International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0127
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 794-797

Compact EBG Based Checkerboard Surface for Radar Cross Section Reduction

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Abstract
In this paper, the reduction in Radar cross section (RCS) is achieved by using a checkerboard which is a composition of two different compact EBG structures. The checkerboard surface has two special EBG patterns, each located in a quadrant of the same ground plane, which can use special features of the EBG pattern to achieve a 10dB RCS reduction. The direction of scattered field can be altered by radar target to minimize the RCS. This alteration can be achieved by covering the target surface with a checkerboard of alternating EBG structures. The designed ch is engineered using Ansys High-Frequency Structure Simulator (HFSS), and the results were compared with RCS results for a perfect electrical conductor (PEC) surface.
Keywords: *: Radar cross section (RCS), perfect electrical conductor (PEC).*

1. Introduction
The electromagnetic band gap structures are most widely used in various applications like reduction of Radar Cross Section (RCS), microwave applications etc., due to its unique characteristics like 0◦ reflection coefficient at resonance frequency [8]. RCS is a measure of a radar target's ability to intercept signals trans receive direction therefore, reduction of RCS is a key parameter to design low visibility radar targets. In past years, various methods have been reported to reduce RCS like circuit loading [1], Shape Changing [2]–[5], radar absorbing material (RAM) [6], [7] etc. A dual band checkerboard surface [8] is presented to reduce RCS at 6.5 GHz and 5.2 GHz with patch size of 0.30λ6.5GHz. Mobius band monopole antenna using several metallic via holes [10] is proposed for the reduction of the RCS of printed antennas resonating at 3.0, 5.0, and 8.0 GHz frequencies. An eight shaped planar EBG [5] with patch size of 0.297λ5.94GHz is proposed to reduce the Specific Absorption Rate (SAR) for the application of wearable antennas. A dual-layer EBG [11] is reported with patch size 0.26λ5GHz to reduce the mutual coupling of patch antenna arrays coupled in the E-plane. In [12] presented a slot EBG with a patch size of 0.171 λ2.70GHz and achieved reduction in RCS more than 4.3 dB. A planar EBG [13] is proposed with a patch size of 0.299λ2.40GHz, for the detection of the permittivity of the various fluids. In [14] presented polarization dependent rectangular electromagnetic band gap (PDEBG) with the patch size of 0.16λ3GHz, whose reflection phases are different, depending upon the polarization state of the incident plane wave. [15] proposed a compact fractal planar EBG structure with a patch size of 0.22 λ2.45GHz. It is used to detect the permittivity of the liquids under test. In [16] proposed polarization dependent electromagnetic band gap (PDEBG) surface with an inclined sheet via with patch size of 0.21λ3GHz. In this study, the phase difference between the x-polarized and y-polarized components of the incident wave is obtained by changing the length, thickness and slope of the via's. Similarly [1] proposed a broad band circularly polarized patch antenna using an artificial ground structure with rectangular unit cell as a reflector with a patch size of 0.13λ6 GHz application, however the reported EBG structures for various applications are limited to give a compact and simple structure. Therefore, in this

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paper a compact checkerboard structure is proposed, it is a combination of Square Loop Electromagnetic Band Gap (SL-EBG) and Two Square Electromagnetic Band Gap (TSLEBG). In this structure compactness is achieved due to square loops and square patches. The design and reflection phase analysis are explained in section II. Checkerboard surface analysis and its application for RCS reduction are discussed in section III and IV respectively. Further proposed work is summarized in section V.

2. Design of EBG Structures and Reflection Phase Analysis

In this section two EBG structures are demonstrated, which are resonating at two different frequencies. The geometry of first EBG structure i.e. SL-EBG shown in Fig.1(a) consists of square loop and four square patches. Similarly, the design and other parameters of second EBG i.e. TSL-EBG shown in Fig. 1(b), which consist of two square loops. The combination of these two EBG structures are used for RCS reduction. These structures are developed on Rogers RT / duroid 6002 (tm) with dielectric constant(εr) =2.95, loss tangent (tanδ) =0.0012, with substrate height of h= 3.35 mm. The other parameters of the EBG structures are mentioned in the Fig.1. In the geometry of SL-EBG and TSL-EBG, inductance is increased due to presence of square loop and the capacitance is increased due to the gap between the square loop and EBG patch. Hence the compactness is achieved. The reflection phase of the infinite array of SL-EBG and TSL-EBG are demonstrated in Fig.2 and 3 respectively. These results are obtained by simulating the infinite array using ANSYS High Frequency Structure simulator (HFSS). The simulated results are shown in Fig. 2 and 3. It is observed that the zero-degree reflection coefficients of SL-EBG and TSL-EBG are obtained at 1.90 GHz and 2.20 GHz with patch size of 0.08λ1.90GHz and 0.10λ2.20GHz respectively. The comparison of proposed SL-EBG and TSL-EBG with other reported EBG structures is presented in Table I. It is observed that the compactness of the proposed structures is helpful in designing of a compact checkerboard surface.

3. Checkerboard Surface Analysis

The checkerboard design and analysis is demonstrated in this section. As shown in Fig.4, the checker board surface with 4×4 EBG structure is designed using SL-EBG and TSL-EBG. Analysing the performance of a checkerboard surface designed for RCS reduction involves understanding and evaluating the mechanisms of phase cancellation, scattering properties, and the overall reduction in back scattered electromagnetic waves. This analysis focuses on the simulation and experimental validation of the checkerboard surface. A checkerboard surface alternates between two regions with contrasting reflection phase characteristics. A Perfect Electric Conductor (PEC) with 0^0 reflection phase acts as a high-reflectivity regions and EBG structures designed to produce a 180^0 reflection phase shift acts as a low-reflectivity regions. The phase difference between these regions creates destructive interference in the back scattered waves, reducing the overall RCS. The checkerboard redistributes scattered energy away from the monostatic (direct reflection) direction, minimizing radar detectability. The RCS reduction can be calculated by [8], [9],

$$RCS Reduction = 10log\frac{[(A_1e^{(jP_1)}+A_2i^{(zP_2)})]^2}{2} \quad (1)$$

Here A1 and A2 represents the magnitude of reflection and P1 and P2 represents the reflection phase of SL-EBG and TSLEBG respectively.

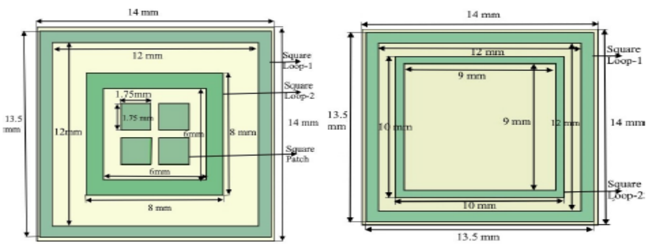

Fig. 1. (a) Square Loop EBG (SL-EBG) structure (b) Two Square Loop EBG (TSL-EBG).

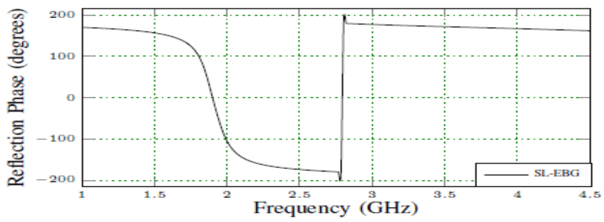

Fig. 2. Simulated reflection phase of Square Loop EBG (SL-EBG).

Figure 1 **Checkerboard Surface Analysis**

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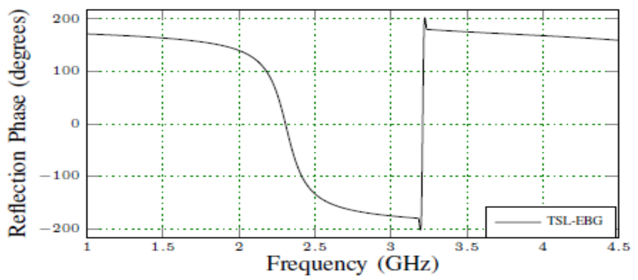
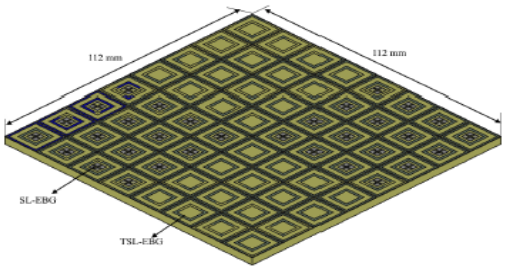


Fig. 3. Simulated reflection phase of Two Square Loop EBG (TSL-EBG).



(a)

Fig. 4. The Single layer checkerboard surface with 4×4 EBG structure.

Figure 2 Structures and Reflection Phase Analysis

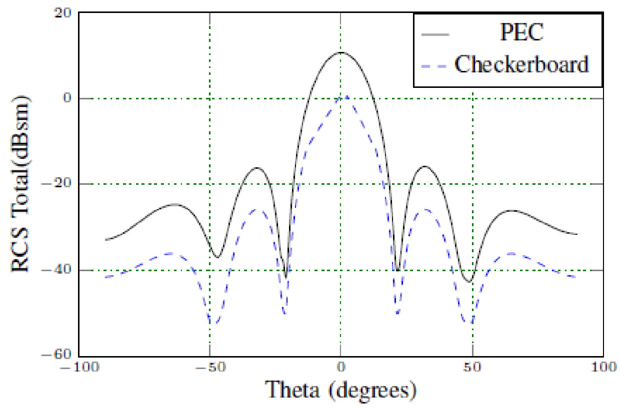


Fig. 5. RCS pattern for checkerboard surface along the principle planes with proposed SL-EBG and PEC at 1.9 GHz

Figure 3 Design of Ebg Structures

4. Application

In this section, application of checkerboard surface that is RCS reduction is demonstrated. The Radar Cross Section(RCS) measures the ability of a radars to detect a target when it is illuminated by electromagnetic waves. In practical the typical RCS measurement is made using two standard horn antennas, one acting as a transmitter and the other as a receiver in a anechoic chamber. In this paper the RCS measurements are carried out using Ansys High-Frequency Structure Simulator (HFSS). The simulated results of RCS reduction are shown in Fig. 5, where the RCS reduction of proposed checkerboard surface is compared with PEC surface. The simulated results show that the proposed checkerboard surface gives a 10 dB RCS reduction as compared to PEC surface. There is a good agreement between calculated and simulated values of RCS. Therefore, proposed checkerboard surface is a good candidate for RCS reduction applications.

Table 1 Comparison of Patch Size and Other Parameter with Previous Work

Sr. No.	Name of EBG	f_c (GHz)	h (mm)	ϵ_r	EBG Patch Size
[1]	AG-EBG	6	3.2	2.2	0.13 λ_{6GHz}
[5]	Eight Shape EBG	5.94	0.7	1.7	0.297 $\lambda_{5.94GHz}$
[11]	LPDL-EBG	5	0.889	3.55, 2.2	0.26 λ_{5GHz}
[12]	Slot EBG	2.70	4	2.2	0.171 $\lambda_{2.70GHz}$
[13]	Jun-EBG	2.4	3.175	2.2	0.299 $\lambda_{2.40GHz}$
[14]	Rectangular PDEBG	3	4	2.2	0.16 λ_{3GHz}
[15]	Cesaro-EBG	2.45	3.175	2.2	0.22 $\lambda_{2.45GHz}$
[16]	Inclined Sheet via PDEBG	3	1.6	4.4	0.21 λ_{3GHz}
[P.E.]	SL-EBG, TSL-EBG (P.E.)	1.90	3.35	2.95	0.08 $\lambda_{1.90GHz}$, 0.10 $\lambda_{2.20GHz}$

P.E.= Proposed EBG.

Conclusion

In this paper,the SL-EBG and TSL-EBG structure has been displayed. The proposed EBG structure has been executed and verified by using FEM-based Ansys High-Frequency Structure Simulator (HFSS). The proposed structure gives periodic size of 0.08λ1.90GHz, from the results it is observed that the good compactness is achieved with the proposed EBG as compared to reported EBGs. The two inner square loops and centered square patches of the proposed EBG leads towards the compactness. The checkerboard formed using SL-EBG and TSL-EBG is used for the reduction of RCS and it is demonstrated.

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Reference

[1]. Nakamura T. and T. Fukusako, “Broadband Design of Circularly Polarization-dependent Using Artificial Ground Structure with Rectangular
[2]. Unit Cells,” IEEE Trans. Antennas Propag., Vol. 59, No. 6, 2103-2110, 2011.
[3]. Maggiora, R., Saccani M., Milanesio D., Porporato M.,” An innovative harmonic radar to track flying insects: The case of Vespa velutina.,”
[4]. Scientific reports. vol.19, No.1, Aug. 2019.
[5]. Dikmen, C. M., Cimen S., Cakir G.,”Planar octagonal-shaped UWB antenna with reduced radar cross section.,” IEEE Trans.Antennas Propag., vol.62, no.6, p.p.2946-2953, 2014.
[6]. Dalal, P., and S. Dhull, “Eight-shaped polarization-dependent electromagnetic bandgap structure and its application as polarization reflector.” Int. J. Microw. Wirel. Technol., Vol.14, No.1, 34-42, 2022.
[7]. Keshwani, V. R., P. P. Bhavarthe, and S. S. Rathod, “Eight Shape Electromagnetic Band Gap Structure for Bandwidth Improvement of Wearable Antenna,” Progress In Electromagnetics Research C, Vol. 116, 37-49, 2021.Modi, A. Y., Balanis C. A., Birtcher C. R., Shaman H. N.,” Novel design of ultrabroadband radar cross section reduction surfaces using artificial magnetic conductors.,”IEEE Trans Antennas Propag. vol.65,no.10, p.p.5406-541, 2017.
[8]. Galarregui, J. C. I., A. T. Pereda, J. L. M. De Falcon, I. Ederra, R. Gonzalo, and P. deMaagt,“Broad band radar cross section reduction using AMC technology.,”IEEE Trans. Antennas Propag., Vol.61, no. 12, p.p. 6136 - 6143, 2013.
[9]. Chen, W., C. A. Balanis and C. R. Birtcher, “Dual Wide-Band Checkerboard Surfaces for Radar Cross Section Reduction,” IEEE Trans. Antennas
[10]. Propag., Vol. 64, No. 9, 4133-4138, 2016. Chen, W., C. A. Balanis, and C. R. Birtcher, “Checkerboard EBG surfaces for wideband radar cross section reduction,” IEEE Transactions on Antennas and Propagation, Vol. 63, No. 6, 2636–2645, 2015.
[11]. W. Jiang, S.-X. Gong, Y.-P. Li, T. Hong, X. Wang and L.-T. Jiang, A Novel Low RCS Mobius-Band Monopole Antenna,” Journal of Electromagnetic Waves and App., vol. 23, no. 14-15, pp. 1887-1895, 2009.
[12]. Azarbar, A. and J. Ghalibafan, “A compact low-permittivity dual-layer EBG structure for mutual coupling reduction,” International Journal of Antennas and Propagation, Vol. 2011, pp.1–6, 2011.
[13]. Han, Z.-J., W. Song, and X.-Q. Sheng, “Gain enhancement and RCS reduction for patch antenna by using polarization-dependent EBG surface,” IEEE Antennas and Wireless Propag. Lett., Vol. 16, pp.1631-1634, 2017.
[14]. Jun, S. Y., B. S. Izquierdo, and E. A. Parker,“Liquid Sensor/Detector Using an EBG Structure,” IEEE Trans. Antennas Propag., vol. 67, no. 5, pp.3366-3373, May 2019.
[15]. Yang, F. and Rahmat-Samii, Y., “Polarization-dependent electromagnetic band gap (PDEBG) structures: Designs and applications.” Microw. Opt. Technol. Lett., Vol.41 pp.439-444, 2004.
[16]. Arif, A., A. Zubair,K. Raiz, M. Q. Mehmood, and M. Zubair, “A novel cesaro fractal EBG based sensing platform for dielectric characterization of liquids,”IEEE Trans.Antennas Propag., vol. 69, no 5, pp. 2887- 2895, Oct. 2020.
[17]. Ullah, S., J. A. Flint, and R. D. Seager, “Polarisation dependent EBG surface with an inclined sheet via,”Loughborough Antennas and Propagation Conference, 637-640, 2009.