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► To cite this version:

Yacouba Coulibaly, Halim Boutayeb, Tayeb Denidni. Gain Enhancement of a Dielectric Resonator Antenna Using a Cylindrical Electromagnetic Crystal Substrate. IEEE Antennas and Propagations Symposium 2007, Jun 2007, Honolulu, United States. pp.1325-1328. hal-00156630

HAL Id: hal-00156630

<https://hal.science/hal-00156630>

Submitted on 22 Jun 2007

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Gain Enhancement of a Dielectric Resonator Antenna Using a Cylindrical Electromagnetic Crystal Substrate

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Introduction

Over the last decades, an increasing attention has been paid to the investigation of Dielectric Resonator Antennas [1-3] due to their attractive features. DRAs have several advantages, such as low losses, high radiation efficiency, high integration, and reduced size. However, one drawback of the DRA is its low gain characteristics. Few studies have been reported to improve the radiation characteristics of the DRA. In [4], a rectangular DRA is placed on different ground plane shapes (coaxially corrugated, strip corrugated and mushroom-like Electromagnetic Band Gap (EBG) substrate) to suppress the surface wave modes. In this communication, we present a new substrate to reduce the surface waves and to increase the gain of a dielectric resonator antenna. In [5,6], circularly periodic Electromagnetic Band Gap (EBG) substrates have been designed in order to enhance the performance of printed dipoles antennas and microstrip slot antennas. The advantage of the circularly symmetric geometries is that a surface wave generated by a source located at its center experiences the same bandgap effect in all radial directions. Using this concept, a new EBG substrate is introduced to increase the gain of a cylindrical Dielectric Resonator Antenna. The proposed EBG substrate is based on the mushroom-like structure [7] and is constructed as a combination of two periodic structures. One periodic structure is composed of metal rings and the other is constituted of vertical metal vias, which are disposed such as to form a radially and circularly periodic structures. The disposition of the vias is based on the analysis proposed in [8].

Numerical results

A cylindrical Dielectric Resonator Antenna and its cylindrical EBG substrate were designed by using the Finite Element method (HFSS-Ansoft [9]). In the simulation process, convergence and minimization of errors were obtained by ensuring that enough iterations were used. Figure 1 shows the schematic of the proposed DRA surrounded by a cylindrical structure composed of metal rings and grounding vias.

The dielectric resonator antenna has a radius R of 15 mm, a height h_d of 10.5 mm and a dielectric constant ϵ_{DRA} of 31.5. The lowest mode $HEM_{11\delta}$ is excited. The dielectric antenna is feed via a coaxial line, which is at the distance 11 mm from the center.

The circularly symmetric EBG structure is composed of strips and metallic vias. The concentric rings of strips are printed on a substrate with a relative permittivity of $\epsilon_r = 2.2$ and thickness $h = 3.2$ mm (Rogers RT/Duroid 5880). In the horizontal plane, the substrate occupies a square of larger 154 mm. The distance from one strip to another is $g = 2$ mm, and the radial period is $P_{r1} = 24.6$ mm. The first metal ring starts at the radius $R + g$, so that the beginnings of the strips are $b + g + (n - 1)P_{r1}$. The vias have the radius $a = 2$ mm, and they are disposed with the same transversal period $P_t = P_{r2}\pi/6$ and the same radial period $P_{r2} = 23.6$ mm. The optimized radial periods are close to $\lambda/4$. According to [8], when the transversal period P_t is kept constant, the cylindrical periodic structure of metallic vias act as a lattice of inductances

to cylindrical waves. The strips act as a lattice of capacitances. The EBG substrate is then the equivalent of the mushroom-like substrate [7] with a circular symmetry.

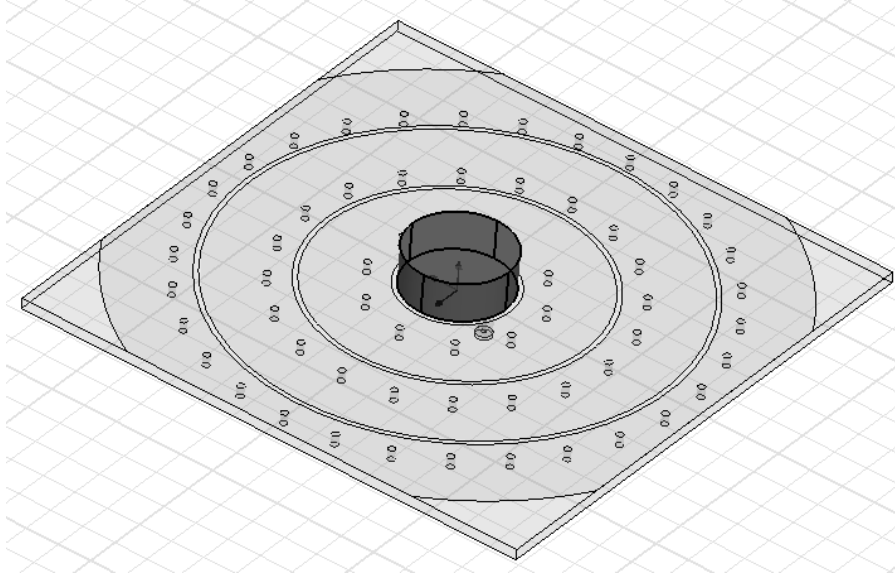


Figure 1: Dielectric Resonator Antenna Surrounded by a cylindrical EBG substrate.

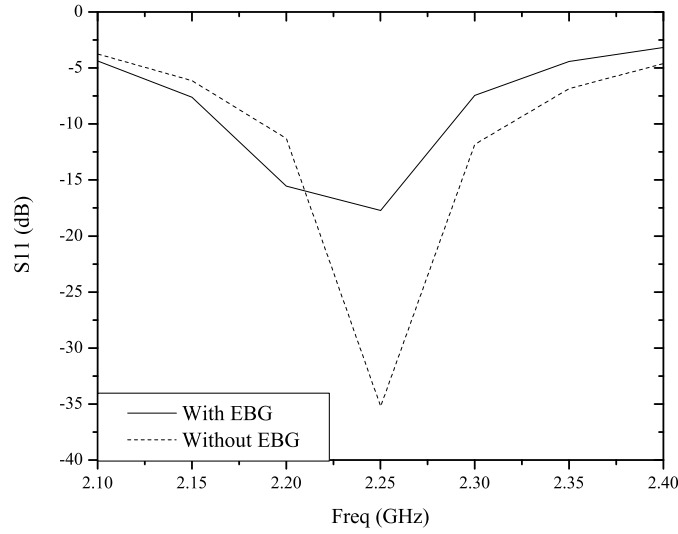


Figure 2: Simulated return loss of the antenna, with and without the EBG substrate.

Figure 2 shows the simulated return loss of the DRA with classical substrate (without the strips and vias) and of the DRA with the EBG substrate. The matching ($S_{11} < -10dB$) of the antenna is obtained around $2.25 GHz$ for both cases. Figure 3 shows the simulated gain of the antenna, with and without the EBG structure. From these curves, the new substrate allows to increase the gain by $3 dB$, due to the reduction of the surface waves. Figure 4 presents the radiation patterns in both H- and E- planes, at $2.25 GHz$, showing that the back lobes radiations are reduced thanks to the EBG substrate.

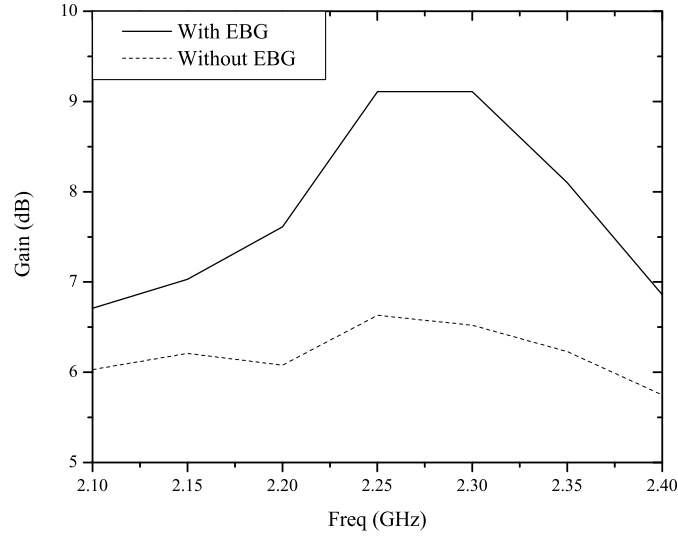


Figure 3: Simulated gain of the antenna, with and without the EBG substrate.

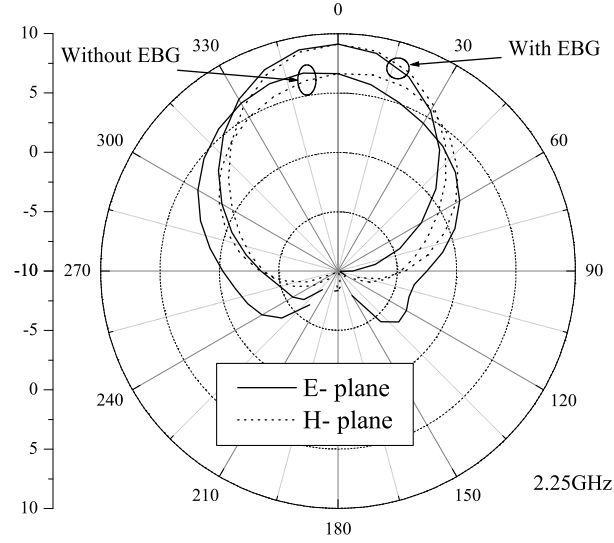


Figure 4: Radiation patterns at 2.25 GHz, in both H- and E- planes, with and without the EBG substrate.

Conclusion

In this paper, a novel technique for the gain enhancement of Dielectric Resonator Antennas using a cylindrical EBG structure has been proposed and demonstrated numerically. The analysis and design of the structure has been based on the fact that the surface wave propagation is reduced in all radial directions thanks to the circular symmetry of the proposed EBG structure. The EBG structure is based on the mushroom-like structure with a circular symmetry. It is composed of a periodic

structure of metallic rings and of a periodic structure of vias. The periods of these two structures have been optimized using a full wave method to maximize the antenna gain. Numerical results have been presented showing that a gain enhancement of 3 dB is achieved with the new substrate. Experimental results will be presented during the conference.

Acknowledgment

The authors gratefully acknowledge the support of this research from National Science Engineering Research Council of Canada (NSERC).

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