International Journal of Microwave and Wireless Technologies, 2017, 9(5), 1179–1184. © Cambridge University Press and the European Microwave Association, 2016
doi:10.1017/S1759078716001276

RESEARCH PAPER

Enhancement of the gain and bandwidth of the microstrip patch antenna with modified ground plane

KALYAN MONDAL[1] AND PARTHA PRATIM SARKAR[2]

In this work, microstrip antenna with W- and V-shaped radiating patches have been proposed. Here square- and circular-shaped modified ground planes have been designed by poly tetra fluoro ethylene (PTFE) substrate with dielectric constant 2.4. Broadband with high gain is obtained by optimum selection of radiating patch with modified ground plane. The ground planes are modified by loading a U-shaped slot. The simulated and measured results are compared. Considering −10 dB impedance bandwidth maximum frequency band of 6.97 GHz (3.04–10.01 GHz) with percentage bandwidth of 106.8% is achieved. The proposed antenna exhibits maximum peak gain of 5.1 dBi. The simulation and measurement have been done by Ansoft designer software and vector network analyzer.

Keywords: Microstrip antenna, Broadband, Antenna design, Measurement and wireless communication

Received 19 June 2016; Revised 12 October 2016; Accepted 13 October 2016; first published online 21 November 2016

I. INTRODUCTION

Development of wireless communication system is possible by the attractive and challenging features of the antennas. The microstrip patch antennas have some challenging characteristics to develop the wireless communication system. The microstrip patch antenna has demand in practical field due to their advantageous properties, such as small size, light weight, low profile, and easy to fabrication and can be used in any printed electronic circuits. With the strong features, they have some inherent demerit such as single operating frequency, narrow bandwidth, and low gain. To overcome the drawbacks, various techniques are reported. In [1], a compact broadband slotted rectangular microstrip patch antenna is designed. A U-shaped slot is loaded on the patch and maximum percentage bandwidth of 24.6% is achieved. It is reported in [2] that, 86.79% bandwidth with 4.1 dBi peak gain is achieved by introducing U-shaped patch with inverted U-shaped slot on the ground plane. The bandwidth of the microstrip patch antenna may be enhanced by introducing impedance matching technique, reported in [3]. The ultra wide band (UWB) is obtained by the monopole concept in [4]. It is reported by Mondal and Sarkar that the bandwidth of the microstrip patch antenna is enhanced by introducing M-shaped radiating patch with U-shaped slot on the ground plane [5]. In [6], broadband is achieved by embedded multiple number of slots on the patch and ground plane of the rectangular patch antenna. Various broadband microstrip patch antennas are reported in [7–10]. In this work, four broadband with high-gain microstrip patch antennas have been designed. The design antenna consists of V- and W-shaped radiating patch with U-shaped slot on the ground plane. The designed antenna is simulated using MOM-based Ansoft designer software.

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II. ANTENNA CONFIGURATION

Antenna-1 and -2 are designed by the W-shaped radiating patch placed on the top of the modified square and circular ground planes, respectively. Similarly antenna-3 and -4 have been designed by the V-shaped radiating patch placed on the top of the same modified ground planes simultaneously. The poly tetra fluoro ethylene (PTFE) substrate with coaxial probe feed is used to design all the antennas. The relative permittivity (ε_r), thickness (h), and loss tangent (tan δ) of the glass PTFE substrate are 2.4, 1.6 mm, and 0.00022, respectively [2]. The necessary parameters and dimensions of the antennas are given in Table 1. All the designed antennas in compact form are presented in Fig. 1.

III. ANTENNA RESULTS AND DISCUSSIONS

The simulated and fabricated results of four antennas with different configurations are presented. The effects of different shapes of the radiating patches with same ground plane and

Table 1. Dimensions of all the antennas (all dimensions are in mm).

Parameters	Antenna-1	Antenna-2	Antenna-3	Antenna-4
A	2	2	2	2
B	17.5	17.5	17.5	17.5
C	6	6	6	6
D	3.5	3.5	3.5	3.5
E	2.2	2.2	2.2	2.2
F	3	3	3	3
G	2.5	2.5	2.5	2.5
H	4	4	4	4
I	5	5	5	5
L	–	23	–	23
M	11	11	11	11
R	16	–	16	–
S	9	9	–	–
T	–	–	12	12

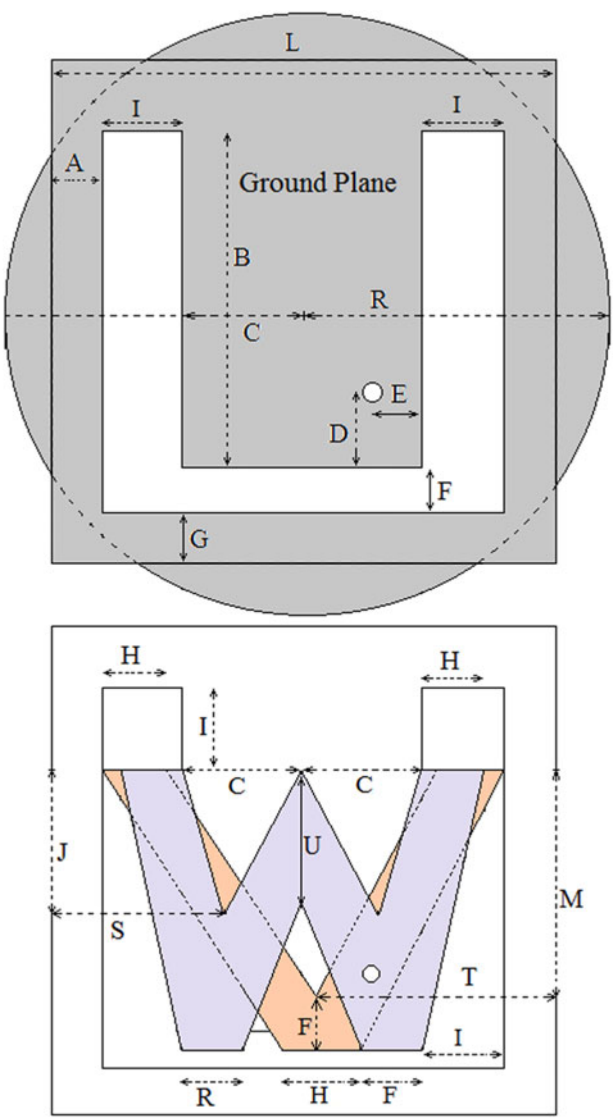

Fig. 1. Modified proposed microstrip patch antenna.

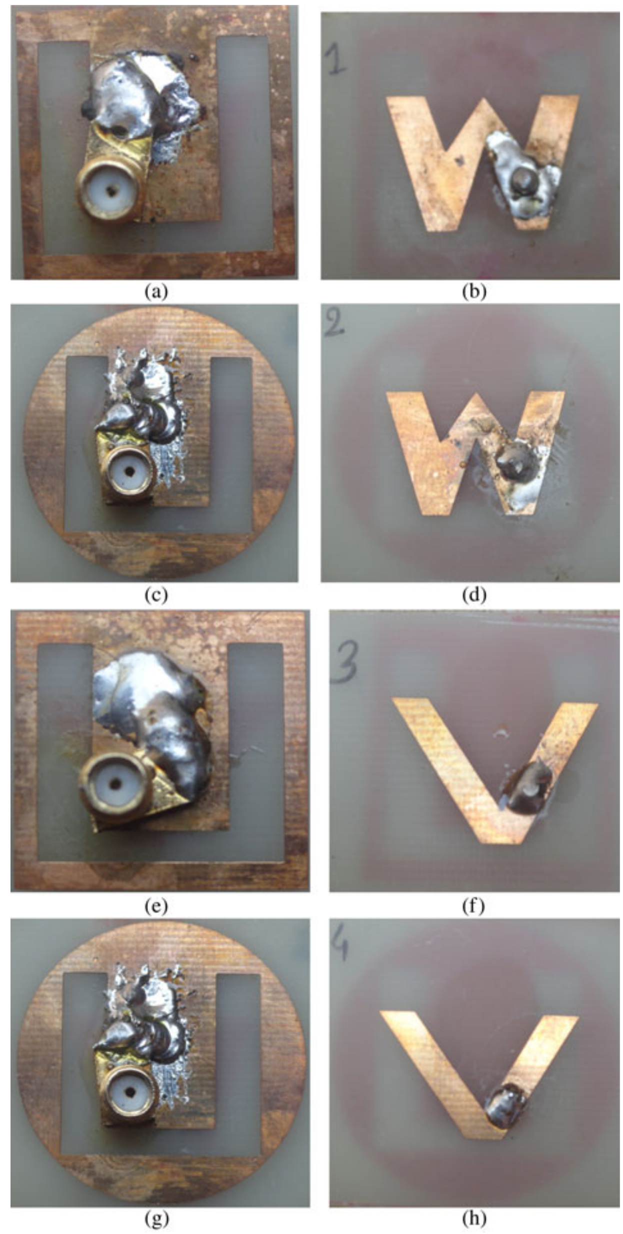

Fig. 2. Panels (a), (c), (e), and (g) are the photographs of ground plane of antenna-1, -2, -3, and -4. Panels (b), (d), (f), and (h) are the photographs of radiating patch of antenna-1, -2, -3, and -4.

different ground planes with same radiating patch are demonstrated. Mainly the antenna gain, bandwidth, and size of the antennas are investigated.

Development of patch by cutting slits in a regular patch, changes the normal surface current density. Consequently, the fringing field also changes as a result the radiation pattern, gain, or other parameters also changes.

A) Results of antenna-1 and antenna-2

The simulated and measured characteristics of reflection coefficient with frequency of antenna-1 and -2 are given in Fig. 3. The simulated and measured frequency bands of antenna-1 and -2 are 5.33 GHz (3.13–8.46 GHz), 5.34 GHz (3.16–8.50 GHz)

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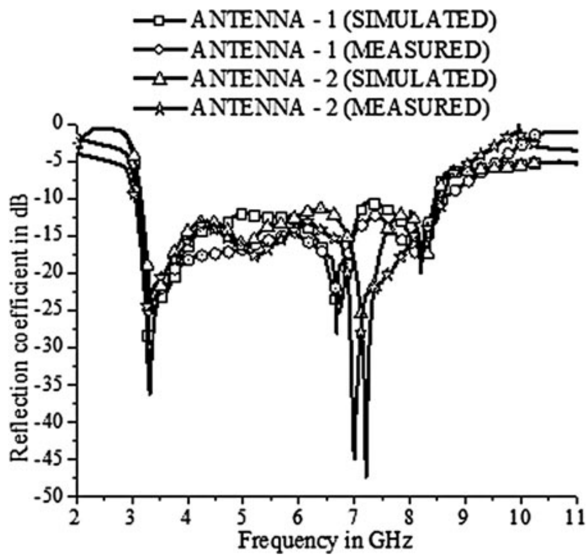

Fig. 3. Reflection coefficient with frequency

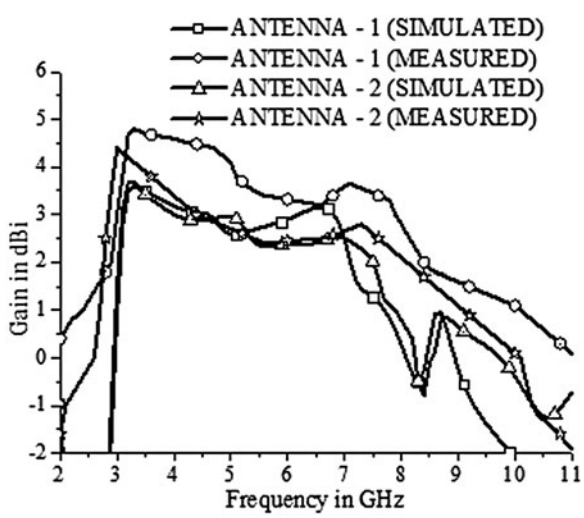

Fig. 4. Antenna gain with frequency

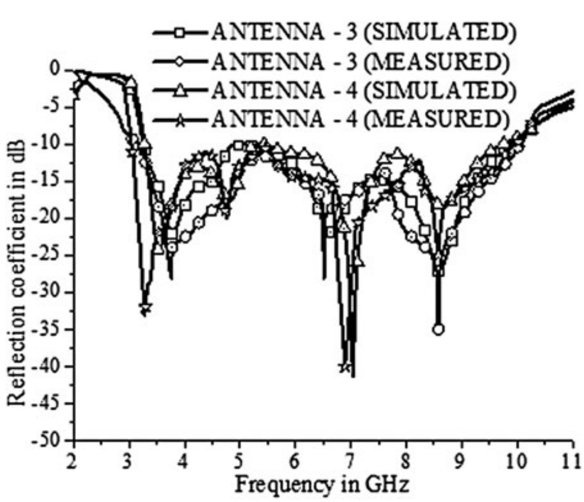

Fig. 5. Reflection coefficient with frequency

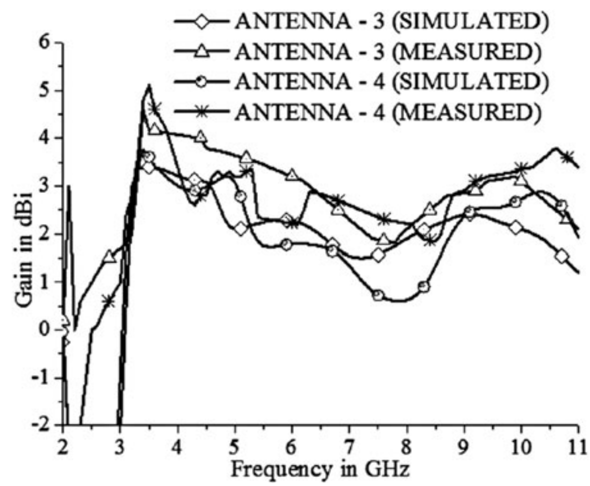

Fig. 6. Antenna gain with frequency response

Table 2. Results of published work with proposed antenna.

Reference no.	Frequency band (in GHz)	% of bandwidth	Peak antenna gain (in dBi)	Dimensions (in mm²)
[1]	0.220	24.6	7	120 × 80
[2]	6.9	86.79	4.1	36 × 36
[3]	0.324	12	8	70 × 70
[4]	5.15	74	4.09	42 × 55
[5]	5.96	103	4.25	26 × 26
[6]	6.02	115	3	34 × 25
Proposed	6.97	106.8	5.1	23 × 23

and 5.52 GHz (3.08–8.6 GHz), 5.54 GHz (3.06–8.60 GHz), respectively. The conventional patch antenna is generally resonant at a single frequency and this frequency may be varied by the modification of the antenna. In both the cases of antenna-1 and -2 three resonant frequencies occurred. The second resonance frequency of the modified antennas is same as that of the conventional antenna. However, the second resonance frequency is generated due to the W- or V-shaped radiating patch and remaining two resonant frequencies are obtained for the coupling effect between U-shaped slots on the ground plane and W- or V-shaped radiating patch.

In all these cases, resonant frequencies at 3.32, 6.72, and 8.18 GHz for antenna-1 and 3.38, 5.05, and 7.22 GHz for antenna-2 are found. The gain of the antenna is shown in Fig. 4.The peak gain of antenna-1 and -2, respectively, 3.7 dBi at 3.3 GHz (simulated), 3.5 dBi at 3.3 GHz (measured) and 3.6 dBi at 3.3 GHz (simulated), 3.6 dBi at 3 GHz (measured) are found. Therefore, the percentage of bandwidth and gain of both the antennas are almost same but size of the antenna-2 is reduced significantly from 804.6 to 529 mm^2.

B) Results of antenna-3 and antenna-4

Antenna-3 and -4 is designed using V-shaped radiating patch. The radiating patch W-shaped is replaced by the V-shaped radiating patch. The simulated and measured results of reflection coefficient and gain are given in Figs 5 and 6, respectively.

Table 3. Simulated and measured results of all antennas.

Results	Antenna	Antenna-1	Antenna-2	Antenna-3	Antenna-4
Simulated	Frequency range (in GHz)	3.13–8.46	3.16–8.50	3.26–9.90	3.28–9.76
	BW (in GHz)	5.33	5.34	6.64	6.48
	% of BW	92	91.6	101	99.4
	Max peak gain (in dBi)	3.7	3.6	3.4	4
Measured	Frequency range (in GHz)	3.08–8.6	3.06–8.60	3.2–10.04	3.04–10.01
	BW (in GHz)	5.52	5.54	6.84	6.97
	% of BW	94.5	95	103.3	106.8
	Max peak gain (in dBi)	3.5	3.6	3.7	5.1

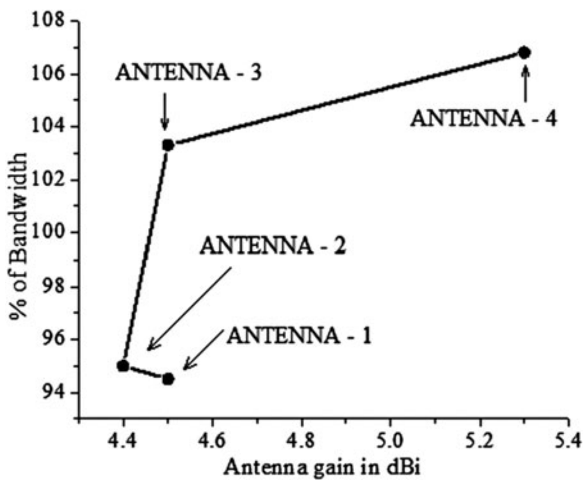

Fig. 7. Percentage of bandwidth (BW) with antenna gain response

Antenna-3 offers frequency band of 6.64 GHz (3.26–9.90 GHz) (simulated) and 6.84 GHz (3.2–10.04 GHz) (measured) with three resonant frequencies at 3.81, 6.62, and 8.6 GHz.

Similarly the proposed antenna-4 offers simulated and measured frequency band, respectively, 6.48 GHz (3.28–9.76 GHz) and 6.97 GHz (3.04–10.01 GHz). In the proposed antenna four resonant frequencies are found at 3.54, 4.82, 6.9, and 8.64 GHz. The third resonance frequency is obtained for the V-shaped radiating patch and remaining due to the coupled of slot and radiating patch. Results of some published work with proposed antenna are given in Table 2. The simulated and measured results of all the antennas are shown in Table 3. Here proposed Antenna – 4 offers the highest gain of 5.1 dBi with maximum 106.8% impedance bandwidth.

The graphical representation of maximum percentage bandwidth with maximum peak gain of all the antennas is given in Fig. 7. It is found from the analysis that the shape and size of the patch and ground plane are responsible to enhance the bandwidth and antenna gain. The novelty of the research work is broad band and outstanding gain, which is obtained by the small-size microstrip patch antenna. Antenna-4 simulated and measured distribution of stable electric field with the angle θ and ϕ are presented in Fig. 8. The three-dimensional (3D) radiation patterns with surface current distributions of all the antennas at first resonant frequency are presented in Fig. 9. From Fig. 9 it is also found that the front radiation is much better compared

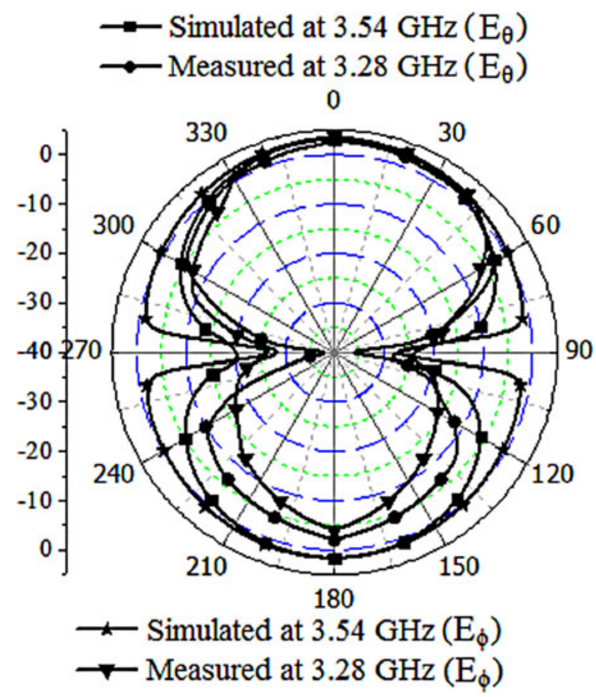

Fig. 8. Radiation pattern of the proposed antenna for $\phi = \theta = 0°$

with back radiation. Front-to-back power ratio of antenna-4 offered attractive results because of back radiation power is negligible compare with others antenna. Considering the power ratio of antenna-4, a good gain of 5.1 dBi is achieved.

IV. CONCLUSION

Four broadband high-gain microstrip patch antennas are designed. 106.8% (3.04–10.01 GHz) bandwidth with peak gain of 5.1 dBi is achieved. The proposed antenna covers the frequency bands: IEEE 802.11a (5.15–5.35 GHz), (5.725–5.875 GHz), (5.15–5.85 GHz) for WLAN, ISM band 5.8 GHz for (WiFi and Bluetooth), HIPERLAN2 (5.45–5.725 GHz), HiSWaNa (5.15–5.25 GHz), C-band (4–8 GHz), and X-band (8–12 GHz). The designed antenna is of planar structure. Such type of broadband and good gain patch antenna may be applicable in modern wireless communication where simple geometrical structure and small size is preferred.

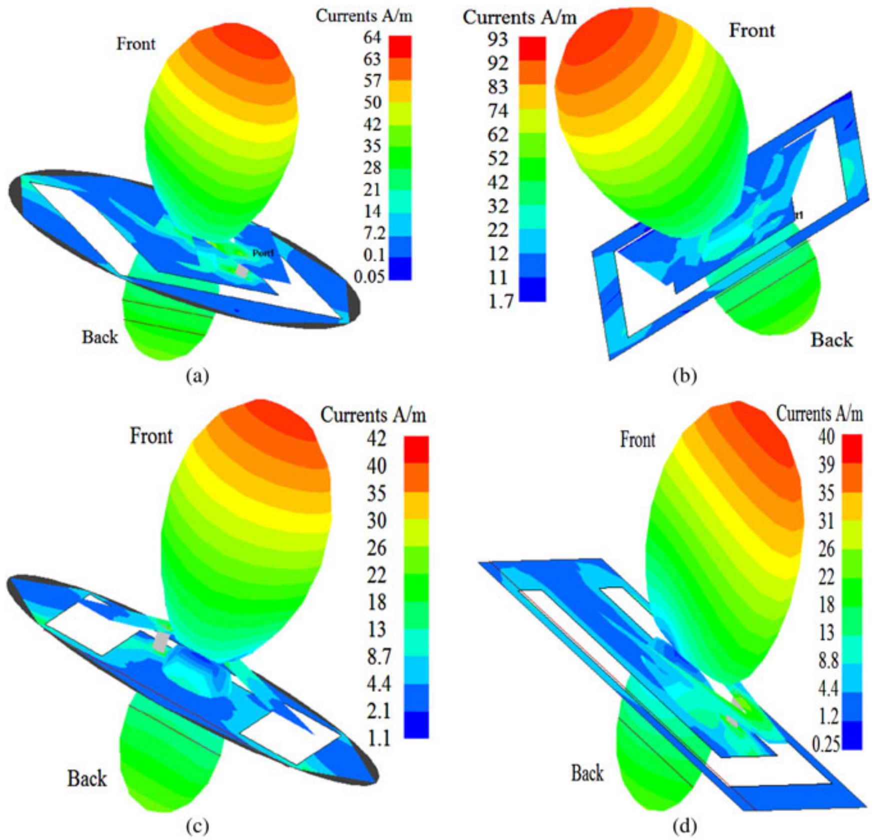

Fig. 9. 3D radiation pattern with surface current distribution (a) antenna-1, (b) antenna-2, (c) antenna- 3, and (d) antenna-4.

ACKNOWLEDGEMENTS

We acknowledge gratefully for measurement facilities provided by JU (Jadavpur University), India and Kalyani University, India.

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https://doi.org/10.1017/S1759078716001276 Published online by Cambridge University Press

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