Isolation Improvement between Closely-Spaced Antennas Using EBG

Ahmad H. Abdelgwad and Mohammod Ali
Department of Electrical Engineering
University of South Carolina, Columbia, SC USA
ahmedha@email.sc.edu, alimo@cec.sc.edu

***Abstract*—Isolation improvement between two closely spaced antennas using a single column EBG is proposed for compact wireless devices. The proposed design developed for the 2.4 GHz WLAN band achieves more than 17 dB isolation improvement between two planar inverted-F antennas (PIFAs) compared to the no-EBG case. As a result, improved MIMO capacity is also achieved. The proposed design can be scaled up or down in frequency and may be implemented for small devices such as, smart watches, Wi-Fi routers, internet of things (IoT) devices etc.**

***Keywords*—EBG structure, MIMO, mutual coupling, PIFA.**

I. INTRODUCTION

Multiple antenna placement and operation are essential for multiple-input multiple-output (MIMO) communication systems. It is well known that such system can significantly improve wireless capacity and quality [1]. For small devices, such as, mobile phones, Wi-Fi routers, smart watches, and IoT devices placing multiple antennas within a small platform inevitably leads to higher mutual coupling between them. Excellent MIMO performance demands low mutual coupling or high isolation between antennas.

Electromagnetic band gap (EBG) structures have been proposed to reduce or suppress the mutual coupling between antennas [2]. Such structures act like bandstop filters if properly designed [3].

In this paper, a single column mushroom EBG is introduced that can significantly improve the isolation between two closely spaced PIFAs. Each PIFA and the EBG are designed to operate at 2.4 GHz. Thus, the concept can be implemented in applications and services that utilize the 2.4 GHz frequency band. The design can be scaled up or down in frequency to make suitable for other applications as well.

II. ANTENNA AND EBG CONFIGURATION

The proposed antenna plus EBG configuration is shown in Fig. 1. There are two PIFAs at the two ends of a printed circuit board (PCB). In between the PIFAs resides a single column mushroom EBG structure. A single column EBG is proposed here to allow its application in compact structures. The PCB is made of FR4 substrate ($\varepsilon_r = 4.4$, and $\tan\delta = 0.02$). An additional FR4 substrate was used to create the EBG structure. All dimensions for 2.4 GHz operation can be seen in Fig. 1. For comparison, a second configuration with no EBG was also considered. For this case, a rectangular slot was etched on the ground plane of the PCB as shown in Fig. 1 (b).

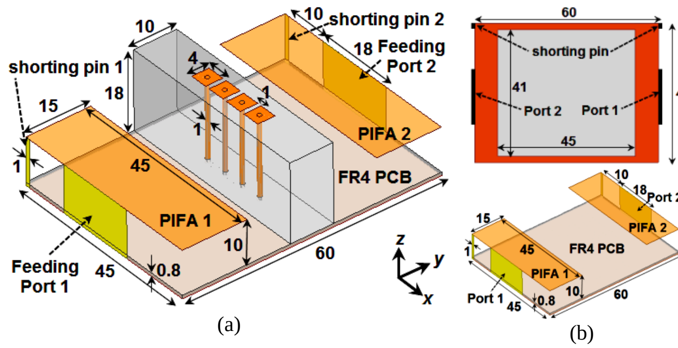

Fig. 1. (a) Antenna and EBG configuration, and (b) no EBG design, (upper) structure (lower) ground plane. (Dimensions are in mm).

III. RESULTS

The design and analyses of the proposed structures were performed using Ansys HFSS. Simulated S-parameters for cases with and without EBG are compared in Fig. 2. For either case, the antenna exhibits operation from about 2.2 to 2.6 GHz within S_{11} < -10 dB. The mutual coupling, S_{21}, without EBG is -8.5 dB at 2.4 GHz. The mutual coupling with EBG is -26 dB at 2.4 GHz. Thus, more than 17 dB isolation improvement is achieved between the antennas using only a single column mushroom EBG at 2.4 GHz. The two antennas have over 20 dB isolation for a bandwidth of 10% which is greater than the bandwidth required for WLAN. Fig. 3 compares the efficiencies of the two configurations. The EBG structure improves the efficiency of each antenna by 11% at 2.4 GHz.

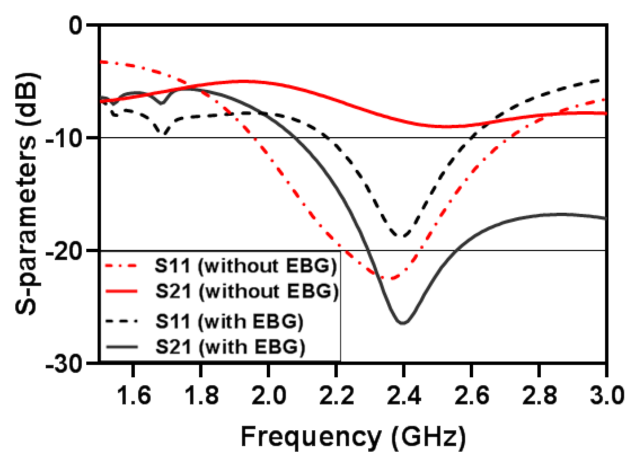

Fig. 2. Simulated S-parameters with and without EBG.

Submitted On: August 28, 2020
Accepted On: September 5, 2020
https://doi.org/10.47037/2020.ACES.J.351121
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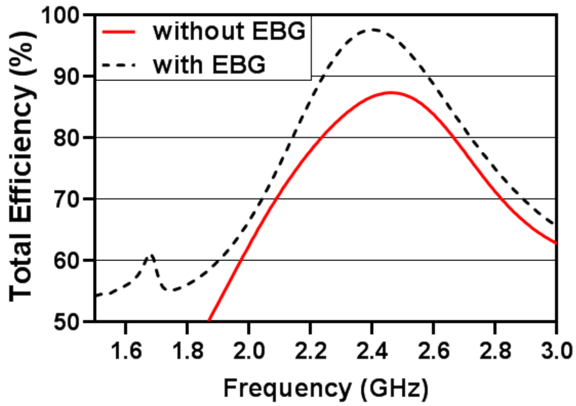

Fig. 3. Antenna efficiency with and without EBG.

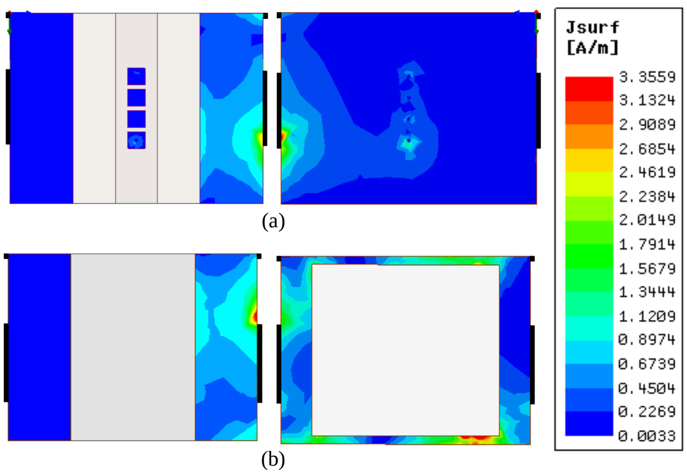

Fig. 4. Surface current distributions (port 2 excited), patches on the left and ground plane on the right: (a) with EBG and (b) without EBG.

Simulated current density distributions for the two studied configurations are shown in Fig. 4. Clearly the EBG significantly inhibits the flow of current between the two antenna ports, thus reducing the mutual coupling between them.

In order to evaluate the diversity and MIMO performance of the two configurations, the mean effective gain (MEG) and the envelope correlation coefficient (ECC) were calculated assuming a uniform propagation environment [4]. The cumulative density function (CDF) data as function of the relative signal to noise ratio (SNR) computed using a maximum ratio combining (MRC) scheme have been plotted in Fig. 5. For comparison, the Rayleigh distribution is also added as a reference. The effective diversity gain (EDG) values at 1% outage probability are 8.33 and 8.90 dB, respectively for the cases with and without EBG. Thus, as seen, the EBG allows improvement in the EDG as well. The capacity of the antennas was also estimated using the equations presented in [5]. The capacities of the antennas with and without EBG are compared in Fig. 6 which clarifies that the EBG allows higher ergodic capacity compared to the one without the EBG. This improvement is attributed to the reduced mutual coupling and the ECC the former of which is also reflected in the efficiencies.

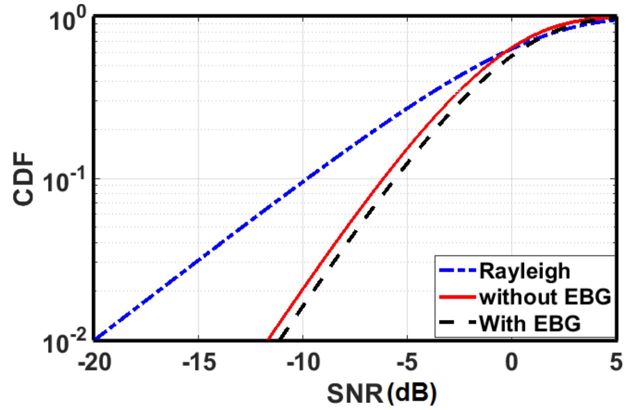

Fig. 5. CDF as function of relative SNR for configurations with and without EBG.

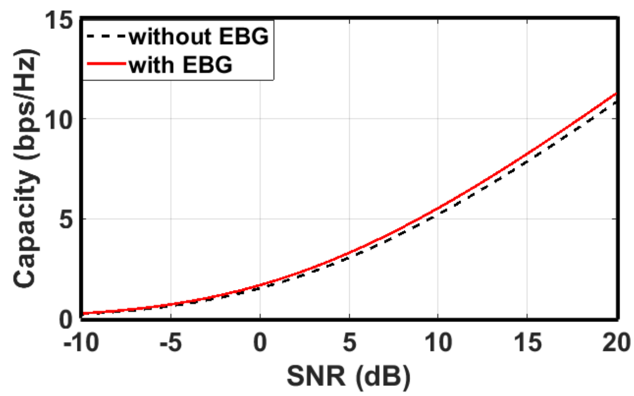

Fig. 6. The Ergodic MIMO capacity with and without EBG.

IV. Conclusion

A single column mushroom EBG structure is proposed to improve the isolation between two closely spaced PIFAs. The designed EBG can improve the isolation between the PIFAs by as much as 17.5 dB compared to the no-EBG case. As a result, the EBG also improves MIMO capacity due to improved antenna efficiencies.

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