International Journal of Electrical Engineering.
ISSN 0974-2158 Volume 11, Number 1 (2018), pp. 87-97

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A Design of Omni-directional Rectangular Slotted Patch Antenna for Wireless Applications

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Abstract

The paper explains the design of omnidirectional rectangular slotted patch antenna with enhanced bandwidth by varying the length of ground plane. Proposed antenna resonates at two distinguished frequencies 2.45 GHz and 7.52 GHz, and also exhibits wider bandwidth (942 MHz and 1194 MHz) and gain (3.87dB and 4.67dB) at ground length 12mm. Designed antenna also adorns omnidirectional pattern at the frequency band of 2.45 GHz, and may be considered as suitable candidate for various wireless applications like Bluetooth (2.4-2.5GHz) of ISM band and X-band satellite communication (7.1GHz – 7.76GHz). Proposed antenna is also fabricated and found that simulated and experimental results are in good agreement with each other.

Keywords: Slotted patch, omnidirectional, bandwidth, radiation pattern

INTRODUCTION

The microstrip antenna was first introduced in 1970's and from there microstrip antenna technology become the most rapidly developing field [1]. Microstrip antennas are gaining momentum in the field of wireless communication system day by day due to its many attractive features such as ease of fabrication, compact size and low cost [2]. The microstrip antenna consists of thin metallic patch and ground plane which are separated by a dielectric substrate [3] [4]. The patch is made up of conducting material such as copper or gold [5]. The dielectric substrate may be of any material according to our requirement such as FR4 epoxy, Rogers RT/Duroid, Teflon etc. Basically used dielectric material is FR4 glass epoxy because it is easily available in the market. The size of microstrip patch antenna has a great influence on the total size of the wireless system and there is generally a trade off between the performance and size of the antenna [6] [7]. The shape of the radiating patch is one of the most important characteristics of microstrip patch antenna; the patch can be of many different shapes such as rectangular, square, circular, elliptical, triangular, dipole, ring etc [8].

There are many applications of wireless technologies in which the role of microstrip antenna is very important such as WiMAX technologies which has frequency range from (2.3 – 2.4GHz), (3.3 – 3.4GHz) and (5.25 -5.85GHz). Bluetooth and WLAN operate in the frequency band of 2.4GHz, ISM (Industrial, Scientific and Medical) band (2.4 -2.5GHz) [8] [9]. These frequency bands were released by FCC (Federal Communication Commission) in 2002 in United States [10]. The FCC allocated the use of frequency ranges from 3.1 to 10.6GHz for UWB applications [11] [12]. By using these frequency ranges the antenna can be designed accordingly for different wireless applications. The microstrip patch antenna can be designed by proper selection of patch design and feeding techniques which are used to provide excitation to the antenna[13][14].

In this paper, a design of slotted patch antenna exhibiting the omnidirectional radiation pattern at the lowest frequency band with an acceptable value of gain has been discussed. The detail of design and results are depicted in section 2 and section 3 respectively

ANTENNA DESIGN AND CONFIGURATION

Figure 1. Patch design of proposed antenna: (a) basic geometry of patch and (b) final geometry of patch

A wideband antenna with V-shaped slots has been designed in this paper. Proposed antenna consists of a rectangular patch with length 28.2 mm and width 36.5 mm. These dimensions of patch have been calculated by using the given below equations (1) to (5). FR4 glass epoxy substrate with dielectric constant 4.4 and thickness 1.6 mm is used to design the antenna at resonant frequency 2.5 GHz. The basic geometry of rectangular patch is shown in Fig. 1(a) and patch with V-slots is shown in Fig. 1(b). Dimensions of slots which are etched from the basic geometry of rectangular patch is shown in Fig. 2. Coordinate system of geometry is used to employ the V-slots at the exact position in the basic structure of patch given in Fig. 3. The XY coordinates of different slot positions is tabulated in Table 1 [15].

$$w = \frac{c}{2fo\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

$$\varepsilon_{reff} = \varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{\frac{1}{2}} \tag{2}$$

$$L_{eff} = \frac{c}{2fo\sqrt{\varepsilon_{reff}}} \tag{3}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \tag{4}$$

$$L = L_{eff} + 2\Delta L \tag{5}$$

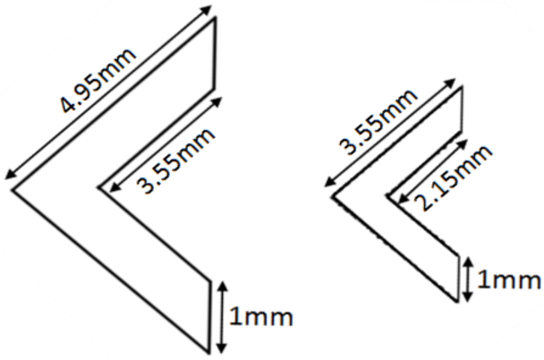

Figure 2. Dimensions of V shaped slots which are etched from the basic geometry of substrate

Table I: Coordinates of different slots position

S. no.	Slot position	Coordinates (X,Y)
1	a	(7.05,12.62)
2	b	(7.05,-12.62)
3	c	(0,-10.55)
4	d	(-7.05,-12.62)
5	e	(-7.05,12.62)
6	f	(0,10.55)
7	u	(0,5)
8	v	(0,-5)

Table II: Parametric values of proposed antenna

Parameters	Description	Values (mm)
S_W	Substrate width	45.6
S_L	Substrate length	50
P_W	Patch width	36.5
P_L	Patch length	28.2
F_W	Feed width	4
F_L	Feed length	14.8
G_W	Ground plane width	45.6
G_L	Ground plane length	12

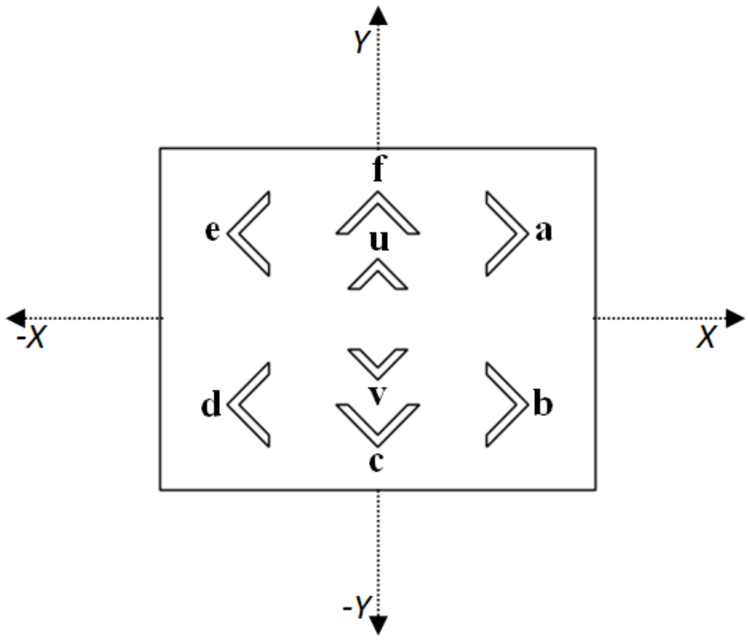

Figure 3. Procedure for applying the V-slots in the patch of proposed antenna

After designing the patch of proposed antenna the 50Ω microstrip feed line is attached with the patch and both are printed on the same side of the dielectric substrate as indicated in Fig 4(a). On the other side of the substrate the ground plane is printed as reported in Fig. 4(b). Partial ground plane also has been introduced to enhance the bandwidth of proposed antenna. The parametric dimensions of antenna are shown in Table 2.

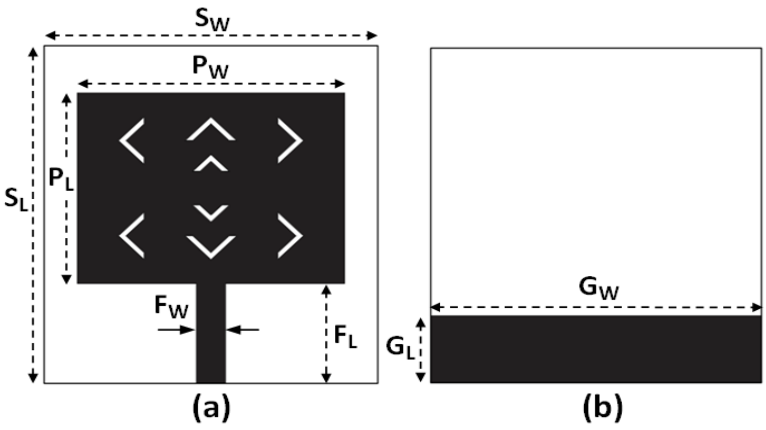

Figure 4. Simulated structures of proposed antenna; (a) front view and (b) back view

RESULT AND DISCUSSIONS

A. Return loss and VSWR

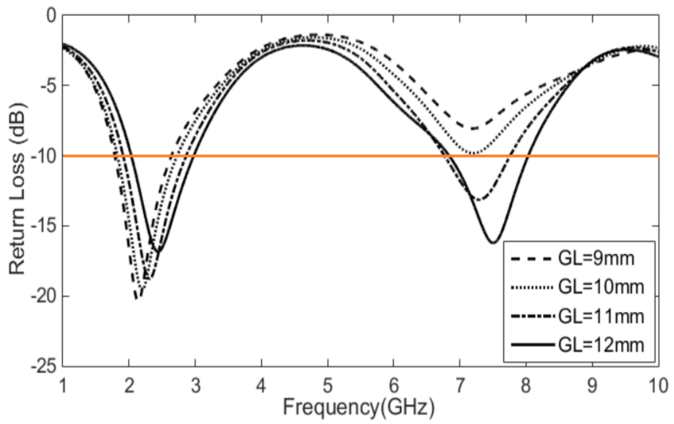

Figure 5. Simulated return loss versus frequency plot of proposed antenna with ground length variations

This section presents the simulated and experimental results of various performance parameters such as return loss and VSWR. Proposed antenna consists of partial ground plane, which exhibits wide bandwidth throughout specified frequency range. The partial ground plane acts as an impedance matching circuit for proposed antenna, and to rectify the impedance mismatch between the feed line and ground plane, it has been introduced. In proposed work, antenna is designed at the resonant frequency 2.5GHz with start and stop frequency 1 GHz and 10 GHz respectively. The length G_L of partial ground plane is varied from 9 mm to 12mm to improve the bandwidth of proposed antenna. Comparison of return loss versus frequency plot of proposed antenna with ground length variations is shown in Fig. 5. It can be contemplated from Fig. 5, that return loss is at acceptable level ($S_{11} \leq$ -10dB), and also exhibits wider bandwidth at G_L=12mm. The comparison of different values of proposed antenna with ground length variations are delineated in Table 3. It also has been observed from Table 3, that the value of VSWR is at acceptable level (VSWR ≤ 2).

Table III: Comparison of results of proposed antenna with ground length variations

Ground length ‘G_L’	Frequency (GHz)	Return loss (dB)	VSWR	Gain (dB)	Bandwidth (MHz)
9mm	2.12	-20.28	1.21	3.44	845
10mm	2.20	-18.21	1.28	3.54	918
11mm	2.30	-18.78	1.26	3.13	942
	7.28	-13.13	1.56	4.70	991
12mm	2.45	-16.84	1.33	3.87	942
	7.52	-16.20	1.37	4.67	1194

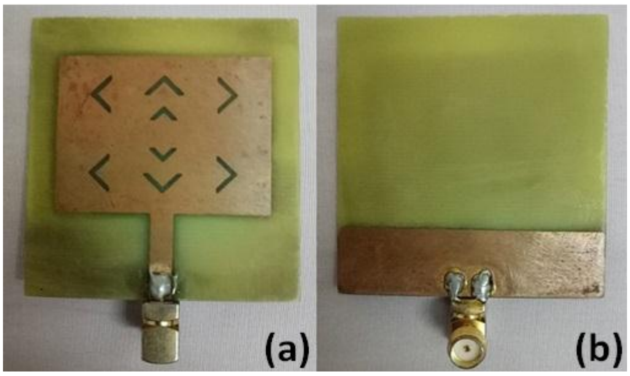

Figure 6. Fabricated structures of proposed antenna; (a) front view and (b) back view

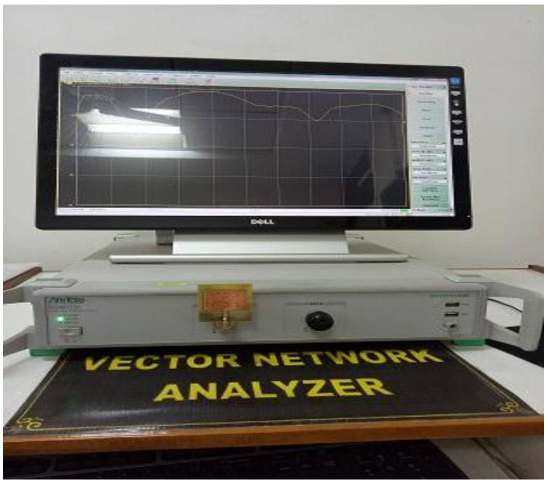

Figure 7. Testing setup for analyzing the return loss and VSWR of proposed antenna

Table IV: Comparison of simulated and measured results of proposed antenna

Proposed antenna	Frequency (GHz)	Return loss (dB)	VSWR	Bandwidth (MHz)
Simulated	2.45	-16.84	1.33	942
	7.52	-16.20	1.37	1194
Measured	2.49	-17.01	1.34	790
	7.53	-11.15	1.77	400

Proposed antenna is fabricated to validate the simulated results with experimental results. Fabricated structure and testing setup of proposed antenna is shown in Fig. 6 and Fig. 7 respectively. VNA (Anritsu (MS46322A) is used for testing the proposed antenna ranging from 1 MHz to 20 GHz. The simulated and experimental results i.e; return loss and VSWR of antenna have been juxtaposed, and shown in Fig. 8 and Fig. 9 respectively. It can also be contemplated that both the results are in good agreement with each other. The comparison of the values of simulated and measured results is tabulated in Table 4. It is very much obvious from Fig. 8, that the proposed antenna exhibit wide bandwidth and can be used for different wireless applications between the specified ranges of frequencies.

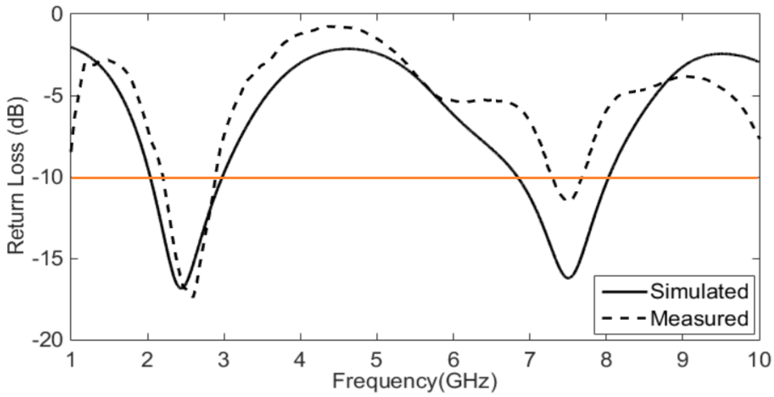

Figure 8. Comparison of return loss versus frequency plot of proposed antenna

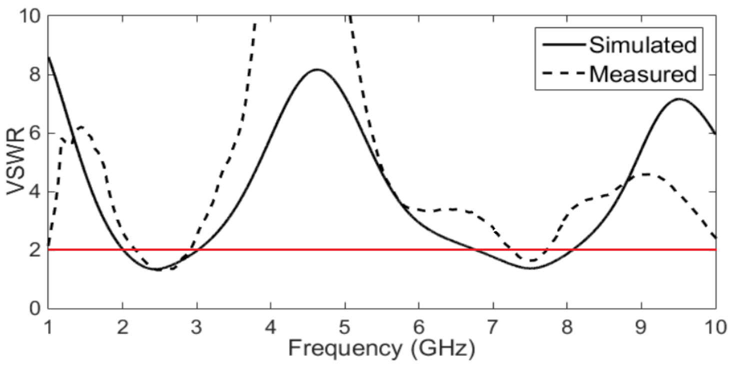

Figure 9. Comparison of VSWR versus frequency plot of proposed antenna

B. Gain and Radiation Pattern

The proposed antenna exhibits the acceptable value of gain at each frequency band of operation. It is observed that antenna depicts 3.87 dB and 4.67 dB of gain at 2.45 GHz and 7.52 GHz frequency bands respectively. E and H plane radiation pattern is also analyzed at respective frequency band. Proposed antenna exhibits the complete omnidirectional and bidirectional radiation pattern at 2.45 GHz frequency band. At higher frequency band of 7.52 GHz the radiation pattern is slightly distorted due to the interference of adjacent bands. The 2D and 3D plots of radiation pattern and gain is shown in Fig. 10.

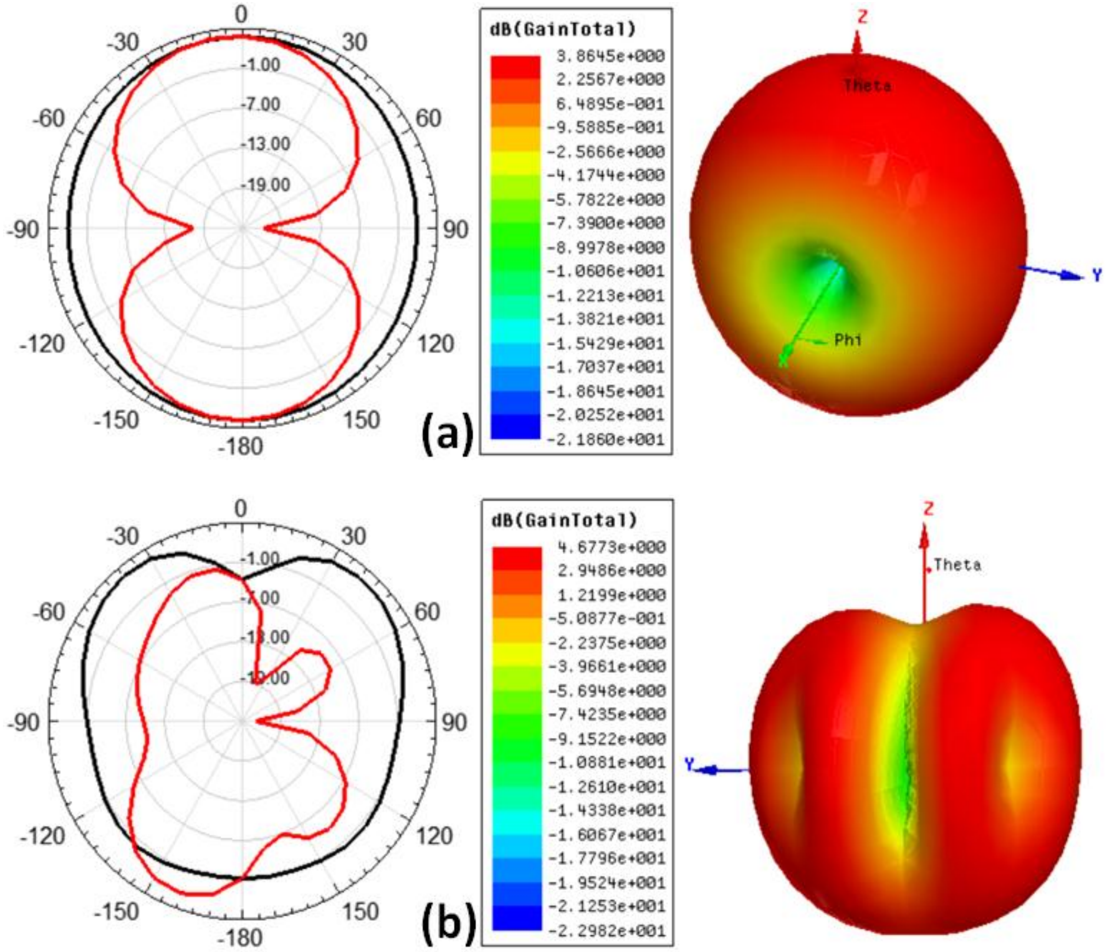

Figure 10. 2D and 3D pattern of proposed antenna at (a) 2.45GHz and (b) 7.52GHz frequency

The comparsion of proposed antenna has been made in the Table V with bexistin antennas

Table IV: Comparison of simulated and measured results of proposed antenna

Ref. No.	Size (mm*mm)	Resonant Frequency (GHz)	Return Loss (dB)	Gain (dB)	Bandwidth (MHz)
Proposed Antenna	36.5*28.2	2.45 & 7.52	-16.84 & -16.2	3.87 &4.67	942 &1194
[16]	40*50	2.53 & 3.5	-29.3 & -18	--------	50 & 310
[17]	72*84.7	091, 2.44 & 5.7	-30, -30 & -30	1.42, 4.69 & 5.7	Narrow
[18]	75*75	3 & 4.3	-21.5 & -22.5	4.45 & 5.4	29.19 & 59.8
[19]	46.4 * 46.4	2.45 & 5.1	-20 & -16.5	6 & 7.2	300 & 600
[20]	30*30	2.52	-36	3.2	40
[21]	42*42	2.54	-23	6	50
[22]	40.3*25.3	1.53/2.75	-23.4/-18.6	--------	Narrow
[23]	50*50	2.33/5.39/7.58	-14 (Maximum)	8.68, 7.3 & 6.33	Narrow

It can be anticipated from the Table IV that proposed antenna is novel as it is compact in size and also premeditates the wider bandwidth.

CONCLUSION

Proposed antenna exhibits the best results at ground length 12 mm, as wideband characteristics has been reported at frequencies 2.45 GHz and 7.52 GHz. It can also be contemplated that by varying the length of ground plane the bandwidth of antenna is increased. wider bandwidth as compared to the other values. Proposed antenna adorns the acceptable value of gain as 3.87dB and 4.67dB at the respective frequency bands of operation. Antenna also exhibits the complete omnidirectional pattern and dipole like pattern at 2.45GHz frequency band, and can be used for wireless applications such as Bluetooth (2.4-2.5GHz) of ISM band and X-band satellite communication (7.1GHz – 7.76GHz). Simulated and Experimental results are also good agreement with other.

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