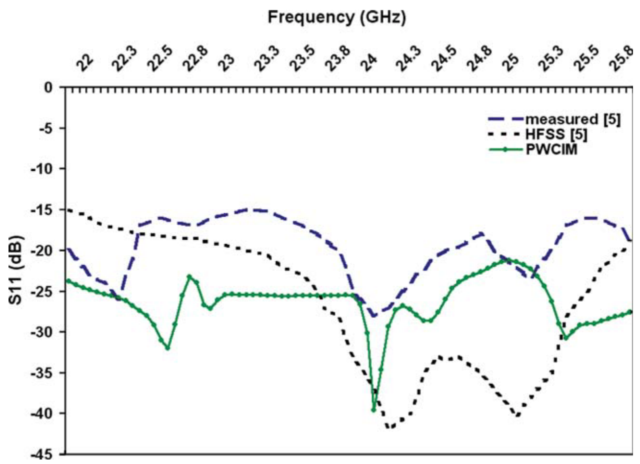

Figure 9 Reflection coefficient of the power divider against frequency. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

4. CONCLUSION

An iterative algorithm based on the iterative wave process has been presented for the modeling of guided-wave properties of the SIW structures. This method presents an efficient and accurate approach to the analysis of large guided-wave structures. The formulation enjoys the merits of CPU time and memory saving. Simulation results have validated the proposed numerical modeling scheme.

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COMPACT HYBRID CPW-FED SLOT ANTENNA ARRAY WITH PATTERN DIVERSITY

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ABSTRACT: *In this paper, a compact hybrid coplanar waveguide (CPW) fed 1 × 2 slot antenna array with radiation pattern diversity is proposed for the wireless local area networks (WLAN) application. The antenna array consists of two rectangular slot radiation elements, two feed slots, a CPW and an open-ended strip. The feed network provides out-phase and in-phase feed with high isolation in a relatively compact structure without any lossy circuits, and difference and sum radiation patterns are achieved in the azimuth plane with wide bandwidths of 480 MHz (20%) and 580 MHz (24.2%). The measured gains of dual-pattern are better than 4.93 and 3.76 dBi in the WLAN band (2.4–2.484 GHz). The proposed dual-port array can be used as pattern diversity in modern mobile system.* © 2011 Wiley Periodicals, Inc. Microwave Opt Technol Lett 53:884–888, 2011; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.25879

Key words: *pattern diversity; compact feed; difference and sum radiation patterns*

1. INTRODUCTION

In the modern wireless communication systems, the antennas with pattern diversity are widely adopted for their advantages in mitigating the multipath fading and increasing the channel capacity [1, 2]. By appropriately processing the receiving signals, the performance of the system can be enhanced even in the interference impaired environments. In recent articles [3–7], several design strategies of the antennas with pattern diversity have been studied. One of the effective methods is the pattern reconfigurable antenna [3, 4]. By controlling the operational states of switches, such as PIN diodes and radio frequency microelectronic mechanical systems (RF MEMS), the structure of antenna element [3] or the configuration of antenna array [4] were changed, providing different radiation patterns. As described in [5], a meandered monopole and a pair of inverted-L antennas with differential fed are designed for pattern diversity with sufficient isolation. In a study by Yang et al. [6], the conical and broadside radiation patterns of a single patch antenna are excited by two different sets of L-shaped probes. More sophisticated feed network proposed in [7] is a 4 × 4 Hadamard matrix feed network for switched radiation patterns of antenna array. The direction of the main lobe can be controlled by input ports. However, the insertion loss and parasitic parameters of RF switches implemented in [3, 4] must be considered in the design. In addition, dual antennas [5] and feed network [6, 7] are not compact and occupy more space. It is difficult to achieve good performance in a space-limited situation. Therefore, the antenna performance can be improved with a simple and compact feed structure without other lossy circuits.

This article presents a 1 × 2 slot antenna array with a compact hybrid CPW feed structure providing pattern diversity for wireless local area networks (WLAN) application. Slot antenna elements are chosen for their intrinsic wide bandwidth. CPW is adopted to provide out-phase and in-phase feed modes with high isolation [8, 9], which is more compact than the design in [6, 7]. Difference and sum radiation patterns are achieved in azimuth plane as pattern diversity, showing an extension of the slot array performed in Ref. [10]. A prototype of proposed array is fabricated and tested. The simulations and experimental results of the reflection coefficient and radiation patterns agree well, and the gains of both patterns are also measured and discussed.

2. ANTENNA CONFIGURATION AND DESIGN

Figure 1 shows the geometry of the proposed 1 × 2 slot antenna array with its compact CPW-slot hybrid feed structure. Two $L_s \times W_s$ slots are etched into the front copper plane, supported by 1-mm thick FR4 ($\varepsilon_r = 4.4$, tan $\delta = 0.01$). There is no ground plane or cavity in the back side. The feed network consists of a CPW in the front side and an open-ended strip in the back side. The gaps between the inner and outer conductor of CPW are used to feed the slot elements. The length of each slot element

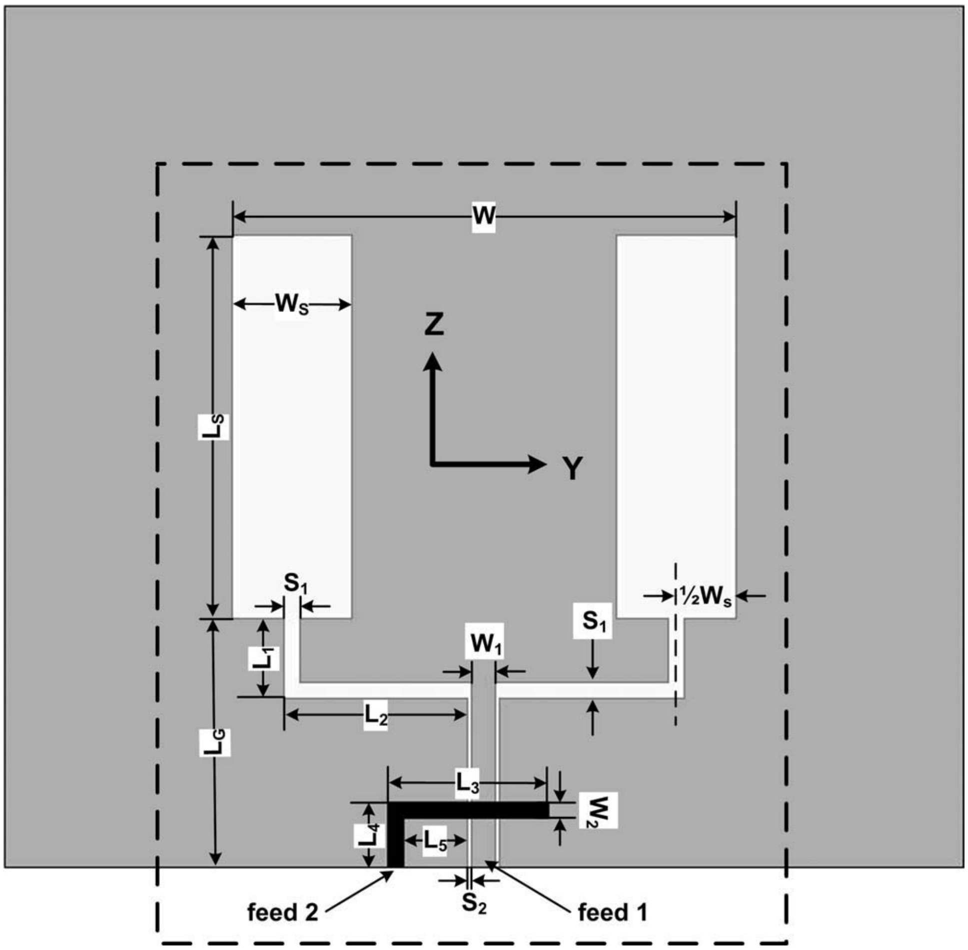

Figure 1 Geometry of the proposed antenna array

is approximately half of the resonant wavelength (λ) at working frequency (f_0), determined by Eq. (1).

$$L_s = \frac{\lambda}{2} = \frac{c}{2f_0 \cdot \sqrt{\varepsilon_{\text{eff}}}} \tag{1}$$

where c is the velocity of light in free space. The distance between the two slot centers is approximately half of the resonant wavelength ($\lambda/2$). Slot radiation property is discussed in the preliminary study [8] and the copper plane size is 107.5×120 mm^2, which is determined by project demands. The total dimensions of the proposed array are 79×63 mm^2.

To realize pattern diversity, out-phase and in-phase excitations are required in the feed network. CPW can support two such modes with high isolation. The working configurations of the two modes are listed in Table 1. When feeding from the Port 1, the out-phase electric field in CPW is excited, as shown in Figure 2(a). Far field radiations of the two slots are cancelled in the broadside, displaying a difference radiation pattern. As illustrated in Figure 2(b), the open-ended strip is capacitively coupled to the CPW, and the in-phase electrical field in CPW is excited by feeding through Port 2. Therefore, a sum radiation pattern is realized in broadside.

The values of each parameter in Figure 1 are optimized by using Ansoft high-frequency structure simulator. For Mode 1, the length and width of the feed slots ($L_1 + L_2$, S_1), and the gap between the inner and outer conductor of CPW (S_2) are tuning parameters to achieve a good match. The characteristic impedance of CPW is set to 50 Ω by tuning S_2. The feed slot provides impedance transition from the radiation slot to the gap between the inner and outer conductor of CPW, realized by optimizing the values of $L_1 + L_2$ and S_1. For Mode 2, the characteristic impedance of the open-ended strip is also set to 50 Ω by tuning W_2. The offset part of the open-ended strip, whose length is L_3–L_5, serves as a shunt capacitance. The impedance matching between the open-ended strip and the slot in two outer conductors of CPW is achieved by tuning L_3. The location parameters L_4 and L_5 are optimized for good isolation between two feed ports. The detailed optimized values of each parameter in Figure 1 are listed in Table 2.

3. FABRICATION AND MEASUREMENTS

A prototype of the proposed antenna array, shown in Figure 3, is fabricated and measured. The measured S parameters for the two ports are shown in Figure 4, compared with simulated data. The reflection coefficients for bandwidths of -10 dB are from 2.20 to 2.68 GHz (20%) and from 2.12 to 2.70 GHz (24.2%) for Ports 1 and 2, respectively. Both modes cover the WLAN band

TABLE 1 Working Configurations of the Two Modes

Modes	Ports	Feed	Radiation Pattern
1	1	Out-phase	Difference
2	2	In-phase	Sum

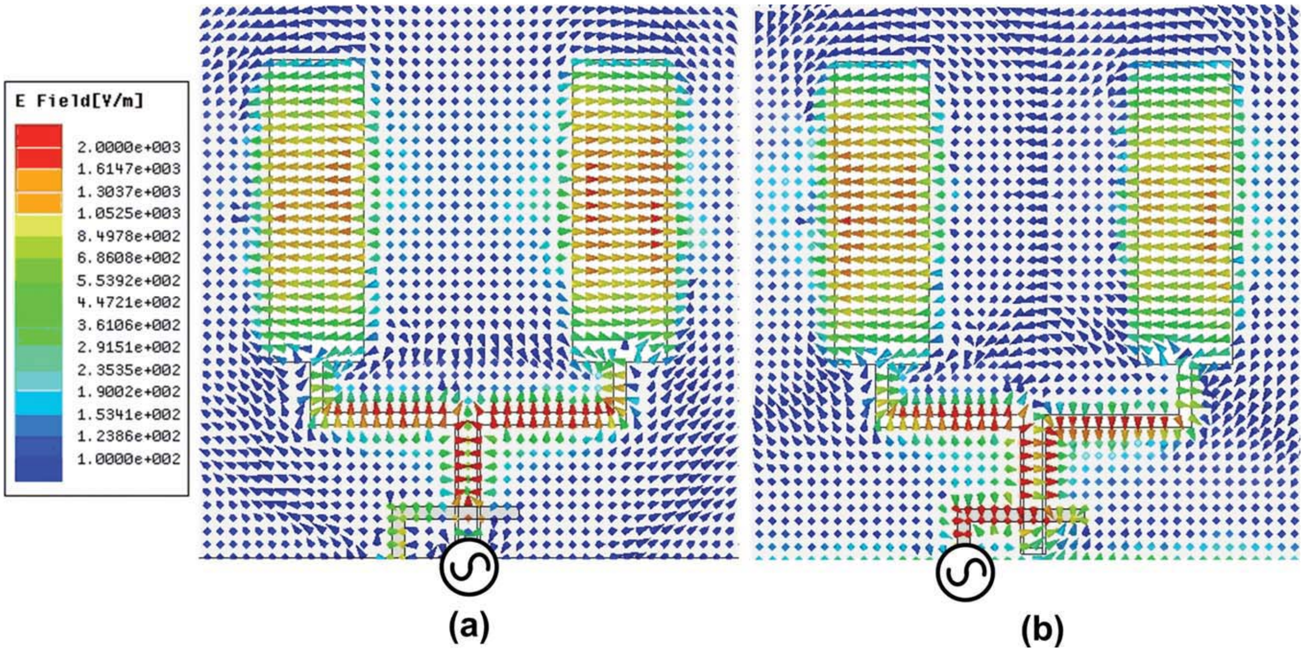

Figure 2 Electric filed distribution in slot: (a) Mode 1 and (b) Mode 2. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

(2.4–2.484 GHz) with a reflection coefficient better than −15.9 dB. The isolation between the two ports is lower than −21 dB in the required band.

TABLE 2 Detailed Dimensions of the Proposed Antenna (unit: mm)

Parameters	L_G	L_S	L_1	L_2	L_3	L_4	L_5
Values	31	48	10	25	20	8	10
Parameters	W	W_S	S_1	S_2	W_1	W_2	
Values	63	15	2	0.5	3	2	

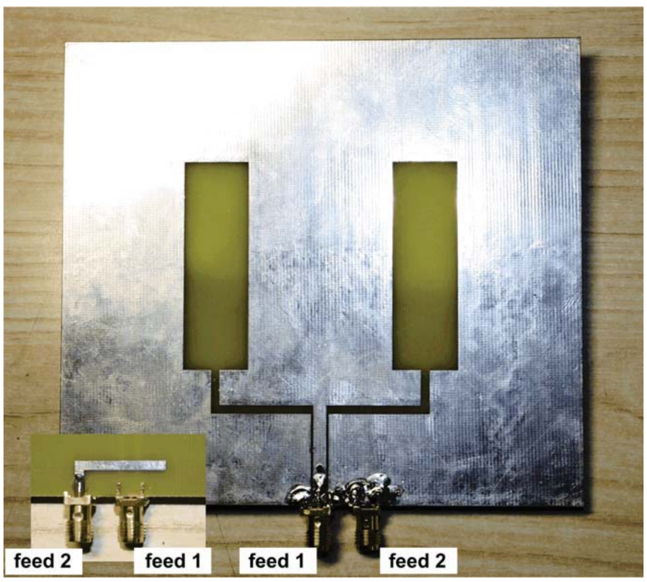

Figure 3 Prototype of the proposed array. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

The simulated and measured normalized radiation patterns of the proposed antenna for both modes at 2.4 GHz in the azimuth plane (X–Y plane) are shown in Figure 5 and agree well. The difference radiation pattern for Mode 1 is illustrated in Figure 5(a). Maximum gain is achieved at the directions of 35°, 145°, 215°, and 320°, and null depth in broadside is better than −10 dB. Cross polarization is introduced by the radiation from the horizontal part of the feed slots. Figure 5(b) shows the sum radiation pattern for Mode 2. Bidirectional main lobes are achieved on the Y and $-Y$ axis, where there are nulls in the difference radiation pattern. From these results, the radiation patterns can be excited by the two modes simultaneously, mitigating the multipath fading in the environment and increasing channel capability.

The simulated and measured gains of the prototype slot array are shown in Figure 6. In the WLAN band of 2.4–2.484 GHz,

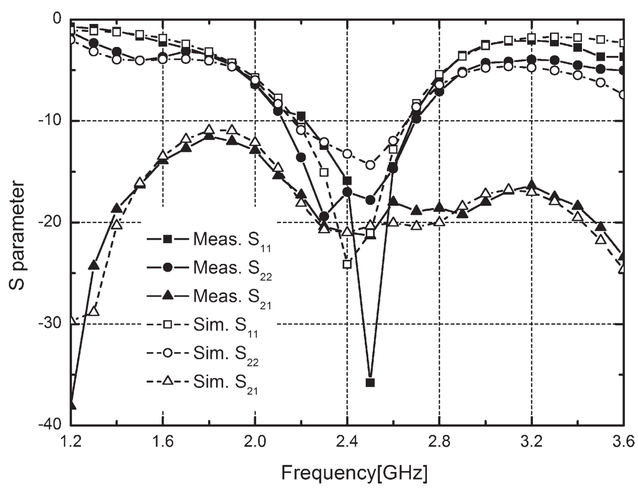

Figure 4 Simulated and measured S parameters of the proposed antenna

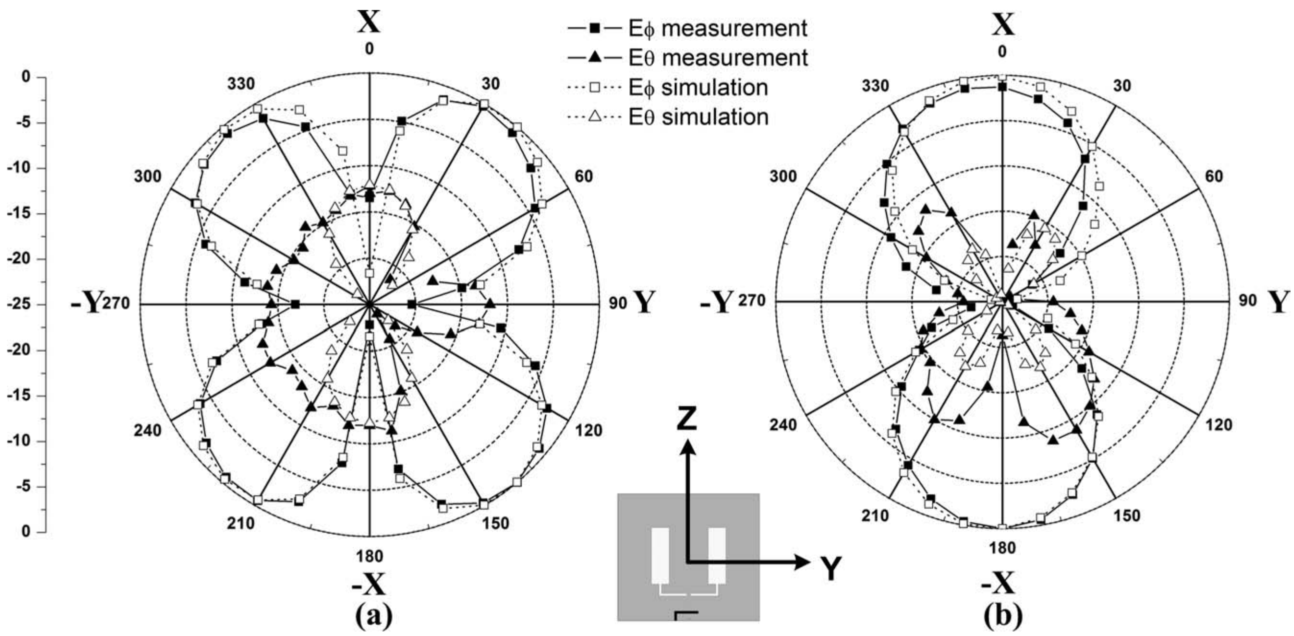

Figure 5 Simulated and measured radiation patterns in the X–Y plane at 2.4 GHz: (a) Mode 1 (b) Mode 2

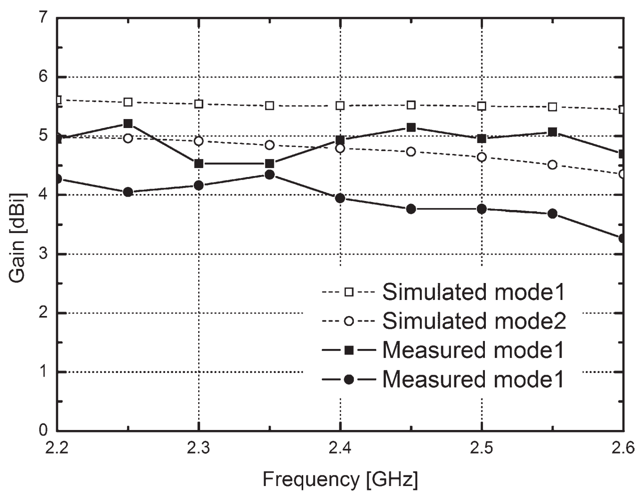

Figure 6 Simulated and measured gain of the proposed array

the measured gain is better than 4.93 and 3.76 dBi in the main beam direction for the difference radiation pattern and the sum radiation pattern. In comparison with simulation, the average losses are 0.7 and 0.9 dB for two modes in the desired band, which are mainly determined by the radiation efficiency of the proposed array.

4. CONCLUSION

In this article, we proposed a slot antenna array with a compact hybrid CPW feed structure with pattern diversity for WLAN application. To excite out-phase and in-phase electric filed in slot elements, a CPW with capacitively coupled strip without extra lossy circuits has been designed, which is more compact than reference designs. Difference and sum radiation patterns are achieved for pattern diversity. A prototype of the proposed array was built and tested. The −10 dB bandwidths of the two patterns are 480 MHz (20%) and 580 MHz (24.2%), with the isolation better than −21 dB in the WLAN band. The measured radiation patterns agree well with the simulation ones. The measured gain is better than 4.93 and 3.76 dBi. Potential application of this bidirectional reconfigurable pattern array is as an access point for WLAN application.

ACKNOWLEDGMENTS

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DUAL-BAND BANDPASS FILTER WITH TUNABLE UPPER PASSBAND

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ABSTRACT: *A microstrip dual-band bandpass filter is developed in this article. Using a pair of square open-loops coupled with a symmetric ladder-shaped resonator, frequencies of this filter are operated at 1.57 and 2.45 GHz. The lower resonance frequency is decided by the length of the square resonators, and the higher one is done by the ladder-shaped resonator. Therefore, both frequency and bandwidth of the upper passband can be controlled flexibly, whereas those of the lower band are fixed. Finally, a filter is fabricated based on the design topology. Measured results have shown very good performance of the filter.* © 2011 Wiley Periodicals, Inc. Microwave Opt Technol Lett 53:888–890, 2011; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.25866

Key words: *bandpass filter; dual-band; ladder shaped resonator; open-loop resonator*

1. INTRODUCTION

Recently, with development of global positioning system and wireless local-area network, systems demand of radio frequency circuits with a dual-band operation. Dual-band bandpass filters (BPFs), as one the most important circuit blocks in these systems, have become more and more attractive. In general, two filters with different passbands connected together can implement the initial type of a dual-band filter. The center frequencies and bandwidths have been obtained to meet performance requirements of two passbands [1]. But this solution increases the insertion loss and the overall size of a resultant filter block. The stepped-impedance resonators were used to make up filters with dual passbands [2–4]. Central frequencies are determined by the aspect ratio of the two characteristic impedances. However, poor insertion loss in these two passbands is introduced because of the large discontinues appearing in the configuration of stepped-impedance resonator. More recently, stub-loaded resonators were applied to constructing dual-band response [5–7]. By regulating the length of the loaded stub, the central frequency of its upper passband can be tuned without affecting the central frequency of the lower passband. Nevertheless, it is not convenient for these filters to meet specific bandwidth requirement. So far, a good performance dual-band BPF design is still a challenge to circuit designers.

In this article, a dual-band BPF with tunable upper passband is developed. A symmetric ladder-shaped resonator is embedded in a pair of square open-loop resonators to obtain the desired frequencies' operation. The upper passband central frequency and bandwidth can be adjusted by changing the length and width of ladder-shaped resonator. Three transmission zeros can be created close to passband edges, good selectivity of the filter is obtained. The frequency of proposed filter can be operated at 1.57 and 2.45 GHz. Simulated and measured results demonstrate better performance of the new design.

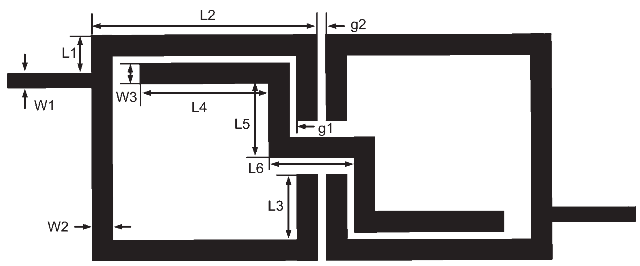

Figure 1 Schematic representation of the proposed dual-band BPF, which consists of a pair of square open-loop coupled with a symmetric ladder-shaped resonator

2. DUAL-BAND BPF DESIGN

The scheme of dual-band BPF is shown in Figure 1. A pair of square open-loop resonators is with electric coupling structure. A half-wavelength in electric size, as the main structure, can be generated with the lower passband with center frequency 1.57 GHz. As the substructure, a symmetric ladder-shaped resonator with a half-wavelength is embedded in the main structure, yields for the upper passband at 2.45 GHz.

To validate above, the BPF is simulated by using HFSS software [8]. A Taconic RF60 dielectric substrate is chosen as main material solution. The substrate parameters are with relative dielectric constant $\varepsilon_r = 6.15$, thickness $d = 0.64$ mm, and a loss tangent $\delta = 0.0028$. Two 50 Ω lines are taped to the open-loop resonators, acting as input and output ports. Meanwhile, the ladder shaped resonator is fed by the two square resonators. Therefore, two passbands are provided without increasing the main size of the resonators.

The upper passband frequency is mainly determined by the entire length of the ladder shaped resonator, which is defined as L. From Figure 1, we have

$$L = 2 \times L4 + 2 \times L5 + L6 + W3. \quad (1)$$

The size of L will be changed simultaneously when we change $L4$. Hence, the upper passband of the BPF can be tunable. Figure 2 illustrates the frequency responses obtained by changing

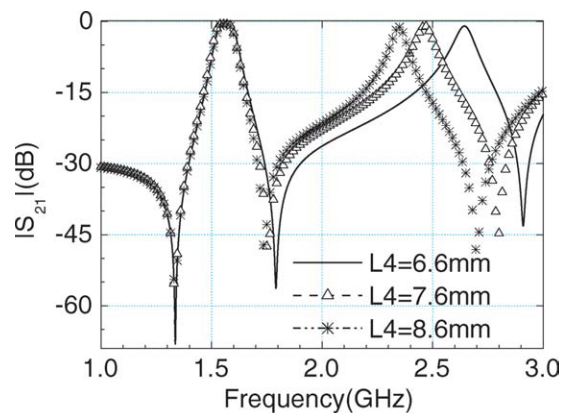

Figure 2 Frequency responses of the proposed dual-band BPF with different $L4$. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]