Design of a Slotted Triple Band Triangular Patch Antenna for 3G and WLAN Applications

Purnima Sharma, S. K. Jha, P. P. Bhattacharya

Abstract - **In this work, a triangular patch slotted antenna is proposed. The proposed antenna is composed of a triangular patch with three triangular slots. Multiple radiation beams are obtained by operating the patch antenna at higher order TM_{02} mode. The presented antenna resonates at 2 GHz, 4.2 GHz and 5.7 GHz which corresponds to 3G, C-band and WLAN application. Characteristics parameters (return loss, VSWR and radiation pattern) are obtained and analysed using HFSS 13.0.**

Keywords - **Third generation (3G), Microstrip Patch Antenna (MPA), Triangular slot, WLAN**

I. Introduction

Recently, planar antennas are used widely in the area of wireless communication for its various characteristics [1]. The applications of planar antennas are in various fields such as in mobile communication, RFID applications, satellite and in the area of military such as rockets, aircrafts and missiles etc [2]. Microstrip patch antenna generally operates at their fundamental TM_{01} mode which produces a single beam. Microstrip patch antenna operating at higher order [TM_{02}] mode has dual symmetric radiation beams [3]. A wide-band and dual-beam U-slot microstrip patch antenna is presented in [3]. There, two radiation beams were obtained by operating patch antenna at higher order TM_{02} mode instead of conventional TM_{01} mode and this antenna is suitable for indoor wireless systems. Slots in printed antennas are widely used for multiband operation. Some antennas for multiband applications, such as U-slot [4], V-slot [5] and bow-tie slot [6] have been reported. A variety of techniques have been used to achieve multiband operation for planar antennas. A printed triple-band and wideband dual-polarized meander-line monopole antenna is presented in [7]. In this design, a metamaterial loading concept is used which improves the impedance matching and causes the proposed antenna to radiate at multiple frequency bands with extended bandwidth. A novel low cost triple-band circularly polarized antenna is presented in [8], which operates at 2.4 GHz, 3.5 GHz and 5.7 GHz bands. This antenna achieves frequency ratio which is suitable for multiband wireless communication systems.

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A linearly polarized compact multiband MIMO antenna system for small mobile unit is presented in [9]. This antenna generates five resonating modes covering various wireless applications and is suitable for Wi-MAX, Wi-Fi, and GPS. A triangular shaped microstrip patch antenna, designed using achip capacitor and T-shaped slit, was presented for multi-band applications in [10]. This antenna is. In [11], a comprehensive analysis of equilateral triangular patch antenna based on the cavity model with a coaxial fed source is studied. It was suggested that the equi-triangular patch can be designed to function as a triple frequency antenna. It was shown that in triangular patch antenna, the broadside modes are TM_{10}, TM_{20} and TM_{21}, but a conical radiation pattern is obtained when it is operated at TM_{11} mode. By using partial ground plane the bandwidth increases by certain amount [12]. It was also observed that resonating frequency increases with partial ground plane [12].

II. Design of Proposed Antenna

The present design consists of a slotted triangular patch on a FR4 substrate with a partial ground plane, as shown in Fig. 1. The design aspects are discussed below in the following sub-section.

A. *Principle of Design*

To design a microstrip patch antenna operating at TM_{02} mode, the patch length L should be λ_d, instead of $\lambda_d /2$ for the fundamental mode, where λ_d is the wavelength in the dielectric substrate [3]. In this design, triangular patch antenna configuration is chosen because it has the advantage of occupying less metalized area on substrate than other existing shapes and also fabrication is easier.

B. *Design Considerations for Proposed Antenna*

While designing, several important parameters were considered as listed below:

- Solution frequency (f_0): The frequency chosen for the simulation is 6 GHz.
- Substrate's dielectric constant (ε_r): The dielectric material used for this design is FR4 with dielectric constant of 4.4.
- Substrate's height (h): To make the antenna compact substrate height is taken to be 1.5 mm.

Figure 1 shows the geometry of proposed triangular patch slotted antenna with microstrip feed.

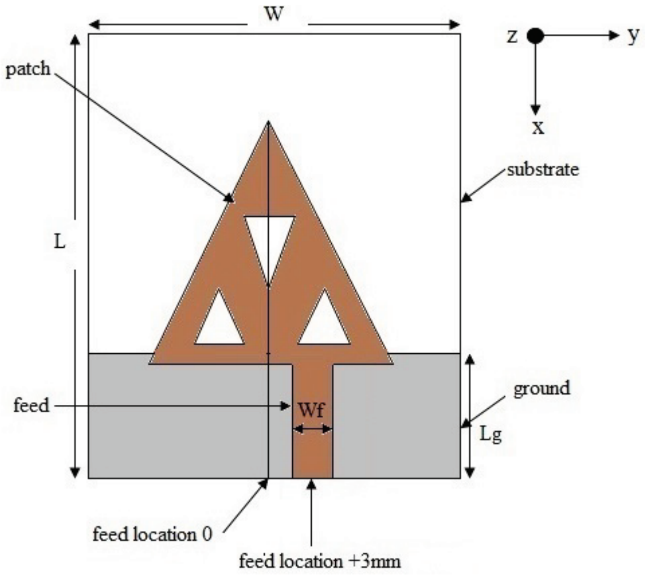


Fig. 1. Geometry of proposed triangular patch slotted antenna

The main specifications of the proposed antenna are summarized in Table I.

TABLE I
DESIGN SPECIFICATIONS OF PROPOSED ANTENNA

Parameter	Value
Solution frequency	6GHz
Dielectric substrate	FR4
Dielectric constant	4.4
Substrate thickness	1.5mm
Substrate loss tangent	0.01

The triangular patch has been proposed for design of the triangular slotted microstrip-patch antenna in this paper. The triangular patch is of 36mm×57mm ($0.63\lambda_d \times 1.0\lambda_d$) dimensions. A truncated ground-plane area of 60mm×24mm ($1.05\ \lambda_d \times 0.42\ \lambda_d$) was selected, where λ_d is the dielectric wavelength at 2.5 GHz. For microstrip patch antennas the input impedance and its variation with feed position are important characteristics [11]. The microstrip feed was located in the xy plane. The ground plane dimensions were found to be very important parameters in the antenna design, as it has strong dependence on bandwidth [12]. The dimensions of antenna are listed in Table II.

TABLE II
DIMENSIONS OF PROPOSED ANTENNA

Physical Dimension	Value
Substrate (L, W, h)	100 x 60x1.5 mm^3
Triangular patch	36x57 mm^2
Width of microstrip feed line (Wf)	4 mm
Ground plane (Lg, W)	24 x 60 mm^2
Feed line length	21.5 mm

In this design three triangular slots are created, as slot antennas are popular design for multiband applications [4-6]. Dimensions are indicated in Fig. 2.

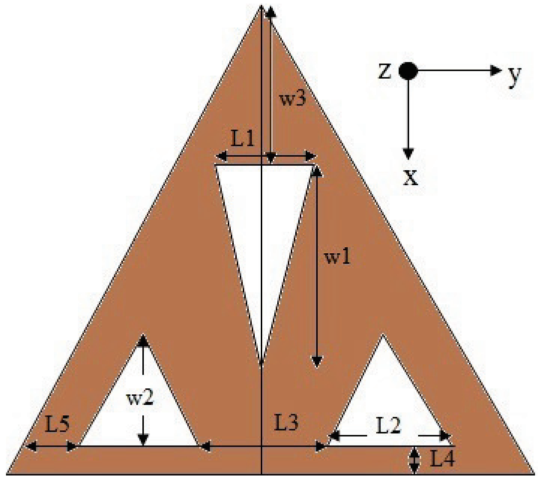


Fig. 2. Geometry of slot

The Cartesian coordinates of the vertices of the center slot are (-5,-5, 1.5), (-5, 5, 1.5) and (20, 0, 1.5). The same for the symmetric slots are (24, ±15, 1.5), (24, ±5, 1.5), (10, ±10, 1.5). The dimensions of the slot are given in Table III.

TABLE III
DIMENSIONS OF SLOT

Dimension	Value (in mm)
L1	10
L2	10
L3	10
L4	4.5
L5	3
w1	25
w2	14
w3	22.5

III. SIMULATION AND RESULTS

The proposed antenna design was simulated using Finite Element Method based HFSS 13.0. The performance parameters such as return loss, VSWR and radiation pattern were obtained from simulations. The parameters that have critically influenced the antenna performance are chosen for parametric study such as Lg and feed location. Figs. 3 and 4 show the simulation results for the return loss at different values of theses parameters.

Fig. 3 shows the effect of variation of microstrip feed location on return loss. Simulations are taken for 3 different locations. From figure it has been analyzed that as feed shifts towards right corresponding shift is observed in resonating frequency. Desired response is found for feed location at +3mm position with respect to center axis. The corresponding return loss values are -26.4 dB at 2 GHz, -12.7 dB at 4.2 GHz and -17.6 dB at 5.7 GHz. At this feed position best impedance match has been achieved. The results are identical for both +3mm and -3mm feed positions except at near third resonating frequency, probably due to different current distribution.

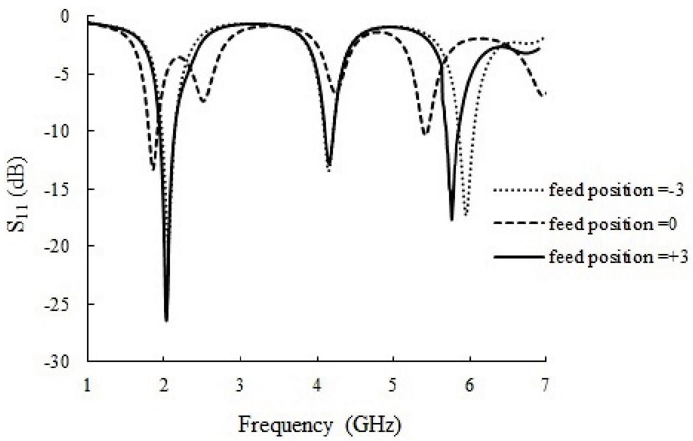


Fig. 3. Effect of feed location on reflection coefficient S_{11} for Lg=23mm and Wf=4mm

Fig. 4 shows the variation of return loss with corresponding variation in ground plane length. The ground plane extends beyond the feed line as indicated in Fig. 1. There is an impact of ground plane length variation on return loss characteristics. The performance of the same structure has been verified with full ground plane, but it was not found to be satisfactory. A shift in resonating frequencies and change in bandwidth have been observed with change in ground plane length. Desired results have been obtained by keeping Lg=24mm. The return loss values are -16.4 dB at 2 GHz, -12.9 dB at 4.2 GHz and -19.9 dB at 5.7 GHz.

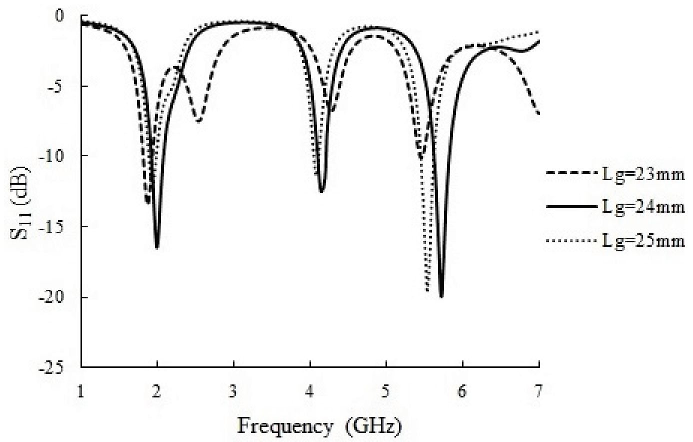


Fig. 4. Effect of variation of ground plane length on reflection coefficient S_{11} for Wf=4mm, feed location=+3mm

Fig. 5 shows the simulated return loss of the proposed antenna for optimized dimensions obtained from parametric study. The optimum dimensions are found to be as follows: Lg=24mm and feed position is +3mm. The first band was around 2 GHz having return loss of -16.6 dB and bandwidth of 7.5% which is suitable for 3G communication. The second band was found to be around 4.2 GHz having a return loss of -13.6 dB and bandwidth of 2.65%, which corresponds to C-band applications. The third band resonates at 5.7 GHz with return loss of -19.9 dB and bandwidth of 3.3%, which is suitable for WLAN applications.

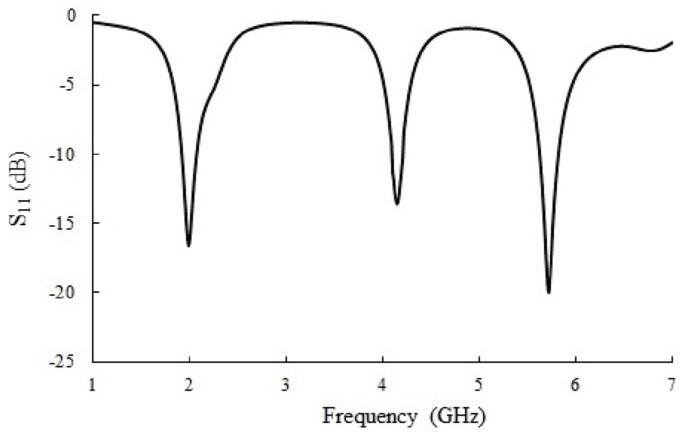
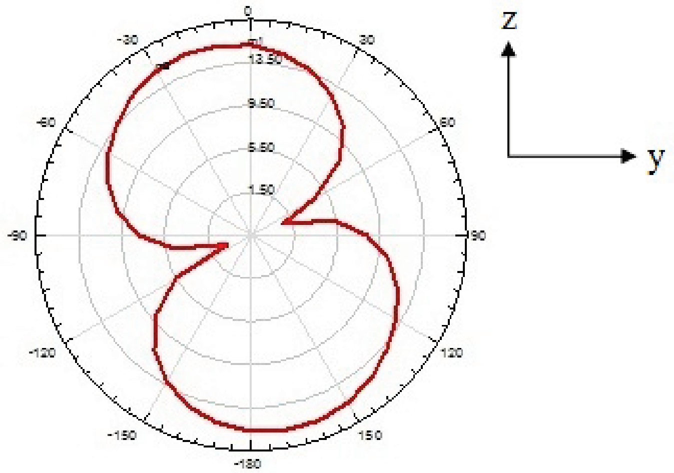


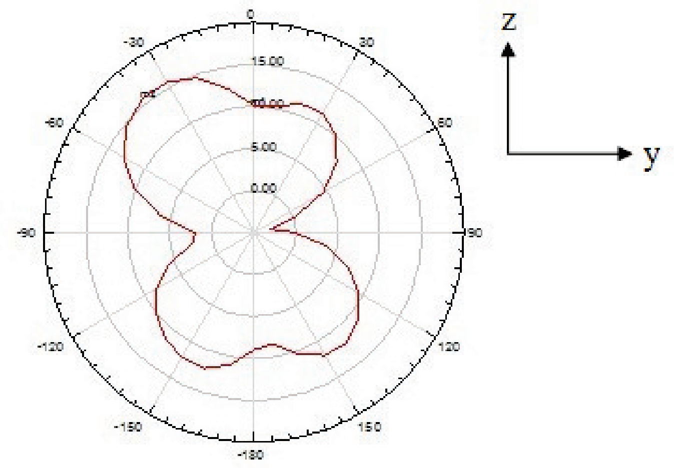
Fig. 5. Simulated return loss S_{11} of proposed antenna for optimized dimensions

The VSWR values obtained after simulation are 1.36, 1.51 and 1.31 at 2 GHz, 4.2 GHz and 5.7 GHz, respectively.

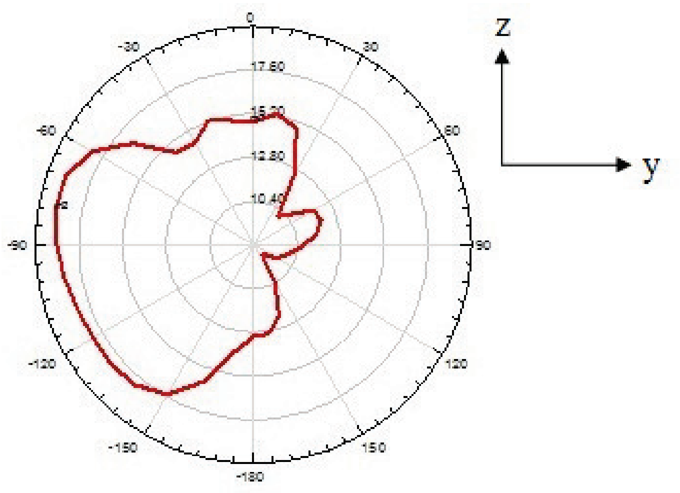
The radiation patterns for designed antenna at three different resonating frequencies are shown in Figs. 6*a*-6*c*. Mismatch effect was properly included in the calculation of antenna gain. The gains of the proposed antenna are 15.1 dBi at 2 GHz, 10 dBi at 4.2 GHz and 14.7 dBi at 5.7 GHz.



(a)



(b)



(c)

Fig. 6. Radiation pattern plot of designed antenna at (a) 2GHz, (b) 4.2 GHz, and (c) 5.7 GHz in yz plane

IV. Conclusion and Future Scope

In this work, a triangular patch slotted antenna operating at higher order TM_{02} mode has been proposed and investigated. This antenna is found to resonate at three different frequencies 2 GHz, 4.2 GHz and 5.7 GHz, which correspond to 3G, C-band and WLAN applications respectively. The antenna may be fabricated and tested in future.

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