A Novel EBG Structure to Improve Isolation in MIMO Antenna

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***Abstract*—A new, and advanced Electromagnetic Band Gap (EBG) structure is reported to reduce the mutual coupling between two tightly spaced rectangular patch antennas. The EBG structure provides more than 20 dB reduction in mutual coupling without degrading far-field patterns, gain, or bandwidth.**

***Index Terms*— RFID, Radar, MIMO systems, millimeter wave (mmWave), mutual coupling (MC), electromagnetic band gap (EBG) structures, fifth generation (5G).**

I. Introduction

In modern communication systems, there is an ever present demand for size reduction. However, miniaturization often gives rise to undesirable Mutual Coupling (MC); the electromagnetic interactions between antennas. Antenna array performance is compromised by MC. Mutual coupling often degrades gain, input impedances, radiation patterns, and side lobe levels [1]. MIMO systems are particularly impacted by MC due to a tight spacing between radiating elements [2]. Moreover, in applications such as Imaging Radar Systems, MC needs to be minimized due to antenna proximity [3]. Hence, many solutions have been suggested to reduce MC. These solutions include EBG [4], parasitic element slots [5], Defected Ground Structures (DGS) [6] and slotted ground planes [7]. Of these, EBGs tend to better preserve radiation pattern and bandwidth. They reduce the MC among radiating elements as they are periodic structures with little surface wave propagation admittance. To suppress surface waves a wideband EBG structure is needed to improve isolation. To meet the requirements discussed above, a new compact EBG structure is presented. The structure is designed to work around 24 GHz. The resulting wideband system is simulated using COMSOL Multiphysics software.

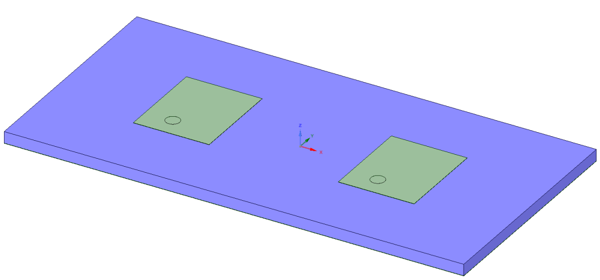

Fig. 1: The MIMO antenna configuration.

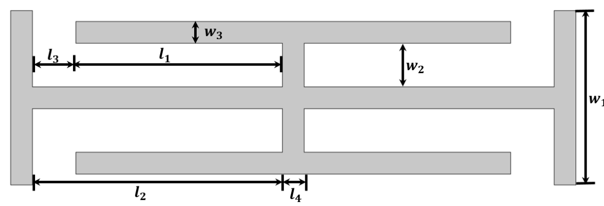

Fig. 2: A unit cell of the EBG structure.

II. Design

A. MIMO Antenna

A two element array is designed. The array elements are rectangular patch antennas. The antennas are designed to operate around 24 GHz. The array is printed on Duroid 5880. The substrate permittivity, ε_r, is 2.2 and has a thickness of 0.5 *mm*. The patch antennas are 3.3 *mm* × 4 *mm*. The separation between antennas, edge-to-edge, is $0.45\lambda_o$ (5.625 *mm*). The antennas are probe fed. The probe coaxial cable is Teflon filled ($\varepsilon_r = 2.1$). The inner conductor diameter is 0.6 *mm* and the outer conductor diameter is 2 *mm*. The feed point is selected to provide 50 Ω input impedance. Figure 1 shows the proposed MIMO antenna setup.

B. EBG Structure

A unit cell of the EBG structure is shown in Figure 2. It is two H-shapes connected. One is rotated 90°. The design parameters are recorded in Table I. A five by three array of EBG unit cells is placed between the antennas. In-addition, six metallic strips are also introduced within the array. The structure of an array is shown in Figure 3. Often, the electromagnetic properties of a surface are modified by utilizing a pattern on the surface. Naturally, the surface impedance will vary with frequency. An EBG structure acts as a filter to impede surface waves. The structure can be modeled as an LC network and the parameters of the EBG structure can be modeled with the formulas presented in [8] and [9]. In order to study the EBG structure's transmission characteristics, a transmission line test was conducted using COMSOL. The full wave electromagnetic simulation includes the effects of a

Table I: EBG unit cell design parameters.

Parameters	l_1	l_2	l_3	l_4	w_1	w_2	w_3
Value (μm)	656	594	750	62.5	500	187.5	62.5

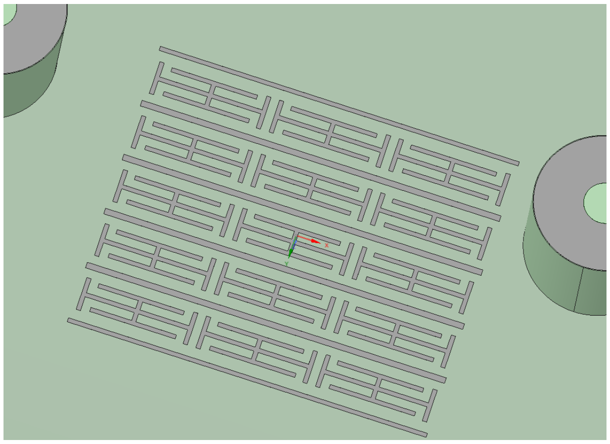

Fig. 3: The EBG array.

finite substrate, metal thickness, and all losses. It was found that a bandgap for the EBG structure shown in Figure 3 exists in the band 22-27 GHz.

III. Results and Discussion

As expected, the introduction of the EBG did not significantly alter the return loss of the antennas. A Comparison of the different antenna parameters is listed in Table II.

Table II: Key antenna performance parameters.

Parameters	With EBG	Without EBG
Bandwidth	290 MHz	270 MHz
Gain	7.88 dBi	7.66 dBi

A. Isolation Coefficient:

Isolation between the antennas can be measured in terms of parameter S_{12}. At the center of the band, the unmodified antenna has an S_{12} of -24 dB. By introducing the EBG structure, S_{12} decreases to around -53 dB as shown in the Figure 4.

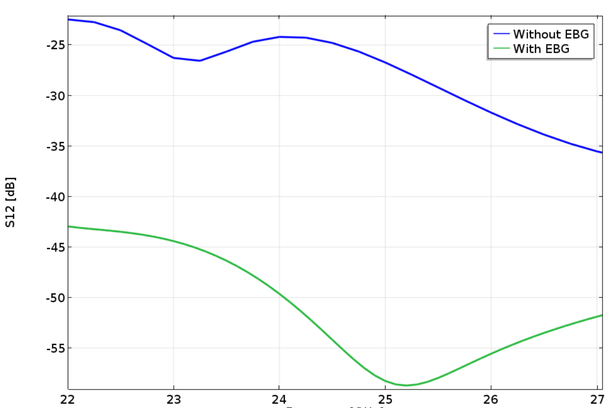

Fig. 4: Antennas Isolation

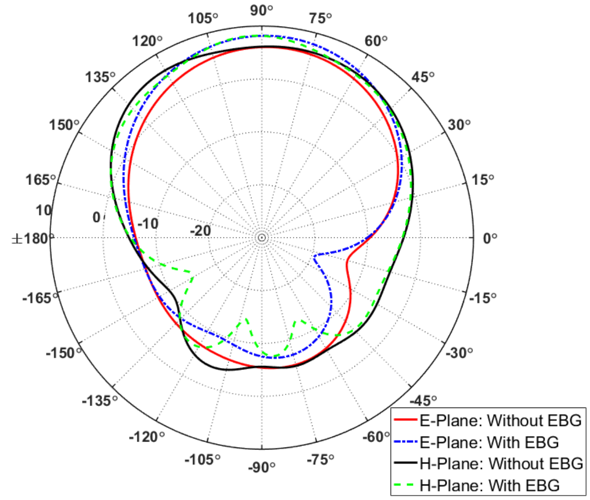

Fig. 5: Radiation pattern

B. Radiation Pattern

Figure 5 illustrates the radiation pattern at resonance. The EBG structure does not degrade the radiation pattern significantly.

IV. Conclusion

In this paper, a novel EBG structure was designed. The EBG structure was used to improve isolation between patch antennas. An approximate 20 dB reduction in mutual coupling was achieved while maintaining key antennas performance parameters.

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