Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 2, Number 1 October-December (2014) pp. 54-59

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Ultra Wide Band Slotted Micro Strip Patch Antenna (MPA) for Bluetooth, IMT, WLAN, WiMAX & Satellite C-band applications

Amarveer Singh[1], Ekambir Sidhu[2] and Tejinder Kaur Gill[3]

[1]Student of Department of Electronics and Communication Engineering, Punjabi University, Patiala
[2]Department of Electronics and Communication Engineering, Punjabi University, Patiala
[3]Student of Department of Electronics and Communication Engineering, Punjabi University, Patiala
E-mail: [1]amarveersingh91@gmail.com, [2]esidhu@pbi.ac.in, [3]tejinder_gill34@yahoo.com

Abstract: *In this paper, a multi resonant slotted Micro Strip Patch Antenna capable of operating in a frequency range of 1.97 GHz to 7.71 GHz has been proposed. The antenna has been designed using slotted substrate of FR4 material having dielectric constant of 4.4 with slotted radiating patch and a defected ground plane. A circular slot has been drilled in substrate to improve the return loss. A partially reduced slotted ground plane has been employed to enhance the antenna bandwidth. The feed line has to be of suitable width so as to match the antenna impedance with the port impedance (50 ohms). A notch has been added in feed line to improve return loss and antenna bandwidth. The antenna performance has been analyzed in terms of antenna parameters such as return loss (dB), bandwidth (GHz), gain (dB), directivity (dBi), antenna impedance (ohms) and VSWR. The antenna has been designed and simulated using CST Microwave Studio (2010). The antenna has bandwidth of 5.74 GHz and resonant at 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 GHz with corresponding return loss of -33.72 dB, -37.1 dB, -36.50 dB and -18.14 dB, respectively. The designed MPA is suitable to be used for bluetooth, International Mobile Telecommunication (IMT), WLAN, WiMAX and C-band (satellite) applications. The antenna has bandwidth of 5.74 GHz and VSWR less than 2. The simulated antenna has been fabricated and tested successfully using network analyser E5071C with anechoic chamber. It has been observed that the practical results obtained by testing the fabricated antenna using Network analyser E5071C closely matches with the theoretical results obtained by simulating the antenna design in CST MWS 2010.*

1. INTRODUCTION

Micro strip patch antenna also termed as patch antenna, is usually fabricated on a dielectric substrate which acts as an intermediate between a ground plane at the bottom side of substrate and a radiating patch on the top of substrate [1]. The patch is usually made of copper with high electrical conductivity. The patch can be designed in many shapes like rectangular, circular, triangular, elliptical, ring, square and any more but most commonly, rectangular shape is widely used [1] because of the simplicity associated with the design. The selection of substrate is the most important parameter while designing an antenna.

The substrate consists of dielectric material which perturbs the transmission line and electrical performance of an antenna. The size of an antenna is dependent on the dielectric constant of a substrate. The size of antenna is inversely proportional to dielectric constant i.e. higher is the dielectric constant, lower is the size of antenna [2]. There are varieties of substrates available with different dielectric constants but in this antenna design, Fire Resistance 4 (FR4) material with dielectric constant of 4.4 has been used. The antenna can be fed by various methods like coaxial feed, proximity coupled micro strip feed and aperture coupled micro strip feed [3]. The feeding can be defined as the means to transfer the power from the feed line to the patch, which itself acts as a radiator. The micro strip feed line has been used in MPA designs because it is relatively simple to fabricate [3].

The micro strip antenna has been commonly used for wireless applications because of small antenna size, low cost, light weight, better efficiency, ease of installation, ease of mobility, and is relatively inexpensive to manufacture on printed circuit board (PCB) of specific characteristics and dimensions. However, a part from its numerous advantages, there are some drawbacks of MPA. It handles less power and has limited bandwidth [4].

The bandwidth of MPA can be improved by either using a slotted patch [5] [6] or by using reduced groundplane [7,8]. The slot on the patch can be of any shape like H-slot [9], E-slot [10], circular, rectangular, etc. These techniques can also be used to improve the return loss along with bandwidth enhancement.

Different shapes of slots have different effect on antenna parameters. More than one slot having different dimensions can be etched on patch simultaneously in order to improve various antenna parameters like return loss, bandwidth.

Section II (Antenna Geometry) explains the geometry of antenna. The top view, bottom view and dimensions of substrate, slots on substrates, patch, slots on the patch, ground plane and slots on ground plane are listed in Section II.

Section III (Results and Discussions) describes the simulated results obtained by using CST MWS (2010) which includes Return loss (S_{11}), Directivity, Gain at corresponding resonant frequencies, VSWR and Smith chart plots.

Section IV (Experimental verification) indicates the top and bottom view of practically designed antenna and describes practical results obtained by testing the practically designed antenna using E5071C Network Analyser.

2. ANTENNA GEOMETRY

The Antenna has been designed and simulated using CST Microwave Studio 2010. Fig. 1 shows the top view of designed slotted MPA. The top view represents the dimensions of substrate, slot drilled in substrate, radiating patch, slots cut on patch, feed line and a notch added to feed line. Fig. 2 represents the bottom view of designed antenna. The bottom view represents the dimensions of defected ground plane and slots cut on ground plane. The dotted portion shown in Fig. 2 indicates the projection of patch and feed line on ground surface. The slotted antenna has been designed using substrate of FR4 material having thickness of 1.57 mm and dielectric constant of 4.4. The radiating patch and ground surface is of PEC (Perfect Electric Conductor) material, both having thickness of 0.02 mm. The dimensions of substrate, radiating patch, slots, feed line and ground plane are listed in Table 1.

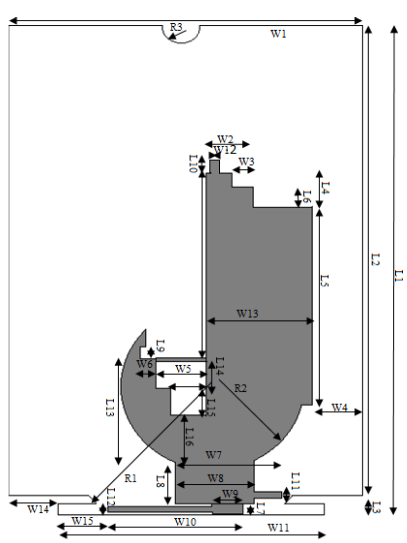

Fig. 1: Top view of Designed Antenna

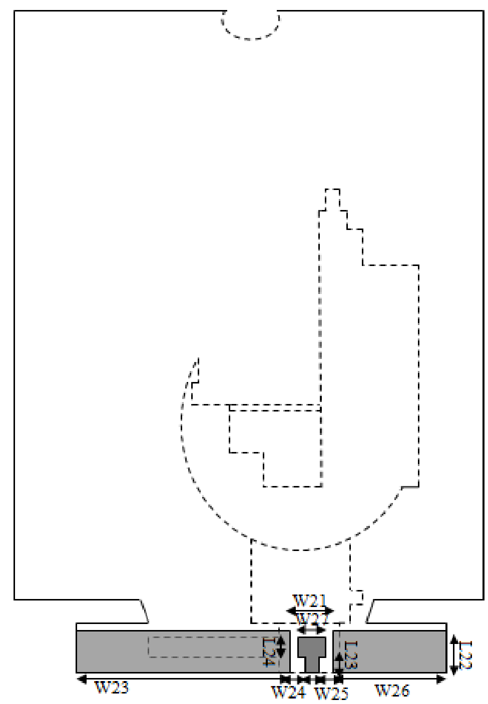

Fig. 2: Bottom view of designed antenna

Table 1: Antenna Parameters

Antenna Parameters	Specifications
Substrate	Length L1=60 mm Length L2=53 mm Length L3=3.5 mm Width W1=50 mm Width W11=40 mm Width W14=5 mm Width W15=8 mm
Patch Length	Length L4=6 mm Length L5=15 mm Length L6=3.5 mm Length L8=6.5 mm Length L9= 2.5 mm Length L10=2.5 mm Length L11=2.5 mm Length L13=19 mm Length L14=4 mm Length L15=4 mm Length L16=10.5 mm

Patch width	Width W2=8.5 mm Width W3=2 mm Width W4=12 mm Width W5=5 mm Width W6=1.5 mm Width W7=15 mm Width W8=10.5 mm Width W12=0.6 mm Width W13=16.5 mm
Feed Line	Length L7=3.5 mm Length L12=2.3 mm Width W9=6.7 mm Width W10=15.5 mm
Radius	R1 (-1,0)=20 mm R2 (0,0)=12 mm R3 (-2,39)=2 mm
Ground Length	Length L22=3 mm Length L23=1 mm Length L24=1.5 mm
Ground Width	Width W21=4 mm Width W23=18 mm Width W24=1.5 mm Width W25=1.5 mm Width W26=18 mm Width W27=2 mm

3. RESULTS AND DISCUSSION

The designed antenna has been simulated using CST Microwave Studio 2010. The antenna performance has been analysed in terms of antenna parameters such as antenna impedance, directivity, gain, impedance bandwidth and VSWR.

The experimental results have been obtained by testing the fabricated antenna using Network Analyser E5071C with anechoic chamber and concluded that the practical results closely matches with the theoretical simulated results.

3.1. Return loss

Fig. 3 indicates the return loss (S_{11}) plot of designed slotted MPA. Practically, the return loss should be less from minimal back reflections. The designed slotted MPA is resonant at four resonant frequencies. The designed MPA has return loss of -33.72 dB, -37.10 dB, -36.50 dB and -18.14 dB at 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 GHz, respectively. The designed antenna has simulated bandwidth of 5.75 GHz.

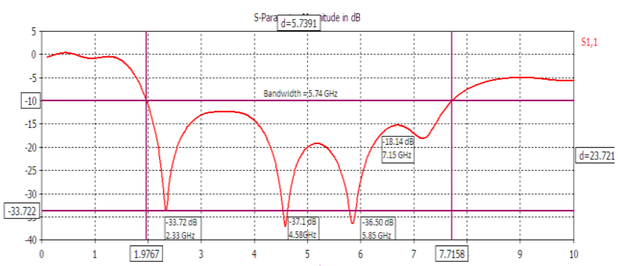

Fig. 3: Return loss plot of Slotted MPA

3.2. Directivity

The directivity has been obtained and analysed at resonant frequencies. The directivity at resonant frequencies 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 GHz is 2.29 dBi, 6.10 dBi, 4.64dBi and 5.35 dBi, respectively. The 3D plot of directivity at resonant frequencies 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 dBi is shown in Fig. 4(a), Fig. 4(b), Fig. 4(c) and Fig. 4(d), respectively.

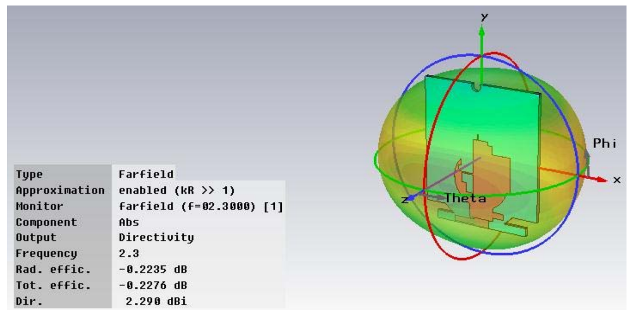

Fig. 4(a): 3D plot of Directivity of MPA at 2.3 GHz

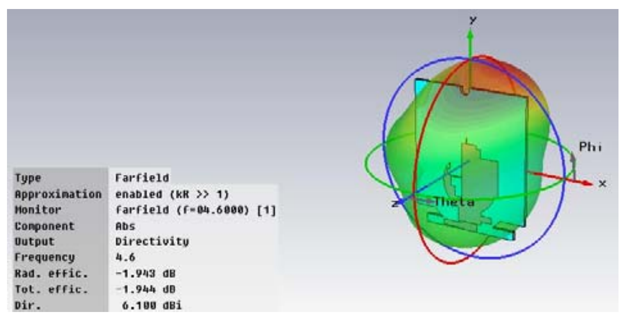

Fig. 4(b): 3D plot of Directivity of MPA at 4.6 GHz

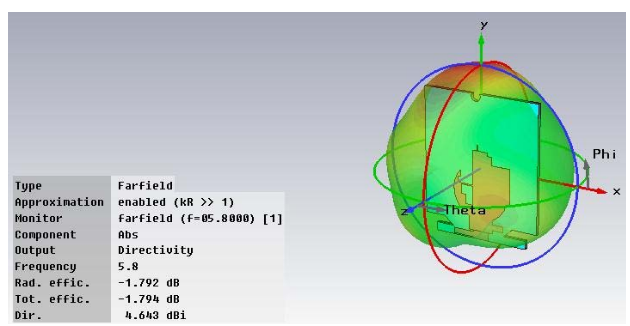

Fig. 4(c): 3D plot of Directivity of MPA at 5.8 GHz

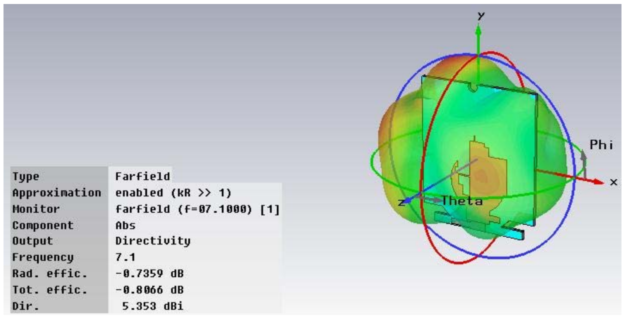

Fig. 4(d): 3D plot of Directivity of MPA at 7.1 GHz

3.3. Gain

Fig. 5(a), Fig. 5(b), Fig. 5(c) and Fig. 5(d) illustrates the 3D plot of gain of designed slotted MPA at resonant frequencies 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 GHz, respectively. The slotted MPA has gain of 2.06 dB, 4.15 dB, 2.85 dB and 4.61 dB at resonant frequencies of 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 GHz, respectively.

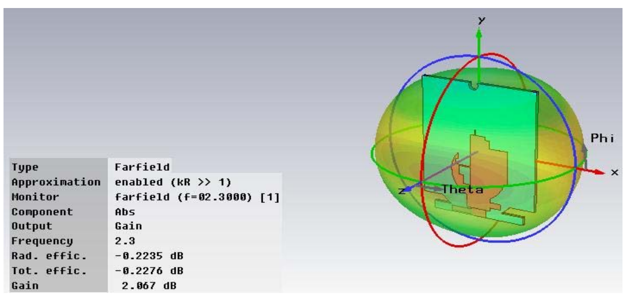

Fig. 5 (a): 3D plot of Gain of designed MPA at 2.3 GHz

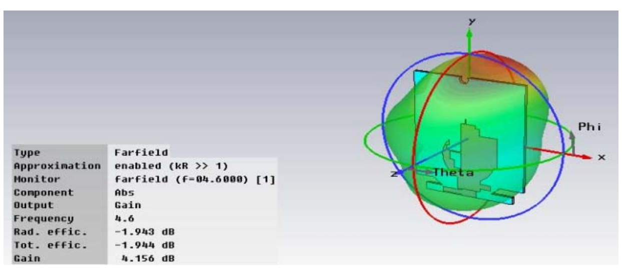

Fig. 5 (b): 3D plot of Gain of designed MPA at 4.6 GHz

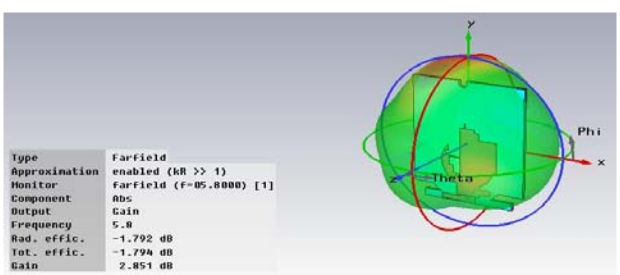

Fig. 5 (c): 3D plot of Gain of designed MPA at 5.8 GHz

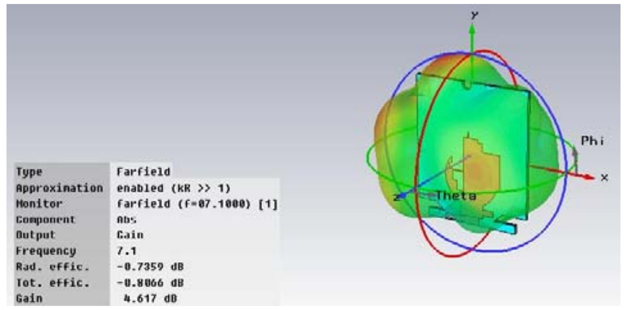

Fig. 5 (d): 3D plot of Gain of designed MPA at 7.1 GHz

3.4. VSWR

Fig. 6 depicts the simulated VSWR plot for designed MPA. Practically, the required value of VSWR should be less than 2. Fig. 6 shows that value of VSWR for designed MPA is less than 2 in the operating frequency range of 1.97 GHz to 7.71 GHz.

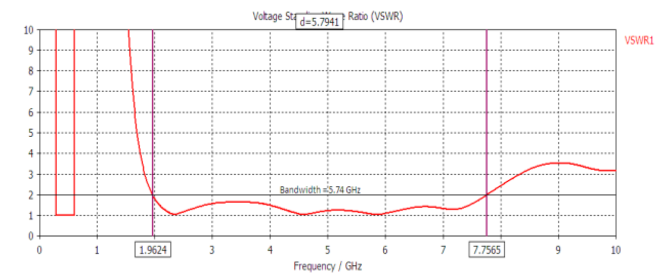

Fig. 6: VSWR plot of designed MPA

3.5. Smith Chart

Fig. 8 indicates Smith chart plot for designed MPA. The Smith Chart plot indicates the variation of impedance of antenna with frequency. The value of impedance should lie near 50 ohms in order to perfectly match the port impedance with the antenna impedance for maximum transfer of power to antenna. The antenna impedance for designed slotted MPA antenna is 52.08 Ω.

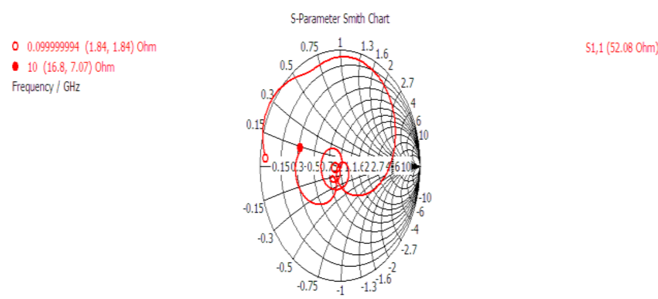

Fig. 8: Smith Chart plot of designed MPA

4. EXPERIMENTAL VERIFICATION

The practically designed antenna is shown in Figure

9(a) and Fig. 9(b). Fig. 9(a) and Fig. 9(b) represents the top and bottom view of fabricated antenna, respectively. The fabricated antenna has been tested using network analyser E5071C with anechoic chamber. The practical experimental results of tested antenna are shown in Fig. 10. The practically tested antenna has impedance bandwidth of 5.51 GHz. The tested has three resonant frequencies a t 2.38 GHz, 4.52 GHz and 5.81 GHz with return loss of -30.58 dB, -32.88 dB and -33.74 dB, respectively.

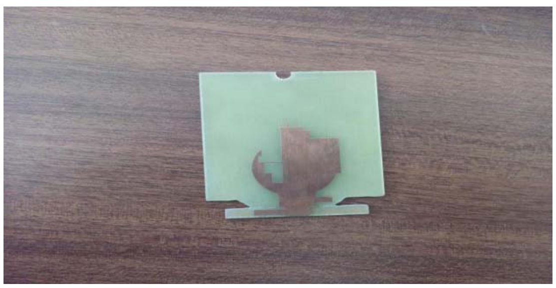

Fig. 9(a): Top View of fabricated antenna

Fig. 9(c): Bottom view of fabricated antenna

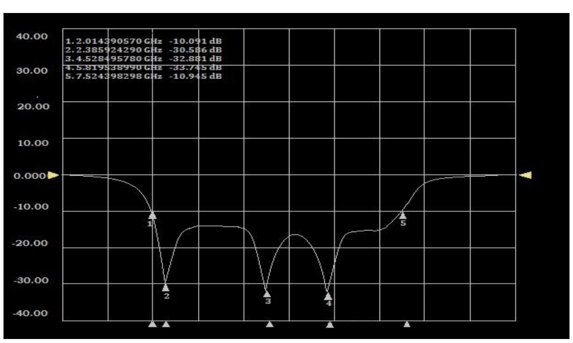

Fig. 10: Experimental results of fabricated antenna

5. CONCLUSION

From the above discussion, it has been concluded that the designed antenna has simulated impedance bandwidth of 5.74 GHz with operating frequency range 1.97 GHz to 7.71 GHz and corresponding resonant frequencies are 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 GHz. The designed antenna has return loss of -33.72 dB, -37.1 dB, -36.50 dB and -18.14 dB at 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 GHz, respectively. The designed antenna has directivity of 2.29 dBi, 6.10 dBi, 4.64 dBi and 5.35 dBi at resonant frequencies of 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 GHz, respectively. The simulated antenna has gain of 2.06 dB, 4.15 dB, 2.85 dB and 4.61 dB at resonant frequencies 2.33 GHz, 4.58 GHz, 5.85 GHz and 7.15 GHz, respectively. The VSWR value for slotted micro strip patch antenna is less than 2 in the operating frequency range of 1.97 GHz to 7.71 GHz. The antenna has been using designed using CST Microwave Studio 2010. The fabricated antenna has been tested using Network Analyser E5071C with anechoic chamber. The practically tested antenna has impedance bandwidth of 5.51 GHz with operating frequency range from 2.01 GHz to 7.52 GHz and corresponding resonant frequencies at 2.38 GHz, 4.52 GHz and 5.81 GHz. The fabricated antenna has return loss of -30.58 dB, -32.88 dB and -33.74 dB at resonant frequencies 2.38 GHz, 4.52 GHz and 5.81 GHz, respectively. It has been observed that the theoretical results have been closely matches with experimental practical results. The designed antenna can be used for Bluetooth (2.4 GHz - 2.5 GHz), International Mobile Telecommunication (IMT) (2.3 GHz–2.4 GHz, 2.7GHz–2.9 GHz, 3.4 GHz–4.2 GHz and 4.4 GHz–4.9 GHz), WLAN (2.4 GHz–2.484 GHz, 5.15 GHz –5.35 GHz and 5.725 GHz–5.825 GHz), WiMAX (2.5GHz–2.69 GHz, 3.4 GHz- 3.69 GHz and 5.25 GHz - 5.85 GHz) and C-band satellite (4 GHz - 6 GHz) applications [8].

6. ACKNOWLEDGEMENT

We would like to thank Professor Ekambir Sidhu, Assistant Professor, Department of Electronics and Communication Engineering, Punjabi university, Patiala, for his kind support, guidance and suggestions.

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