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# Slot Loaded Microstrip Antenna for GPS, Wi-Fi, and WiMAX Applications Survey

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## ABSTRACT

A tri-band slot loaded microstrip antenna is proposed. The tri-band characteristics of antenna are achieved by incorporating a combination of symmetrical Y-shaped and asymmetrical U-shaped slot. The Y-shaped slot is placed symmetrically where as U-shaped slot is placed asymmetrically to the center of the patch to achieve the desired tri-band characteristics. The return loss characteristics show that the percentage impedance bandwidth achieved for global positioning system (GPS), Wireless Fidelity (Wi-Fi), and wireless metropolitan area networks (WiMAX) band are 1.78%, 5.28%, and 10.41%, respectively. The parametric study of the antenna is presented. The simulation results of proposed antenna are compared with measured results and found in good agreement.

**Key words :** Symmetrical Y-shaped slot, asymmetrical U-shaped slot, global positioning system (GPS), wireless fidelity (Wi-Fi), and wireless metropolitan area networks (WiMAX).

## 1. INTRODUCTION

Microstrip antenna are popular for their attractive features of planar antennas such as low profile, light weight, conformal shaping, low cost, simplicity of manufacture and easy integration to circuits, and their use in dual frequency band applications appears very attractive [1]. In some applications, two or more bands with an arbitrary separation are required. Also, modern wireless communication devices have the ability to integrate more than one standard into a single system. Due to the limited space, it often requires the antenna that can work at several frequencies simultaneously [2]. In general, several techniques for obtaining dual-frequency behaviour have been reported in the literature [3] such as, orthogonal-mode dual-frequency patch antennas, multi-patch dual frequency patch antennas, and reactively-loaded patch antennas. The reactively-loaded patch antennas are one of the most popular techniques for obtaining dual-frequency behaviour. This includes multilayer stacked patch antennas fabricated by using circular [4], annular [5], rectangular [6], and triangular [7] patches, patch antenna loaded with active devices [8], [9]. However, this method renders antenna more complicated with larger volume.

Reactively loaded microstrip patch antenna is the most popular technique for obtaining a dual-frequency behaviour that consists of a single radiating element in which the dual resonant behavior is obtained by connecting microstrip stub [10] at the radiating edges of a rectangular patch. This method does not allow a frequency ratio higher than 1.2 [10]. Higher values of frequency ratio can be obtained by using two lumped capacitors connected from the patch to the ground plane [11]. By using single shorting pin located near the edge of the patch [12], multiple shorting pin [13], located symmetrically with respect to the patch axes, dual-band operation can also be realized. Some other dual-wideband monopole antennas use a modified Minkowski fractal geometry [14], half-Sierpinski fractal gasket [15], modified fractal slot fed by CPW [16], and bi-band rectangular array antenna [17].

Another simple method to achieve the dual frequency behaviour in a microstrip antenna by embedding a pair of stepped slots on the patch [18]. The U-shaped slot loaded patch antenna can display dual frequency behavior [19-26]. Some of them use pair of symmetrical U-slots [22, 26]. It is interestingly noted that, when the length of the two arms of the U-slot approaches to zero, the design proposed in [26] will degenerate into a slot loaded dual band antenna [1]

Here, we present the symmetric Y- and asymmetric U-shaped slots loaded tri-band compact patch antenna for wireless applications. The proposed antenna has been designed for triple band which cover the frequency band 1.561-1.589 GHz, 2.393-2.523GHz, and 3.30-3.661 GHz for GPS, Wi-Fi, and WiMAX applications, respectively. The Y-shaped slot is placed symmetrically and the asymmetric U-shaped slot is placed asymmetrically to the center of the patch to achieve the desired tri-band performance. When patch is loaded with only Y-shaped slot, the antenna resonates at Wi-Fi (2.48 GHz) and WiMAX (3.48 GHz) frequency bands. But when patch is loaded with Y-shaped slot along with U-shaped slot placed asymmetrically to the patch center, the antenna resonates at 1.5775 GHz, 2.4525 GHz, and 3.3625 GHz. The antenna configuration and details of the dimensions of the geometrical parameters are given in following section.

## 2. ANTENNA CONFIGURATION

The configuration of the proposed tri-band antenna is shown in Figure 1. The antenna consists of a ground plane a rectangular patch loaded with symmetric Y-shaped slot is placed symmetrically and asymmetric U-shaped slot is placed asymmetrically with respect to the feed point. The proposed antenna is designed on FR4 substrate with dielectric constant 4.4 and loss tangent 0.018. The proposed antenna utilizes ground plane and patch with dimensions 61 x 46 $mm^2$ and 41.5 x 26.5 $mm^2$, respectively. The thickness of substrate is 3.2 mm is selected due to which we get enhanced bandwidth for all three bands and good reflection coefficient value of microstrip antenna. The detail dimensions of the proposed antenna are given in Figure1.

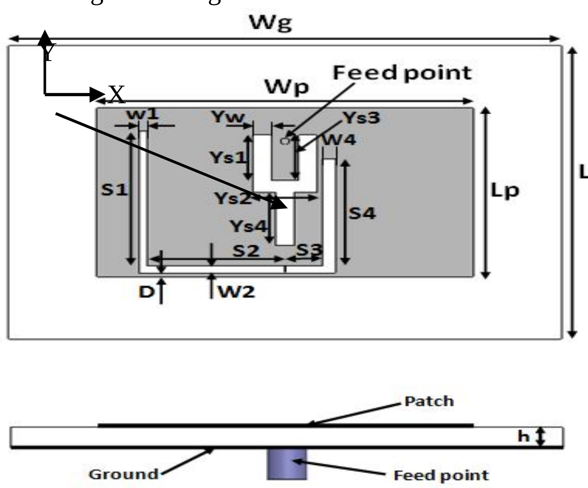
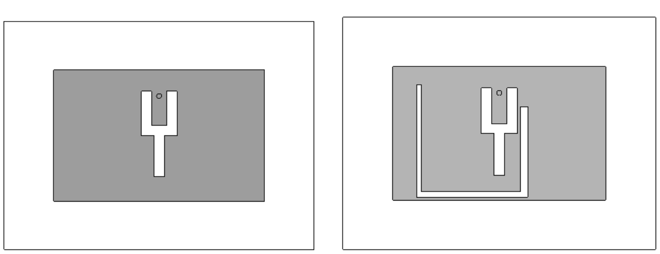



**Figure 1:** Configuration of proposed patch antenna.

In order to investigate the effect of the shape parameters of the slots on the proposed antenna, we simulated two prototypes with all the other dimensions of the patch and the feed position unchanged. The one with symmetric Y-shaped slot is referred as antenna 1 as shown in Figure 2 (a) and the other with the combination of symmetric Y-shaped and asymmetric U-shaped slot is antenna 2, shown in Figure 2 (b).



(a) (b)

**Figure 2:** Geometry of (a) antenna 1, (b) antenna 2 (dimensions are shown in Figure 1).

All the simulation has been carried out on Ansoft's High Frequency Structure Simulator (HFSS) software which is based on Finite Element Method (FEM) numerical techniques [27] to optimize the shape parameters of proposed patch antenna. Optimized results are also compared with measurement and CST Microwave Studio [28] simulation result.

The optimized value of the shape parameters of proposed antenna are given in Table 1.

| Antenna parameter | Value (mm) | Antenna parameter | Value (mm) |
|---|---|---|---|
| Wg | 61 | s1 | 22.3 |
| Lg | 46 | s2 | 15.2 |
| Wp | 41.5 | s3 | 4.1 |
| Lp | 26.5 | s4 | 17.9 |
| h | 3.2 | w1 | 0.9 |
| Ys1 | 7 | w2 | 1.1 |
| Ys2 | 7 | w4 | 1.5 |
| Ys3 | 7 | D | 0.6 |
| Ys4 | 8.3 | Feed position | (0, 8) |
| Yw | 2 | | |

## 2. RESULT AND DISCUSSION

Intially, microstrip antenna was loaded with Y-shaped slot (antenna1) to achieve dual band behavior at 2.48 GHz and 3.48 GHz center frequency. Further, to achieve resonant frequency at 1.5775 GHz, asymmetric U-shaped slot is placed asymmetrically to feed position. Figure 3 demonstrates how the existence of asymetric U-shaped slot affects the S11 of the proposed antenna. It is observed that the antenna 1 gives two operating band at 2.48 GHz and 3.48 GHz frequency. Adjusting the values of the shape parameters of the asymmetric U-shaped slot, antenna 2 exhibits three resonances with S11 better than -10 dB over the bandwidth of the three operating bands of 28 MHz, 130 MHz, and 361 MHz. Antenna 2 covers the required bandwidths of the GPS L1(1.561-1.589 GHz), Wi-Fi (2.393-2.523 GHz), and WiMAX (3.30-3.661GHz) bands.

The $S_{11}$ parameter is measured by Agilent Technology (E8364B, 10MHz-50GHz) VNA network analyzer. The network analyzer with fabricated prototype is shown in Figure 4.

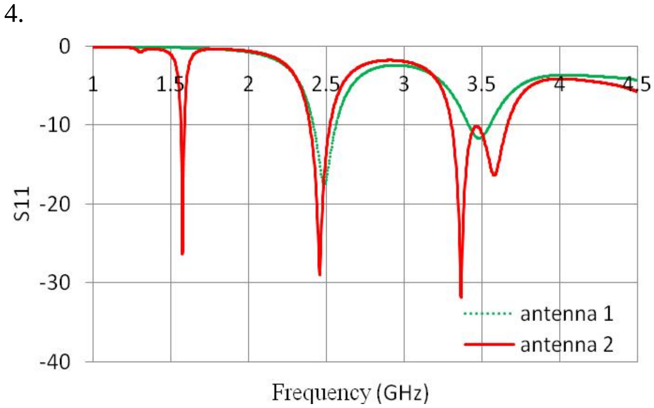



**Figure 3:** Variation of return loss for antenna1 and antenna 2.

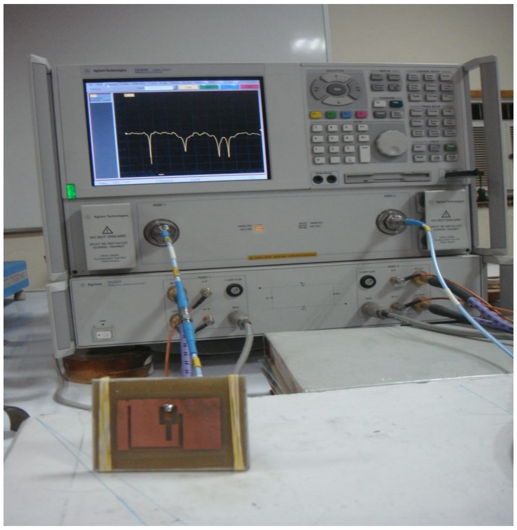


**Figure 4:** Fabricated antenna with network analyzer.

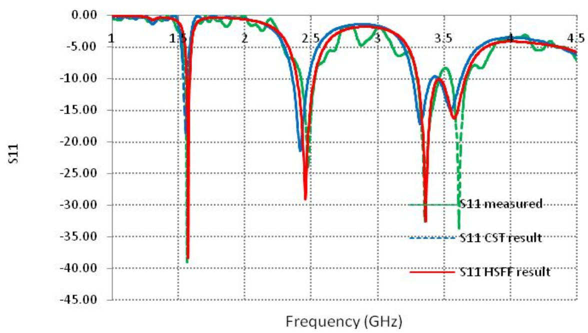



**Figure 5:** Return loss for proposed antenna.

The measurement and simulated results for the proposed antenna are shows in figure 5 which are in good agreement.

### 3.1 Parametric Analysis of Y-shaped Slot Loaded Antenna

Figure 6 shows the simulated return loss results of Y-shaped slot loaded antenna for different length Ys1, by keeping other dimensions of the antenna 1 fixed as given in Table I. By proper adjusting the value of parameter Ys1, the return loss better than -10 dB at 2.5 GHz and 3.5 GHz center frequencies is achieved, respectively. Figure 7 shows the effect of variation of the length Ys2 on simulated return loss. It is observed that with increase of Ys2, the first resonant frequency decreases and the second resonant frequency increases. Figure 8 shows the effect of width of the slot Yw on the return loss result. It is clearly seen that with increase of Yw, there is no very significant change in first resonant frequency but second resonant frequency slightly increases and give resonance below –10 dB at Yw = 2mm. By parametric analysis of the antenna 1, we achieved the optimized value of centre resonant frequency (below -10 dB) at 2.5 GHz and 3.48 GHz with bandwidth of Wi-Fi (2.415-2.561 GHz) and WiMAX (3.413-3.55 GHz), respectively.

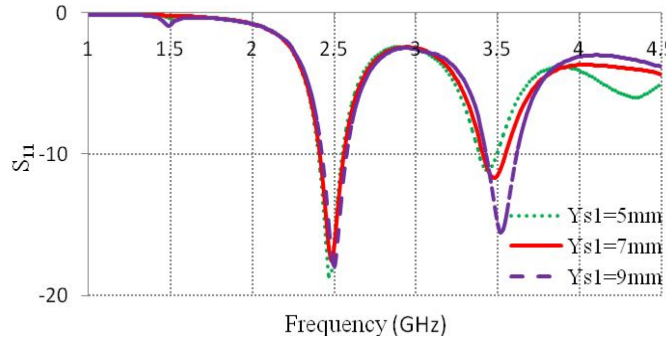



**Figure 6:** Simulated return loss of the antenna 1 with different Ys1.

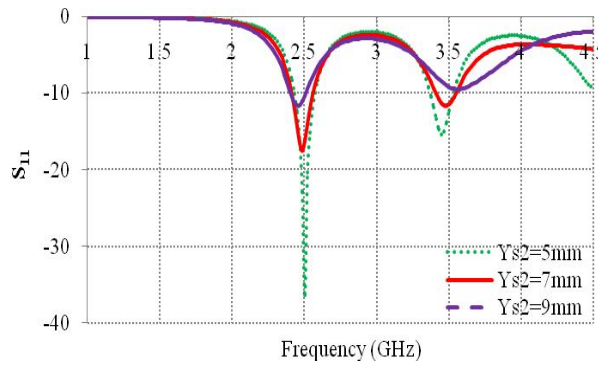



**Figure 7:** Simulated return loss of the antenna 1 with different Ys2.

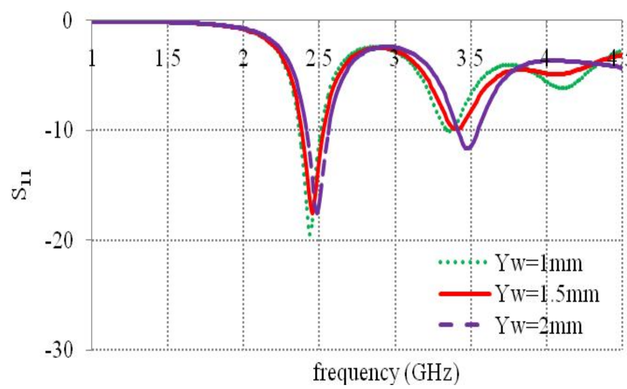



**Figure 8:** Simulated return loss of the antenna 1 with different Yw.

### 3.2 Parametric Analysis of the Proposed Antenna

Figure 9 shows the effect of the length of left arm of asymmetric U-shaped slot s1 on simulated return loss. It is observed that due to increasing the slot length s1, the inductance will increase because the diversion of surface current around the slots will be more intensive. Hence, the frequency of first and third resonant mode decreases. Dual resonance appears in the third band because one is appearing by symmetric Y slot and other is asymmetric U-shaped slot.

Hence the bandwidth increases at certain values. The Wi-Fi band (2.4-2.5 GHz) is not affected by varying this parameter. Similar changes are observed by varying the width of left arm of asymmetic U-shaped slot (w1) and the results are shown in figure 10. Figure 11 shows the effect of length of lower left arm of asymmetic U-shaped slot (s2) on the return loss results. It is clearly seen that with increase of the s2, no change has been observed on the resonant frequency of first band (GPS L1) and second band (Wi-Fi). It is interestingly noted that the dual band is observed at the center frequency of the third frequency band (WiMAX) depends inversely on s2. Similar changes are observed by varying the length of right lower arm of asymmetic U-shaped slot (s3) and the results are shown in figure 12. Figure 13 shows the effect of the length of right arm of asymmetic U-shaped slot (s4) on simulated return loss. It is observed that with increase of s4, the first and third resonant frequency decreases and the third band is converted from dual band to single band. The Wi-Fi band (2.4-2.5 GHz) is not affected by varying this parameter. Figure 14 shows the effect of the width of right arm of asymmetic U-shaped slot (w4) on simulated return loss. It is observed that with increase of w4, the first resonant frequency decreases and the third band is converted from dual band to single band and also increases the resonant frequency. The Wi-Fi band (2.4-2.5 GHz) is not affected by varying this parameter.

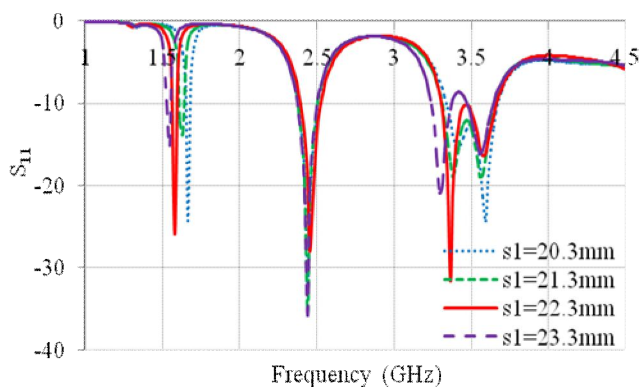
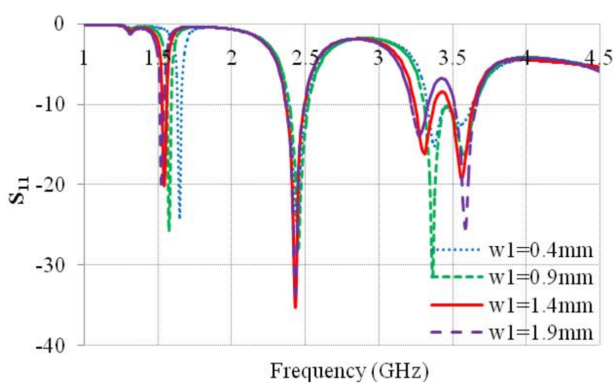



**Figure 9:** Simulated return loss of the antenna 2 with different s1.

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**igure 10:** Simulated return loss of the antenna 2 with different w1.

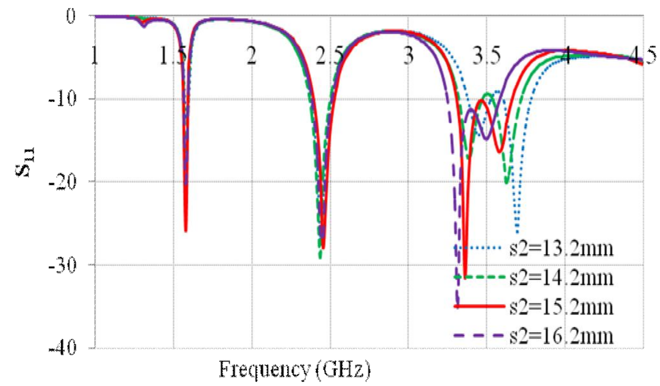


**Figure 11:** Simulated return loss of the antenna 2 with different s2.

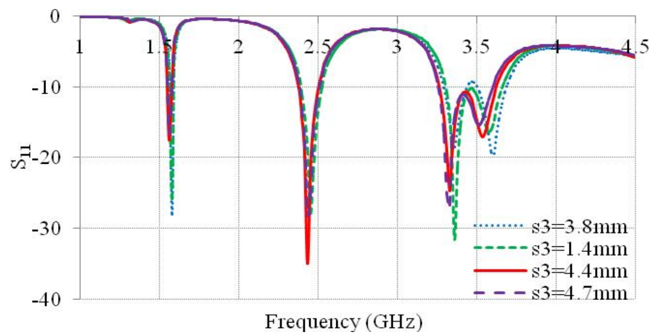


**Figure :12** Simulated return loss of the antenna 2 with different s3.

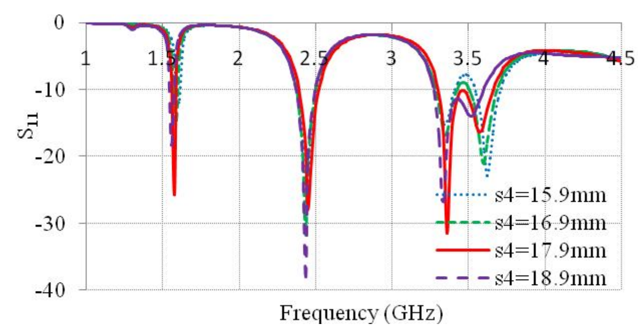


**Figure 13:** Simulated return loss of the antenna 2 with different s4.

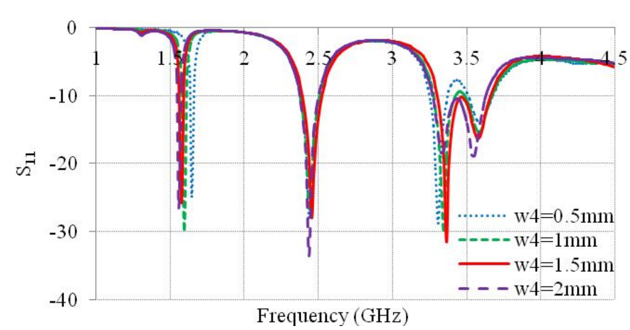


**Figure 14:** Simulated return loss of the antenna 2 with different w4.

## 4. RADIATION PATTERNS

The simulated 2-D radiation patterns of the proposed antenna in the E- and H-plane are plotted using Ansoft's HFSS and validated with the measured results are given in Figure 14 at three different resonating frequencies (1.577 GHz, 2.452 GHz and 3.362 GHz). The simulated and measured results are found almost in good agreement on second and third resonant frequency band. Radiation patterns are found to be almost omnidirectional.

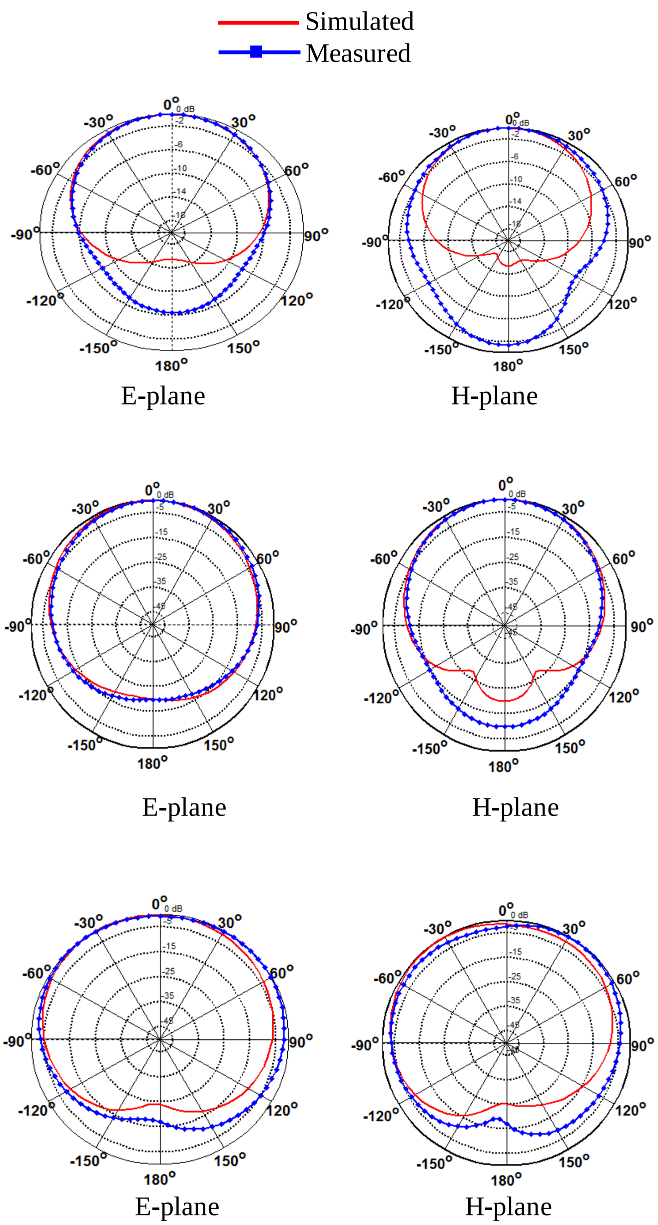


**Figure 14:** Radiation patterns at 1.577 GHz, 2.452 GHz, and 3.362 GHz.

## 5. CONCLUSION

A tri-band antenna with low frequency ratio has been proposed that consists of two different slots. One is symmetric Y-shaped and the other is asymmetric U-shaped slot. When patch is loaded with Y-shaped slot along with U-shaped slot placed asymmetrically to the patch center, the antenna resonates at 1.577 GHz, 2.452 GHz, and 3.362 GHz, achieving lower frequency ratios of 1.55 and 1.37, respectively for triple band applications. The proposed antenna covers the wireless application bands like GPS L1 (1.561-1.589 GHz), Wi-Fi (2.393-2.523 GHz), and WiMAX (3.30-3.661 GHz). The percentage impedance bandwidth for GSM, Wi-Fi, and WiMAX bands are 1.78%, 5.29%, and 10.37%, respectively. The parametric study of proposed antenna is good insight on the effects of various dimensional parameters. The bandwidth and frequency ratios can be tuned by variation of slot length and width of the asymmetric U-shaped slot. Good agreement is obtained between the measured and simulated results. The proposed antenna is a good candidate for wireless applications.

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