# A Slotted Rectangular Microstrip Patch Antenna for Wideband Wireless Applications

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***Abstract*— This paper presents the utilization of slots with full and partial ground plane in rectangular Microstrip Patch Antenna (MPA). The partial ground plane has been introduced to increase the bandwidth of designed antenna. Proposed antenna is designed on FR4 glass epoxy substrate with 1.6mm thickness and dielectric constant 4.4. Designing and simulation has been carried out by using HFSS V13 software. MPA with full ground plane works on four resonant frequency bands, but the value of gain and bandwidth is less. Proposed antenna with varying partial ground plane has been designed and observed that it adorns the optimal results at ground length 12mm. The MPA with partial ground plane with ground length 12mm works on two resonant frequency bands (2.21GHz and 7.06GHz) with the value of gain (3.92dB and 4.71dB) and bandwidth (949MHz and 1030MHz) respectively. These values are at the acceptable level which meets the requirement of wireless application such as bluetooth (2.41 – 2.49GHz) and point to point high speed wireless communication (5.92 – 8.5GHz).**

**Keyword-**MPA, FR4, HFSS, bluetooth, slotted patch, microstrip

## I. INTRODUCTION

Microstrip patch antennas have been widely used in the field of wireless communications like mobile, radar and satellite because of its unique features such as compact size, ease of fabrication, low profile, less weight and ease of installation [2]. Now days, the antenna with multiband and wideband characteristics are more preferred in the wireless systems [3]. These antennas are capable of working on different applications when installed on wireless devices. By the use of multiband or wideband antennas a single device can be used for various wireless applications under specified range of frequencies [4]. Due to these features and large demand, microstrip antennas become a major area of research for the researchers [5]. Numerous researches have been carried out in recent years by the researchers to achieve multiband and wideband applications [6]. Slotted patch antennas are designed to achieve multiband characteristics [7]. But few drawbacks have been observed in this antenna design such as it exhibits less bandwidth and less value of gain [8]. To remove these drawbacks the work has been done on the ground plane of antenna because it acts as impedance matching circuit for the antenna [9]. Partial ground plane [10], defected ground plane [9], and slotted ground plane have been designed by many researchers to achieve wideband characteristics and high value of gain for different wireless standards [11]. These antennas can be capable of work under various wireless applications such as WiMAX, WLAN, Wi-fi, bluetooth, satellite communication and radar communication [12].

In this paper slotted rectangular patch antenna is designed for wideband applications. Proposed design is analysed for both the multiband and wideband characteristics by using full and partial ground plane. Detailed design and simulated results of proposed antenna with the variation in ground plane is discussed in section 2 and 3.

## II. ANTENNA DESIGN AND CONFIGURATION

The proposed antenna uses the FR4 glass epoxy substrate board with the thickness of 1.6mm and dielectric constant 4.4. Proposed antenna is designed by using the frequency of 2.5GHz, which lie in the range of bluetooth application. Dimensions of the rectangular patch have been calculated by using the equations (1) to (5) as shown below [1]. By using these equations the length and width of proposed antenna is found to be 28.2mm and 36.5mm respectively. The line feeding technique is used to provide the excitation to the designed antenna and the position of feed is optimized to get a good impedance matching, hence located at the centre below the radiating element as shown in Fig. 1(a). Full ground plane with length and width equal to the dimensions of the substrate is shown in Fig. 1(b) and partial ground plane with width 45.6mm and length 10mm is shown in Fig. 1(c). In the proposed antenna design the slots has been introduced to obtain the novel structure of microstrip antenna. The exact position and the symmetry between the slots are very necessary to obtain the accurate results from the designed antenna. These slots help the antenna to exhibit multiband characteristics and are also helpful in increasing the gain and bandwidth of antenna. Process of designing the slots and positioning the slots in the rectangular patch along with the parametric description is shown in Fig. 2. Dimensions of the designed antenna are tabulated in Table I.

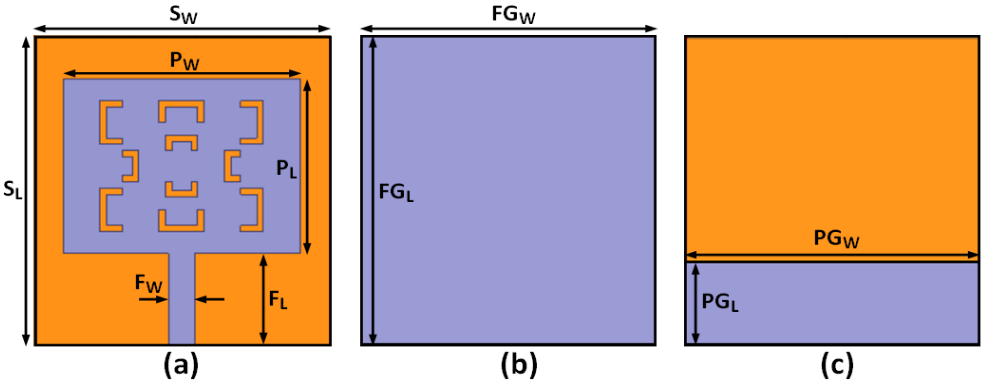


Fig. 1. Proposed antenna design; (a) front view, (b) back view with full ground plane and (c) back view with partial ground plane

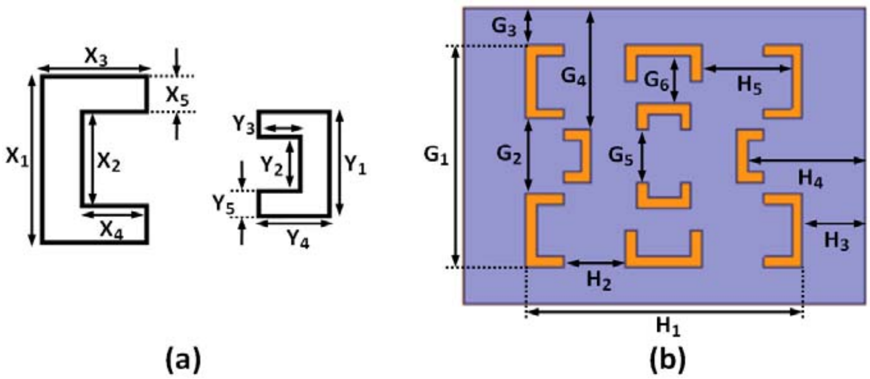


Fig. 2. Procedure for employing the slots; (a) dimensions of slots and (b) positioning of the slots in the rectangular patch

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{\frac{1}{2}} \quad (2)$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.246\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (4)$$

$$L = L_{eff} + 2\Delta L \quad (5)$$

Where,

$c$ = Velocity of light in free space.

$h$ = Substrate height.

$\varepsilon_r$ = Relative permittivity of the substrate.

$W$ = Width of rectangular patch.

$L$ = Length of rectangular patch.

$L_{eff}$= Effective length.

$\varepsilon_{eff}$ = Effective dielectric constant.

$f_{o=}$ Resonant frequency.

$\Delta L$= Length extension.

TABLE I. Parametric Values of Proposed Antenna

| Parameters | Values (mm) |
|---|---|
| $S_W$=$FG_W$=$PG_W$ | 45.6 |
| $S_L$=$FG_L$ | 50 |
| $P_W$ | 36.5 |
| $P_L$ | 28.2 |
| $F_W$ | 4 |
| $F_L$ | 14.8 |
| $PG_L$ | 10 |
| $X_1$ | 7 |
| $X_2$=$Y_1$=$G_5$ | 5 |
| $X_3$ | 3.5 |
| $X_4$=$Y_4$ | 2.5 |
| $X_5$=$Y_5$ | 1 |
| $Y_2$ | 3 |
| $Y_3$ | 1.5 |
| $G_1$ | 21.1 |
| $G_2$ | 7.1 |
| $G_3$ | 3.55 |
| $G_4$ | 11.625 |
| $G_6$ | 4.55 |
| $H_1$ | 25.25 |
| $H_2$=$H_3$ | 5.625 |
| $H_4$ | 10.625 |
| $H_5$ | 8.125 |

## III. RESULT AND DISCUSSIONS

This section presents the complete detail of simulated performance parameters of the proposed antenna such as return loss, VSWR, bandwidth, gain and radiation pattern. All the parameters have been obtained by using Finite Element Method (FEM) based simulator called High Frequency Structure Simulator (HFSS) version 13.

### *A. Return Loss and Bandwidth*

Return loss of the proposed antenna is also called as the $S_{11}$ parameter; it describes the relationship between the terminals and input-output ports of antenna system. $S_{11}$ parameter; represents the amount of power at input port of antenna which is reflected back and the remaining power which is radiated by the antenna. The value of return loss is less than or equal to -10dB at a particular frequency band for the antenna to work efficiently for practical applications. Fig. 3; represents the return loss versus frequency plot of proposed antenna with full ground plane. It is observed that antenna exhibits multiband behaviour and works on four resonant frequencies such as 3.51GHz, 5.94GHz, 6.69GHz and 8.80GHz with corresponding return loss of -20.19dB, -17.27dB, -18.14dB and -51.26dB respectively. But the antenna with full ground plane does not work on a resonant frequency on which the antenna is designed and also shows the narrow bandwidth of few MHz at all the frequency bands of operation. Further to increase the bandwidth and to make the antenna work on designed resonant frequency, the length of ground plane is varied. Return loss versus frequency plot of proposed antenna with length variation is shown in Fig. 4 and the values of performance parameters are tabulated in Table II.

As observed in Table II, the ground length with 12mm exhibits the better results as compared to the other variations. So, $PG_L$ parameter is restricted to 12mm because of its wideband characteristics and better results. The return loss and VSWR versus frequency plot of proposed antenna with $PG_L$=12mm is shown in Fig. 5 and Fig. 6 respectively. VSWR plot of proposed antenna describes that how well the antenna impedance is matched with respect to the transmission line connected to the antenna. Proposed antenna satisfies the condition of VSWR less than or equal to 2 for the resonant frequency bands of operation.

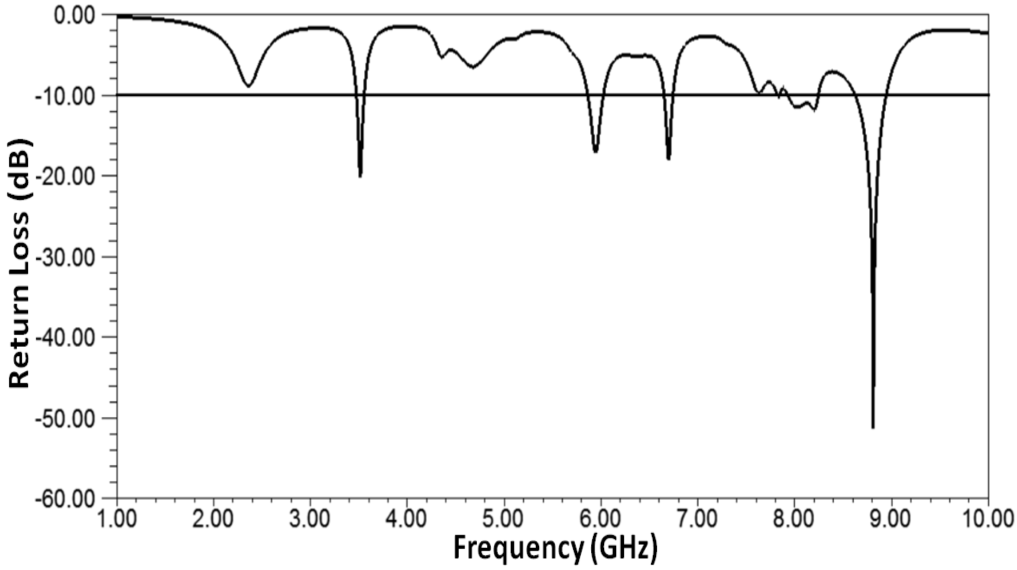


Fig. 3. Return loss versus frequency plot of antenna with full ground plane

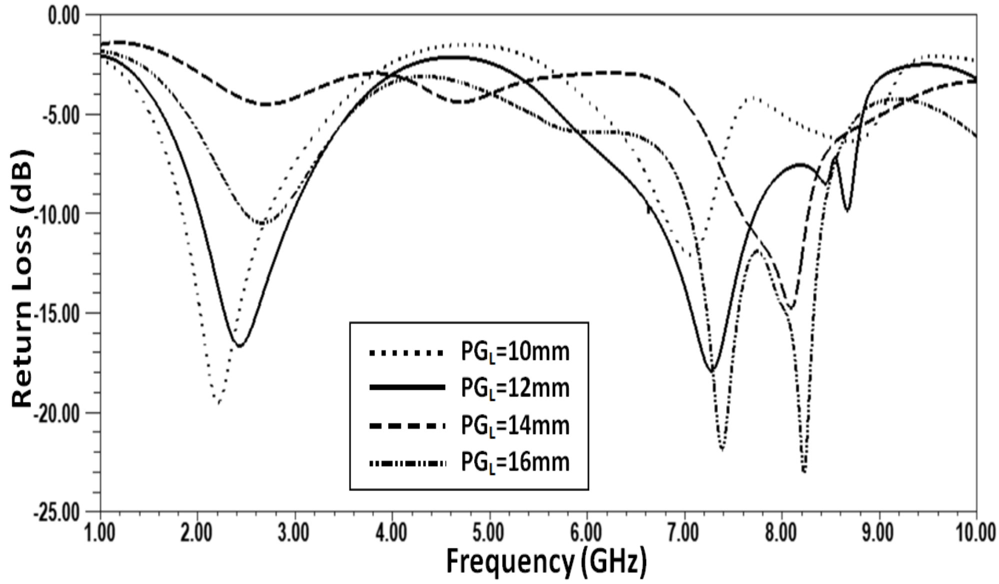


Fig. 4. Return loss versus frequency plot of antenna with ground plane length variation

TABLE III. Performance of Proposed Antenna with Ground Length Variation

| Variation in $PG_L$ (mm) | Center Frequency (GHz) | Operating Frequency Range (GHz) | Return Loss (dB) | Bandwidth (MHz) | Gain (dB) |
|---|---|---|---|---|---|
| 10 | 2.20 | 1.85 – 2.71 | -19.48 | 860 | 4.31 |
| | 7.06 | 6.79 – 7.25 | -12.08 | 460 | 4.65 |
| 12 | 2.21 | 2.025 – 2.974 | -16.65 | 949 | 3.87 |
| | 7.06 | 6.69 – 7.72 | -17.90 | 1030 | 4.71 |
| 14 | 2.66 | 2.50 – 2.84 | -10.50 | 340 | 3.30 |
| | 7.73 | 7.05 – 8.42 | -11.90 | 1370 | 4.40 |
| 16 | 8.08 | 7.585 – 8.265 | -14.77 | 680 | 3.86 |

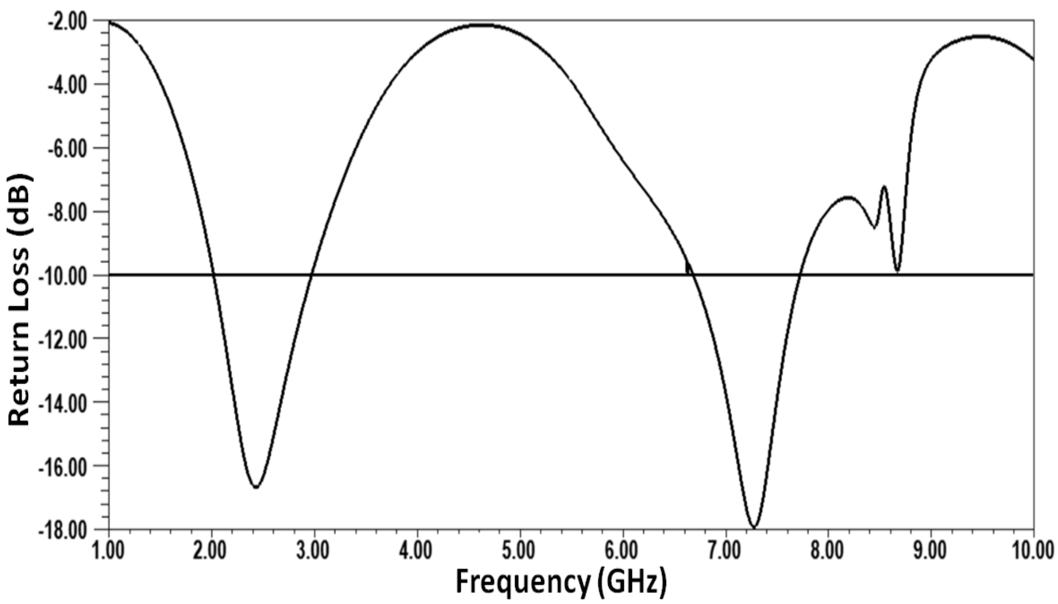


Fig. 5. Return loss versus frequency plot of antenna with $PG_L$=12mm

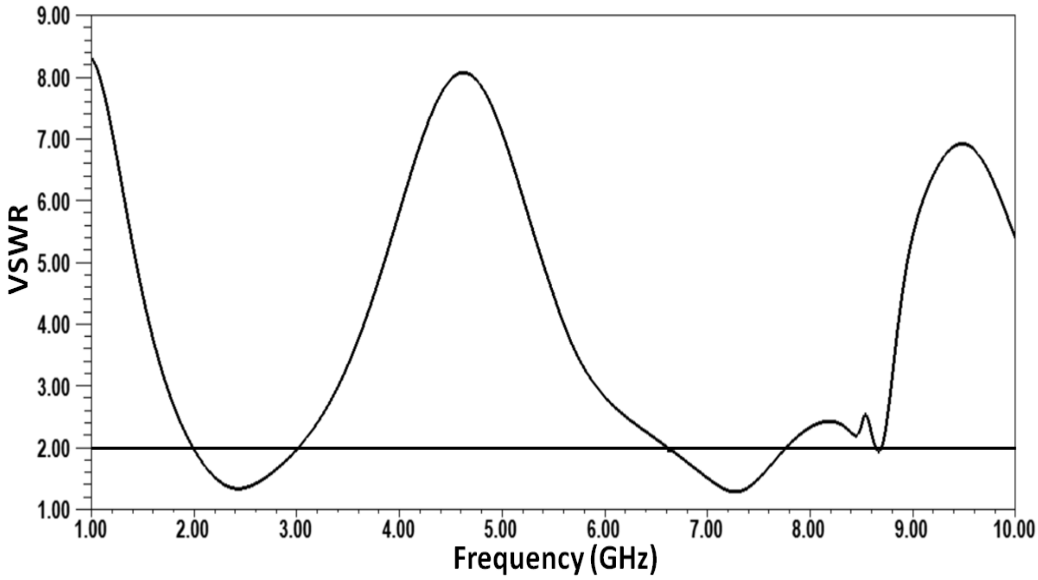


Fig. 6. VSWR versus frequency plot of antenna with $PG_L$=12mm

### *B. Gain and Radiation Pattern*

The efficiency and the directional capability of antenna can be represented or analysed by gain of antenna and it is expressed in decibels. Proposed antenna with full ground plane shows the value of gain as -4.47dB, 2.43dB, 2.09dB and 10.01dB at 3.51GHz, 5.94GHz, 6.69GHz and 8.80GHz frequency bands respectively. It shows negative value of gain at lowest frequency band and a large value of gain as 10.01dB at highest frequency band. Though, the proposed antenna with full ground plane shows the large value of gain but it exhibits narrow bandwidth. Further, to increase the gain and to obtain omnidirectional radiation pattern, proposed antenna is modified by varying the ground plane length. Finally the antenna with partial ground plane length 12mm is designed which exhibits omnidirectional and dipole like radiation pattern at lowest frequency band of 2.21GHz. Radiation pattern graphically represents the field strength variation of the radio waves. 2D and 3D radiation pattern for the final geometry of proposed antenna is shown in Fig. 7.

## IV. CONCLUSION

A novel design of rectangular microstrip slotted patch antenna with line feeding technique for wideband applications has been designed and investigated in this paper. Two types of ground planes are used in the proposed design such as full ground plane and partial ground plane. Proposed antenna with full ground plane exhibits multiband characteristics and claims very less/narrow bandwidth. The results of proposed antenna with varying ground length have been contemplated and noticed that it depicts optimal results at ground length

12mm.The proposed antenna with partial ground plane at ground length 12mm exhibits wideband characteristics and shows the bandwidth of 949MHz and 1030MHz for respective frequency bands. It also shows the acceptable value of gain and good omnidirectional radiation pattern at lowest frequency band of operation. So, it is concluded that the proposed antenna with partial ground plane can be used for different wireless standards such as bluetooth (2.41 – 2.49GHz) and point to point high speed wireless communication (5.92 – 8.5GHz).

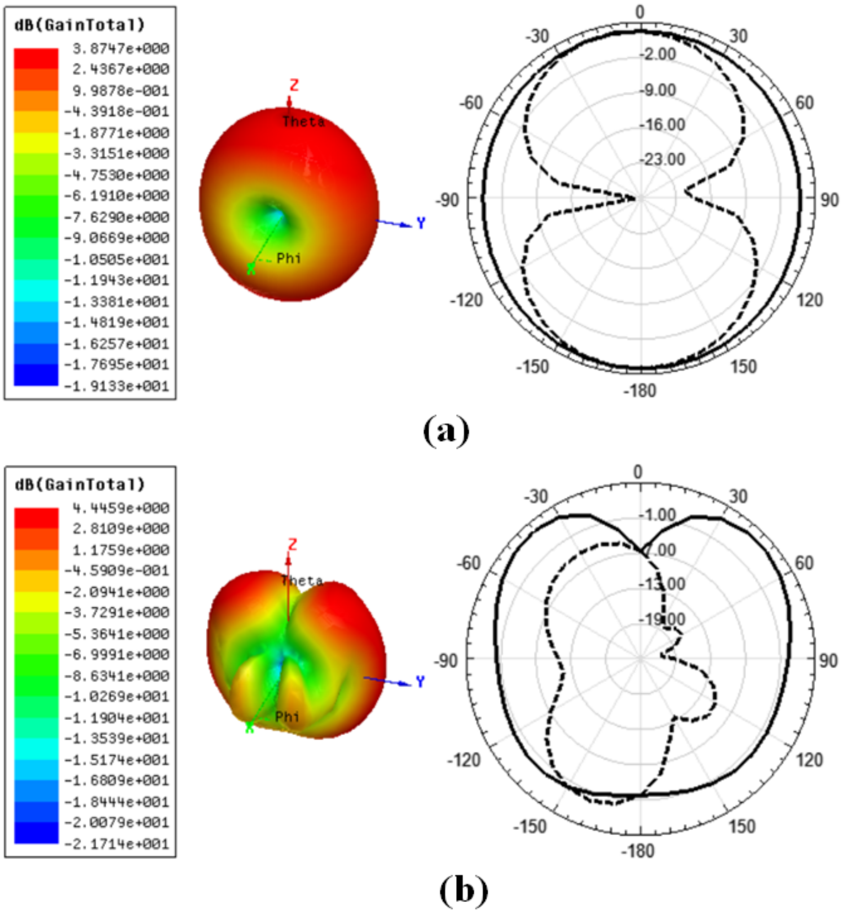


Fig. 7. 2D and 3D radiation pattern of proposed antenna; (a) 2.21GHz and (b) 7.06GHz

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