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Wide-Band Patch Antenna Array with Low Cross-Polarization Characteristics

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Abstract—In this letter, a two-element wide-band patch antenna array with low cross-polarization is presented. The patch is excited by a magnetic-coupled loop. The two elements are placed symmetrically about the center of the array. Compared to the conventional feeding structure, the proposed feeding structure has the advantages of simple structure and much lower cross polarization. Parametric studies show the usefulness of the proposed feeding structure. Prototypes for the element and array have been fabricated and tested. The antenna array can achieve an impedance of 29.1% for VSWR < 2 and a stable gain around 11.2 dBi. Unidirectional radiation patterns with low cross polarization less than -18 dB within the 3-dB beamwidths are obtained. The height of antenna is about 0.12λ (where λ is the free-space wavelength referring to the center frequency of the working band). Moreover, the proposed antenna is dc grounded, which is suitable for outdoor base station applications.

1. INTRODUCTION

Microstrip patch antennas are currently widely used in modern wireless communication systems, due to their merits such as low profile, lightweight and ease of manufacture. However, conventional patch antennas have major disadvantages of limited bandwidth [1]. Many wide-band techniques have been proposed to tackle the narrow bandwidth problem, including slot loading, using L-shaped probe feed, aperture coupled feed, or adding air layers between the patch and the ground.

One way to improve the patch antenna bandwidth is to cut slot in the radiating patch, such as U-slot [2, 3], V-slot [4] and E-shaped patch antennas [5]. Another type of wide-band single patch antenna uses a modified probe feed structure, and a wide-band L-shaped probe-fed patch antenna is proposed in [6]. Often, the asymmetry of the patch and feed structure leads to additional cross polarization. A design of an aperture-coupled microstrip antenna array was discussed in [7]. A wide-band dual-polarized antenna which is electrically fed and magnetically fed is presented in [8]. Other wide-band patch antennas as V-shaped patch and folded V-shaped patch are proposed and investigated in [9, 10].

In this letter, a wide-band two-element patch antenna array with low cross-polarization is proposed and investigated. In the proposed design, the two elements are placed symmetrically about the center of the array. A new feeding structure of array is adopted for achieving the purpose of suppressing the cross-polarization. Measured results are given, showing that the prototypes with single element exhibit an impedance bandwidth of 37.4% for VSWR < 2 from 1.74 to 2.54 GHz, while the two-element antenna array can achieve a bandwidth of 29.1% from 1.7–2.28 GHz for VSWR < 2 and a peak gain of 11.7 dBi.

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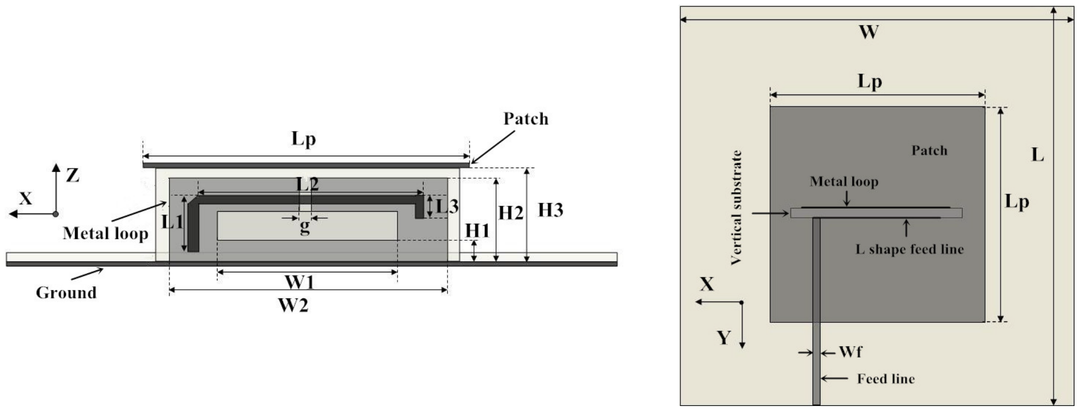
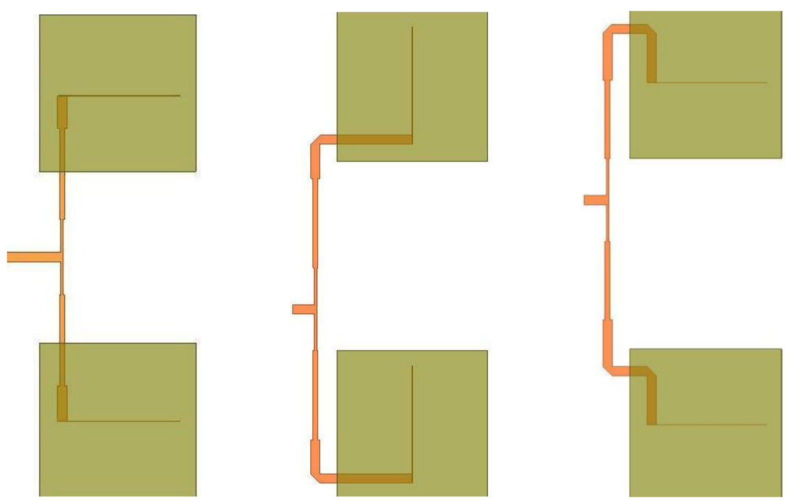


(a) (b)

Figure 1. The structure and detailed dimensions of the antenna element. (a) Side view. (b) Top view.



(a) (b) (c)

Figure 2. Various feed structure design of the array antenna. (a) Ant. 1 (proposed), (b) Ant. 2, (c) Ant. 3.

2. ANTENNA DESIGN AND DISCUSSION

The configuration of the proposed patch antenna element is shown in Fig. 1. The radiating patch embedded with two via holes is supported by two dielectric posts with a distance of 0.12λ above the ground plane. The feed structure is composed of a magnetically-coupled loop printed on one side of a vertical FR4 substrate and an open-ended L-shape transmission line printed on the other side. The dielectric substrate is with a dielectric constant of 3.38, loss tangent of 0.0037 and thickness of 1.6 mm, and the substrate is placed on the top surface of the ground plane. The microstrip feed line with a width of $Wf = 3.6\,\text{mm}$ is printed on the upper layer of the substrate. One end of the feed line is directly connected to the L-shape transmission line, and the other end of the feed line is connected to a 50 ohm SMA connector. This geometry is convenient for the deployment of the feed network of the antenna array, which will be addressed later. The final dimensions of the key parameters can be chosen as: $W = 133\,\text{mm}$, $L = 163\,\text{mm}$, $Lp = 62\,\text{mm}$, $L1 = 10\,\text{mm}$, $L2 = 45.5\,\text{mm}$, $L3 = 5\,\text{mm}$, $W1 = 35$, $W2 = 55\,\text{mm}$, $H1 = 4.2\,\text{mm}$, $H2 = 17.2\,\text{mm}$, $H3 = 18.6\,\text{mm}$, $g = 1.5\,\text{mm}$.

A two-element array antenna based on the mentioned element is designed. The element spacing is chosen to be 0.75λ to avoid the overlap between two adjacent elements as well as grating lobes. The

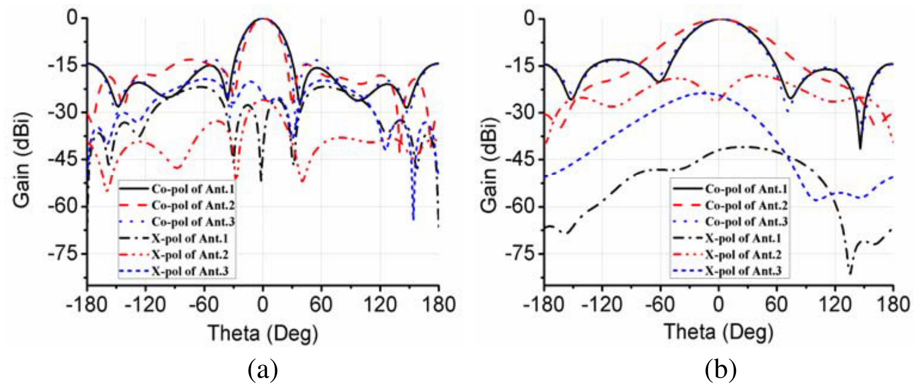


Figure 3. Radiation patterns of various antenna designs. (a) xz-plane at 2 GHz. (b) yz-plane at 2 GHz.

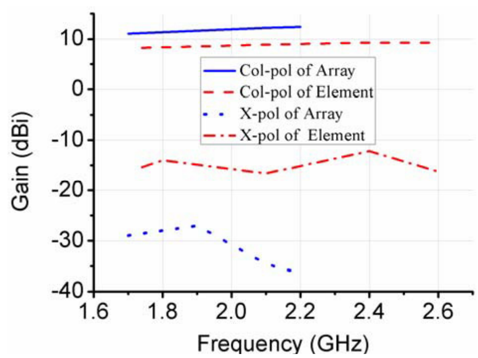


Figure 4. The co-polarization and cross polarization at the broadside direction in the E-plane of the array and element.

feeding network is printed on the top layer of the substrate. The overall size of the array antenna is $120 \times 345\,\text{mm}^2$.

In the proposed design, instead of using the conventional feeding structure that feeds at the same sides as illustrated in Fig. 2(b) and Fig. 2(c), we adopt the feeding structure shown in Fig. 2(a) (Ant.1). In this new structure, the magnetically-coupled loop and L-shaped transmission line are on the outer side and inner side of the vertical substrate, respectively. The co-polarization (Co-pol) is excited in phase, and the cross polarization (X-pol) is excited out of phase. Fig. 3 illustrates the radiation patterns of the three antennas at 2 GHz. It is seen that the cross polarization in yz-plane of Ant. 1 is much lower than that in Ant. 2 and Ant. 3. The cross polarizations of the three antennas are summarized in Table 1. It is shown that the cross polarization can be suppressed effectively when using the proposed feeding structuring. Fig. 4 shows the co-polarization and cross polarization at the broadside direction in the

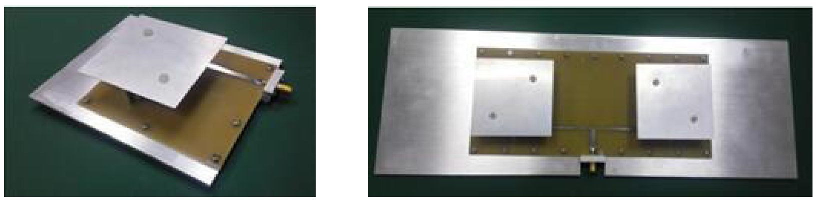
Table 1. Comparison of various antenna designs.

Antenna	X-pol (dB)			
	Broadside direction		Maximum	
	xz-plane	yz-plane	xz-plane	yz-plane
Ant. 1 (Proposed)	−41	−41.9	−21.9	−40.9
Ant. 2	−25.9	−25.9	−25.9	−19
Ant. 3	−24.3	−24.3	−19.3	−23.6

E-plane of the array and element. It is seen that the cross polarization is less than -27 dB and -12 dB for the array and the element over the operating band, respectively, which shows the effectiveness of the proposed feeding structure in reducing the cross polarization.

3. EXPERIMENTAL RESULTS

To demonstrate the validity of the proposed design, prototypes of the single-element and two-element arrays are fabricated and tested. Photographs of the prototypes are shown in Fig. 5. Fig. 6 shows the simulated and measured results of VSWR of the element. The simulated and measured VSWR < 2 bandwidths are 37.4% and 39.2%, respectively. Fig. 7 shows the simulated and measured VSWRs and gains of the array. It is seen that the VSWR < 2 bandwidth is 29.1% with the operating frequency varying from 1.7–2.28 GHz. The antenna gain varies from 10.3 to 11.7 dBi, and a peak gain of 11.7 dBi is achieved at the frequency of 2.2 GHz.



(a) (b)

Figure 5. Photographs of the proposed antennas. (a) Element. (b) Array.

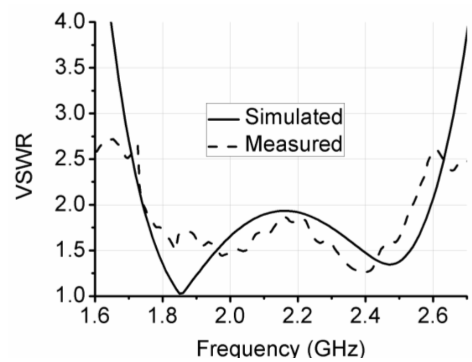
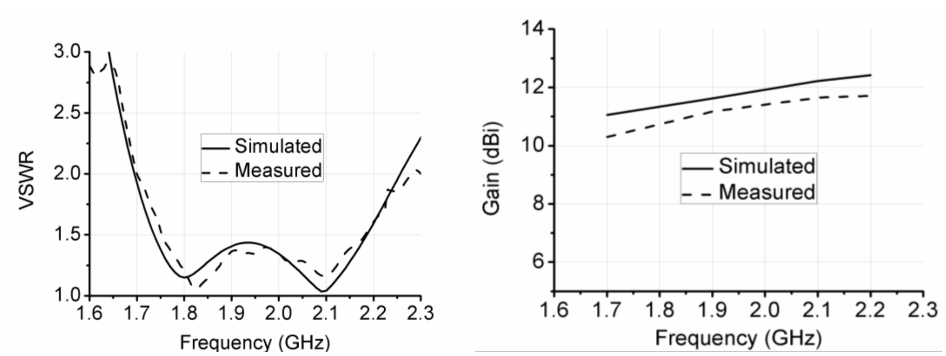


Figure 6. Simulated and measured results of VSWR against frequency of the element.



(a) (b)

Figure 7. Simulated and measured results of the array. (a) VSWR, (b) gain.

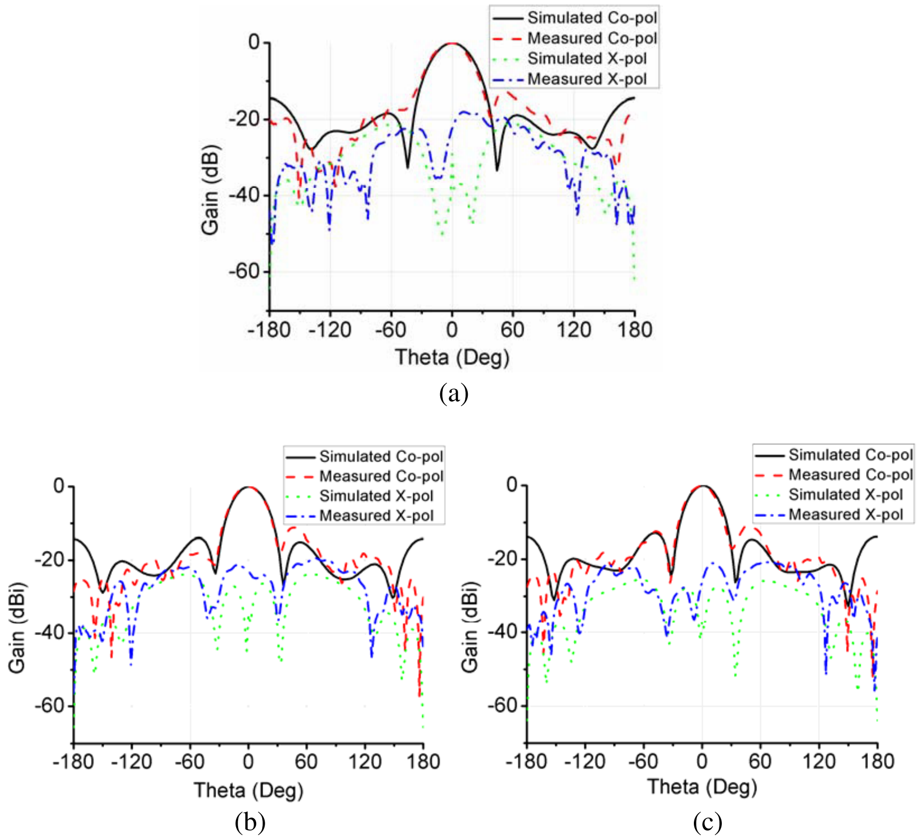


Figure 8. Simulated and measured radiation patterns of the array. (a) E-plane at 1.7 GHz. (b) E-plane at 1.9 GHz. (c) E-plane at 2.2 GHz.

The measured and simulated radiation patterns in the E-plane for the antenna array at the frequencies of 1.7 GHz, 1.9 GHz and 2.2 GHz are illustrated in Fig. 8. It can be seen that the proposed antenna radiates a maximum power towards the broadside direction. Good consistency between the simulated and measured results is attained. The array can achieve a 3-dB beamwidth around 29°, and the cross polarization keeps a low level of below -18 dB in the working frequency band, which is acceptable for general applications.

4. CONCLUSIONS

A wide-band patch antenna array with low cross-polarization has been demonstrated. A new feeding structure of array is adopted for achieving the purpose of suppressing the cross-polarization. Prototypes for the element and array have been manufactured and tested. The measured VSWR < 2 impedance bandwidths for the element and array are 37.4% and 29.1%, respectively. The radiation performance including radiation pattern, gain, cross polarization is satisfactory within the operating band. Moreover, the antenna structure is simple and easy to fabricate, and the array can be easily expanded into a larger array through the array module method.

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