Indian Journal of Pure & Applied Physics
Vol. 54, November 2016, pp. 727-732

A compact broadband microstrip patch antenna for WiMAX/LAN/Wi-Fi/WLAN applications

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Received 8 January 2016; revised 8 July 2016; accepted 22 August 2016

A broadband crucifix shape patch type microstrip antenna with rectangular modified ground plane has been presented. Two slots have been loaded on the rectangular ground plane and high gain wide-band response has been obtained. The -10dB bandwidth of the proposed antenna is around 6.3 GHz with a percentage bandwidth of 115%. Maximum positive gain of 4.32 dBi (measured) and multi operating frequencies at 2.46 GHz, 5.46 GHz and 7.52 GHz, respectively have been achieved. Different simulated antenna responses have been investigated with variation of slots dimensions and its position on the ground plane. The measured frequency band is 2.1 GHz to 8.88 GHz with a percentage of bandwidth 123.5%. The proposed antenna has been simulated using Ansoft designer software. Simulated results have been confirmed by measured results. The antenna is suitable for modern broadband wireless communication systems such as Bluetooth (2.4 – 2.485 GHz), WiMAX (3.4 – 3.6 and 3.7 – 4.2 GHz), LAN (5.47 – 5.725 GHz), WiFi 802.11y (3.6 – 3.7 GHz) and WLAN 802.11b/g/a (5.31 – 6.32 GHz).

Keywords: Broadband, Computer simulation, Microstrip patch antenna (MPA), Planar structure, Wireless communication

1 Introduction

The microstrip patch antennas are very popular due to their inherent properties of light weight, small size, fabrication simplicity, etc. However the bandwidth of the conventional microstrip patch antenna is narrow[1]. This is the main drawback of dipole microstrip patch antenna. To enhance the bandwidth several research works are published. It was reported in different journals that the multi frequency bands can be generated by different shapes of antenna[2-6]. Monopole antenna is presently designed by the researchers for the purpose of broad band[7-11]. However gain of the monopole antenna is reduced with the increase of bandwidth. The main challenge of the researcher is to enhance the gain and bandwidth. The conventional microstrip antennas like circular and rectangular have narrow bandwidth. By the modification of ground plane or radiating patch it has been enhanced[12-18]. The proposed crucifix shaped compact microstrip patch antenna has been designed with modified rectangular ground plane. In this work a large bandwidth with high gain is achieved. The proposed antenna has been fabricated using PTFE substrate with ε_r = 2.4 and thickness 1.6 mm. The simulation has been done using Ansoft designer software based on method of moment. The proposed antenna parameters have been measured using Agilent Network Analyzer and standard microwave test bench. The measured results are compared with the simulated one.

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2 Antenna Structure

Figure 1 shows the ground plane of the proposed broadband antenna with two slots loaded on it whereas the Figs 2 and 3 show the proposed antenna and photograph of practical antenna, respectively. The antenna–1 is designed by introducing a big slot on the ground plane. Antenna–2, Antenna–3 (Proposed), Antenna–4 and Antenna–5 are obtained by the variation of *Y* parameter of Fig. 2 from 9 mm to 12 mm. The parametric dimensions of all the antennas are given in Table 1. The radiating cross shape patch is separated from the rectangular ground plane by 1.6 mm of PTFE substrate with ε_r = 2.4 and loss tangent[12] = 0.00022. The proposed antenna is microstrip type in the sense of metallic ground plane is retained under the 48.91% radiating patch after introducing a big slot on the ground plane.

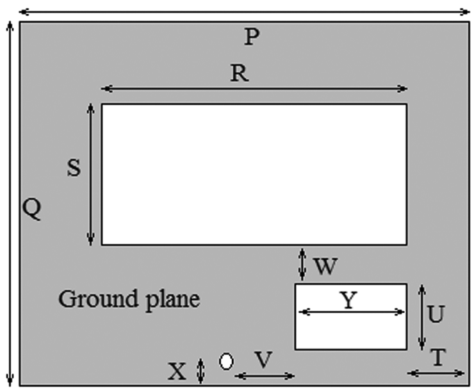

Fig. 1 — Modified rectangular ground plane of the proposed antenna

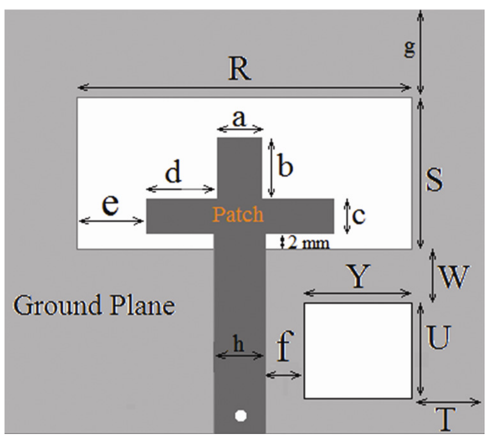

Fig. 2 — Proposed micristrip patch antenna

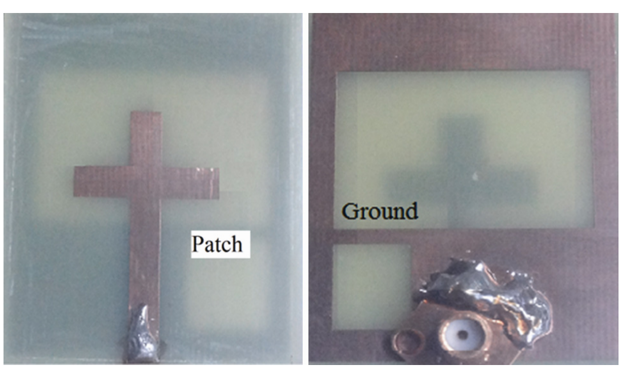

Fig. 3 — Photograph of proposed antenna

3 Parametric Study of the antenna

A slot of dimensions 29 × 17 mm^2 is incorporated on the ground plane at the optimum position of the crucifix patch antenna. The simulated results of reflection coefficient, gain and radiation patterns are presented in Figs 4, 5 and 8-11. The resonant frequencies at 2.48 GHz, 5.34 GHz and 7.62 GHz with simulated peak gain of 3.34 dBi are found. By loading an additional slot with dimensions of 10 × 9 mm^2 at the optimum position on the ground plane, the reflection coefficient, bandwidth and gain are enhanced. The value of parameter *Y* is varied from 9 mm to 12 mm and others parameters remain constant as shown in Table 1. The simulated frequency band and peak gain of the antenna have been improved by approximately 115% and 3.39 dBi. The three resonant frequencies at 2.46 GHz, 5.46 GHz and 7.52 GHz are merged and a broadband is formed. So, the gain and frequency band have been tuned by the additional slot on the optimum position of the ground plane.

Table1 — Parameters and dimensions of all the antennas (all dimensions are in mm)

Parameters	Antenna - 1	Antenna - 2	Antenna – 3 (Proposed)	Antenna - 4	Antenna - 5
P	36	36	36	36	36
Q	35	35	35	35	35
R	29	29	29	29	29
S	17	17	17	17	17
T	-	3	3	3	3
U	-	9	9	9	9
V	5	6	5	4	3
W	-	4	4	4	4
X	1	1	1	1	1
Y	-	9	10	11	12
a	5	5	5	5	5
b	6	6	6	6	6
c	4	4	4	4	4
d	6.5	6.5	6.5	6.5	6.5
e	5	5	5	5	5
f	-	3	2	1	0
g	3	3	3	3	3
h	6	6	6	6	6

4 Results and Discussion

This work shows the variation of reflection coefficient and gain with respect to the frequency of different antenna parameter dimensions. From the simulated results it is found that results of crucifix shape patch as shown in Figs 4 and 5 are much better than the results of circular and rectangular microstrip patch antenna considering bandwidth, gain and compactness.

Figure 4(a) shows the reflection coefficient versus frequency for different values of *Y* and *f* parameters. From Fig. 4(a) it is clear that the resonance frequency is not changed significantly due to variation of *Y* and *f* parameters. The total number of resonance is constant for all the antennas. The position of the radiating patch with feed is shifted from proposed position and results are obtained as shown in Fig. 4(b). In all the cases bandwidth is less compare to the proposed. Figure 5 shows the variation of gain

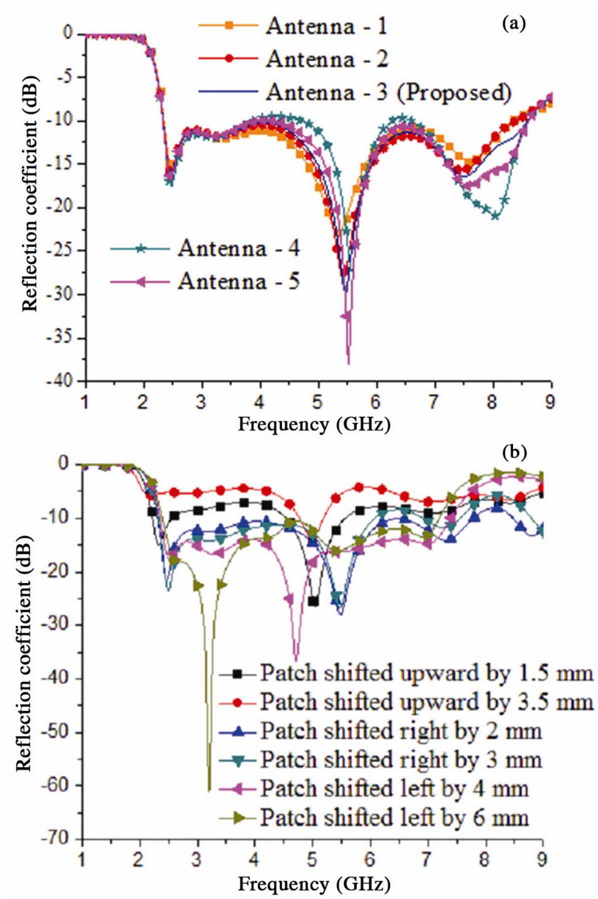

Fig. 4 — (a) Reflection coefficient at different value of *Y*, *f* and *U* and (b) reflection coefficient at different position of the patch

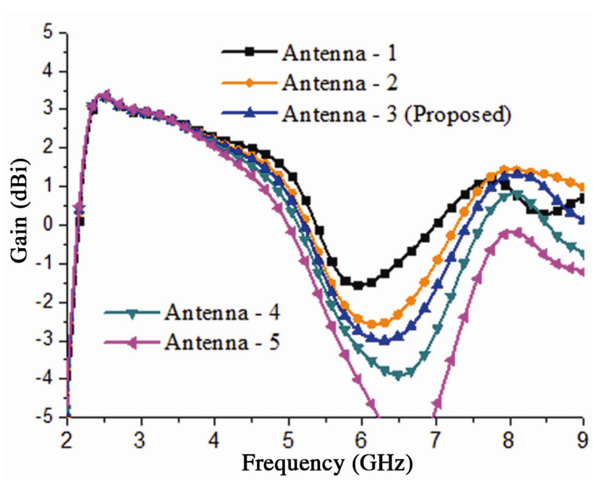

Fig. 5 — Antenna gain versus frequency at different value of *Y*, *f* and *U*

with respect to the variation of *Y* and *f* parameters. The gain is maximum at the condition of *Y* = 0 mm, *f* = 0 mm and bandwidth is not significantly large. The proposed antenna for *Y* = 10 mm and *f* = 2 mm shows broadband as well as highest gain of 4.32 dBi.

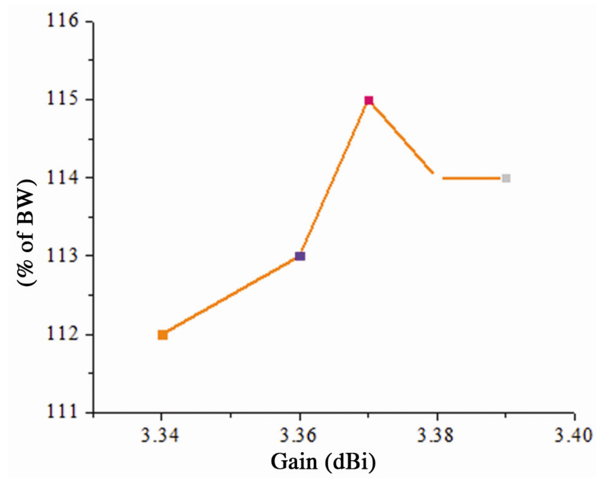

Fig. 6 — Bandwidth (in %) vs peak gain (in dBi)

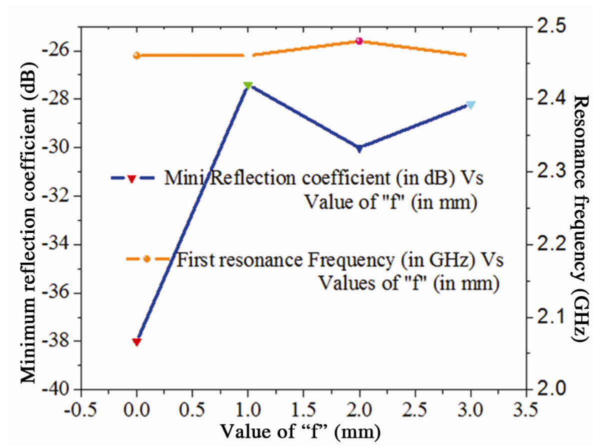

Fig. 7 — Variation of reflection coefficient and resonance frequency with different value of *f*

The variation of percentage bandwidth with respect to the gain (in dBi) is shown in Fig. 6. The percentage bandwidth is almost linearly increased with the antenna gain. The variation of minimum reflection coefficient and resonance frequency for the different values of the design parameter *f* (0 mm to 3 mm) is shown in Fig. 7. The simulated and measured results of the proposed antenna are shown in Figs 8 and 9, respectively. The simulated result covered the frequency range from 2.32 GHz to 8.62 GHz for $s_{11} \leq -10$ dB with 115% bandwidth. The resonance frequency at 6.75 GHz is found for Crucifix radiating patch with simple ground plane. For the loaded slots on the ground plane wavelength is varied.

The conventional patch antenna generally resonates at a single frequency and it may be varied by the modification of the antenna. In all the cases three resonant frequencies are generated. The 2nd resonance

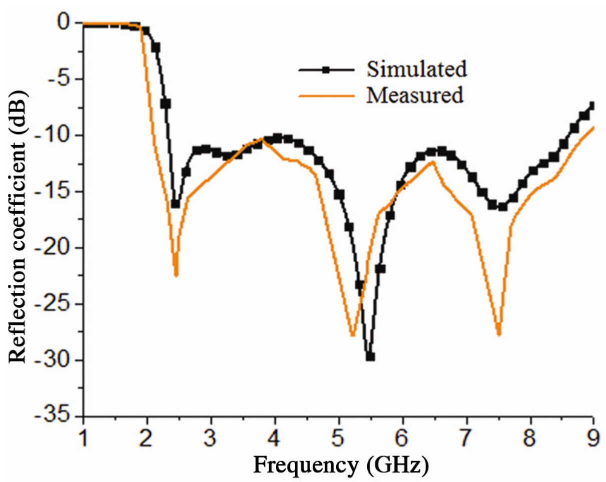

Fig. 8 — Reflection coefficient versus frequency response of proposed antenna

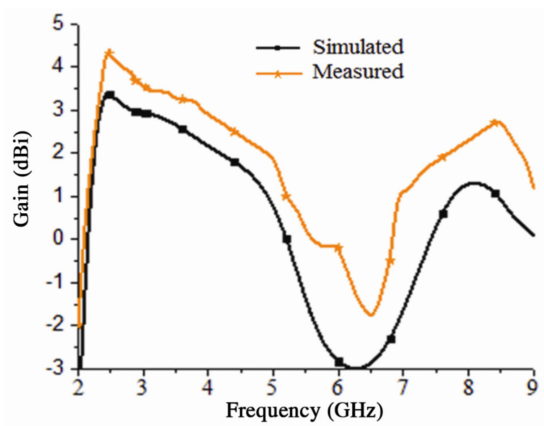

Fig. 9 — Simulated and measured gain of proposed antenna

frequency of the modified antenna is same as that of the conventional antenna. However, the 2nd resonance frequency is generated due to the crucifix radiating patch and remaining two resonant frequencies are obtained for separate current paths through the ground plane bypassing the slots.

The 1st resonant frequency is reduced from 6.75 GHz to 2.46 GHz. The broad frequency band is obtained by staggering effect of all three resonant frequencies. The measured percentage bandwidth is123.5% which covers frequency band from 2.1 GHz to 8.88 GHz with highest gain 4.32 dBi.

Generally, bandwidth of microstrip antenna[1] is approximately 2–3%. Percentage bandwidth is achieved by dividing the bandwidth by resonant frequency. If there are multiple resonant frequencies, average of them is taken. In this case more than 100% bandwidth is achieved. This is very fruitful for application in wireless communication. The Simulated

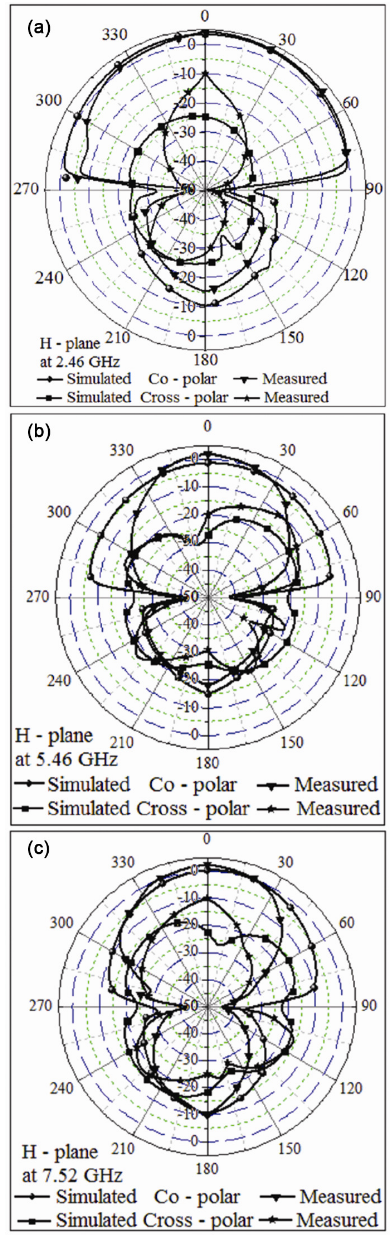

Fig. 10 — The H – plane co – polar and cross – polar radiation pattern of the proposed antenna at (a) 2.46 GHz, (b) 5.46 GHz and (c) 7.52 GHz

and measured *H*-plane and *E*-plane radiation patterns at different resonant frequencies of the proposed antenna are shown in Figs 10 and 11, respectively.

The *H*-plane and *E*- plane radiation patterns are obtained by the variation of polarized components E_φ and E_θ with the azimuth angle φ and elevation angle θ, respectively. For the *H*- plane radiation pattern, the co-polarized and cross-polarized are represented by the field components $E_\varphi = 0^0$ and $E_\varphi = 90^0$. Similarly for the *E*-plane, the co and cross polarized are

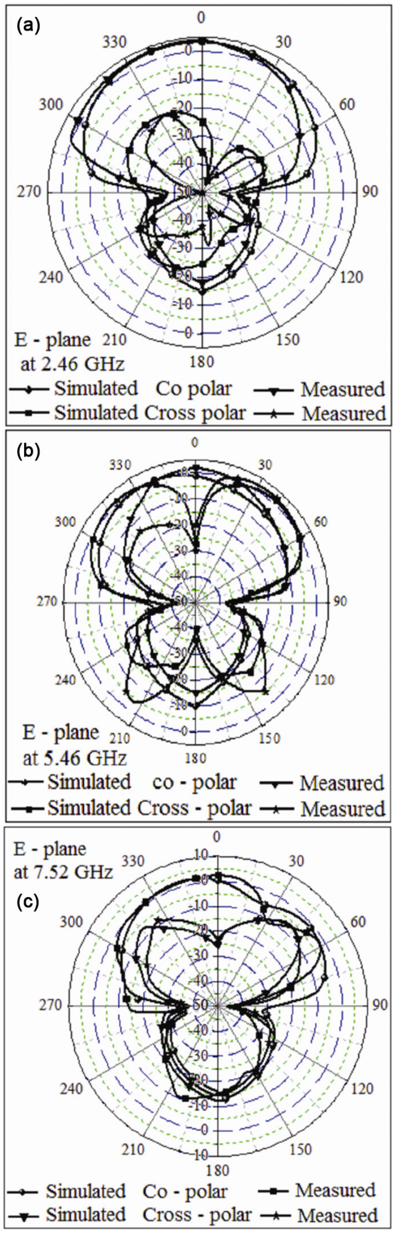

Fig. 11 — The E - plane co – polar and cross – polar radiation pattern of the proposed antenna at (a) 2.46 GHz, (b) 5.46 GHz and (c) 7.52 GHz.

represented by $E_\theta = 0^0$ and $E_\theta = 90^0$, respectively. The co-polarization is much better than cross-polarization. In all the figures back radiation is observed due to the 53.73% ground plane under the patch is retained. The simulated and measured radiation patterns of the proposed antenna are in good agreement. Some mismatch occurs due to the imperfection fabrication or measurement processes. All the simulated and measured results of the proposed antenna are shown in Table 2.

It is found from all the designed antennas that the three resonant frequencies are generated by the coupling effect between the radiating patch and slots on the ground plane. These three resonant frequencies are combined each other by the staggering effect and a broadband is achieved. For the enhancement of bandwidth (123.5%), the little bit antenna gain (in dBi) is reduced and a peak gain of 4.32 dBi is achieved. The proposed work results are more attractive than previously published work. Few numbers of published work results with proposed are presented in Table 3.

Table 3 — Results of all the references and proposed work

Reference No.	Max bandwidth (GHz)	Peak gain (dBi)	% of bandwidth (Max)	Dimensions (mm^2)
Ref. [2]	1.55 – 2.15	2.8	32%	19 X 28
Ref.[3]	4.96 – 5.96	3.51	18.3%	18 X 37
Ref. [4]	1.961 – 2.470	3.59	23%	22 X 76
Ref. [5]	3.22 – 4.30	2.7	28.72%	20 X 38.5
Ref. [6]	2.140 – 2.750	2.24	25%	45 X 30
Ref. [7]	3.22 – 6.55	4.35	68.04%	27 X 35
Ref. [8]	3.1 – 10.6	5.3	109%	28 X 34
Ref. [9]	0.355 – 1.067	3.56	90.3%	24 X 17
Ref.[10]	1.38 – 3.98	4.1	97%	20 X 34
Ref. [11]	3.87 - 7.63	2.51	65.4%	31 X 24.57
Ref. [12]	4.5 – 11.4	4.1	86.79%	36 X 20
Ref. [13]	2.2 – 8.22	3	115%	34 X 25
Ref. [14]	4.55 - 5.6	-	27%	104
Ref. [15]	1.93 – 3.745	3.9	63.97%	60 X 50
Ref. [16]	3.15 – 4.63	4	38%	15 X 15
Ref. [17]	2.63 – 7.27	4.69	92.5%	35 X 35
Ref. [18]	1.93 – 3.64	2.43	61.4%	55 X 15
Proposed	2.1 – 8.88	4.32	123.5%	36 X 35

Table 2 — Simulated and measured results of the proposed antenna

Antenna	Lower frequency (GHz)	Higher frequency (GHz)	Resonance frequency (GHz)	Frequency band (GHz)	% of Bandwidth	Peak gain (dBi)	Minimum reflection coefficient (dB)
Antenna – 1	2.33	8.32	2.48, 5.34 and 7.62	5.99	112	3.34	-23
Antenna – 2	2.33	8.4	2.46, 5.44 and 7.48	6.07	113	3.36	-28
Antenna – 3 (Proposed)	2.32	8.62	2.46, 5.46 and 7.52	6.30	115	3.37	-30
Antenna – 4	2.33	8.58	2.48,5.58 and 8.06	6.25	114	3.38	-27
Antenna – 5	2.34	8.6	2.46, 5.52 and 7.6	6.26	114	3.39	-38
Antenna – 3 (Measured)	2.1	8.88	2.46, 5.22 and 7.51	6.78	123	4.32	-28

5 Conclusions

This paper presents the design of a simple microstrip antenna with very large bandwidth of 6.78 GHz with maximum peak gain of 4.32 dBi for broadband applications. The simulated and measured bandwidths are from 2.32 GHz to 8.62 GHz and from 2.1 GHz to 8.88 GHz. This is achieved by crucifix shaped microstrip patch and rectangular slot loaded ground plane with coaxial feed. The measured data demonstrates that it is in agreement with the simulated data. Antenna bandwidth is broad and at the same time the gain is reasonable high. The compactness of the antenna is very good, due to modified patch and ground plane. The area reduced is 63% for proposed patch antenna. This proposed antenna is very suitable for modern broadband wireless communication such as Bluetooth (2.4 – 2.485 GHz), WiMAX (3.4 – 3.6 and 3.7 – 4.2 GHz), LAN (5.47 – 5.725 GHz), WiFi 802.11y (3.6 – 3.7 GHz) and WLAN 802.11b/g/a (5.31 – 6.32 GHz). This may also be used as a body mounted antenna.

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