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Design of a Bandwidth-Enhanced Planar Printed Antenna with Two Dipoles

Yu Chun Guo, Lei Chang[*], Jian Qiang Zhang, and Xiao Long Yang

Abstract—This paper presents a broadband planar printed antenna comprising two dipoles with different lengths and a transition structure of microstrip (MS) to coplanar stripline (CPS). These two dipoles are serially connected through CPS. By adding trapezoid and stepped patches, the dipole elements are modified for enhancing the impedance matching of the antenna. In addition, a tapered transition is adopted in the CPS to achieve improved impedance matching. The current work shows a good agreement between measured and simulated results. The measured bandwidth is from 2.43 to 8.04 GHz for VSWR ≤ 2, corresponding to 107.2% fractional bandwidth. Measured peak gain ≥ 4.0 dBi is obtained in the whole operating band.

1. INTRODUCTION

Many applications such as satellite communication, wireless personal area networks, and radar systems require wideband antennas [1]. Planar printed quasi-Yagi antennas come with many advantages such as light weight, low cost, and easy fabrication. These antennas are most desirable for the applications in wireless communication [2, 3]. However, planar printed quasi-Yagi antenna design for wideband applications is still facing many challenges: broadband impedance matching and consistent radiation patterns.

Different methods have been employed to enhance the bandwidth of planar printed quasi-Yagi antennas. A quasi-Yagi antenna fed by a simple coplanar waveguide (CPW) gains a 10 dB return loss bandwidth of 44% [4]. The utilization of a bowtie dipole as a driven element in quasi-Yagi antennas is an effective method to improve the bandwidth [5, 6]. Wide fractional bandwidths of 48% and 75% are obtained in [5] and [6], respectively. The study mentioned in [7] achieves 75% fractional bandwidth of quasi-Yagi antenna with the use of a dual-resonant driver in association with a balun formed by a stepped structure. In [8], a quasi-Yagi antenna with a MS-to-CPS balun has a fractional bandwidth of 70%.

An alternative method using a dual-dipole structure to achieve wide operating bandwidth is presented in [9–11]. These two dipoles with different lengths producing multiple resonant frequency bands expand the impedance bandwidth (49% in [9], 49.7% in [10] and 78.4% in [11]).

In this paper, a planar quasi-Yagi antenna with modified CPS and double-dipole structures is presented. The dipole element is composed of trapezoid and stepped patches. CPS is designed using a tapered transition. The proposed antenna obtains a wide bandwidth having range of 2.43 to 8.04 GHz for VSWR ≤ 2. Here, we describe the details of the suggested antenna as well as measured and simulated results.

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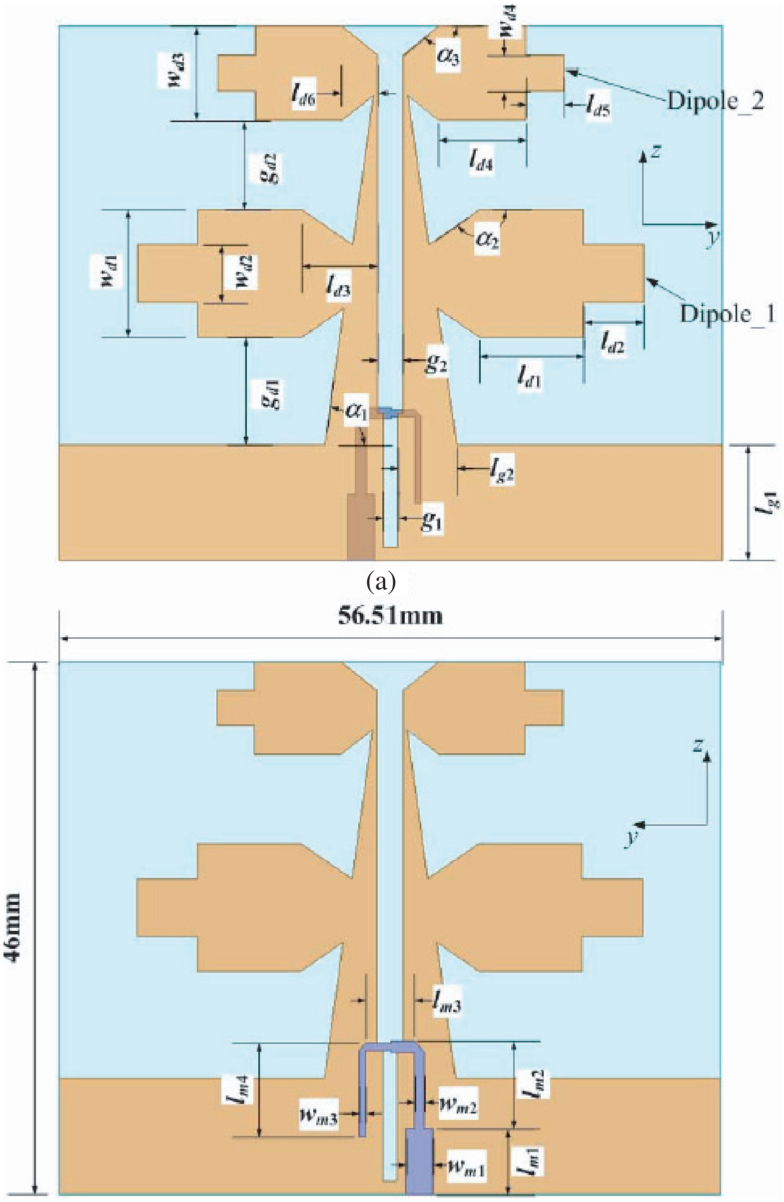
2. ANTENNA DESIGN

The geometry of the proposed antenna is depicted in Fig. 1. This antenna has been manufactured on both sides of a Taconic RF-35 substrate having dielectric constant $\varepsilon_r = 3.5$, thickness $h = 0.762\,\mathrm{mm}$ and loss tangent $\tan\delta = 0.0018$. The overall dimensions of the proposed antenna are $56.51\,\mathrm{mm} \times 46\,\mathrm{mm}$.

The antenna consists of a MS-to-CPS balun and two dipoles with different lengths. A similar balun is also used in [6]. These two dipoles are connected through a CPS printed on the top of substrate, while an MS is on the bottom. To achieve a good impedance matching performance, the dipole elements are modified by adding trapezoid and stepped patches, and a tapered transition is adopted in the CPS. A 50-Ω MS line with width of $w_{m1} = 1.76\,\mathrm{mm}$ is connected to the balun.

The width of the slotline is g_1. The gap of the CPS is g_2. A stepped structure with $g_1 < g_2$ is used in the CPS to improve the impedance matching, which was discussed in detail in [11]. The CPS



(a)

(b)

Figure 1. Geometry of the proposed antenna. (a) Front view. (b) Back view.

Table 1. Parameters of the proposed antenna.

Parameters	Value	λ_0	Parameters	Value	λ_0
l_{d1}	12.38 mm	0.216	g_1	1.08 mm	0.019
l_{d2}	4 mm	0.070	g_2	2.07 mm	0.036
l_{d3}	6.22 mm	0.108	g_{d1}	9.25 mm	0.161
l_{d4}	7.5 mm	0.131	g_{d2}	7.75 mm	0.135
l_{d5}	3.63 mm	0.063	l_{g1}	10 mm	0.174
l_{d6}	2.72 mm	0.047	l_{g2}	4.715 mm	0.082
w_{d1}	11 mm	0.192	w_{m1}	1.76 mm	0.031
w_{d2}	3 mm	0.052	w_{m2}	0.75 mm	0.013
w_{d3}	8 mm	0.139	w_{m3}	0.45 mm	0.008
w_{d4}	3 mm	0.052	l_{m1}	5.5 mm	0.096
α_1	82.727°		l_{m2}	7.3 mm	0.127
α_2	114.115°		l_{m3}	4 mm	0.070
α_3	137.413°		l_{m4}	7.75 mm	0.135

is modified by using a tapered transition structure, which is defined by parameters l_{g2} and α_1.

Dipole_1 is the long dipole. The length of the trapezoid patch is l_{d3}. The lengths of the stepped rectangular patch are l_{d1} and l_{d2}, respectively. The widths of the stepped rectangular patch are w_{d1} and w_{d2}, respectively. The angle of the trapezoid patch is α_2. The short dipole is Dipole_2, defined by parameters l_{d6}, l_{d4}, l_{d5}, w_{d3}, w_{d4}, and α_3. The optimized dimensions of the proposed antenna are given in Table 1. λ_0 is the free-space wavelength at 5.23 GHz.

We use HFSS 15 for evaluating the design of the antenna in this work. It allows an achievement of broad impedance bandwidth in range of 2.49 GHz to 7.95 GHz under the condition of VSWR ≤ 2 by using optimized parameters.

To verify the effect of the modified CPS with a tapered transition structure on improving impedance matching performance, simulated VSWRs of the antennas with and without tapered transition are shown in Fig. 2. The parameters (l_{g2}, α_1) with different values are also studied, and the simulated results are shown in Fig. 3. It is shown that the tapered transition has obvious effects on the low cutoff frequency of the antenna and the impedance matching around 6.5 GHz.

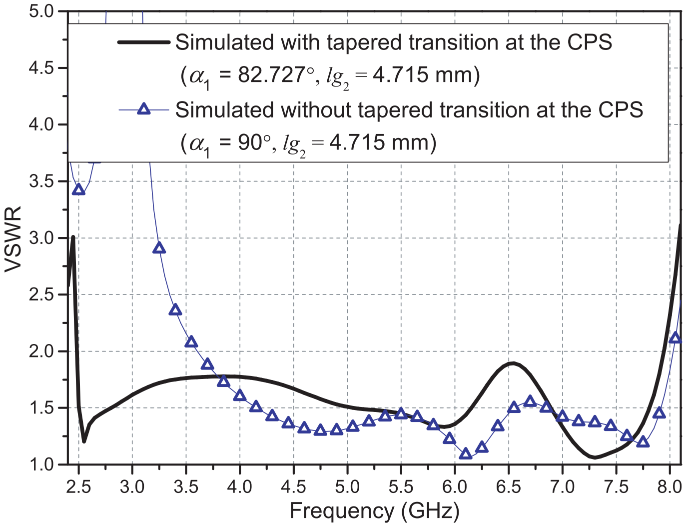
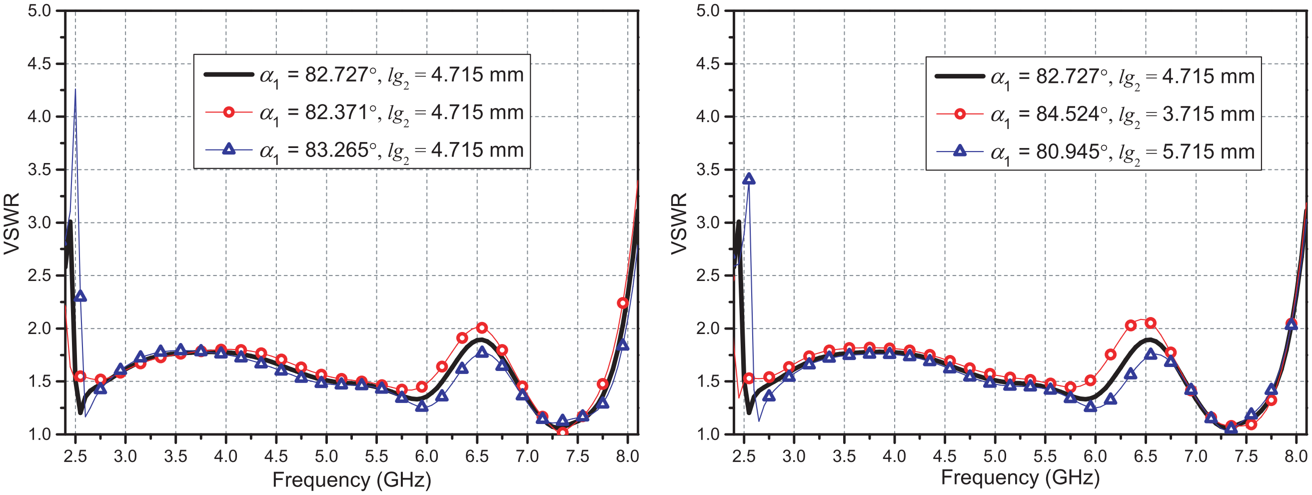


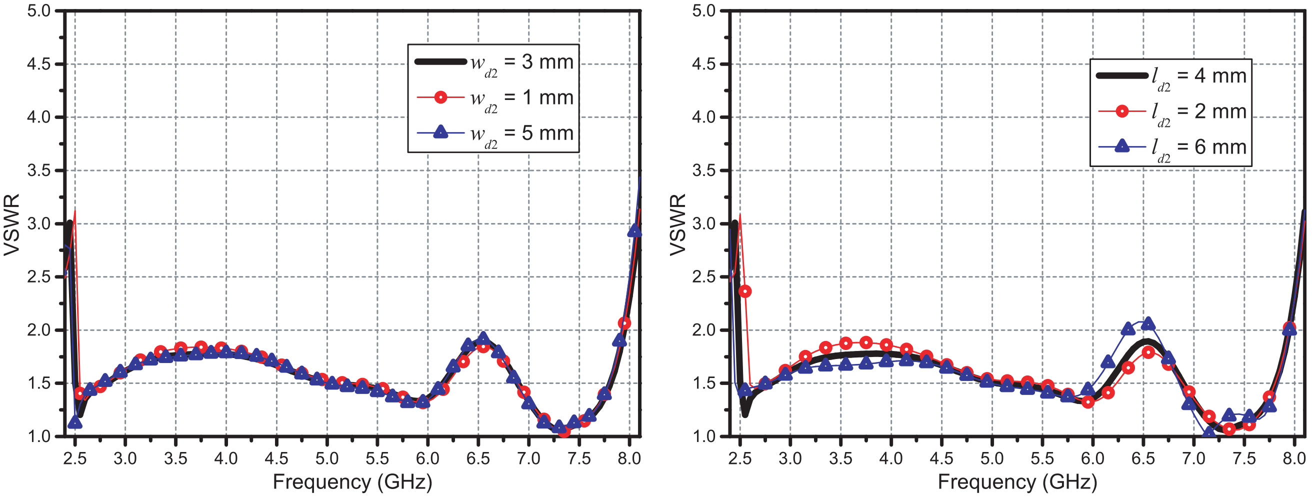
Figure 2. Effects of the tapered transition at the CPS on the VSWR.



(a) (b)

Figure 3. The effects of the parameters l_{g2} and α_1 on the VSWR: (a) l_{g2} remains the same and α_1 is with different values; (b) α_1 is set according to different values of l_{g2}.

The effects of parameters l_{d2} and w_{d2} upon the VSWR of the proposed antenna are depicted in Fig. 4. The values of VSWR decrease in 3.25–5.25 GHz and increase around 6.5 GHz by increasing parameters l_{d2} and w_{d2}. The outcomes of changing parameters l_{d5} and w_{d4} on the VSWR are also studied, as shown in Fig. 5. It is clear that parameters l_{d5} and w_{d4} have significant influence on the impedance matching performance. The influences of stepped patches on the impedance matching are mainly concentrated near 4 GHz and 6.5 GHz. Fig. 6 shows the current distributions of the antennas at 6.5 GHz with and without stepped patches. It can be seen that the stepped patches are applied to reduce the reverse current at the end of these two dipoles and improve the impedance matching.



(a) (b)

Figure 4. The effects of the parameters (a) w_{d2} and (b) l_{d2} on the VSWR.

Figure 7 shows effects of the trapezoid patches on the VSWR. The trapezoid patches have two functions: One is to perform impedance transformation to reduce the first resonant frequency, and the other is to reduce the reverse current at the junctions of two dipoles and CPS near 6.55 GHz, as shown in Fig. 8.

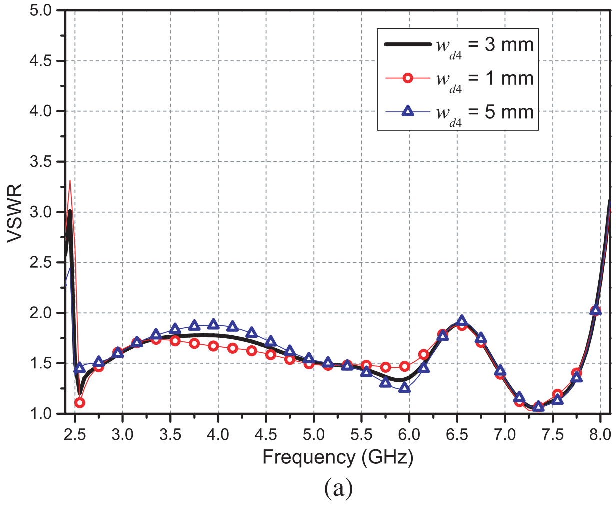


Figure 5. The effects of the parameters (a) w_{d4} and (b) l_{d5} on the VSWR.

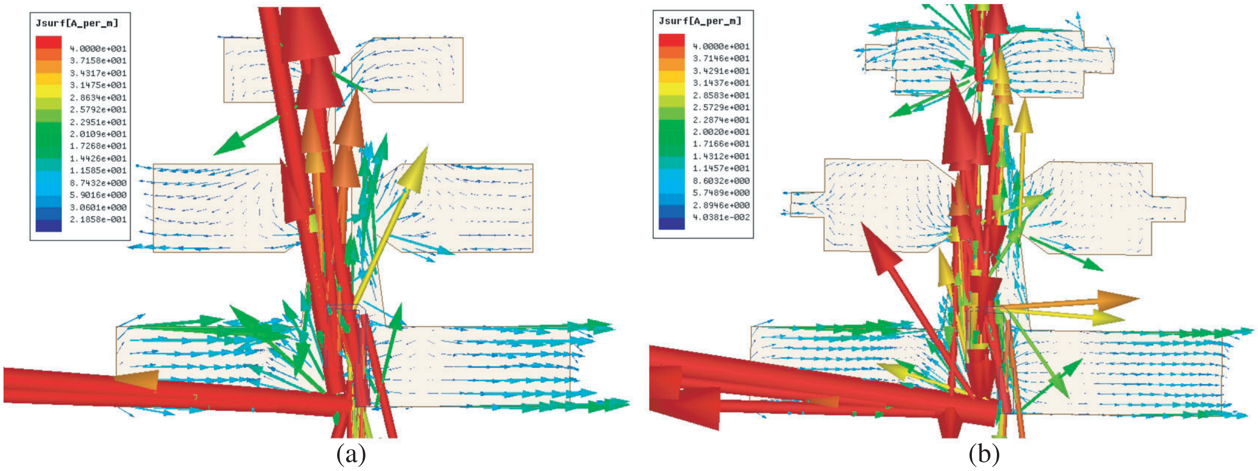


Figure 6. Current distributions of the antennas at 6.5 GHz: (a) without stepped patches and (b) with stepped patches.

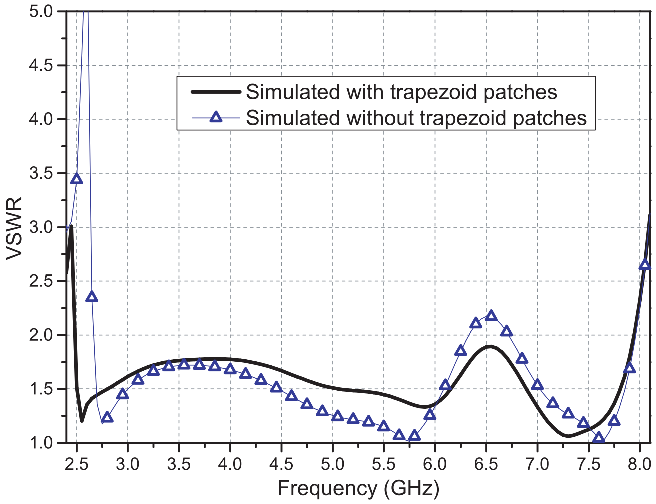
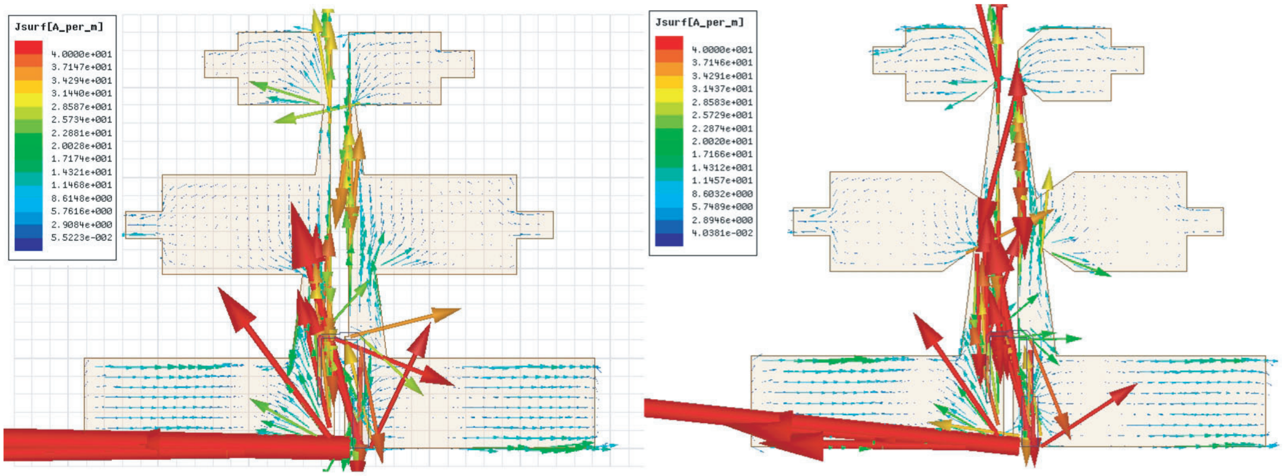


Figure 7. Effects of the trapezoid patches on the VSWR.



(a) (b)

Figure 8. Current distributions of the antennas at 6.55 GHz: (a) without trapezoid patches and (b) with trapezoid patches.

3. MEASURED RESULTS AND DISCUSSIONS

In order to affirm the simulation results, the proposed antenna has been manufactured as per values for the optimized parameters. Photographs of the proposed antenna are depicted in Fig. 9. The comparison between measured values of the proposed antenna in terms of VSWR and the simulative results is given in Fig. 10. The antenna can obtain a wide measured bandwidth in range of 2.43 GHz to 8.04 GHz (107.2%). It can be observed that the measured results are in a good agreement with the simulated ones. A comparison between the proposed antenna and recently reported planar antennas using dual-dipole structure [9–11] is presented in Table 2. λ_L is defined as a free space wavelength at the lowest frequency of impedance bandwidth. It is shown that the proposed antenna with smaller overall size has wider impedance bandwidth.

The peak gain of the proposed antenna is presented in Fig. 11. It can be seen that the measured peak gain is higher than 4 dBi over the whole operating band. The simulated and measured results of normalized patterns in two principle planes are depicted in Fig. 12. It is shown that the proposed antenna demonstrates stable radiation patterns.

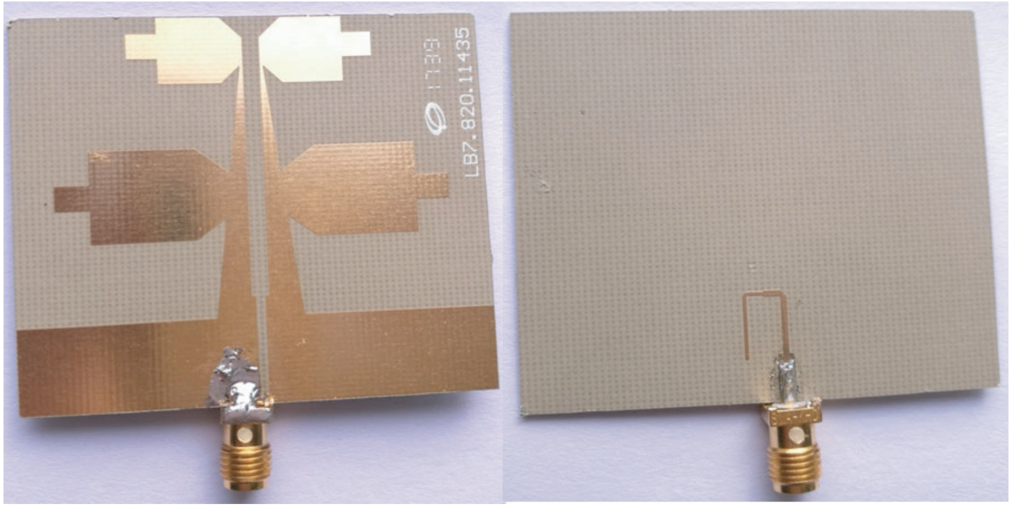


Figure 9. Photograph of the fabricated antenna.

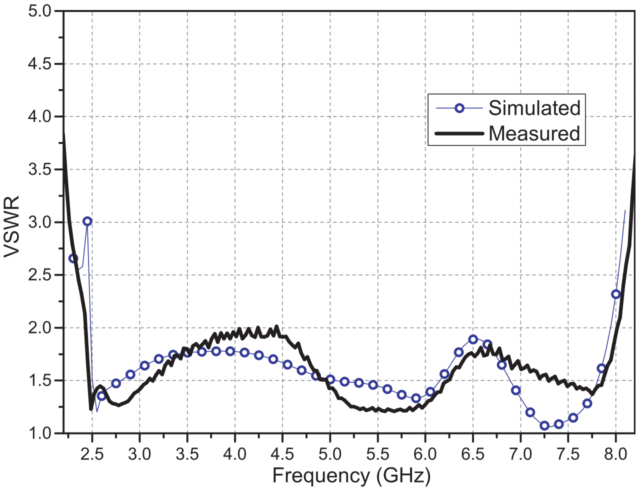


Figure 10. Simulated and measured VSWR of the proposed antenna.

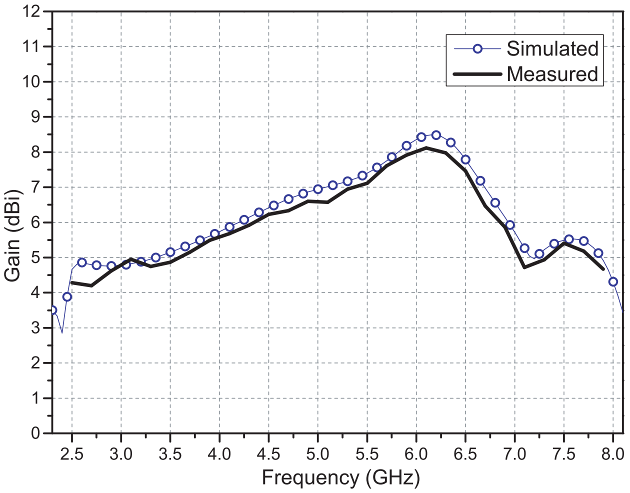
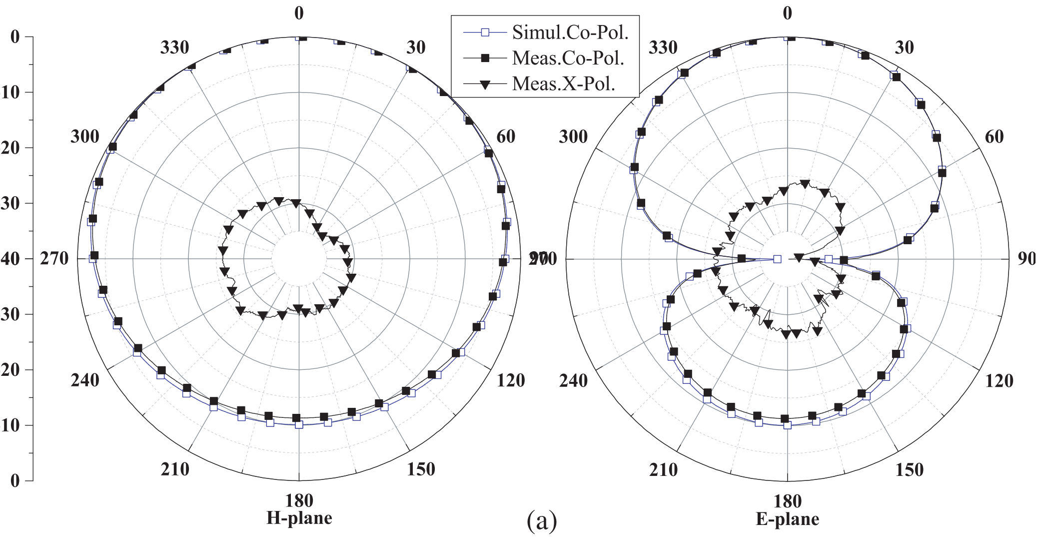


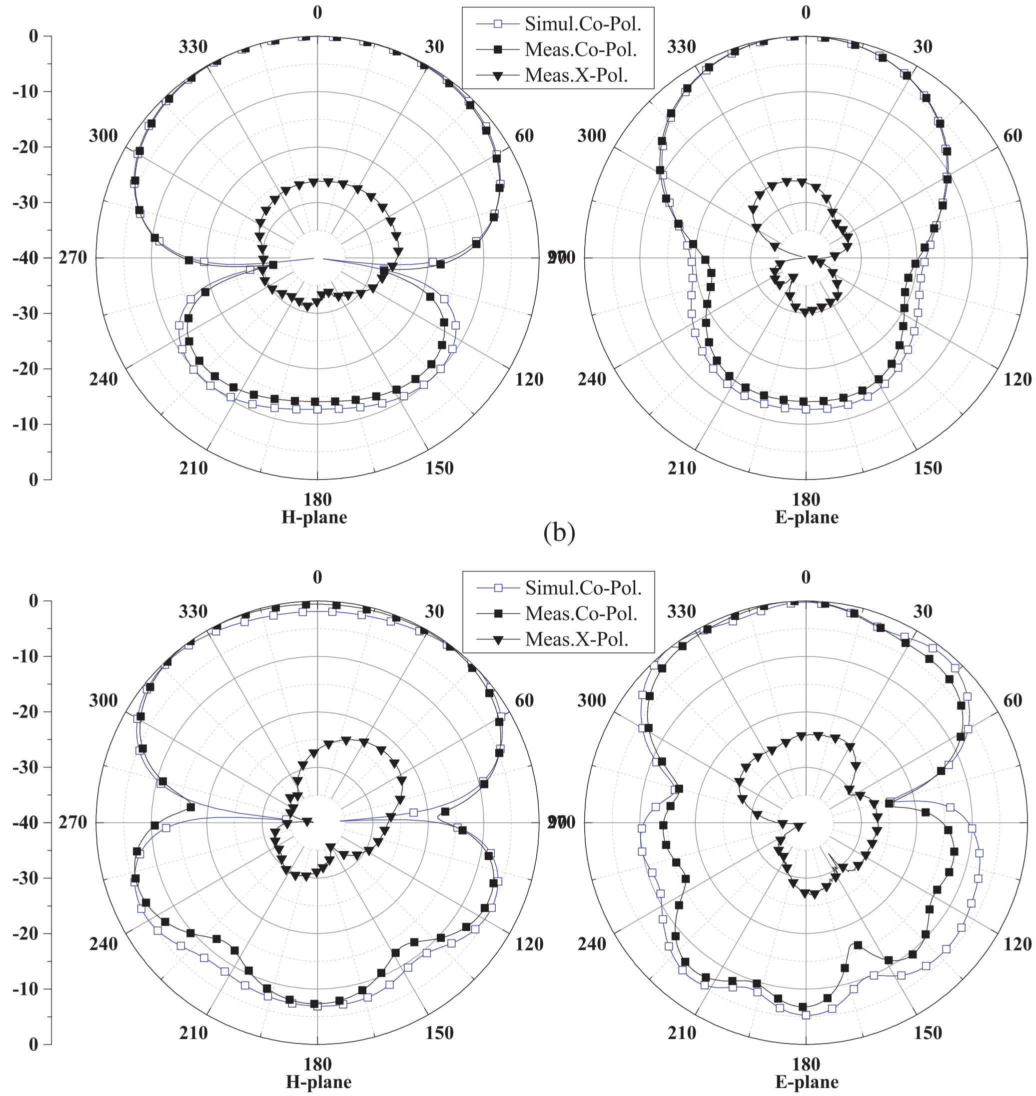
Figure 11. Simulated and measured peak gain of the proposed antenna.

Table 2. Comparisons of proposed and other antennas using dual-dipole structure.

	ε_r	Overall size (λ_L)	VSWR	Bandwidth	Gain (dBi)
Proposed (without director)	3.5	$0.46 \times 0.37 \times 0.006$	≤ 2	107.2% (2.43–8.04 GHz)	≥ 4.2
				56.2% (3.9–6.95 GHz)	≥ 5.5
[9] (without director)	4.4	$0.65 \times 0.57 \times 0.009$	≤ 2	49% (1.7–2.8 GHz)	≥ 5.5
[10] (without director)	4.4	$0.64 \times 0.43 \times 0.009$	≤ 2	49.7% (1.68–2.79 GHz)	≥ 5.86
[11] (with two directors)	4.4	$0.74 \times 0.48 \times 0.008$	≤ 2	78.4% (1.59–3.64 GHz)	–
				76.9% (1.6–3.6 GHz)	≥ 6.4



(a)



(b)

(c)

Figure 12. Radiation patterns of the proposed antenna at (a) 3 GHz, (b) 5 GHz, and (c) 7 GHz.

4. CONCLUSION

A planar antenna has been proposed for the applications of wideband. By using two modified dipoles with trapezoid and stepped patches, and a tapered transition structure in a CPS, the proposed antenna obtains a wide impedance matching bandwidth. A prototype of the proposed antenna is manufactured and tested. The measured results indicate that it operates in the frequency band of 2.43–8.04 GHz (corresponding to 107.2% fractional bandwidth) for VSWR ≤ 2. A measured peak gain ≥ 4.0 dBi is obtained in the entire operating frequency band.

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