A Broadband CPW-Fed Loop Slot Antenna With Harmonic Control

Xian-Chang Lin and Ling-Teng Wang

***Abstract*—In this letter, photonic bandgap (PBG) structures with cross-shaped or square-shaped lattices have been incorporated into the feed network for harmonic suppression. Experimental results show that PBG structures not only exhibit well-behaved bandstop characteristics, but also enhance the bandwidth of the proposed antennas. For the proposed antenna with square-shaped lattices, the 10-dB return loss bandwidth could reach 1541 MHz (1525∼3066 MHz), which is about 70% with respect to the center frequency of 2200 MHz while, for the antenna with cross-shaped lattices, the bandwidth could reach 1320 MHz (1560∼2880 MHz), which is about 60% with respect to the center frequency of 2200 MHz.**

***Index Terms*—Broadband antenna, CPW-fed loop slot antenna, harmonic suppression, photonic bandgap (PBG).**

I. INTRODUCTION

THE CPW-fed slot antennas have been widely used for wireless applications since they are compatible with monolithic integrated circuits and active solid-state devices. Furthermore, CPW-fed slot antennas exhibit a larger bandwidth with bi-directional radiation patterns [1]. Among the recent researches, a CPW-fed loop slot antenna with a tuning stub to enhance the bandwidth has been proposed [2]. By adjusting the location of a widened tuning stub, good impedance matching can be easily obtained. It is found that the larger the spacing between the ground plane and the widened tuning stub, the wider the fundamental bandwidth. However, bandwidths of higher order modes will increase simultaneously, which may cause a potential problem of the electromagnetic interference and compatibility.

To alleviate this serious symptom of the conventional CPW-fed loop slot antenna, the photonic bandgap (PBG) structure is a promising solution in this regard. PBG structures, originating in the optical regime and scaleable to microwave applications, are renowned for the capability to prohibit the propagation of electromagnetic waves along one or more directions within certain bands of frequencies. PBG structures have been utilized to eliminate the harmonic modes in the microstrip patch antennas successfully [3] due to their appealing low-pass filter characteristics [4]. In [5], the conventional CPW-fed loop slot antenna incorporated with a PBG structure in the feed network has been proposed and the PBG structure

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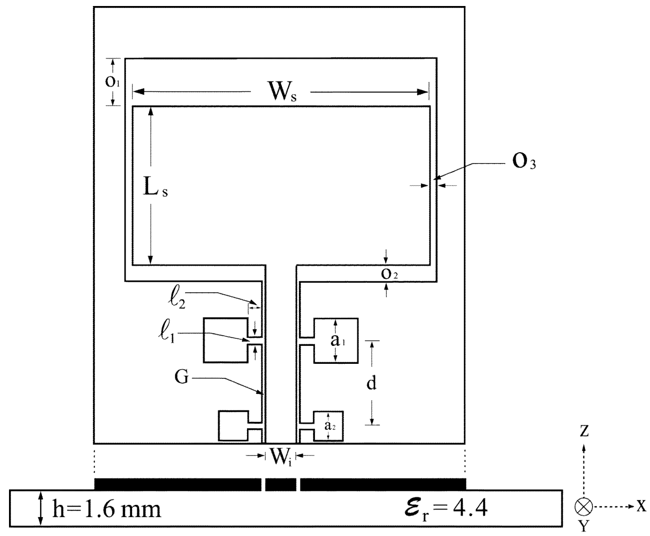


Fig. 1. Geometry of the broadband loop slot antenna with square-shaped lattices.

with square-shaped lattices has demonstrated excellent performances of harmonic suppression and bandwidth enhancement. In this work, the use of PBG structures with different lattice shapes to prohibit harmonic modes and broaden the bandwidth is discussed in detail.

II. ANTENNA DESIGN

In the first design, a CPW-fed loop slot antenna with square-shaped lattices in the feed network has been implemented, as shown in Fig. 1. The proposed antenna is fabricated on an inexpensive FR4 substrate with dielectric constant $\varepsilon_r = 4.4$ and thickness $h = 16.6$ mm. The slot antenna has width (W_S) of 40 mm, length (L_S) of 21.5 mm, and three gap widths of $O_1 = 5.5$ mm, $O_2 = 2$ mm, and $O_3 = 1$ mm. The conventional CPW-fed line is designed with the strip width (W_i) of 4 mm and the gap width (G) of 0.4 mm, corresponding to the characteristic impedance of 50 Ω.

In Fig. 1, the PBG structure with square-shaped lattices is etched on both sides of the ground plane along the feed line. Each lattice is composed of a narrow transverse slot and a square hole. Each narrow transverse slot has the dimension of $\ell_1 \times \ell_2$ $(1 \times 2\ \mathrm{mm}^2)$, but square holes have two different dimensions, which are the large square with $a_1 = 5.5$ mm and the small square with $a_2 = 4$ mm. Moreover, the distance (d) between two squares is chosen as 12.25 mm.

In the second design, the geometry of the proposed antenna is shown in Fig. 2 and the parameters of the antenna are identical to the previous design except $O_1 = 4$ mm. Moreover, a PBG

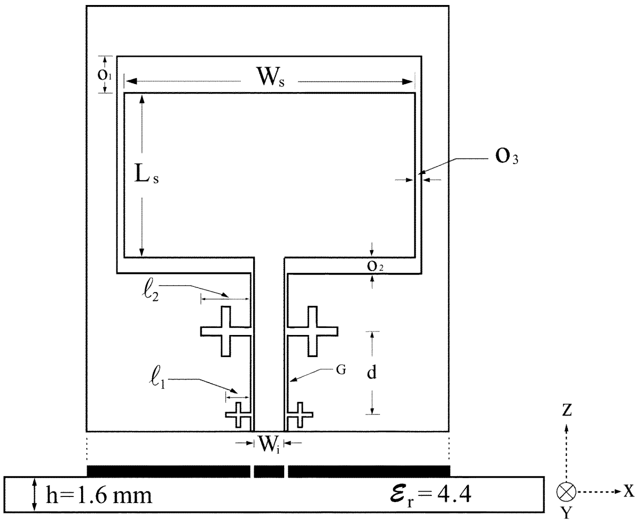


Fig. 2. Geometry of the broadband loop slot antenna with cross-shaped lattices.

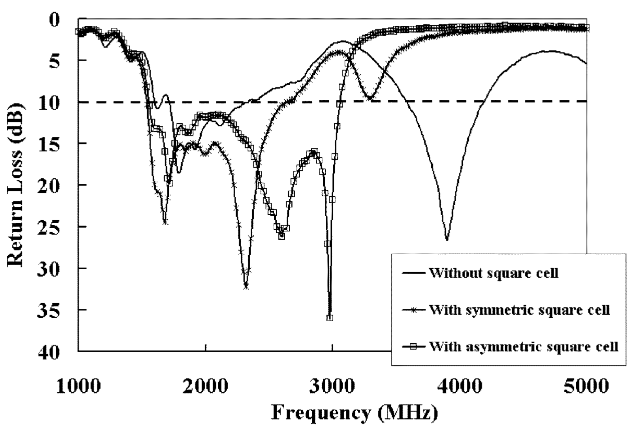
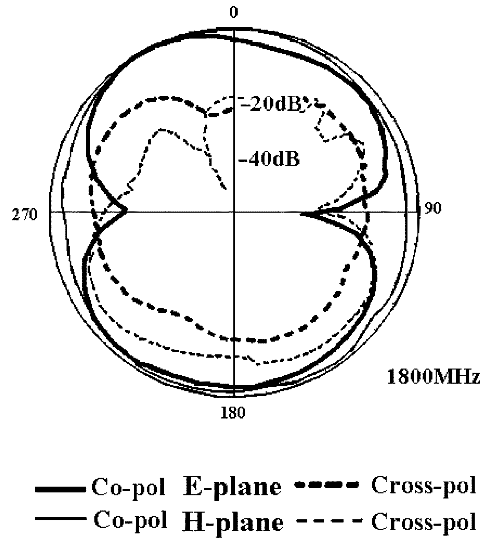


Fig. 3. Measured return losses of the broadband loop slot antenna with square-shaped lattices.

structure with cross-shaped lattices has also been exploited to suppress harmonic modes with two different lattice dimensions, which are $\ell_2 \times \ell_2$ $(7 \times 7\ \mathrm{mm}^2)$ and $\ell_1 \times \ell_1$ $(3 \times 3\ \mathrm{mm}^2)$ respectively, and the distance (d) between two lattices has been chosen as 11 mm. It can be found that proposed PBG structures in this letter are much compact than previous designs [4], [6] since the distance between two lattices is less than half guided wavelength, facilitating the integration of the antenna into the ground plane with limited space.

III. Experimental Results

The center frequency of the original antenna without PBG structures has been designed around 2200 MHz. Although the bandwidth of the original antenna reaches almost 720 MHz, that of the first higher order mode with a deteriorated radiation pattern also reaches 600 MHz, as shown in Fig. 3. In order to suppress the higher order mode, the PBG structure with cut-off frequency around 3200 MHz has been incorporated into the feed network. It is found that the symmetric PBG structure $(a_1 = a_2 = 4\ \mathrm{mm})$ demonstrates inadequate stopband rejection, leading to imperfect elimination of the higher order mode.



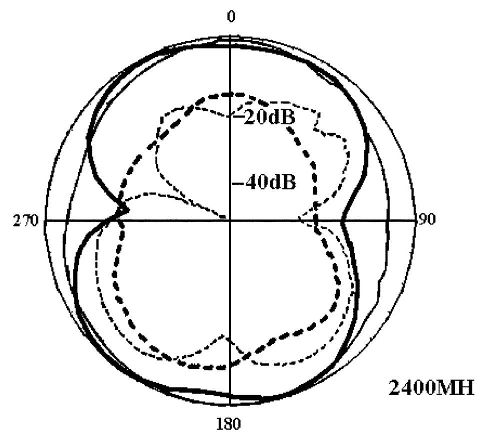


Fig. 4. Measured radiation patterns of the proposed antenna with square-shaped lattices at 1800 and 2400 MHz.

To further enhance the stopband rejection, the square (a_1) has been enlarged to 5.5 mm. As indicated in Fig. 3, this asymmetric PBG structure not only forbids the first higher order mode successfully, but also enhances the bandwidth simultaneously. The 10 dB return loss bandwidth of the proposed antenna could reach 1541 MHz (1525~3066 MHz), which is about 70% with respect to the center frequency of 2200 MHz.

Fig. 4 shows the measured radiation patterns in two principal planes at $f = 1800$ Mhz and $f = 24\,800$ Mhz. It is noted that the radiation patterns are nearly omnidirectional in H-plane, and the maximum gain of the proposed antenna is 4.6 dB at $f = 2200$ Mhz. However, the radiation patterns in two principal planes will deteriorate in the broadside direction $(\theta = 0^\circ)$ when $f \geq 2800$ Mhz.

In the second design, the PBG structure with cross-shaped lattices has been exploited to suppress the first higher order mode and it can be found that, with the presence of the asymmetric PBG structure, the antenna shows well-behaved harmonic suppression characteristic since it possesses a deeper stopband rejection than does the symmetric counterpart. On the other hand, the 10-dB return loss bandwidth of the second design can reach 1320 MHz (1560~2880 MHz), which is about 60% with respect to the central frequency of 2200 MHz, as shown in Fig. 5.

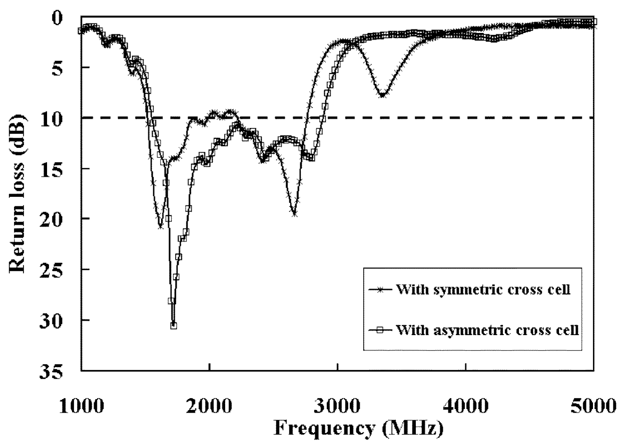


Fig. 5. Measured return losses of the broadband loop slot antenna with cross-shaped lattices.

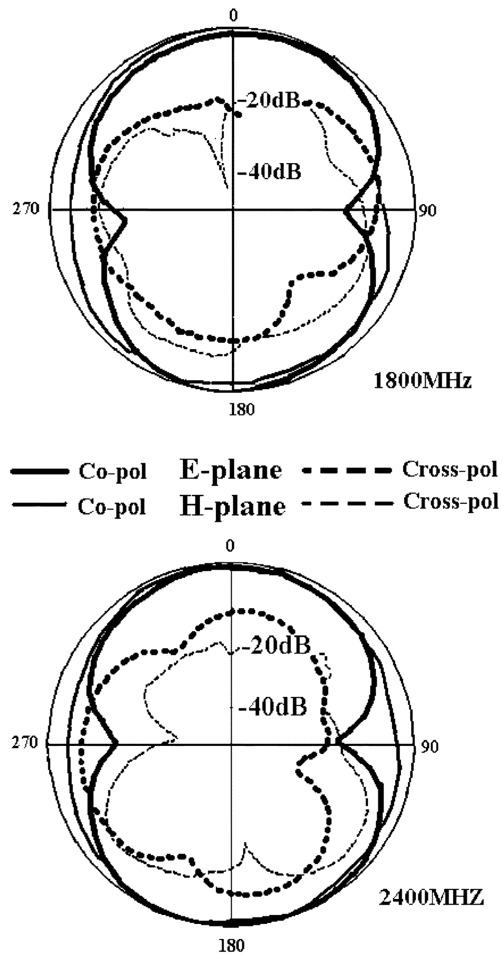


Fig. 6. Measured radiation patterns of the proposed antenna with cross- shaped lattices at 1800 and 2400 MHz.

Fig. 6 shows the measured radiation patterns in two principal planes at $f = 1800$ Mhz and $f = 2400$ Mhz. The co-polarization radiations in H-plane also are nearly omni-directional and the maximum gain of the proposed antenna is 3 dB_i at $f = 2200$ Mhz. However, cross-polarization radiations in two principal planes will deteriorate when $f \geq 2600$ Mhz.

It should be noted that a traditional CPW-fed loop slot antenna shows a large cross-polarization level, attributed to the radiations from two slots parallel to the CPW-fed line in the loop slot. Furthermore, the cross-polarization will deteriorate as the lengths of parallel slots increase. This shortcoming can be vanquished by patch-shielded design [7]. This technique retains the copolarization level but significantly lower the cross-polarization level at the expense of drastic bandwidth reduction. The large size of the shielding patch, the lower level of the cross polarization, indicating that with a moderate size of shielding patch the lower level of cross polarization and the sufficient bandwidth could be attained simultaneously. However, it appears to be unfeasible to lower the cross-polarization level significantly in this work because of the inadequate size of the shielding patch. How to lower the cross-polarization level without the expense of bandwidth reduction needs a further investigation.

IV. Conclusion

In this work, a broadband CPW-fed loop slot antenna incorporated with the PBG structure of diverse lattice shapes in the feed network has been investigated and implemented experimentally. The compact PBG structures not only successfully get rid of the higher order modes but also facilitate the impedance matching of the antennas, leading to significant bandwidth augmentation. The experimental results show that bandwidths of the proposed antennas with different lattice shapes are 1541 MHz (70%) and 1320 MHz (60%), respectively.

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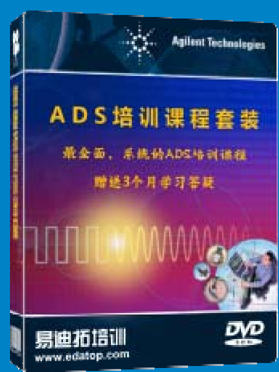

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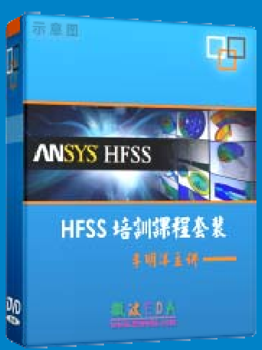

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