Quad band operated microstrip patch antenna for WiMAX application

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Abstract. The paper describes a light-weight monopole planar antenna with a rectangular radiating patch and a slotted ground plane for WiMAX (Worldwide Interoperability for Microwave Access) applications. WiMAX is a wireless broadband communication technology based around the IEEE 802.16 that provides point-to-multipoint wireless networking system and high-speed data across a wide range. The antenna designed for the aforementioned applications shows operation at 2.5 (lower WiMAX)/ 3.7, 4.5 (middle WiMAX)/ 5.5 (upper WiMAX) GHz with total bandwidth of about 110 MHz/ 150 MHz/ 160 MHz/ 120 MHz. With its appealing characteristics, the planar monopole patch antenna meets the requirements of low weight, low cost, less complex structure and standard pattern of omnidirectional radiation.

Keywords: Antenna, Gain, Monopole, Microstrip, Quad band, Slots, WiMAX

1. Introduction

Researchers had used recent developments to build high efficiency, high gain, and miniaturized antennas with omnidirectional patterns in order to fulfil the demand of increasing advanced wireless technologies [1],[2],[3],[4]. The microstrip patch is a kind of low-profile radio antenna which can be installed on any surface. It comprises of a rectangular sheet or metal "patch" loaded on a relatively larger metal part called a ground plane [5],[6],[7]. A monopole antenna is a radio antenna class comprising of a linear rod-shaped conductor, generally perpendicularly loaded over a particular type of metallic surface, namely a ground part. In it the transmitter input signal is applied, and the output to the receiving side is generally taken between the lower end of the monopole and the back plane generally acting as ground part. This lower part of the monopole is attached to one side of the antenna feedline, and the another side is embedded to the ground part, which oftenly acts as earth [8],[9],[10].

Many types of antennas are available in literature for WiMAX applications [11]. A, T and C-shaped monopole microstrip antenna is designed in [12]. By combining the triangular and rectangular patch in [13], a monopole is proposed for WiMAX applications. In [8], the author discusses the U-shaped microstrip antenna for WiMAX operation. [14] reports a dual-band monopole antenna for WLAN and WiMAX application. However, these reported antennas have many disadvantages like large size, unstable radiation pattern, and less bandwidth.
The presented paper describes a microstrip quad band patch antenna operating at 2.5/3.7/4.5/5.5 GHz, thereby covering the entire WiMAX applications. The evolution of designed antenna is discussed in detail from the conventional microstrip patch structure. The antenna utilizes rectangular patch with microstrip feeding to fulfil the criteria of impedance match of 50 ohms. The back plain (ground) of the antenna consists of two rectangular slots. Parametric investigations are performed in details to judge the impedance matching criteria of the designed antenna. The dielectric material acting as substrate for the designed configuration is FR-4, having a total height and dielectric constant of 1.6 mm and 4.4.

### 2. Antenna Design Approach

The designing of the said configuration is performed via High Frequency Structure Simulator (HFSS) v.13.0 software. Initially, antenna is designed using rectangular patch with symmetrical feed line and full ground part. It is termed as antenna N represented as in figure 1 (a). The utilization of these conventional structure resulted in the operation at 2.5 and 4.5 GHz, as illustrated in figure 4.

![Figure 1: Topology of the Antenna N showing (a) Front and (b) back orientation](image)

The next stage of the antenna is designed with symmetrical feed line and a rectangular etching in the ground plane as depicted in figure 2 named as antenna O. The etching of these ground plane improves the impedance matching around 4.5 GHz and helps the antenna to operate at three bands. Also, there is a slight change in the achieved dual resonance from Antenna N which may be due to change in current length path due etching. The S11 results of the antenna configuration O is given in figure 4.

![Figure 2: Topology of the Antenna O showing (a) Front and (b) back orientation](image)

In the next stage another rectangular perturbation is provided in the ground part to obtain the final quad band antenna named as antenna P (proposed configuration), as depicted in figure 3. This introduced second rectangular slot intervenes the surface current flow further which in return make the antenna to operate at 2.5, 3.7, 4.5, 5.5 GHz, as demonstrated in figure 4.
The final antenna with detailed optimized dimensions is demonstrated in figure 5. The configuration utilizes rectangular patch (RW x RL) with microstrip feeding (FW x FL) to meet the impedance match criteria of 50 ohms. The back plain (ground) of the antenna consists of two rectangular slots ((TL x VW) and (UW x UL)). The detailed layout are illustrated in Table 1.
Table 1. Dimensions of the proposed design

| Rw=38.01mm | Tw=47.61mm |
| RL=24.45mm | Uw=2mm    |
| FL=12.9016mm | Vw=3.5mm  |
| Fw=3mm     | TL=39.03mm|
| Fw=3mm     | UL=14mm   |

3. Parametric Study

To characterize the impact of the slots on performance of the antenna its parametric investigations are done. Since the performance of the design is mainly influenced by FW, UW and VW the study is computed for FW, UW and VW.

3.1 Observation about slot width (UW)

The effect of rectangular patch UW on impedance match criteria is observed. The study is computed by varying the width (UW) of the smaller rectangular slot in the ground plane. The variation of the reflection coefficient with respect to UW is shown in the figure 6(a). The Figure clearly describe the choice of dimension of UW=2 mm as it gives better impedance matching at all the quad band.

3.2 Observation about slot width (VW)

The effect of rectangular patch VW on impedance match criteria is observed. The study is computed by varying the diameter of the rectangular patch. The variation of the reflection coefficient with respect to VW is shown in the figure 6(b). The best impedance match is observed for VW=3.5 mm.

3.3 Observation about feed line (FW)

The effect of rectangular patch FW on impedance match criteria is observed. The study is performed by varying the feed width FW and keeping the feed length FL constant. The variation of the reflection coefficient with respect to FW is shown in the figure 6(c). The best result is obtained with FW=3 mm.
4. Result and Discussion

The simulation S11 result for the said configuration is demonstrated in the Fig 7. The antenna shows operation of the antenna at 2.5 (lower WiMAX)/ 3.7, 4.5 (middle WiMAX)/ 5.5 (upper WiMAX) GHz, with bandwidth ranging from 2.45-2.56 GHz, 3.63-3.78 GHz, 4.43-4.59 GHz, 5.45-5.53 GHz, respectively. The obtained result and the optimized dimensions make it useful for the entire WiMAX bandwidth applications. The current distribution plot of the antenna is demonstrated in Fig 8. It shows that for the quad band operation the entire radiating patch and slotted ground plane exhibits dense current pattern.

Figure 7. Reflection Coefficient of the Proposed Antenna

The 3D total gain pattern for the proposed antenna is depicted in Fig 9. The designed configuration shows gain of around 1.02 dB at 2.5GHz, -2.5 dB at 3.7 GHz, -2.9 dB at 4.5 GHz and 2.69dB at 5.5 GHz, respectively.

The radiation pattern of the antenna for phi=0 degree and phi=90 degree is demonstrated in Fig 10. It can be visually perceived that the pattern is stable with high co-polarization value at the designed quad frequencies
Figure 8. Surface current pattern for frequencies (a) 2.5, (b) 3.7, (c) 4.5 and (d) 5.5 GHz.
Figure 9. 3D gain plot for frequencies (a) 2.5, (b) 3.7, (c) 4.5 and (d) 5.5 GHz

Figure 10: Radiation Pattern of the proposed antenna at (a) 2.5, (b) 3.7, (c) 4.5 and (d) 5.5 GHz

5. Conclusion

This paper demonstrated a rectangular microstrip antenna to cover the lower (2.5 GHz), the middle (3.5, 4.5 GHz) and the upper (5.5 GHz) band of WiMAX applications. Parametric analysis is done to investigate and fix the proper antenna dimensionsto accomplish the expected results. The said configuration is designed using a rectangular patch and a rectangular slotted ground plane. To excite the patch microstrip feeding has been used. The said configuration has an omni-directional radiation pattern and with acceptable gain and has the advantage of simple configuration and good impedance matching.

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