Absorbing Surfaces using EBG Structures

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***Abstract*—The scope of this paper is to present a systematic and versatile method, with minimal computational requirements, that incorporates the use of electromagnetic band-gap structures in stealth technology. Ground structures are used to ensure zero transmittance resulting to angle independence of the incident radiation. A realistic scenario is examined where a metallic cube is fully covered by electromagnetic band-gap structures and the radio cross section is estimated. Varying the angle of incidence, it is observed that for the worst case scenario of 0°, the reduction of the radio cross section is almost 10 dB. The results of the proposed concept appear to be very promising for various EMI/EMC applications.**

***Index Terms*—electromagnetic compatibility, electromagnetic interference, stealth technology, electromagnetic band-gap ,metamaterials.**

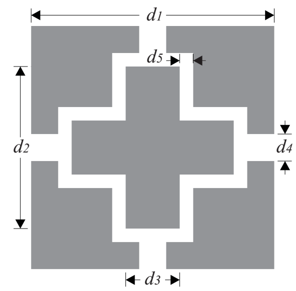

Figure 1: The unit cell of the cross-EBG structure, where d_2 = 10 mm, d_3 = 2.5 mm, d_4 = 0.5 mm and d_5 = 1 mm.

I. Introduction

In recent years the emerging technology of electromagnetic band-gaps (EBGs) has attracted the electromagnetic and antenna community researchers' attention. Their ability to exhibit a forbidden band or band-gap of frequencies in which incident waves at various directions are unable to propagate, since they interfere destructively, make them unique. Before the EBGs era, various techniques had been developed in order to efficiently design absorbing surfaces. The term absorbing surface is used to describe those geometries that have the ability to reduce effectively the transmission and reflection of the incident radiation. The definition of absorption, obtained in terms of the S-parameters is $A(\omega) = 1 - T(\omega) - R(\omega)$, where $T(\omega) = |S_{21}|^2$ is the transmittance and $R(\omega) = |S_{11}|^2$ the reflectance of the device. The absorbing surfaces can be used for shielding as well as in stealth technology. One of the techniques used in the design of absorbing surfaces is the "chiroshield" technique [1] which offers high absorption but with the cost of a relatively large size on the operational frequency. The idea of using ferrites [2] led to even better results but yet they do not have the flexibility and precision that the design of EBGs offers. Other geometries with high surface resistance [3] have been used but due to the fact that they consist of metallic parts along the propagation direction makes them difficult to construct. Towards this end, the bolometric frequency selective materials [4] were introduced that demand very low temperatures and do not always offer high absorption. Finally the new technology of metamaterials also attempted to offer high absorptivity solutions but usually dependent on the angle of incidence and polarization, since they consist of a metallic and electric resonator, with plane symmetries at $x = 0$, $y = 0$, but not at $x = y$, assuming that the absorbing surface lies at plane $z = 0$.

In this paper we use a systematic and versatile method used in stealth technology, with minimal computational requirements, since the only information needed is the reflection coefficient amplitude of a plane wave which impinges at the periodic EBG geometry, at various directions. The unit cell used is uniplanar, easily fabricated, without vias, symmetrically at planes $x = 0$, $y = 0$ and $x = y$. A metallic cube, fully covered by the cross-EBG [5] structure, is examined. The radio cross section (RCS) is estimated with the conventional 3D finite difference method in time domain (3D-FDTD) [6]. Varying the angle of incidence from 0 to 90° it is observed that for the worst case scenario of normal incidence (0°), the reduction of the radio cross section is almost 10 dB.

II. Theoretical Background

In order to characterize a material as an effective absorber it is necessary to know the absorption coefficient A. Geometries with good absorbers' characteristics could prove promising in shielding microwave structures and in stealth technology. In the last case, it is necessary to know the RCS which is a measure of how detectable an object is with radar. A larger RCS indicates that an object is more easily detected. Quantitatively, RCS is calculated in three-dimensions as,

$$\sigma = \lim_{r\to\infty}\left(4\pi r^2 \frac{W_s}{W_i}\right) \tag{1}$$

where σ is the RCS, W_i is the incident power measured at the target, and W_s is the scattered power seen at a distance r away from the target.

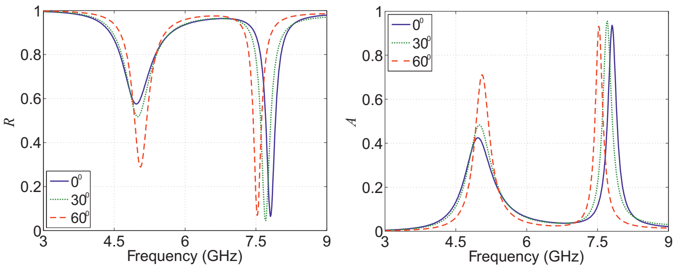

Figure 2: The reflectance R (left), and absorption A (right) for the cross-EBG.

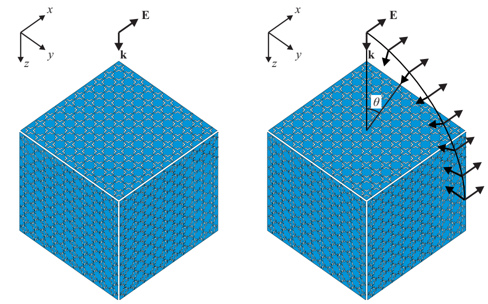

Figure 3: The shielded metallic cube geometry by cross-EBG for the simulation of RCS, when θ is fixed (left) and when varies (right).

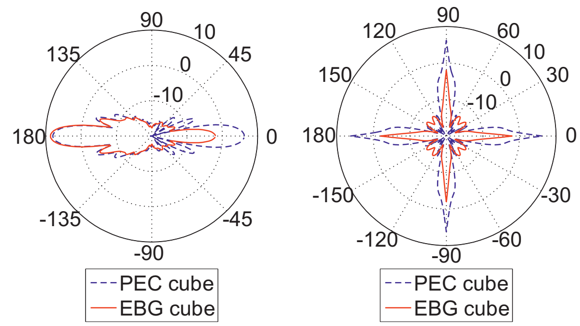

Figure 4: RCS graph in the cases of unshielded and shielded metallic cube at 7.756 GHz. Firstly (left), the plane wave impinges normally at the cube ($\theta = 0$) and the RCS is estimated on E-plane. Secondly (right), the angle of indecent plane varies and the RCS value at $(0, \theta, 0)$ point is plotted.

III. Design Of The Proposed Geometry

The structure of the cross-EBG structure, used to create the metallic cube shape cover, is shown in Fig.1. The unit cell dimensions are identical to those of [5], while the substrate is FR-4 with $\epsilon_r = 4.4$ and $\tan\delta = 0.025$ at 10 GHz, and height 1.5 mm. The absorption and reflectance curves are shown in Fig. 2, while varying the angle θ. The transmittance is zero due to the grounded substrate. From the simulation results the absorption reaches about 94% at 7.75 GHz for $\theta = 0°$, while it slightly changes for the other two angles.

The absorbing cross-EBG surface retains its ability of high absorption through a wide range of angles of incident radiation, a characteristic that will be used to create a periodic surface of cross-EBG structures that will be referred to as cross-EBG cover. In order to prove the shielding ability of the cross-EBG cover, we examine the scenario where it fully covers a metallic cube. Firstly, we measure the RCS of the metallic cube on its own. Afterwards, each side of the cube is covered by 10×10 cross-EBG structures and the RCS is measured again. The geometry of the cube covered by the cross-EBGs is shown in Fig. 3 along with the polarization and the direction of the incident wave.

Figure 4 shows the simulation results at E-plane (zx-plane). It is observed that after shielding the cube with the cross-EBGs, where the transmitter and receiver are co-located at point $(x, y, z) = (0, 0, 0)$ (Fig. 3), the coefficient is minimized approximately 10 dB.

Relative results appear also while the angle of incident plane wave varies. In that case, the transmitter and receiver are co-located at point $(r, \theta, \phi) = (0, \theta, 0)$ and we take account only the RCS value at this point. Specifically for an angle range of $0° \leq \theta \leq 30°$, coefficient σ is constantly smaller when the cube is shielded than when it is not. For $30° \leq \theta \leq 90°$ the value of the coefficient σ is always under -15 dB, which practically means zero. As a result it has been proven that cross-EBG surface covers can effectively shield metal surfaces. It is important to mention that the only information needed was the value of the reflectance coefficient of the unit cell, thus leading us to a non-complicated design which reduces the computational cost.

IV. Conclusions

In this work, we have proved the shielding ability of the cross-EBG cover by measuring the RCS of a metallic cube that is fully covered by it. The results were very promising for a wide range of angles for the incident wave. The only information required for the design of the structure was the reflection phase behavior of the cross-EBG unit cell which resulted in a much reduced computational effort.

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