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SCATTERING ANALYSIS OF A PRINTED DIPOLE ANTENNA USING PBG STRUCTURES

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Abstract—A novel broadband design of a printed dipole antenna using PBG (photonic band-gap) structures is proposed and studied in the electromagnetic scattering. The high surface impedance and a frequency gap are used to reduce RCS (radar cross section) across needed frequency range (3.7–4.5 GHz). Because the high surface impedance restrains the surface waves, the obtained results show that RCS is reduced by 15 dB at resonance frequency and radiation characteristics of the antenna at operating frequencies are improved. The method of RCS reduction is suggested, and experimental results are presented.

1. INTRODUCTION

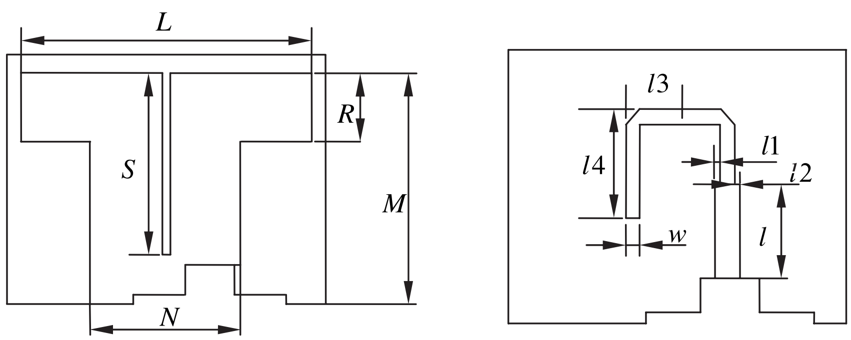
Microstrip printed dipole antenna with thick and high permittivity substrate above PEC (perfect electric conductor) ground plane [1–3] can excite surface waves that are strongly scattered at the edge of substrate or ground plane. PBG structures are often used for high impedance ground plane, suppressing surface waves at operating frequencies [4–7]. In the frequency range having a very high surface impedance, the tangential magnetic field is very small [8], thus behaving as a PMC surface. So these waves can be suppressed by the PBG structures.

In this paper, a microstrip printed dipole antenna using PBG structures is proposed [9]. For this design [10], the form of coupling feed is used, the size of the proposed antenna (45 mm × 35 mm) is obtained and the ground plane uses PBG having the Structure of the square loop [11]. FMM (Fast Multipole Method) [12–15] is used to analyze scattering property of the printed dipole antenna. The RCS is reduced by 15 dB at resonance frequency and the performance of antenna radiation keep unchanging compared with the microstrip printed dipole antenna not using PBG structures.

A comparative investigation has been conducted to study the radiation and scattering characteristics of the microstrip printed dipole antenna above an ideal PEC surface and a realistic metallic PBG surface. Details of the proposed antenna design and experimental results are presented and discussed.

2. ANTENNA DESIGN

Figure 1 shows the structure and dimensions of the proposed antenna, whose conductor is fabricated on an inexpensive substrate with the effective dielectric constant of 2.65 and the substrate thickness of 1.6 mm. The printed dipole antenna is defined by its length $L = \lambda_0/2 = 50\,\text{mm}$, $R = 12\,\text{mm}$, $M = \lambda_0/4 = 25\,\text{mm}$, $S = 27\,\text{mm}$ and $N = 0.4L \times 0.5L = 23\,\text{mm}$. The form of coupling feed is used at the reverse side of substrate. For achieving efficient excitation and good impedance matching, the length of the protruded strip is denoted as L, $l1$, $l2$, $l3$ and $l4$ of which the optimal length are found to be 14 mm, 0.5 mm, 0.5 mm, 7.5 mm and 14 mm. By varying the length of L, $l1$, $l2$, $l3$ and $l4$, the wideband operation of the microstrip printed dipole antenna can be excited with good impedance matching. The maximum impedance bandwidth (2.5–4.0 GHz) is formed.



(a) front side (b) reverse side

Figure 1. Geometry of the proposed microstrip printed dipole antenna.

Figure 2 shows PBG ground having the Structure of the square loop. According to Bragg reflection factor in optics, it is obtained that the period of PBG structure is about a half of wavelength. Period aperture is used to carve on the ground to achieve PBG structure.

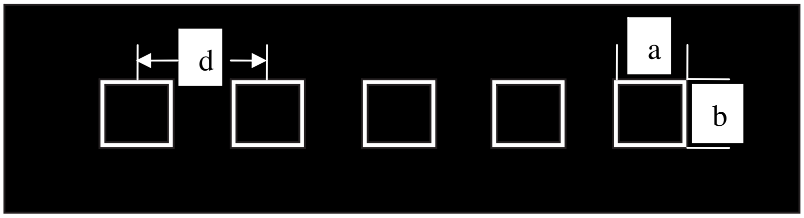


Figure 2. Geometry of the proposed PBG ground.

The distance between apertures is a constant, which determines the frequency of PBG structure. The centered frequency f of a gap frequency range is function of structure period and the wavelength in the centered frequency is two times as long as the period d. So f is given by

$$f = \frac{c}{2d\sqrt{\varepsilon_e}} \tag{1}$$

where c is the speed of light, d is structure period and ε_e is relative permittivity.

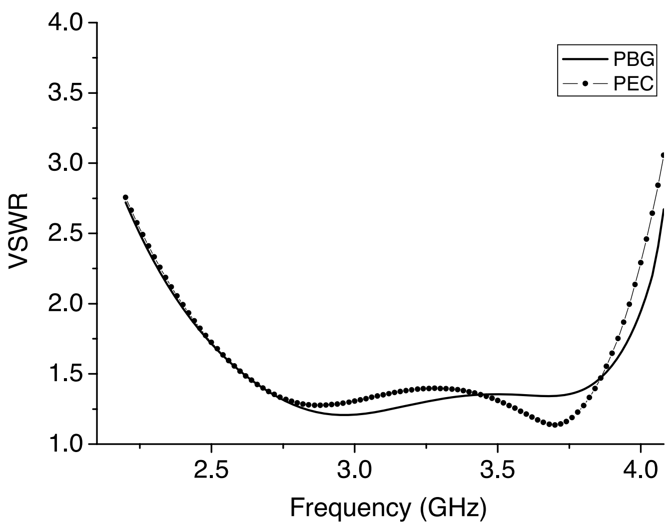


Figure 3. Measured VSWR for the proposed antenna.

3. EXPERIMENT RESULTS

Figure 3 gives the a comparative investigation for the microstrip printed dipole antenna above an ideal PEC surface and a realistic metallic PBG surface of which both size are 200 mm × 45 mm. Used for high impedance ground plane, upper limit frequency (4.5 GHz) is used as the centered frequency of PBG. According to the formula (1) d can be achieved. b can be obtained from formula (2)

$$b = d/2 \tag{2}$$

and

$$a = br \tag{3}$$

Here $r \in (0, 1)$, and r is equal to 0.2 on this paper.

It is clearly seen that the VSWR for the proposed antenna basically keeps unchanging and meets the requirement of broadband design, which is that VSWR is below 1.5 across the frequency range (2.5–4.0 GHz).

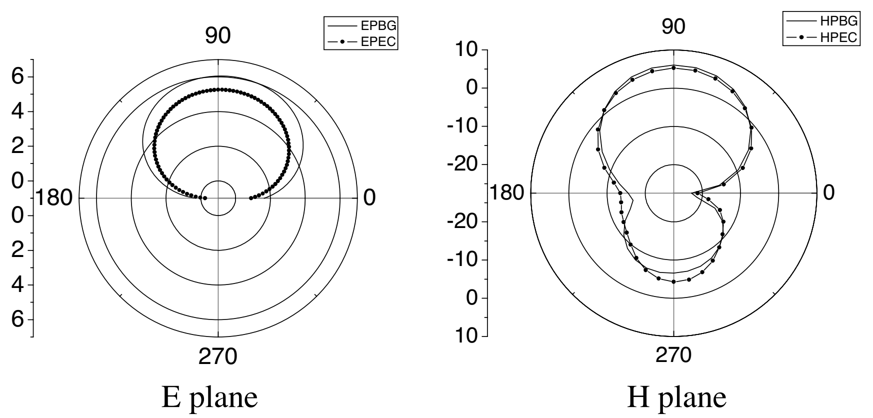


Figure 4. Measured radiation patterns for PBG and PEC.

Radiation characteristics of the antenna at operating frequencies within the impedance bandwidth obtained have also been studied. Figure 4 plots the measured radiation patterns in the E plane and H plane for the microstrip printed dipole antenna above an ideal PEC surface and a realistic metallic PBG surface. Results show that the proposed antenna above a realistic metallic PBG surface has a peak antenna gain of about 6.06 dB comparing with 5.27 dB above ideal PEC surface. The results show that PBG surface gives a good gain.

To validate the analysis presented, RCS calculations over a frequency band (2–5 GHz) are done by Fast Multipole Method. Figure 5 shows the result of RCS calculation when a plane wave with θ polarization is incident on the proposed antenna at the angle $(\theta = 60°,\ \varphi = 45°)$.

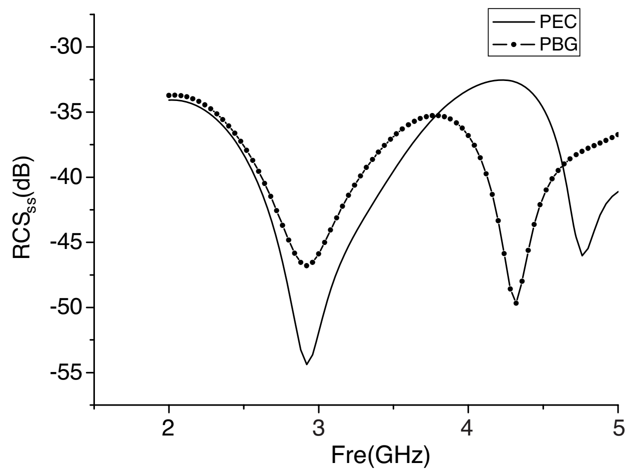


Figure 5. Comparison of monostatic RCS between PBG and PEC.

The results show that PBG ground plane can reduce RCS from 3.7 GHz to 4.5 GHz. Because the high surface impedance on the upper frequency restrains the surface waves, RCS at the resonating point(4.2 GHz) is reduced by 15 dB. But the monostatic RCS at the frequency range from 3 GHz to 3.7 GHz is increased, of which reason is that the PBG ground plane having the Structure of the cycle ring-shaped aperture is not a continuous surface and leads to increase edge diffraction [16]. Though the centered frequency of PBG is chosen, the frequency range needed reducing RCS is determined because of suppression of the surface waves.

4. CONCLUSION

A novel design of a printed dipole antenna using PBG structures is proposed. The discipline of RCS reduction is discovered. With the results, the centered frequency of reduction can be chosen according to requirement and consequent of reduction is obvious. Moreover, radiation characteristics of the antenna above a realistic metallic PBG surface are better than above an ideal PEC surface. The work is useful for the study of antenna RCS and RCS reduction.

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