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Planar Double-Band Monopole Antenna with Photonic Crystal Structure

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Abstract

Background/Objectives: A new Double-Band monopole antenna is proposed in this paper. Four improved prototype of the proposed antenna is investigated. **Method/Statistical Analysis:** Final structure consists of a C-shaped slot on the patch and a spiral stub in ground plane to operate in two bands and enhance the bandwidth. Numerical simulation is performed for the antenna with Ansoft HFSS13.0, which is a kind of simulation software based on Finite Element Method and Rsoft Photonics CAD as photonic software. **Findings:** The influence of a photonic crystal substrate on the performance of a monopole antenna is simulated. Photonic crystal has been used as substrate to increase the bandwidth and gain. The antenna has two resonant frequencies in 5 GHz and 10.5 GHz with impedance bandwidth of 56% and 52.38% respectively. The gain of designed structure is about 3.4 dB. **Applications/Improvements:** The proposed antenna can operate in Wireless LAN in the U-NII-2/2e bands (channel 52 - 140, frequency range 5.260 - 5.725) for first the band and X-band for second band.

Keyword: Bandwidth, Double-Band, Gain, Monopole Antenna, Photonic Crystal

1. Introduction

According to electronic limitation to reduce the size of device, enhance the speed of data entertainment in modern Industry, scientists tried to find a solution like using photon instead of electron[1-2]. Therefore, in the last few decades, researchers concentrate their attention on Photonic Crystals (PhC) in Nano-scale to reach superior speed and capacity. This kind of PhCs due to their particular attribute and high potential in optoelectronic, are lead to integrated optics applications in telecommunication, information technology, medicine, military industry and The current study deals with the design and implementation of an antenna with EBG structure in the substrate. Photonic crystals (PCs) are periodic dielectric or magnetic structures which under certain conditions prohibit the propagation of electromagnetic waves within certain frequency bands. A 2-D PC structure can have a photonic bandgap for TE, TM or both. The use of PCs structure is becoming attractive for many researchers in electromagnetic and antenna field. PCs had been used to improve the performance of various antennas such as patch antenna and resonant antenna. Microstrip patch antenna is promising to be a good candidate for future wireless . has shown that surface wave loss would be dominating factor at wavelength. To reduce the surface wave loss, either effective permittivity or thickness of material is reduced. To reduce the effective permittivity, the property of material is thickness of material is reduced. To reduce the effective permittivity, the property of material is artificially altered with the help of periodic implantation of foreign object in the homogeneous host material. In this paper a new monopole antenna on photonic crystal substrate for double-band application is presented.

2. Antenna Design

In this section, a monopole antenna with a rectangular patch and its cylindrical EBG substrate are designed by using a finite element method . The monopole antenna

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is designed on the FR4 substrate of relative permittivity 4.4 and the thickness 0.8 mm, as shown in Figure 1. The rectangular patch has a width W of 9 mm and a length L of 9.5 mm. The length and width of microstrip feed line are 1.5 mm and 7mm respectively. Other parameters are shown in Table 1.

3. Design of Photonic Crystal

The proposed structure in substrate as it is shown in Figure 2 is a triangular lattice of air columns with a radius *r* and lattice constant *a* drilled in a dielectric medium with a dielectric constant εr = 4.4. The dimensions of dielectric are 12 mm × 19mm. After defining the basic

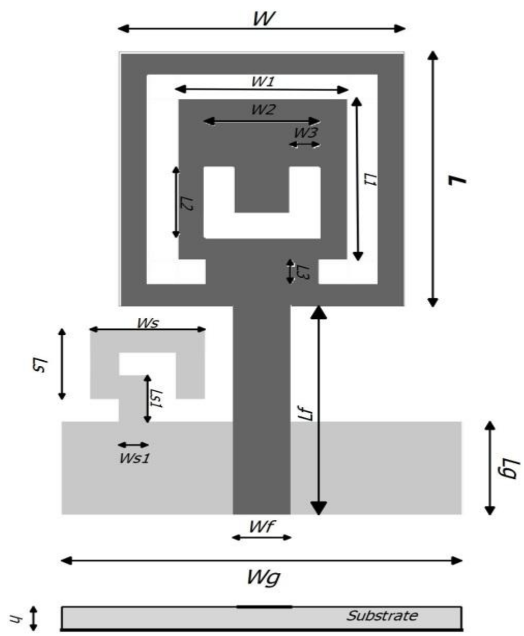


Figure 1. The geometrical configuration of antenna.

Table 1. Design values of the antenna in figure 1

Param.	*Values*	*Param.*	*Values*
W	9 mm	L	9.5 mm
W_g	12 mm	L_g	5.4 mm
W_1	6 mm	L_1	6.5 mm
W_2	4 mm	L_2	3 mm
W_3	1 mm	L_3	1 mm
W_f	1.5 mm	L_f	7 mm
W_s	3 mm	L_s	2.5 mm
W_{s1}	1 mm	L_{s1}	2 mm

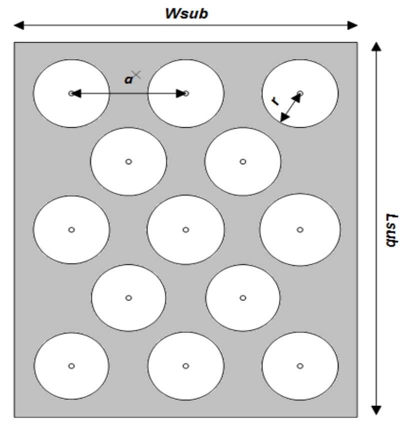


Figure 2. Structure of photonic crystal in substrate.

photonic crystal geometry, the dispersion relation for a normal incident plane wave can be calculated. The so called for the structure is obtained by keeping the dielectric constant fixed, sweeping the *r/a* ratio and recording the width of the gap. This gap map then allows us to choose the *r/a* value that maximizes the available photonic band gap for the desired frequency of operation. The dispersion diagram our structure was computed with the plane wave expansion (PWE) method and the result is shown in Figure 3. It can be seen that a complete band gap exists, which forbid propagation in the normalized frequency ($\omega\alpha/2\pi c$) range from 0.09 to 0.125. The main parameters of the PCs structure can be accurately computed by the program RSoft. From the 'gap map' it is found that the bandgap occurs for the $r/a \in [0.2, 0.4]$. The maximum complete bandgap arises around $r/a = 0.3$. Together with a central normalized frequency 0.107 this gives a physical lattice period $a = 3.21$ mm and rod radius $r = 0.963$ mm. In order to explain the procedure of the antenna design, four antennas (Ant. 1-4) are illustrated in Figure 4. As we all know, the length of the conventional monopole is about a quarter-wavelength. Therefore, we can tune the length of the radiator to obtain the best impedance matching. Figure 5 shows that the first resonant frequency of Ant. 1 is at 5 GHz and the second resonant frequency is about 9.5 GHz with low impedance matching. In Ant. 2 a C-shaped slot in patch is added. As can be seen, we have a better return loss in comparison to antenna 1. In Ant. 3, a spiral stub is embedded on the ground plane to enhance the matching. Therefore, the introduction of spiral stub in Ant. 3 can improve the impedance matching at higher band. The cooperation of slot in patch and spiral stub in Ant. 4 shows that the impedance bandwidth of the

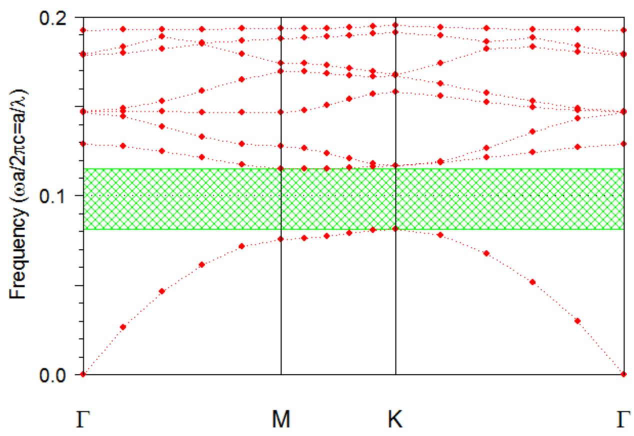


Figure 3. Dispersion diagram of the proposed antenna.

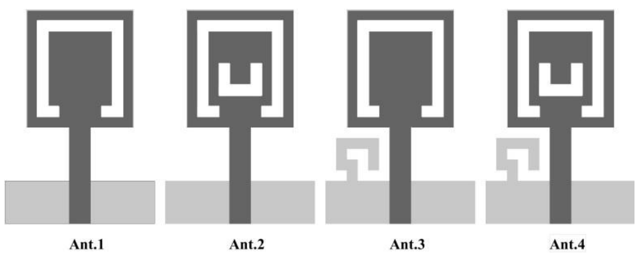


Figure 4. Four structure for proposed antenna.

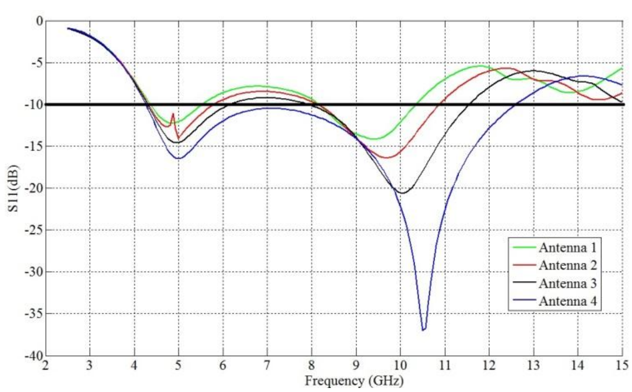


Figure 5. Return loss for antenna 1-4.

monopole antenna is greatly enhanced. According to the results of Ant. 2 (without stub) and Ant. 4 (with stub) in Figure 4, the spiral stub acts as an important component for antenna performance. In fact, a ground plane stub is added to improve impedance matching[14, 15]. In short, the stub plays a key role in S11. From the analysis of antenna design we can conclude that the technique of adding open-loop slot in patch and embedding the stub on the ground can increase the impedance bandwidth.

4. Simulation and Analysis

After choosing the best structure for patch and ground plane, we should compare the antenna with and without the PCs structure. The software package Ansoft HFSS v.13 has been used for the simulation of proposed antenna. Figure 6 shows the return loss versus frequency for both configurations of antenna. It can be seen that the proposed antenna before adding PCs structure has no resonant frequency. Whereas after placing the PCs in the substrate two resonant frequencies in 5 GHz and 10.5 GHz with are achieved. Also the 10-dB impedance bandwidths of two operation frequencies are 56% and 52.38% respectively. As can be seen in Figure 7. Gain receives from proposed antenna structure (PCs substrate) is found to be 3.4 dB and without any PCs structures shows a value of 1.3 dB at operating frequency. The Photonic Crystal (PCs), due to its frequency bandgap, can decrease the surface-wave modes significantly and thus improves the gain and radiation efficiency.

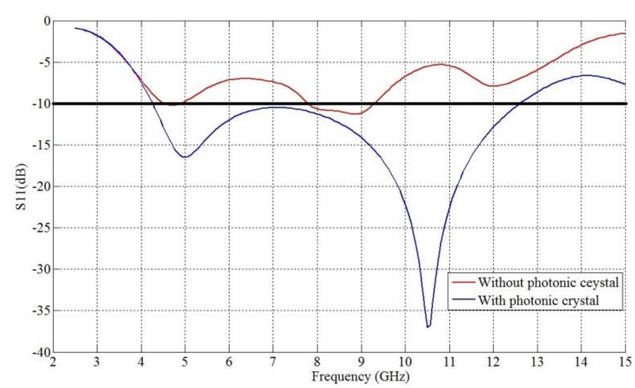
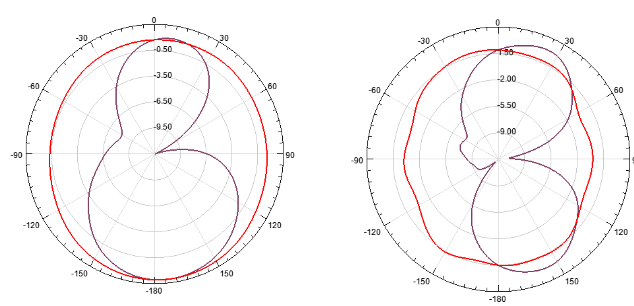


Figure 6. Return loss response of the proposed antenna with and without Photonic Crystal.



(a) (b)

Figure 7. Far field radiation pattern, **(a)** without photonic crystal **(b)** with photonic crystal.

5. Conclusion

This article presents a new monopole antenna using PCs structure as substrate. The proposed antenna has two resonant frequencies in 5GHz and 10.5 GHz with 56% and 52.38% impedance bandwidth respectively. The gain of designed structure is about 3.4 dB and the antenna can operate in Wireless LAN in the U-NII-2/2e bands (channel 52 – 140, frequency range 5.260––5.725GHz) for first the band and X-band for second band.

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