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Electromagnetic Band Gap (EBG) Structure Antenna Design For Wide Band Applications

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Abstract *—Electromagnetic band gap (EBG) structures that are engineered to achieve desired transmission and reflection characteristics in specific frequency bands, have long been actively studied in the microwave regime for a wide variety of applications. They have also been used as superstrates for directivity enhancement of antennas as well as substrates for height reduction of conformal antennas.In this study we develop some guidelines for systematically designing Enhanced Bandwidth antenna systems, comprising of a microstrip patch antenna (MPA) covered by a planar EBG substrate. At the beginning, the investigations of EBG were mainly on wave interactions of these structures at optical frequencies and hence PBG emerged with the name of photonic band-gap structures.EBG is due to the interplay between macroscopic and microscopic resonances of a periodic structure.The major Area of interest EBG structure gain with its enomourous advantage it offers like Mutual Coupling, Surface Wave Suppression at microwave frequencies. In my study I Concentrate on Mashroom EBG antenna which is a part of planer structure of microstrip patch array and using multiple layers of substrate we can achieve great Bandwidth enhancement.*

Keywords- ADS (Advance Design System), FSS (Frequency selective surfaces), EM (Electromagnetic), MoM (Methods of Moments).

I. INTRODUCTION

The Use of Antenna Over the past Decade has been shown highly grown due to the basic wireless equipment's usage has been increased. As the Number of different wireless applications are working on the same environment with the fix parameters like Specific Bandwidth, Frequency and Limited Gain it creates some limited Space for the Users. Only Some Parameters Can be change as the design of antenna is changed, also it can provide some effective advantages of Enhancement in the gain and bandwidth of the antenna [1].

In this paper, we propose a design based on concept of electromagnetic band gap (EBG) structures for enhancement of gain and bandwidth and compare the results with the edge feed microstrip patch antenna operating at 10 GHz resonating frequency for X band applications. The surface wave which are excited in the dielectric substrate are suppressed by placing square-lattice metal pads with grounding vias beneath the patch, which not only improves the gain but also increase its frequency bandwidth. It has been shown that, placing EBG cells in *E*-plane is suffcient for surface wave reduction and it is not required to have *H*-plane EBG cells. This EBG structures is used in microstrip array antennas between radiating array elements in *E*-plane to reduce mutual coupling between them by suppressing surface waves. But we are using EBG structures in both E-plane and H-plane over a single microstrip patch antenna. Our proposed antenna gives better performance compare to the conventional rectangular microstrip patch antenna. A substantial gain and bandwidth enhancement has been obtained. The design and simulation have been done by using Advanced Design System Simulator (ADS).

A periodic structure can give rise to multiple band-gaps. However, it should be noted that the band-gap in EBG is not only due to the periodicity of the structure but also due to the individual resonance of one element. A study revealed the mechanisms to form a band-gap in an EBG. The band-gap formation in EBG is due to the interplay between macroscopic and microscopic resonances of a periodic structure. The periodicity governs the macroscopic resonance or the Bragg resonance. It is also called the lattice resonance. Microscopic resonance is due to the element characteristics and it is called the Mie resonance. When the two resonances coincide, the structure possesses a band-gap having maximum width. Depending on the structural characteristics and polarization of the wave, one resonance mechanism (i.e. either the multiple scattering resonance or the single element scattered resonances) can dominate over the other. The characteristic property of stop bands at certain frequencies enables many applications using EBG [1]. At this stop band, all electromagnetic wave will be reflected back and the structure will act like a mirror. At other frequencies, it will act as transparent medium.

II. LITERATURE REVIEW

By reviewing some papers, we have extracted some points about EBG and use of it. As we use Electromagnetic Band Gap Antenna, the Gain and Bandwidth is effectively increase as compare to Conventional microstrip Patch antenna. As the Band Gap structure exhibits more power and reduce the mutual coupling between the patches of antenna. So it effectively, suppress surface waves. Here are some reviews shown below.

In one paper, Authors Suggested Two methods in terms of bandwidth broadening for monopole slot ultra wideband (UWB) antennas supporting mobile terminal applications.The original antenna has a bandwidth of 9.27 GHz (1.73–11 GHz) that covers PCS1900, UMTS2000, TD-SCDMA, WLAN 802.11b/g or Bluetooth, LTE, WiMAX, and UWB frequency range. In this letter, by cutting two new slots on the ground plane, the antenna can expand its bandwidth to 9.33 GHz (1.67–11 GHz) that is available at extra DVB-H, DCS1800 services.Two different methods are investigated to broaden the bandwidth of the monopole antennas [2]. One can cut slots on the system ground plane. The additional resonances generated by the introduction of the slot can couple to original resonances of the antenna, which can contribute to bandwidth enhancement. Another popular method is to etch shapes of electromagnetic band-gap (EBG) structure on the antenna. The inherent characteristics of dielectric materials are helpful to improve the impedance bandwidth.

In anotherpaper, Authors uses four different types of EBG structure for bandwidth enhancement of Microstrip patch array. The four ground plane designs for the 2× 2 microstrip patch antenna array (MPAA) are; spiral artificial magnetic conductor (SAMC) ground plane,an SAMC embedded with a large spiral artificial magnetic conductor (LSAMC), an SAMC embedded with small spiral patch cells (SSAMC), and an SAMC embedded with small spiral mushroom-type electromagnetic band-gap patches (ESEBG) [3].

Also apaper introduce a technique to enhance the bandwidth of the noise suppression, the GSPL structure is implemented by using multiple vias in the mushroom-like electromagnetic bandgap structure.Under the concept of multiple vias, the lower and upper bound cutoff frequencies of the bandgap are influenced by the position of the vias [4]. An optimum position for the vias is found to achieve maximum stopband bandwidth.

One paper has a mushroom-like EBG structure is analyzed using the finite-difference time-domain (FDTD) method. Its band-gap feature of surface-wave suppression is demonstrated by exhibiting the near field distributions of the electromagnetic waves. The mutual coupling of microstrip antennas is parametrically investigated, including both the E and H coupling directions, different substrate thickness, and various dielectric constants. It is observed that the E-plane coupled microstrip antenna array on a thick and high permittivity substrate has a strong mutual coupling due to the pronounced surface waves [5]. Therefore, an EBG structureis inserted between array elements to reduce the mutual coupling.

In a paper, compact elongated mushroom electromagnetic band-gap (EM-EBG) structure, exploiting the thickness of the substrate to achieve higher isolation compared to the case of the conventional mushroom EBG (CM-EBG), is proposed for the enhancement of the performances of patch antenna arrays.

III. Microstrip Patch antenna Designing with EBG substrate

The ADS (Advanced Design System 2011) simulator is used to design antenna and measure the parameters of the antenna. It analyzes 3D and multilayer structures of general shapes. It has been widely used in the design of MMICs, RFICs, patch antennas, wire antennas, and other RF/wireless antennas. It contains several different simulation techniques like transient solvers, frequency domain solvers, integral equation solver, multilayer solver, asymptotic solver and eigenmode solver to best suit various applications [9]. There are many kinds of boundary schemes and excitation techniques available in this software. This program was chosen due to the author's familiarity with them and also because models may be created using multiple variables. This makes geometry changes to the model easy and effortless.These simulators are basically used to calculate and plot the S_{11} parameters, VSWR, smith chart, current distributions, input impedance as well as the radiation patterns.

We Can have have the known frequency and the Substrate parametres like h, ε and f0 to find the size of antenna using the transmission line.the basic EBG antenna designing parametrs are

- $L = \mu_0 h$
- $C = W\,\varepsilon_0\,(1+\varepsilon_r)/(\pi*(\cosh(2W+g/g)))$; Where W = width of Patch in λ, g= gap between the EBG unit cells, μ_0, ε_0 are the dielectric constants.
- $W = 1/\sqrt{L}*\sqrt{C}$
- $B.W. = 1/\eta*\sqrt{L}/\sqrt{C}$ [3]

Microstrip patch with EBG structure in ADS tool.

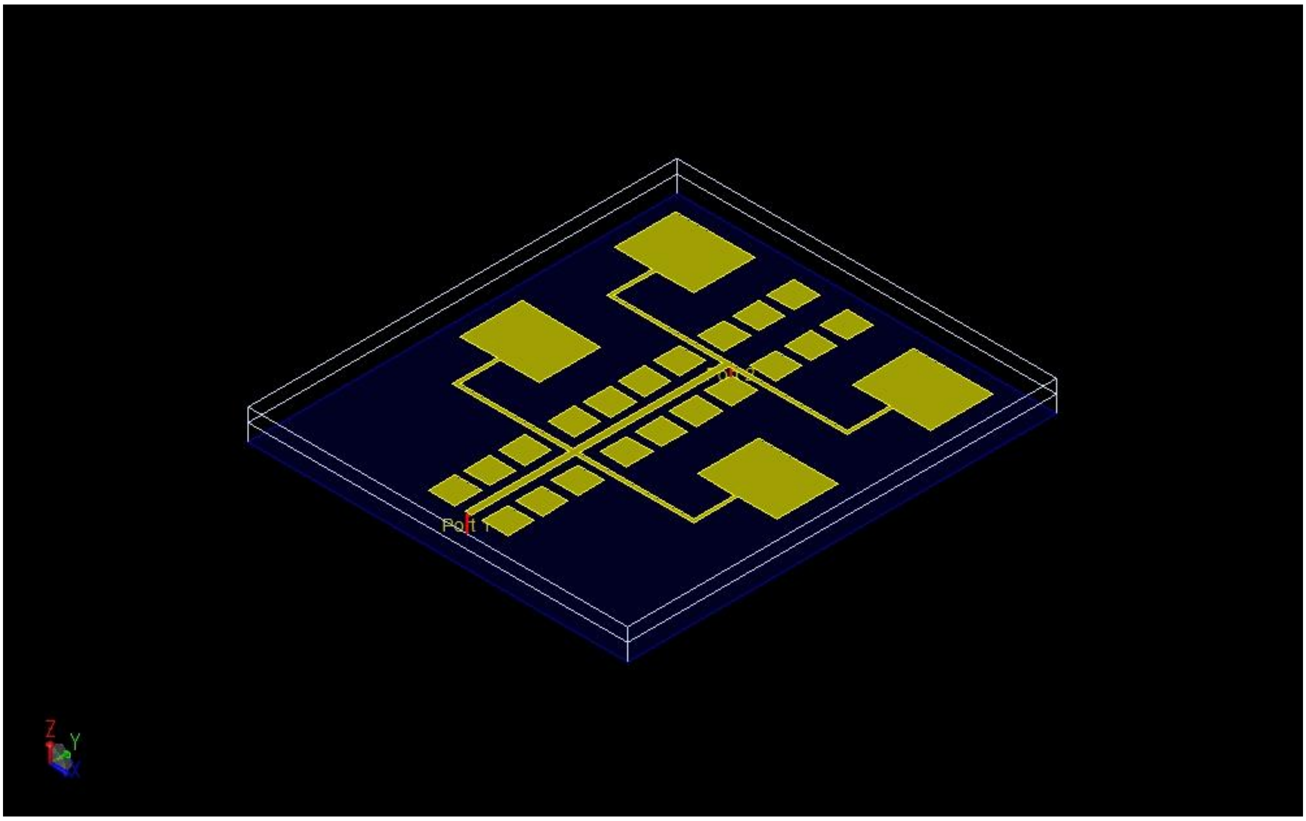

Figure 1: Microstrip Patch with EBG Substrate 3D View in ADS Tool.

2x2 Microstrip patch array is proposed with 2x2 EBG substrate with respect to the Rectangular Ground Plane. Where, the conventional patch has length L=7 mm and width W=9mm separated by 18 mm and the substrate thickness h=1.92 mm. the material used for the substrate is Rogers_RO3010 which has die-electric constant ε_r=10.2, TanD=0.0035.

Proposed EBG Substrate:

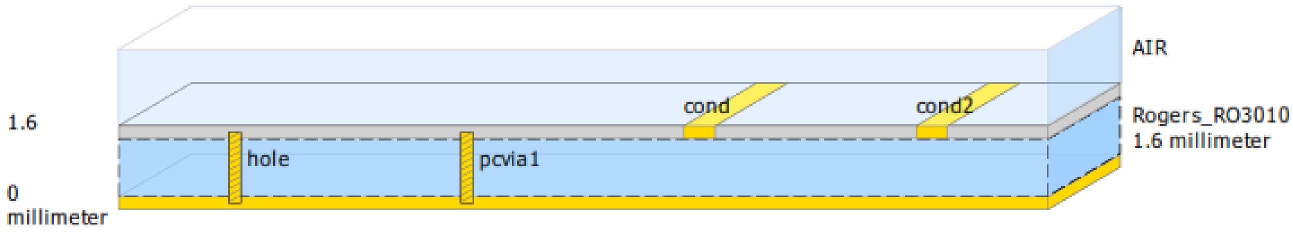

Figure 2: EBG Substrate Design in ADS Tool.

IV. RESULTS

It is easy to simulate the design through computer before real time implementation. The ADS tool helps us to determine the impedance bandwidth, return loss, gain and directivity. This simulator also helps to reduce the fabrication cost because only the antenna with the best performance would be fabricated. The simulated results of antenna with EBG and without EBG has been shown in Figure 3 and Figure 4.

Return loss and bandwidth

The return loss of patch antenna without EBG is -34db at 2 GHz and -35db at 7.6 GHz at resonating frequency and return loss of proposed antenna with EBG is -48db at 3.5 GHz and -42db at 7 GHz at resonating frequency. Also with EBG substrate we are getting up to -70db at 0.6 GHz resonating frequency as shown in Figure 2.

The bandwidth can be calculated from Figure 2 and Figure 3.The bandwidth of patch antenna without EBG is from 1.6 to 2.2GHz, 7.6 to 8 GHz i.e 8% and bandwidth of patch antenna with EBG is from 0.6 to 1.2 GHz, 1.8 to 2.2 GHz, 3.4 to 3.6 GHz, 6.8 to 7.2 GHz which is 16%.The bandwidth of patch antenna with EBG is approximately double than the conventional patch antenna.

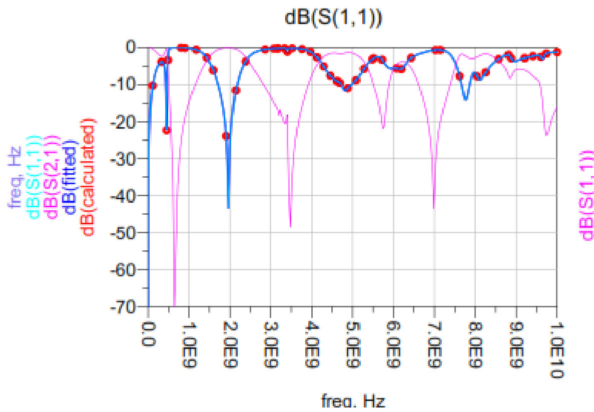

Figure 3: Return Loss S11 and S21 with EBG.

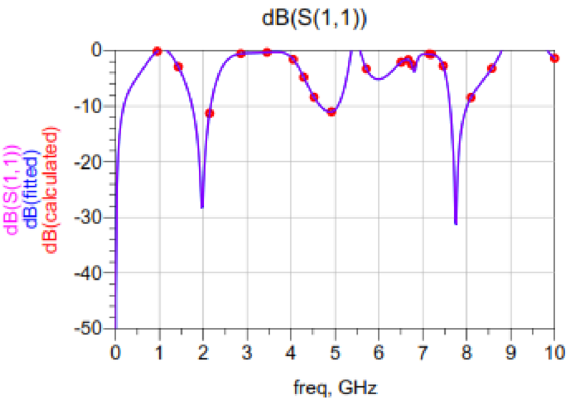

Figure 4: Return Loss S11 and S21 without EBG.

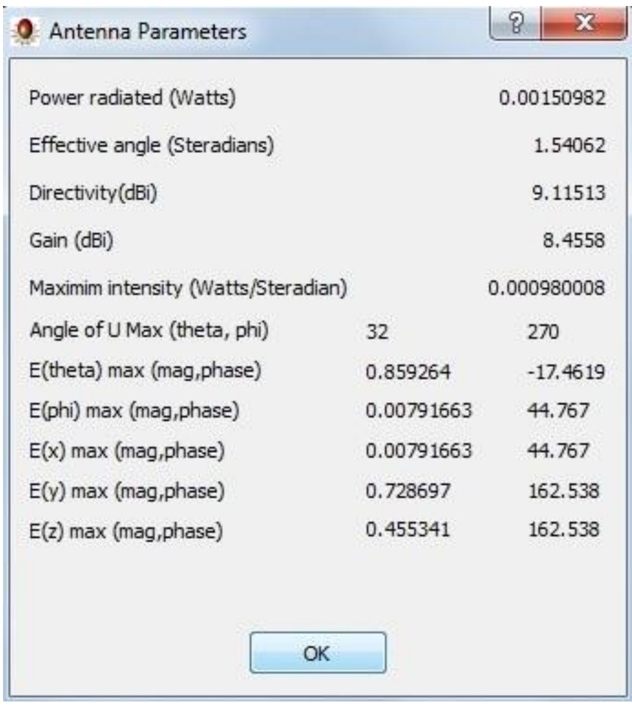

Figure 5: Far-field Parameters with EBG Substrate.

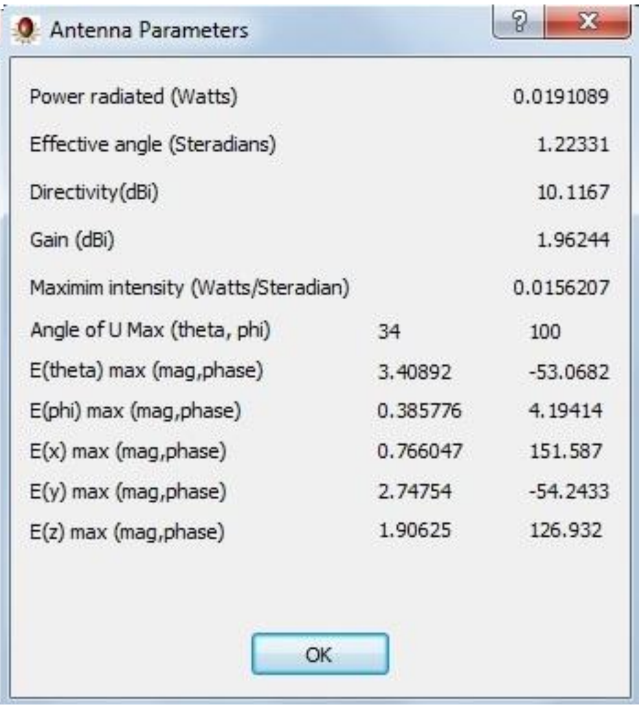

Figure 6: Far-field Parameters with EBG Substrate.

As we can see from above parameters, the Gain of Antenna with EBG substrate is 8.45 dbi while Antenna without EBG substrate has Gain 1.96 dbi. So, Antenna with EBG substrate has greater Gain Enhancement with the same proposed dimensions of Antenna.

V. CONCLUSION

This paper includes the simulation results for Microstrip Patch Antenna both with and without EBG Substrate having same dimensions. We can see from above results that the Gain and Bandwidth are effectively improved when EBG substrate is placed near by Microstrip Patch. The proposed structure provides simple implementation awith effective outcomes. It is possible to design simple and effective different EBG substrate to improve Bandwidth and Gain using different Die-electric materials.

VI. REFERENCES

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