A Compact EBG using Interdigital Capacitors Resonators Technique for LTE System

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Abstract **-This paper proposes a new compact Electromagnetic Band-Gap (EBG) structure using ring resonator with interdigital capacitor. The resonance frequency can be controlled as desired, while the size of EBG unit cell is very compact with its length of λ/8 compared with λ/2 of a conventional ring resonator. In order to accomplish the study, return loss (S_{11}) and radiation pattern of a horizontal dipole antenna placed above the EBG surface are analyzed. The simulation results show that the antenna with the proposed EBG can be operated for 4G LTE band (1.72-1.88 GHz) with the S_{11} less than -10 dB and the gain of 8 dB.**

Index Terms **— Compact EBG structure, Interdigital capacitor, ring resonator, LTE antenna.**

1. Introduction

Electromagnetic Band-Gap (EBG) structures are essentially periodic artificial media, which display defensive electromagnetic wave propagation properties in frequency ranges and specified directions. The EBG structures have been prosperously employed to achieve novel high-efficiency devices such as antennas, filters, waveguides, etc. One important issue in antenna research is to reduce the size of antenna structures using EBG. Also, comfort of design, low cost and lightweight are needed to be concerned. Therefore, EBG antenna is the benefit of miniaturization to execute a compact system at a relatively low frequency band (1-10 GHz). Thus, strong interest exists in employing EBG structures to enhance antenna performance. EBG structure is utilized as high impedance ground plane to suppress undesired surface waves and mutual couplings. This leads to an enhancement in maximum gain, smooth pattern, side/back lobes reduction, etc. On the other hand, EBG structure provides in-phase image currents with respect to currents in antenna. This allows low-profile antenna realizations that are impossible on ordinary ground planes. Due to these advantages, many researches are focused on compact EBG structures applied for antenna systems using vias, mitering lines, meandered loops, inter-digital capacitors, etc.

This paper proposes a novel compact EBG structure using resonator with interdigital capacitor. The design is based on EBG mushroom type. With the interdigital capacitor technique, size of the proposed EBG unit cell can be reduced form λ/2 to λ/8 caused by the slow wave effect [1] and harmonic resonance frequency can be controlled as desired. Additionally, the 10×10 EBG unit cells are connected into an array used as a reflector for a dipole antenna in order to increase gain up to 8 dB at the resonance frequency suitable for LTE system (1.8 GHz). The total size of the proposed EBG reflector is very compact compared with the conventional planar reflector for the same value of gain. The design of EBG and antenna are shown in next section.

2. EBG Design and Simulation results

The proposed EBG structure has been designed on the FR4 substrate with εr = 4.4, loss tangent = 0.018 and thickness = 3.2 mm. Schematic of the proposed compact EBG is shown in Fig.1. The surface structure is a lattice of material pads mounted on a substrate. Each unit cell of the lattice consists of a resonator with interdigital capacitor. The effect of slow wave results to reduce size of unit cell to be about 1.1×1.2 cm at the resonance frequency of 1.8 GHz. The simulation results shown in Fig.2 including the reflection phase behavior in Fig.2(a) considerably depending on the polarization due to its asymmetry, which means that the reflection phases for x and y polarizations are not the same. The reflection phase moves downward and crosses through zero at the resonant frequency. The reflected waves are in-phase when the reflection phase falls between ±90 deg [2]. This is also the bandwidth of the EBG structure. Fig. 2 (b) shows the value of S_{11} as the resonance frequency can be seen at 1.8 GHz. In order to reduce size of the EBG structure lesser than λ/2, the finger sizes and gap (W_4 W_6 and L_5) must be adjusted, that capacitance is introduced by the gaps between neighboring pads and inductance is provided by the narrow branches. The series inductors combined with the shunt capacitors constitute an array of parallel LC circuits, which has high surface impedance at resonant frequency, leading to a larger fringe capacitor compared to the conventional mushroom-like structure. Thus, very compact EBG structure can be obtained at lower frequencies. When connecting unit cells into an array 10×10, the result has feature like of S curve as shown in Fig 3. Fig. 4 shows a horizontal dipole on the proposed EBG structure for surface-wave propagation, which can be useful to improve antenna radiation patterns. Therefore, the surface waves are avoided and the multipath is absence, resulting in the improved radiation pattern.

The result of simulation S_{11} shows the resonance response at 1.8 GHz, also the gain of antenna with EBG is 8.09 dB. The radiation pattern is directional.

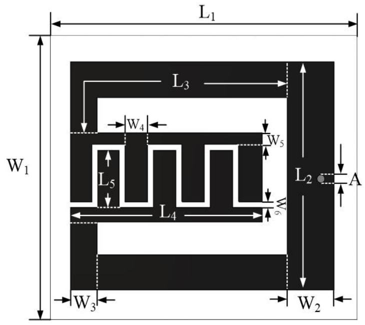
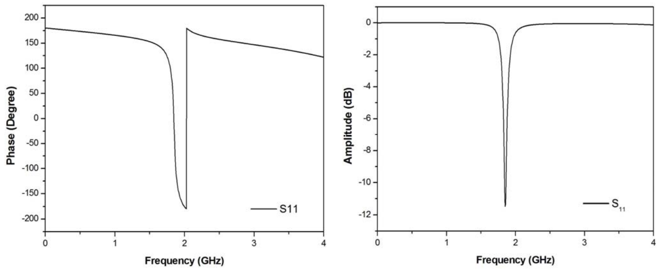
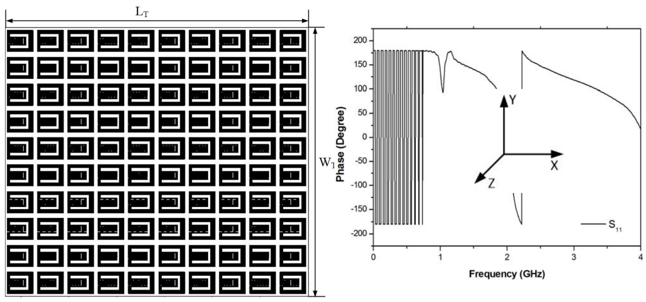


Fig. 1 The surface EBG unit cell structure.



(a) (b)

Fig. 2 The EBG unit cell simulation results
(a) Reflection phase result and (b) Return loss (S_{11}).



(a) (b)

Fig. 3 EBG 10*10 unit cell simulation results.
(a) Structure total of EBG (b) Reflection phase results.

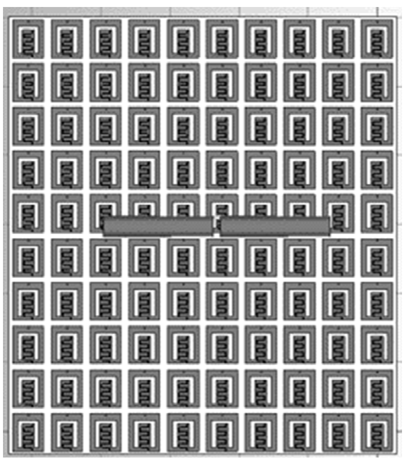
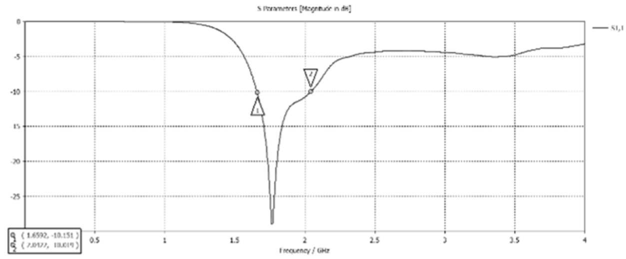
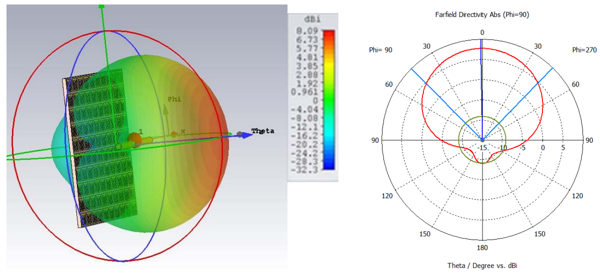


Fig. 4 Dipole antenna with EBG reflector.



(a)



(b)

Fig. 5 Simulation results of dipole antenna with EBG
(a) return loss (S_{11}) and (b) gain and radiation pattern.

To design EBG, CST program has been employed, resulting in parameters as follow: W_1= 10.1 mm, W_2= 1.76 mm, W_3= 1.01 mm, W_4= 0.86 mm, W_5= 0.52 mm, L_1= 11.87 mm, L_2= 8.256 mm, L_3= 8.9 mm, L_4= 7.23 mm, L_5= 2.08 mm, and A = 0.3 mm. respectively.

3. Conclusion

In this paper, a novel EBG structure has been introduced. It has a compact configuration and easy to be integrated with other RF components. Simulations have shown effectiveness of the compact EBG structure in surface wave suppression and in-phase reflection. Further, a dipole antenna mounted on the EBG ground plane has shown a great improvement in radiation performance. The radiation patterns show a more focused beam with 8.09 dB maximum gain and reduction of back radiation.

Acknowledgment

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