction due to reflection angle

Phase gradient($\Delta\phi$)	Reflection angle	RCS reduction at boresight (dB)
10°	11.53°	13.06
20°	19.47°	17.45
30°	30°	17.56
40°	41°	17.34
50°	56°	10.62

To compare levels of RCS reduction, the reflection angle according to the change of linear phase gradient $\Delta\phi$ is represented and the five types of EGS are designed. Levels of RCS reduction due to each different reflection angle are shown in Table 1 and Fig.4 shows that RCS characteristics was compared with EGS(reflection angle of 11.53°, 30° and 56°) and PEC. The simulation result is in good agreement with Eq. (5). RCS reduction about from 10 dB to 17 dB due to each different reflection angle can be obtained. It has maximum levels of RCS reduction at reflected angle from 19.47° to 41° because side lobe of EGS is closed to boresight when reflected angle is bigger than 41°. A detail of the 2D periodic EGS structure monostatic and bistatic RCS measurement results will be presented at the conference.

4. Conclusion

In this paper, the RCS characteristics of the Electromagnetic Gradient Surface(EGS) structure is analysed and discussed. Using theoretical calculations and simulations, it was shown that EGS structure can reduce the radar cross section. The maximum levels of RCS reduction(17.56dB) can be obtained at reflected angle 30°. Using the EGS structure can reduce the radar cross section and control level of RCS reduction.

Acknowledgments

This work was supported by Defense Acquisition Program Administration and Agency for Defense Development under the contract UD090088JD.

References

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