

Study on Band Gap Behaviour of Electromagnetic Band-Gap(EBG) Structure With Microstrip Antenna

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Abstract— The popularity of microstrip antennas are increasing day by day because of easy analysis and fabrication, and their attractive radiation characteristics microstrip antenna using simple electromagnetic band gap (EBG) substrate has higher gain than conventional microstrip antenna. In this paper we propose to mushroom like Electromagnetic Band Gap (EBG) structure with different diameter of vias was designed to analyze the behavior of the EBG structure. Mushroom-like electromagnetic band-gap (EBG) structures exhibit unique electromagnetic properties that have led to a wide range of electromagnetic device applications and a simple, compact EBG microstrip antenna is proposed in this study that covers a wideband of 2.5 to 3.7 GHz ISM band, Bluetooth and UHF RFID applications. The use of the EBG Structure improves the radiation pattern of the antenna. The electromagnetic band gap structure is a periodic structure which exhibit a band gap over a certain frequency range over which the propagation of the electromagnetic wave is prohibited. Zeland IE3D simulations have been carried out to investigate and characteristics of the performance with improved design is under consideration in EBG Structure.

Keywords— EBG Structure, Vias Surface wave, Wide band width, Band gap, Periodical Structure, Microstrip Antenna

I. INTRODUCTION

In recent years, electromagnetic band gap (EBG) structures have attracted increasing interests because of their desirable electromagnetic properties that cannot be observed in natural materials. In this respect, EBG structures are a subset of metamaterials[10]. diverse research activities on EBG structures are on the rise in the electromagnetics and antenna community, and a wide range of applications have been reported, such as low profile antennas, active phased arrays, TEM waveguides, and microwave filters. In this study, a simple and compact EBG Microstrip antenna is proposed that conformal with short wave, medium and long range wireless network operation. It covers the frequency of 2.5 -3.37 GHz and the design could be adopted for single band WLAN/ PAN applications and considerable improvement in terms of bandwidth and radiation pattern in obtained which confirmed the suitability of compact design for ISM band (WLAN, IEEE 802.11b/g) Bluetooth and UHF RFID applications. The first electromagnetic band gap structure conceptualized and manufactured was in 1987 by Yablonovitch, then at bell communication research in New Jersey. EBG structure are defined as artificial periodic (or sometimes non periodic)

object that prevent/assist the propagation of electromagnetic wave in a specified band of frequency for all incident angles and all polarization states[1-2]. The term band gap is well known in the semiconductor physics in relation to the propagation of the optical waves. The photonic structures associated with this phenomenon are named as Photonic Band Gap structures (PBGs)[9]. Recently, this concept has been scaled down to microwave and millimeter wave frequency bands resulting in a more appropriate term EBG.

A periodic structure (EBGs) applied to microwave planar waveguides can produce pass band or stop band characteristic. By proper selection of dimensions and periods certain waves are allowed to propagate through, while the other waves such as surface waves can be suppressed. The surface wave propagation is a serious problem of microstrip antennas. Surface waves reduce antenna efficiency and gain, limit bandwidth, increase end-fire radiation and cross-polarization levels, and narrow the applicable frequency range of microstrip antennas. Additionally, the miniaturization of microstrip antennas and their integration with microstrip circuits is hindered because high dielectric substrates are required to achieve these objectives [3-4]. To avoid this, the substrate is periodically loaded so that the surface waves cannot propagate along the substrate. Also, other surface wave coupling effects like mutual coupling between array elements and interference with board systems can be suppressed. Furthermore, it increases the mutual coupling of the antenna array which causes the blind angle of a scanning array [5]. The feature of surface-wave suppression helps to improve antenna's performance such as increasing the antenna gain and less power wasted when reducing backward direction.

Microstrip antennas have been used widely and continue to be popular in commercial applications due to their light weight, low profile, low cost and ease of integration with MMIC fabrication technology. In particular, the ease of integration with MMIC leads to low cost manufacturing. The major limitations of a patch antenna on a high dielectric constant substrate are its low efficiency due to surface wave loss and inherently narrow bandwidth. Frequency-selective surface have currently attracted considerable attention due to the growing interest in utilizing electromagnetic band-gap (EBG) structure [6-7]. The particular role of an electromagnetic band gap (EBG) technique is that it can be applied to improve performance of a planar antenna designed

on a high dielectric material. By loading the EBGs periodically on the substrate, a band gap can be created for frequencies around the operating frequency of the antenna. Such structure can stop the propagation of surface waves, which can be excited along the high dielectric substrate material supporting MMIC components. By doing this more power can be coupled to a space wave instead of being wasted in the substrate.

In general, EBGs can be realized as 1-D (one dimensional), 2-D or 3-D. In the proposed paper 2-D EBG structure is carried out.

II. SURFACE WAVE PROPAGATION

Surface wave are excited on microstrip antenna when the substrate $\epsilon_r > 1$. Besides end fire radiation, surface wave give rise to coupling between various elements of an array. Surface wave are launched into the substrate at an elevation angle θ lying between $\pi/2$ and $\sin^{-1}(1/\sqrt{\epsilon_r})$. These waves are incident on the ground plane at this angle shown, get the reflected from there, then meet the dielectric-air interface, which also reflect them. Following this zig-zag path, they finally reach the boundaries of the microstrip structure where they are reflected back and diffracted by the edges giving rise to end-fire radiation.

On other way in the boundary, if there is any other antenna in proximity, the surface wave can become coupled into it. Surface waves will decay as $1/\sqrt{\epsilon_r}$ so that coupling also decreases away from the point of excitation. Surface wave are TM and TE modes of the substrate. These modes are characterized by waves attenuating in the transverse direction (normal to the antenna plane) and having a real propagation constant above the cut-off frequency [9]. The phase velocity of the surface waves is strongly dependent on the substrate parameters h and ϵ_r . Figure-1 shows the blocking of propagation surface wave on waveguide by using EBG (PBG) structure.

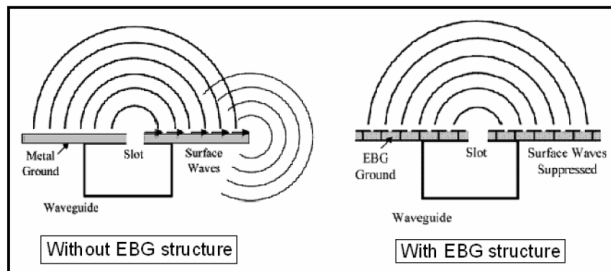


Figure 1: Blocking of Surface Wave Propagation using EBG Structure

III. Electromagnetic Band Gap (EBG) structure

The basic design of EBG structure is shown in figure 2 known as mushroom like EBG structure. This structure has frequency range where the surface impedance is very high. The equivalent LC circuit acts as a two-dimensional electric filter in this range of frequency to block the flow of the surface waves [11]. The central frequency of the band gap is shown in

equation 1. The inductor L results from the current flowing through the vias, and the capacitor C due to the gap effect between the adjacent patches. Thus, the approach to increase the inductance or capacitance will naturally result in the decrease of band-gap position.

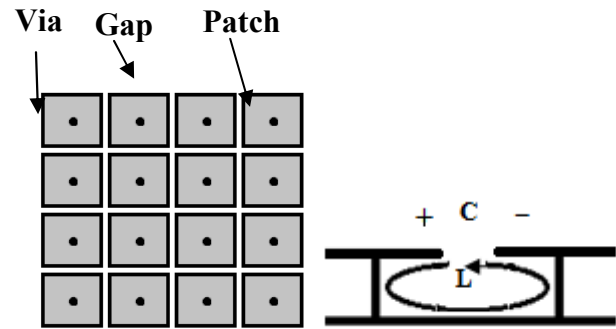


Figure 2: 2D EBG Structure

Central frequency of Band Gap is given by-

$$f_c = \frac{1}{(2\pi\sqrt{LC})} \quad (1)$$

where

$$L = \mu_o h \quad (2)$$

$$C = W\epsilon_o \frac{(\epsilon_r + 1)}{\pi} \cosh^{-1} \left(\frac{2W+g}{g} \right) \quad (3)$$

The bandwidth of electromagnetic band gap is given by

$$BW = \frac{1}{\eta} \sqrt{\frac{L}{C}} \quad (4)$$

In this proposed paper 9mmX9mm periodic rectangular patches with 0.5mm gap was designed and simulated. The radius of the vias is 0.156mm. Figure-3 shows the layout view of the 4 by 4 mushroom like EBG structure[8-9] Each patch is connected to the ground plane by using a via placed at the center of the patch. The band gap frequency was determined by using Zeland IE3D.

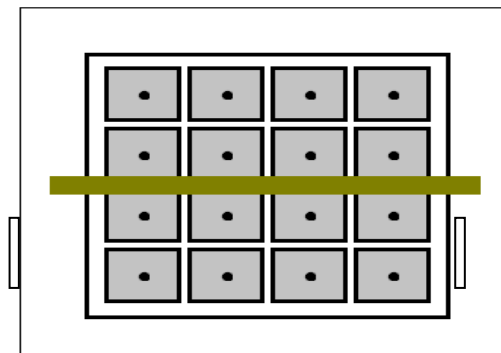


Figure-3 4x4 Mushroom like EBG structure

IV. PARAMETRIC ANALYSIS OF EBG STRUCTURE WITH DIFFERENT RADIUS OF VIAS

The EBG patch antenna characteristics are determined by both the EBG parameters and the radiation patch dimensions. Only the mushroom EBG structure is presented here. The simulation of the EBG has been done with 0.156mm, 0.2mm, 0.3mm, 0.4mm and 0.5mm radius of the vias.

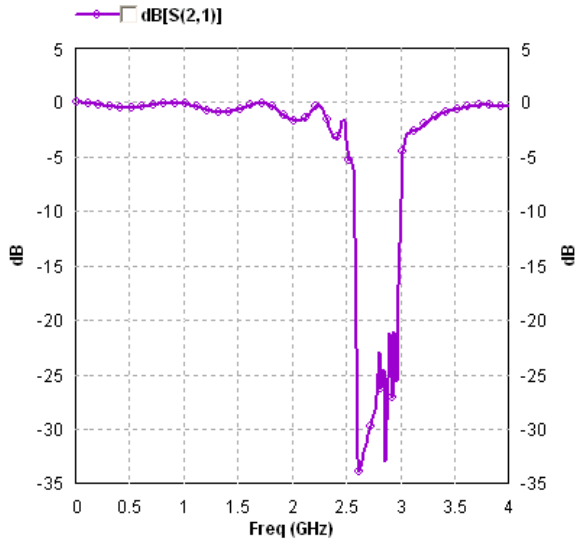


Figure-4(a) Band gap with 0.156mm radius of vias

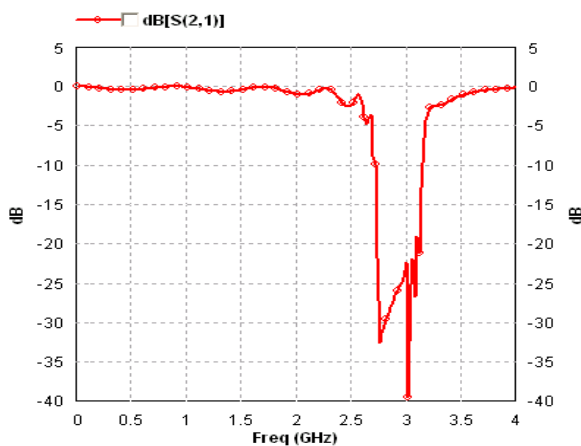


Figure-4(b) Band gap with 0.2mm radius of vias

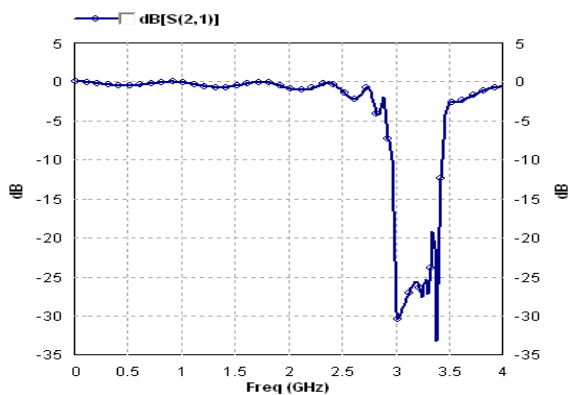


Figure-4(c) Band gap with 0.3mm

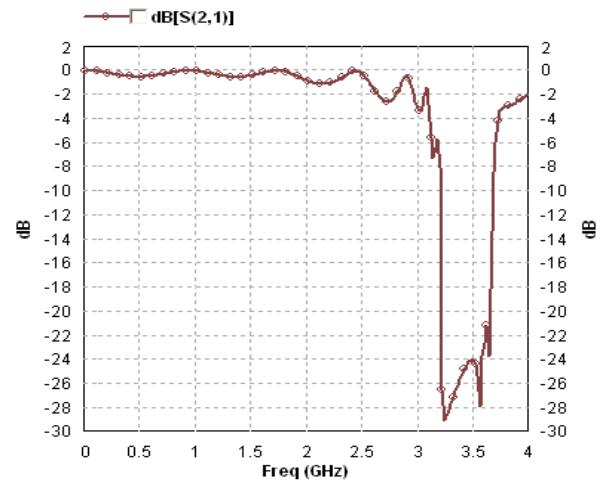


Figure-4(d) Band gap with 0.4mm radius of vias

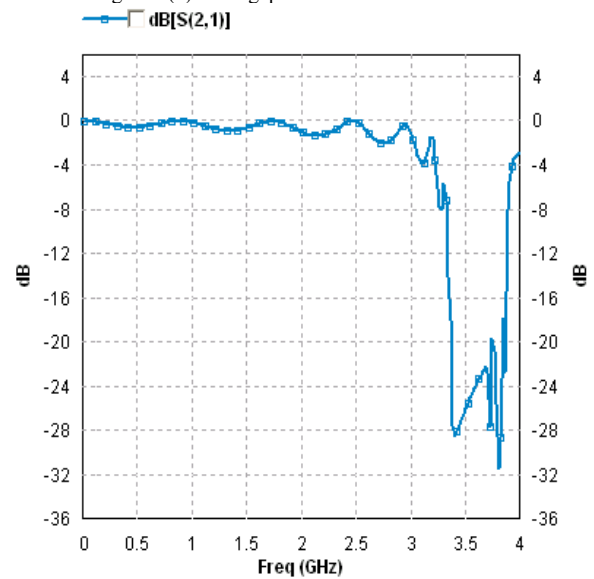


Figure-4(e) Band gap with 0.5mm radius of vias

V. RESULTS AND DISCUSSION

Figure-3 shows the 4x4 mushroom like EBG structure with suspended line. The comparison of band gap characteristics is shown in Figure 4(a), 4(b), 4(c), 4(d) and 4(e) with 0.156mm, 0.2mm, 0.3mm, 0.4mm and 0.5mm radius of vias respectively. It is evident from the figure 4 that the band gap in case of the mushroom like EBG with 0.156mm vias is approximately 2.5 GHz to 3 GHz and the band gap in case of 0.2mm vias is approximately 2.7 GHz to 3.2 GHz. 2.9 GHz to 3.4 GHz band with 0.3mm, 3.2 GHz to 3.7 GHz with 0.4mm and 3.4 GHz to 3.9 GHz with 0.5mm is achieved.

VI. CONCLUSION

A 4x4 mushroom like EBG structure with suspended line with 0.156mm, 0.2mm, 0.3mm, 0.4mm and 0.5mm has been proposed. The S21 parameter (band gap) of the EBG structure

with different vias radius has been studied, which in turn results the shifting of the band gap towards the higher frequency band. In general if we increase the radius of the EBG then the band gap will shift to the higher frequency range. All the simulation has been done using Zeland IE3D.

VII. REFERENCES

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