

Design and Integration of a Planar EBG for UWB Applications

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Abstract

Due to their efficiency in suppressing the propagation of simultaneous switching noise (SSN) between power and ground planes in electronic packages and PCBs, electromagnetic bandgap (EBG) structures have received widespread acceptance. Consequently, different configurations of EBGs (e.g., mushroom-type, planar and hybrid EBGs) have been developed. Planar EBGs are considered to be the most cost-effective because they require no vias or additional components. Hence they have received widespread acceptance. However, much of the work on planar EBGs has focused on suppressing SSN in a narrow band of frequencies. In this paper, we design and measured a planar EBG for ultrawideband (UWB) applications. We also study the impact of integrating a microstrip line in close proximity to the EBG. Our results reveal that the EBG causes resonances in the insertion loss of the transmission line. At the resonance frequencies, strong electromagnetic interaction occurs and much power is coupled away from the line into the cavity (e.g., at 5.6 GHz, 60% of power is lost from the line). To prevent such performance degradation after integration, EBGs should be designed under consideration of other components to be integrated in their immediate vicinity.

Keywords: Electromagnetic bandgap (EBG), ultra-wide band (UWB), microstrip transmission line, simultaneous switching noise (SSN).

1. Introduction

In 2002, the Federal Communications Commission (FCC) allocated the spectrum from 3.1 GHz to 10.6 GHz for unlicensed ultra-wideband (UWB) applications [1], [2]. Since the UWB communications technology provides very high data rates over a short distance, it has received much attention in the wireless communication sector. Consequently, components of UWB communication systems, especially antennas [3]-[6] have been extensively investigated.

However, as a result of the large bandwidth available, UWB signals may possibly interfere with signals from other electronic systems. Hence, to make it coexist with other existing services, the FCC stipulates that the maximum permissible EIRP (equivalent isotropically radiated power) density is -41.3 dBm/MHz [2], [7]. As a result of this very low power level, any noise coupled to the RF circuits of an UWB system may deteriorate the entire system performance. Therefore, one of the

challenges in designing Microsystems for UWB applications is to ensure that there is complete isolation between the noisy digital components and the sensitive RF circuits. One way to achieve this isolation is by using electromagnetic band gap (EBG) structures. So far, both mushroom-type and planar EBGs have been designed to cover the frequency range used by UWB devices (e.g., as in [8]-[10]). However, in these works as well as in many other publications on EBG design, the impact of the interaction between the EBG and other packaging structures such as transmission lines, vias and planes is not considered.

In this work, a compact EBG for UWB, WLAN, Bluetooth and UMTS applications is designed, fabricated and measured. Furthermore, the impact of integrating the EBG in close proximity to microstrip lines is studied.

In section two, the modelling, simulation and measurement of the planar EBG on FR4 substrate is

first discussed. This is followed by a presentation of the effects of the EBG on the transmission coefficient of the microstrip line in section three.

2. Design and Measurement

In this section, modeling, simulation and measurement of a planar EBG for UWB applications is presented.

A. Modeling and Simulation

The planar EBG was designed to cover all frequencies used for UWB, WLAN, Bluetooth and UMTS applications. It consists of 2 metal layers and one dielectric layer (FR4; $\epsilon_r=4.4$ and $\tan \delta=0.02$). Figure 1: shows the top view of the EBG, an enlarged view of a unit patch and the interconnection between any two patches. Each patch has a length of 12mm and width of 6 mm. The patches are separated by a distance of 0.5mm and are interconnected by a metal strip, whose dimensions are given in Figure 1. The EBG is 38.5mm^2 large and consists of a 3*3 array of patches.

For the EBG design, a combination of analytical and numerical techniques was used. The inductance and capacitance of a unit patch cell and the interconnecting strips needed to achieve a -50 dB stopband from approximately 2 GHz to 12 GHz were first analytically estimated. For the extraction of the S-parameters, Ansoft HFSS (a 3D full-wave EM field solver which employs the finite element method to solve Maxwell's equations in the frequency domain) was used. A continuous power-ground plane pair, having the same dimensions as the planar EBG (dielectric thickness = 0.2mm, width=length=38.5mm) was used as the reference. It was simulated with the same software using same boundary and excitation conditions within the same frequency range, as the EBG.

B. Fabrication and Measurement

Both structures were fabricated using FR4 substrate technology, and measured. The measurement was performed using a vector network analyzer (VNA) in a frequency range of 100 MHz to 12 GHz. SMA connectors were used to interconnect the DUTs and the ports of the VNA. After the measurements, the S-parameters were extracted and compared. This comparison is shown in Figure 2. It can be seen from this figure that the proposed EBG structure significantly eliminates SSN coupling over the complete range of frequencies, where the RF/analogue circuits for WLAN, Bluetooth, UWB and UMTS operate, as expected. Approximately 10

GHz stopband bandwidth (considering the -50 dB bandwidth) was achieved, thus blocking the propagation of noise within the required band, as predicted.

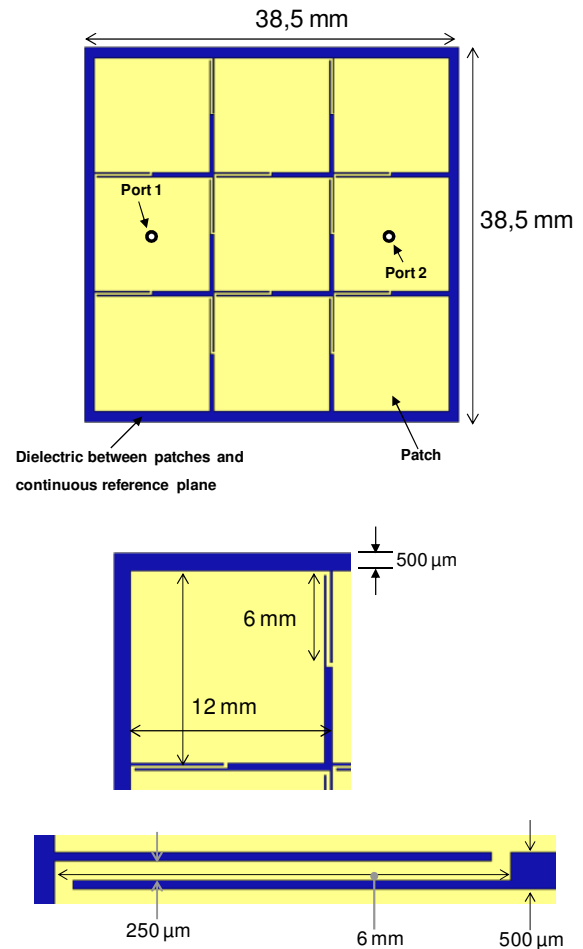


Figure 1: Planar EBG for UWB, WLAN, Bluetooth and UMTS applications. Top view (top), unit cell (middle), metal strip interconnecting two patches (bottom).

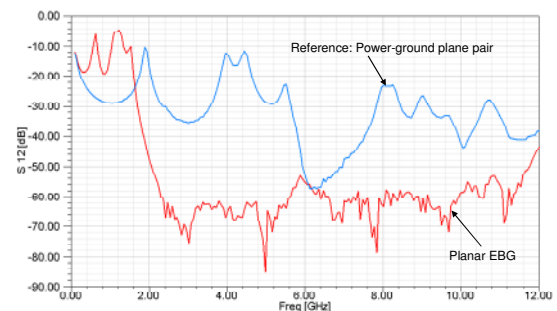


Figure 2: Illustrating the efficiency of the planar EBG in suppressing noise within the entire UWB range.

2. Integration of EBG with Transmission Lines

A microstrip line was chosen to study the integration of transmission lines and the EBG. For these investigations, a 3 layered board, whose cross-sectional view is shown in Figure 3 (top), was designed. The board consists of three metal layers and two dielectric layers. The top metal and dielectric layers as well as the second metal layer were used as the signal line, substrate and return-path of a microstrip transmission line, respectively. The second metal layer also serves as the top/patterned layer of the EBG and the third layer serves as the continuous reference layer of the EBG. In other words, a microstrip line is mounted on the EBG shown in Figure 1; such that the reference layer of the microstrip line is the patterned layer of the EBG, which consists of the periodic patches. The top view of the board is shown in Figure 3 (bottom), in which the position of the microstrip line is illustrated. In this figure, the top dielectric layer is made transparent for illustrative reasons.

The microstrip line investigated here has a width of $180\text{ }\mu\text{m}$, thickness of $17\text{ }\mu\text{m}$ and a length of 30 mm . For the purpose of comparison, a standard microstrip line routed above a continuous power-ground plane pair with no slots or patches, and having the same dimensions as the line routed over the EBG, was also analyzed.

The insertion losses of both microstrip lines were computed using HFSS and a comparison of the S-parameters obtained is shown in Figure 4. As seen in this figure, the insertion loss of the transmission line routed over the continuous power-ground plane pair is free of resonances. However, in the case where the transmission line is routed over the EBG, there are dips on the insertion loss. The frequencies at which these dips occur correspond to resonance modes of the parallel-plates which form the EBG. The presence of these dips can be explained as follows: The return-current of the microstrip line flows partly as conduction current on the metal strips which interconnect the patches of the EBG, and partly as displacement current between the gaps. This excites the parallel-plate modes. Around the resonance frequencies of the parallel-plates, strong coupling occurs between the microstrip line and the parallel-plates. Consequently, much of the power to be transported along the microstrip line is coupled through the slots/slits between the patches of the EBG to the cavity. Part of this power is lost in the cavity and part is radiated at the edges of the plates. For example, at about 5.6 GHz , approximately 60% of power is lost from the microstrip line. At 10.2 GHz , at least 80% of the power is coupled away from the microstrip line and

lost. This may lead to serious system failures. For the results presented in this section, both the microstrip line and the EBG were excited at the same time.

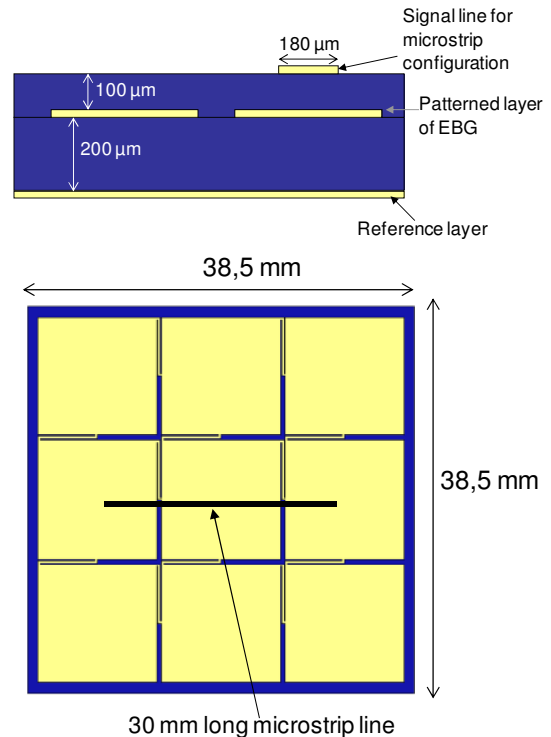


Figure 3: Cross-sectional view of board showing microstrip line routed over EBG (top); Top view of EBG showing position of microstrip line. Note: The top dielectric layer is made transparent for illustrative reasons (bottom).

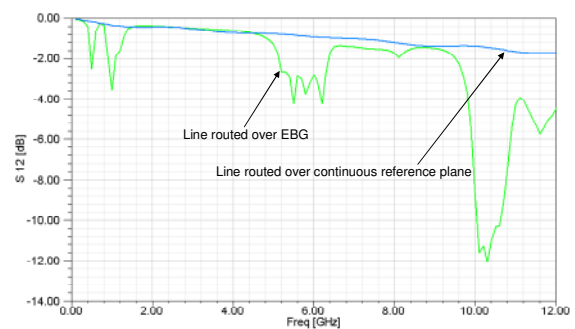


Figure 4: Impact of EBG on insertion loss of microstrip line

6. Summary

We modeled, designed and fabricated a planar EBG for UWB applications. This EBG was integrated together with a microstrip line and the impact of the EBG on the transmission coefficient of the line was

investigated. Our results reveal that at the resonance frequency of the parallel plate forming the EBG, there is strong coupling between the transmission line and the EBG. Consequently, much of the power to be transmitted along the line is lost. This may lead to system failure. Hence, the impact of EBGs on transmission lines must always be considered at the beginning of the design cycle.

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