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Wideband Dual-Polarized Dipole Antenna with Differential Feeds

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Abstract—A wideband dual-polarized dipole antenna is presented using the differential feed technique. The proposed antenna consists of two horizontal bow-tie dipoles and four vertically oriented meandering strips. Two pairs of differential-fed L-shaped microstrip feed lines are used to excite the antenna. Due to the differential-fed technique, the cross polarization level can be reduced to $-35\,\mathrm{dB}$. With the introduction of the meandering strips connecting the radiating patch to the ground plane, the height of the antenna is about $0.102\lambda_0$. A parametric study is performed to provide information for designing and optimizing such an antenna. The proposed dipole antenna has been fabricated and measured. The impedance bandwidth of 48.3% ($S_{11} < -10\,\mathrm{dB}$) from 2.57 GHz to 4.21 GHz is achieved. The measured isolation between the feeding ports is better than 30 dB over the operating band. Moreover, the antenna has a compact structure and good unidirectional radiation pattern, making it conveniently integrated with microwave differential circuits and applied in the base station systems.

1. INTRODUCTION

Dual-polarized antennas with wide impedance bandwidth have been frequently used in various wireless base station systems. They can mitigate the multipath fading problem and increase channel capacity by means of polarization diversity [1]. To work effectively, many techniques have been developed to achieve dual-polarized antenna with high isolation and low cross-polarization level [2, 3]. The simple technique is to use dual slot-coupling feedings with multilayer construction [4]. A dual-polarized planar antenna composed of three dielectric substrate layers and one air layer was introduced in [5]. With the use of two H-shaped slots placed in a “T” configuration, the isolation between the two input ports was better than 36 dB, whereas the impedance bandwidth was only 20.9%. Two vertically stacked multilayered Yagi antennas with single and dual polarization were presented in [6], the high gain was obtained by increasing the number of the layers. However, the antennas had a complicated structure and large size. The hybrid feeding is another technique which also been widely used to obtain high isolation. A dual-polarized single microstrip patch antenna was proposed in [7] with hybrid feeding. By using two in-phase aperture-coupled feeds and two out-of-phase gap-coupled probe feeds, a high isolation better than 40 dB were obtained. Whereas it was narrow in bandwidth. A dual-hybrid-feed structure comprising a pair of meandering strips and an annular-ring coupling slot was used in [8] to achieve dual polarization performance. However, the feed network for the proposed antenna was too complicated.

Due to their various advantages including low-noise, high-linearity, and large-dynamic range, differential circuits are popular in microwave circuits [9]. However, most antennas are excited by single feeding port, which make it bulky when integrated with differential circuits. For this, several differential antennas have been proposed for various communication systems [10, 11]. To connect with differential integrated circuits compatibly, a differential wide-slot antenna was presented in [12] for UWB systems.

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For their relatively low cross polarized fields, the differential antennas can also be applied in the base station systems.

In this paper, a wideband dual-polarized dipole antenna comprising of horizontal bow-tie patches and vertically oriented meandering strips is presented for base station applications. The bow-tie patches are used as an electric dipole for their wideband properties. The meandering strips are employed as a magnetic dipole and reduce the profile of the antenna. To improve the isolation level and reduce the cross polarization, the differential-fed technique is introduced. The L-shaped microstrip feed lines with a phase difference of 180° are located near the meandering strips to excite the antenna. When it is connected with the microwave differential circuits, the balun is not needed. Details of the antenna design and its measured and simulated results are described and analyzed.

2. ANTENNA DESIGN

The geometry of the proposed dual-polarized dipole antenna is shown in Figure 1. The antenna constructed by two horizontal bow-tie patches and four vertically oriented meandering strips, is printed on 1-mm-thick FR4 substrates with dielectric constant (ε_r) of 4.4 and loss tangent (tanδ) of 0.02. Each bow-tie patch printed on the horizontal substrate has a length of $0.25\lambda_0$ (λ_0 is the free space wavelength at the center frequency). The ends of the bow-tie patch, which operate as an electric dipole, are attached to the ground plane by the meandering strips. The overall length of the meandering strip is about $0.24\lambda_0$ close to that of the horizontal bow-tie patch. Each pair of meandering strips act like a magnetic dipole is printed on the vertical substrate for low profile. To excite the orthogonal dual linearly-polarized modes, two pairs of differential-fed L-shaped microstrip feed lines are printed near the meandering strips. Each pair of L-shaped feed lines are excited with the equal amplitudes and 180° phase difference, which can reduce the cross-polarization level. With the aid of simulation by electromagnetic simulation software Ansoft HFSS, the key parameters are optimized for good performance. The detailed dimensions of the proposed antenna are shown in Table 1.

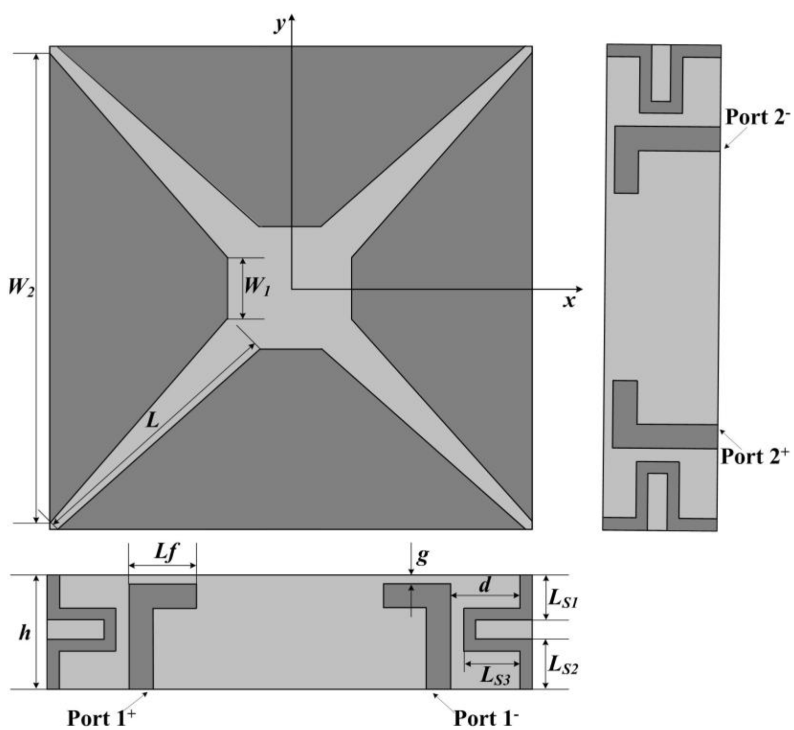


Figure 1. Geometry of the proposed dual-polarized antenna.

Table 1. Optimal geometrical parameters of the proposed antenna.

Parameters	W_1	W_2	L	Lf	h
Unit(mm)	5	38	22.6	5.5	9
Parameters	Ls_1	Ls_2	Ls_3	g	d
Unit(mm)	4	3.5	5	0.5	5.5

3. PARAMETRIC STUDY

Usually, a dual-polarized antenna with wide impedance bandwidth is needed by the base station systems. In this section, the parametric study is performed to provide useful information for designing such an antenna. When one parameter is studied, the others are kept constant.

3.1. Parameters for the Bow-Tie Patch: W_2, L

To illustrate the effect of the bow-tie patch on the performance of the antenna, Figure 2(a) gives the simulated S_{11} for various W_2. It can be seen that the width of the bow-tie patch has a significant effect on the higher band. As W_2 increases from 36 mm to 38 mm, the higher resonant frequency shifts down dramatically, and the impedance matching becomes better. Thus, W_2 was selected to be 38 mm for good impedance matching in the higher band. Figure 2(b) shows the simulated S_{11} versus L. When L increases from 18.6 mm to 22.6 mm, both the lower and higher resonant frequencies decreases. In addition, better impedance matching can be achieved when L increases. Therefore, L can be set to be 22.6 mm for good impedance matching in the whole operating band.

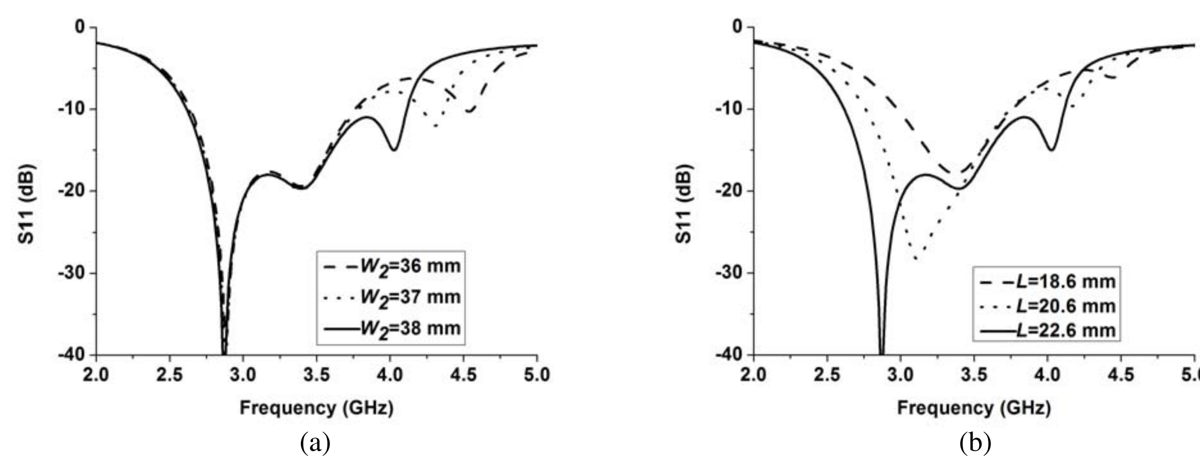


Figure 2. Effect of the bow-tie patch on the antenna performance. (a) Width of the patch (W_2). (b) Length of the patch (L).

3.2. Parameters for the Meandering Strip: Ls_3

To demonstrate the effect of the meandering strip on the performance of the antenna, the simulated S_{11} for various Ls_3 is given in Figure 3. From the graph, it is clearly visible that the lower resonant frequency is influenced by the length of the meandering strip. When Ls_3 increases from 5 mm to 7 mm, the lower resonant frequency decreases largely, while the higher resonant frequency changes slightly. However, over increasing the length of the meandering strip will cause poorer impedance matching in the whole operating band. Thus, $Ls_3 = 5$ mm was selected for good impedance matching and wide impedance bandwidth.

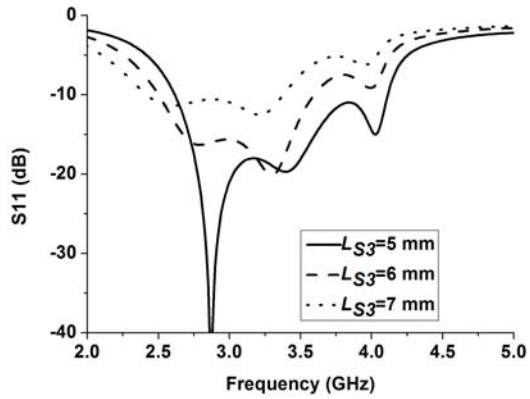


Figure 3. Effect of the meandering strip on the antenna performance.

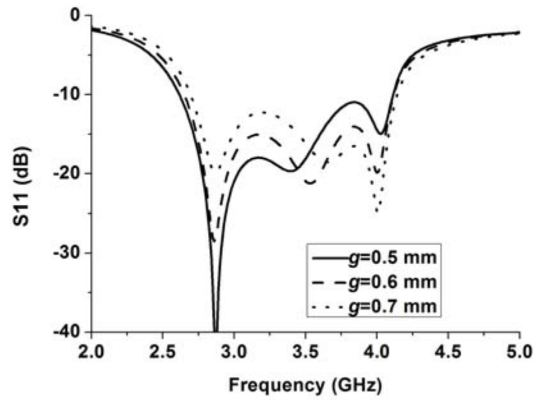


Figure 4. Effect of the L-shaped feed line on the antenna performance.

3.3. Parameters for the L-Shaped Feed Line: *g*

In order to exhibit the function of the L-shaped feed line, Figure 4 shows the simulated S_{11} for various g. As depicted in the graph, the middle resonant frequency is sensitive to the gap g. A smaller gap g gives lower resonant frequency in the middle band. In other words, due to the coupling between the L-shaped feed line and the radiating patch, a new resonant frequency can be excited in the middle band. Therefore, by carefully adjusting the gap between the L-shaped feed line and the radiating patch, the proposed antenna can meet the requirements for 3.5 GHz WiMAX systems.

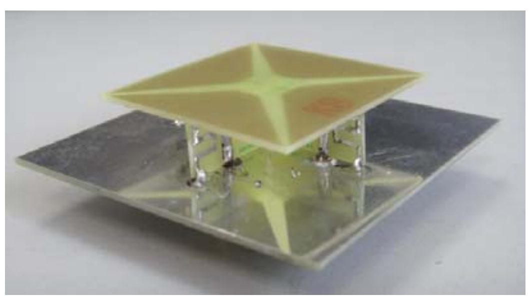
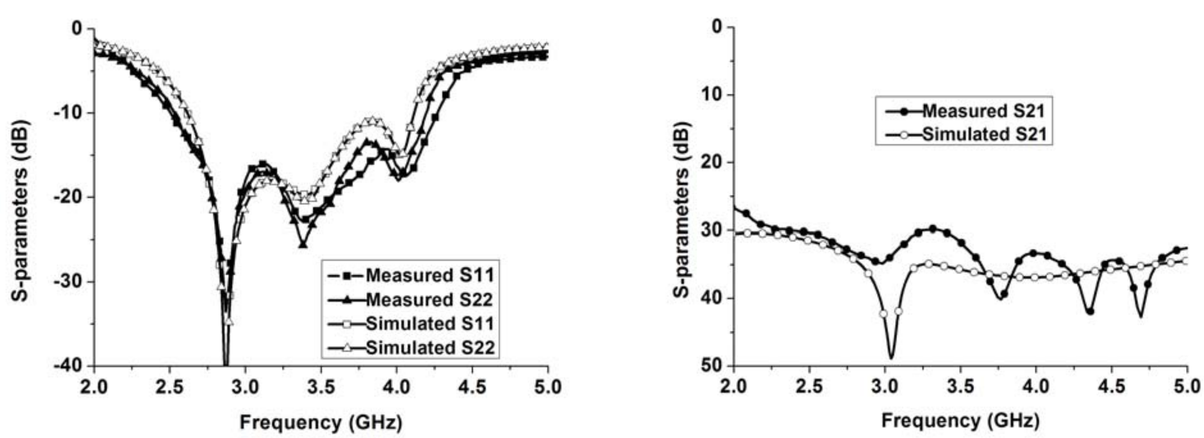
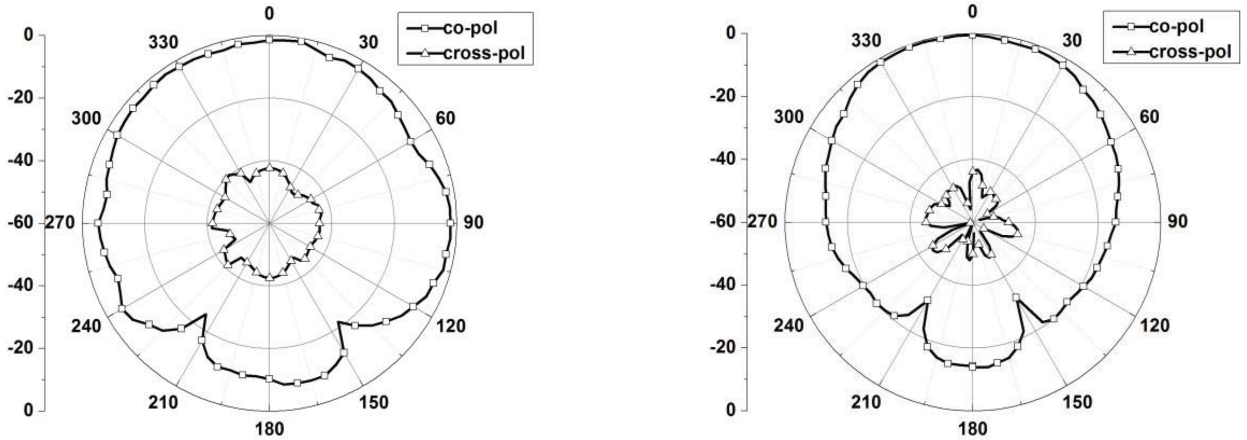


Figure 5. Measured and simulated reflection coefficient of the antenna.



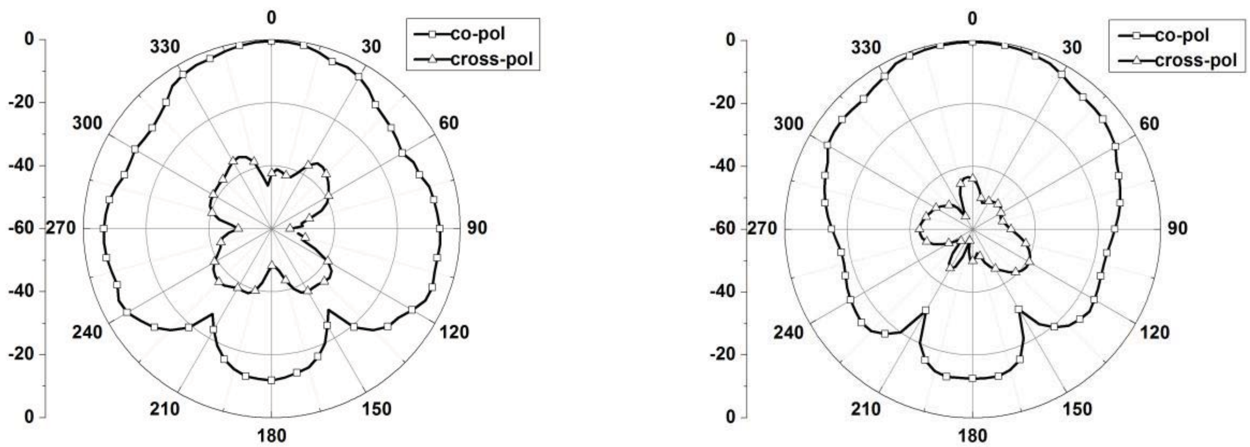
(a) (b)

Figure 6. Measured and simulated S parameters. (a) S_{11}, S_{22}. (b) S_{21}.



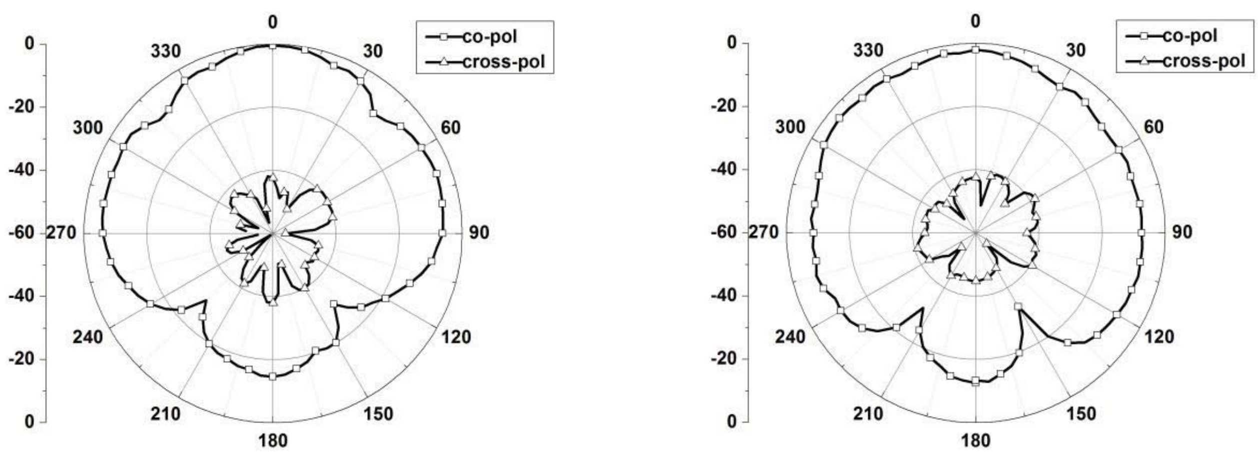
x-z plane *y-z* plane

(a)



x-z plane *y-z* plane

(b)



x-z plane *y-z* plane

(c)

Figure 7. Measured radiation patterns at (a) 2.8 GHz, (b) 3.5 GHz, and (c) 4 GHz.

4. EXPERIMENTAL RESULTS AND DISCUSSION

A prototype of the proposed dual-polarized dipole antenna shown in Figure 5 has been constructed and experimentally studied. The antenna is measured with WILTRON 37269A vector network analyzer and a fully automated anechoic chamber. Figure 6 shows the measured and simulated S parameters of the proposed antenna. It is observed that, the measured impedance bandwidth of the proposed antenna is 48.3% from 2.57 to 4.21 GHz. The measured isolation between the two feeding ports is better than -30 dB over the operating band. A slight difference between the simulated and measured results is mainly caused by the fabrication tolerance and losses in the measurement circuits.

The measured x-z plane (E-plane) and y-z plane (H-plane) radiation patterns at 2.8 GHz, 3.5 GHz, and 4 GHz are plotted in Figure 7. When port 1 is differential excited, port 2 is connected to a match load for 0° polarization (similarly port 2 excites 90° polarization mode). It can be seen that the antenna has good unidirectional radiation patterns in the E-plane and H-plane. The main beam of the radiation is always fixed in the broadside z-direction. It is caused by the combination of electric dipole and magnetic dipole, which can reinforce the radiating power in the broadside direction and suppress it in the back side. In addition, the cross polarization within the main lobe remains is less than -35 dB. The measured gain of the proposed antenna over the operating band is illustrated in Figure 8. When port 1 is excited, the measured gain is about 7.4 dBi for 0° polarization. When port 2 is excited, the measured gain is about 7.5 dBi for 90° polarization. There is a little difference between the two feeding ports, which may be caused by the asymmetric factors brought in the fabrication process.

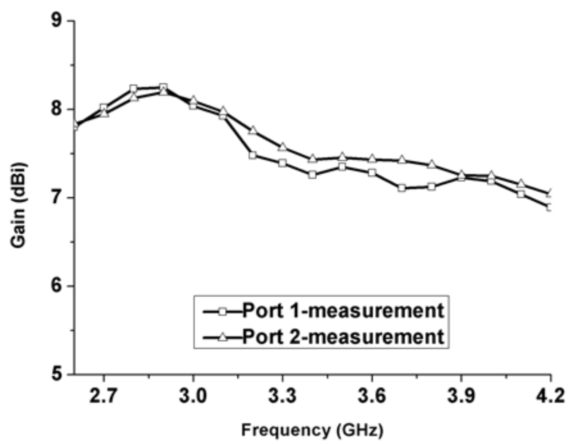


Figure 8. Measured gain of the proposed antenna.

5. CONCLUSION

In this paper, a wideband dual-polarized dipole antenna composed of horizontal bow-tie patches and vertically oriented meandering strips is proposed. By using bow-tie patches as an electric dipole, the impedance bandwidth of the antenna can be improved. With the use of meandering strips worked as a magnetic dipole, the profile of the antenna can be reduced. The proposed antenna is excited by two pairs of L-shaped feed lines with the equal amplitudes and 180° phase difference. When it is connected with the microwave differential circuits, the balun is not needed. The parametric study is performed to provide information for designing and optimizing such an antenna. Moreover, the proposed antenna has the advantages of unidirectional radiation pattern, high isolation, and low cross polarization.

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