Low-profile Checkerboard Electromagnetic Band-Gap Surface

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***Abstract* – In this paper, low-profile checkerboard Electromagnetic Band-Gap (EBG) surface maintaining wide bandwidth performance is proposed. The EBG surface is composed of two kinds of unit cells to make destructive interference in bore-sight. To obtain RCS reduction for wideband, 180° phase difference points of unit cells are placed at proper frequencies. The height of the EBG surface is 3.175 mm and the RCS reduction is achieved from 8 GHz to 16 GHz whose the operation bandwidth is 66.7%.**

***Index Terms* — Wideband, EBG, HIS, Checkerboard, Radar Cross Section, RCS Reduction.**

1. Introduction

In recent times, stealth technology has been developed rapidly. Artificial Magnetic Conductors (AMCs) has been researched to reduce Radar Cross Section (RCS). Electromagnetic Band-Gap (EBG) surface, also called High Impedance Surface (HIS), of Checkerboard type can reduce RCS level of the plane for bore-sight direction compared to Perfect Electric Conductor (PEC) by causing destructive interference [1]-[4]. Many researches has been represented for wideband RCS reduction. To obtain wideband EBG surface simply, height of the substrate is high to achieve the reflection phase curves to be a gentle slope [4]. Then, -10 dB RCS reduction can be achieved easily for wideband. In [4], the checkerboard EBG surface have 63% RCS reduction bandwidth. However, practically not only the operation bandwidth is important but also the height of the surface should be low because the overall weight of the plane should be light and it is easy to apply to the curved structure.

In this paper, by modifying reflection phase curve low-profile checkerboard EBG surface having wide bandwidth is proposed to reduce the weight.

2. Design of the Unit Cell

The unit cell is designed on the Taconic TLY-5 substrate whose dielectric constant is 2.2 and loss tangent is 0.0009. The geometry of the unit cell is shown in Fig. 1. The size of the unit cell is 15 mm x 15 mm and the height of it is 3.175 mm. The each parameter of the unit cells is represented in Table I, and *w1* is 1 mm and *w2* is 0.775 mm, respectively. In Fig. 2, the reflection phase curves and its difference are shown. To compose the checkerboard EBG surface, two kinds of the unit cell is used and those have 180° phase differ-ence for several frequencies where maximum RCS reduction is caused by destructive interference. In addition, the phase difference for -10 dB RCS reduction can be calculated by (1).

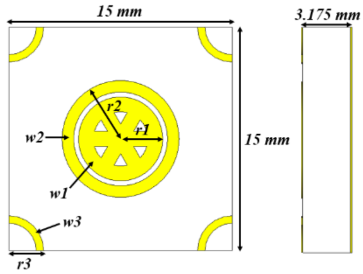

Fig. 1. Configuration of the Unit Cell.

TABLE I
Variable Parameter Values of the Unit Cells

	r1	*r2*	*r3*	*w3*
Unit Cell 1	2.83 mm	3.93 mm	2.33 mm	0.5 mm
Unit Cell 2	3.7 mm	4.8 mm	1.2 mm	0.1 mm

$$\text{RCS Reduction} = 10\log\left[\frac{A_1 e^{jP_1} + A_2 e^{jP_2}}{2}\right]^2 \quad (1)$$

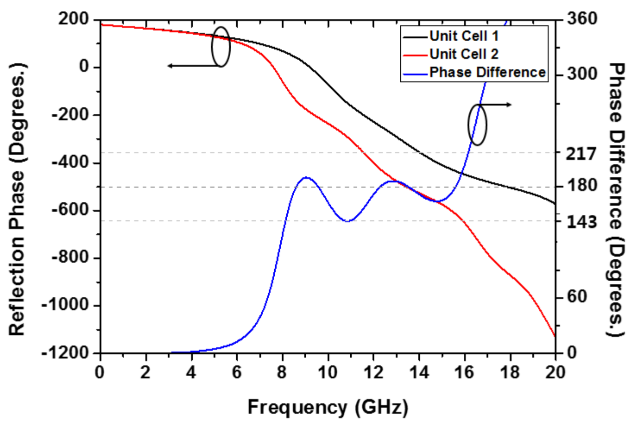

Fig. 2. Reflection Phase Curve for Unit Cell 1 and Unit Cell 2 and Phase Difference.

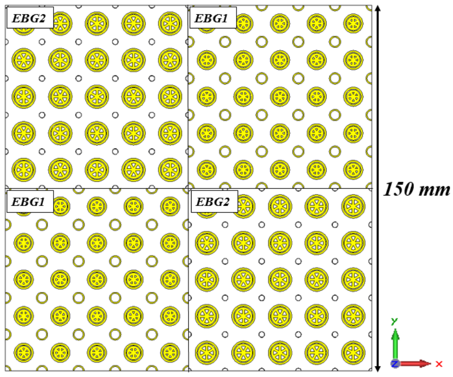

Fig. 3. Checkerboard EBG surface composed of EBG1 and EBG2.

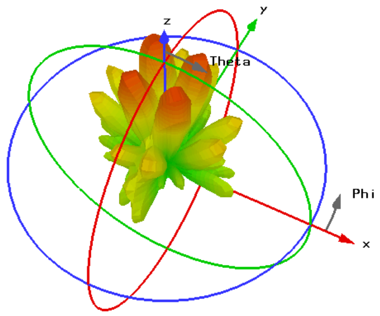

Fig. 4. Reflection Beam Pattern of Checkerboard EBG Surface at 9.7 GHz.

In (1), A_1 and A_2 are amplitude and P_1 and P_2 are phase of reflection coefficient of the unit cells. A_1 and A_2 can be assumed as unity for simple calculation. Then, the phase difference range for RCS reduction less than -10 dB is from 143° to 217° from (1). That is, the maximum RCS reduction is occurred at 180° and ±37° is for the limit of -10 dB RCS reduction. As shown in Fig. 2, the maximum RCS reduction point is -10 dB RCS reduction bandwidth can be expected from 8 GHz to 16 GHz.

3. Design of the Checkerboard EBG surface

In Fig. 3, each EBG is composed of 5 x 5 unit cells and the whole checkerboard EBG surface is composed of 2 x 2 sub-array. Since each unit cell is 15 mm x 15 mm, the total size of the checkerboard EBG surface is 150 mm x 150 mm. When each sub-array has out-of-phase at certain frequency, the reflection beam pattern have null for vertical and horizontal directions as shown in Fig. 4.

4. Result of the Checkerboard EBG Surface

CST Microwave Studio 2016 is used for this research. In Fig. 5, simulation and measurement result are represented. In simulation result, the maximum RCS reduction is -45 dB at 13.3 GHz. As the phase difference for -10 dB RCS reduction is 8 GHz to 16 GHz, -10 dB RCS reduction of the checkerboard EBG surface has 66.7% bandwidth which is from 8 GHz to 16 GHz.

For measurement, a double rigid horn antenna whose operation frequency is 2 to 18 GHz is used. To avoid multi reflection, time gating function of Vector Network Analyzer (VNA) is applied. As shown in Fig.5, measurement result is reasonable compared to simulation result. -10 dB RCS reduction band is except near 11 GHz (10.44 GHz to 11.48 GHz). The reason of over -10 dB near 11 GHz is fabrication error.

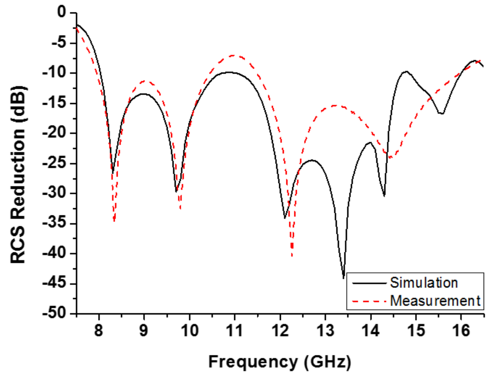

Fig. 5. Monostatic RCS Reduction of Checkerboard EBG Surface(simulation and measurement result).

5. Conclusion

In this paper, the low-profile checkerboard EBG surface having wide bandwidth is proposed. The proposed checkerboard EBG surface has similar bandwidth(66.7%) but the height of the structure is reduced compared to [4].

Acknowledgment

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