Mutual Coupling Reduction in Array Elements Using EBG Structures

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***Abstract*—A 2D electromagnetic band gap (EBG) structure is designed on the ground plane of 1×2 rectangular patch antenna array to reduce the mutual coupling between the two elements and enhance the radiation pattern. An isolation of −41 dB has been achieved with the EBG structure relative to −20 dB without the EBG.**

***Index Terms*—Electromagnetic Band Gap, Patch Antenna Array, Mutual Coupling**

I. Introduction

During the last decade tremendous advances have been made in the wireless technology. The use of high frequency bands result in miniaturization of the circuits. Antennas play a vital role in wireless communication. The radiation properties of antennas, when used in close proximity of other circuit elements, are highly affected by their presence. Microwave researchers are constantly in an effort to reduce these effects while designing the RF front ends to achieve the required results.

Mutual coupling between the elements in an array configuration has an adverse effect on the radiation pattern, return loss, and directivity of the antenna. Substrates of different permittivities, different thicknesses, negative permittivity, and negative permeability are being used [1]. Researchers are making use of defected ground structures (DGS), a simplified form of EBG, to enhance the radiation properties of microstrip patch antenna arrays [2]. EBG makes use of the periodic structures to create a frequency band gap. These periodic structures can suppress surface waves to reduce mutual coupling between array elements as suggested in [3], where a mushroom-like EBG structure is analyzed and an 8 dB reduction in mutual coupling is achieved. These structures can help in improving the operation bandwidth [4] of the microstrip antennas which are considered narrow band antennas.

This paper makes use of the surface wave suppression property of the EBG structure to reduce mutual coupling between a 1×2 rectangular microstrip patch antenna array (MPAA). COMSOL Multiphysics is used as simulation tool for this design.

II. Simulation Setup

A single patch antenna with length $L_p = 16$ [mm] and width $W_p = 12.45$ [mm] was designed on a lossless substrate of permittivity $\epsilon_r = 2.2$ and height 0.794 [mm] in COMSOL. The patch was fed with a coaxial feed of inner conductor radius 0.034 [mm] and outer conductor radius 0.114 [mm]. The patch resonated at 7.45 GHz.

Patch antennas are commonly used in array configuration to achieve high directivity and gain. In antenna arrays, mutual coupling has an adverse effect on the performance of the antenna elements. The main purpose of this paper is to reduce the mutual coupling between array elements. Therefore, the single rectangular patch was arranged in a 1×2 array configuration to take into account the mutual coupling between the two elements. The substrate dimensions were 30×60 [mm]^2 and the edge to edge separation between the patches was set to d = 6 [mm] which is $0.15\lambda_0$, where λ_0 is the free space wavelength at resonant frequency 7.45 GHz. EBG structure is used to increase the isolation between the two patches.

A unit cell of the EBG structure can have an I-shape, H-shape, circle, square etc. In this paper, a star shaped unit cell, shown in Fig. 1, has been optimized to reduce the mutual coupling between the antenna elements. A rectangle of width W=0.3 [mm] and length L=2 [mm] was rotated at $45°, 90°,$ and $135°$ to generate the star shape.

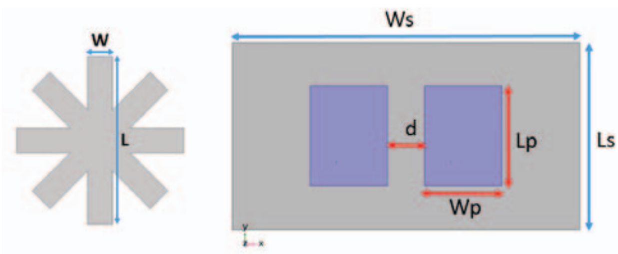

Fig. 1. Left: Unit cell of the EBG structure; Right: Top view of 1×2 patch antenna array on substrate.

The unit cell shown in Fig. 1 (left) was arranged in a 2D EBG structure. The first unit cell (top left) in Fig. 2 is offset, from the center, in x and y by -5 [mm] and 11.5 [mm], respectively. The horizontal and vertical edge to edge separation between any two unit cells is 0.5 [mm] and 1 [mm], respectively.

III. Simulation Results

The meshing used in COMSOL was set to normal with physics based meshing enabled, which means that there should be at least five mesh elements per wavelength. The patch array was simulated without the EBG structure to observe the S-parameters of the antenna. One patch was excited while the

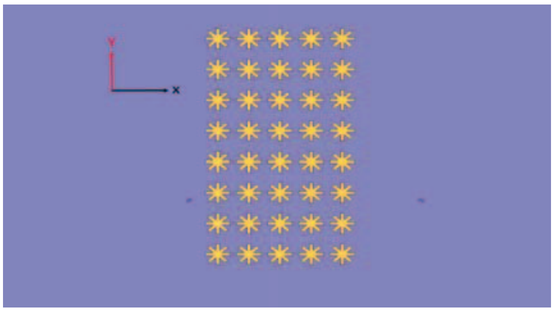

Fig. 2. 1×2 patch antenna array with the EBG structure between the patches.

other one was match terminated. Another simulation was run in the presence of the EBG structure to see its effect on the coupling. Figure 3 shows the S-parameters (S_{11} and S_{21}) for both the simulations.

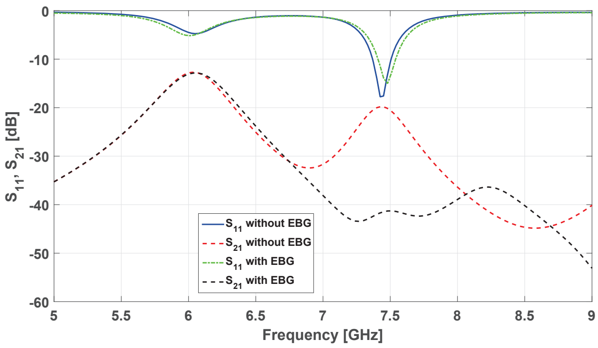

Fig. 3. S-parameters of the 1×2 patch array with and without the EBG structure.

Without the EBG, coupling (S_{21}) between the two elements is -20 dB at the resonant frequency. The second patch (right in Fig. 1) is not excited but radiations from the excited patch induces a current on it and disturbs the fields of the overall antenna.

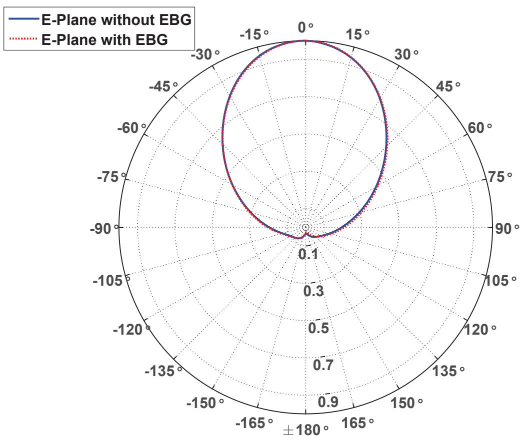

Fig. 4. Normalized E-plane far-field pattern [V/m] for a 1×2 patch array with and without the EBG structure.

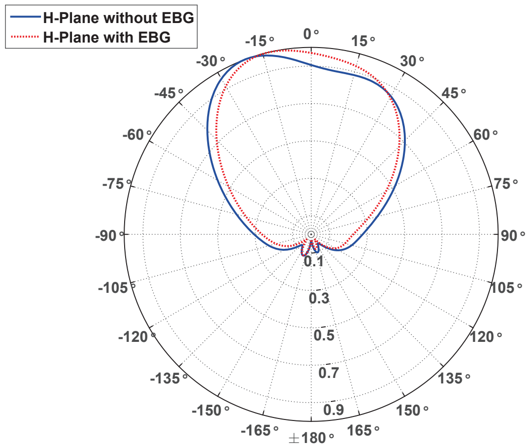

Fig. 5. Normalized H-plane far-field pattern [V/m] for a 1×2 patch array with and without the EBG structure.

With implementation of the EBG structure (S_{21}) dropped to -41 dB and the effect on the second patch is reduced to a higher degree. The second patch is placed perpendicular to the direction of current due to which the couping is more in the H-plane. The effect of coupling and decoupling on the normalized far-field [V/m] for both, E,H-planes, is presented in Figs. 4 and 5, respectively. The H-plane pattern in the presence of the EBG structure has recovered to the conventional pattern of a patch antenna.

IV. Conclusion

A star shaped DGS has has been arranged in a 2D EBG structure to improve the isolation between two patch antennas operating at the same frequency. The designed structure resulted in increased isolation from -20 dB to -41 dB. The EBG structure suppresses the surface waves and stops them from interfering with the adjacent patch.

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