Design and Simulation of a Multiband Slot Antenna for GPS/WLAN/WiMAX Systems Using CST

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Abstract. Design of a four band i.e. multiband slot antenna incorporating Global Positioning System, Wireless Local Area Networks (for IEEE 802.11 b&g and IEEE 802.11a) and Worldwide Interoperability for Microwave Access is presented in this paper. The antenna is designed for frequency of 1.57GHz for GPS, 2.5GHz for IEEE 802.11 b&g WLAN, 3.5GHz for WiMAX and 5.3GHz for IEEE 802.11a WLAN system. The antenna configuration comprises of a rectangular slot with triangular cuts at the corners to achieve impedance matching. It is designed and simulated using CST Studio Suite. The simulated antenna is fabricated on the economical substrate i.e FR-4 using standard photolithography process and tested in vector network analyzer (Anritsu-MS2027C). The designed antenna shows exceptional results in terms of return loss, voltage standing wave ration (VSWR), radiation pattern and bandwidth. Results conclude that the designed antenna is well suited for various applications as mentioned.

1. INTRODUCTION

In the domain of wireless communication, antennas play a requisite role in transmission and reception of EM (Electromagnetic) signals, and there are different types of antennas with different properties. With a lot of improvements in different wireless communication standards, it is required to integrate various wireless communication systems such as GPS, WiMAX and WLAN standards into one wireless device. Because of this, various antennas have been studied, e.g., the multiband patch antenna having different polarization states in [1], the dual-band monopole antenna for the WiMAX systems in [2] and the dual-band loop antenna for the 2.45/5.2/5.8 GHz bands in [3]. Slot antennas of compact size, wider bandwidth, and simple integration with other devices are better equipment for the design of multiband antennas. Different designs of multiband antennas have been proposed in the previous years, [4-22].

This paper presents the design of a multiband slot antenna for GPS/WiMAX/WLAN [7, 9, and 16] systems. The designed multiband antenna is simulated using the Computer Simulation Technology (CST) microwave studio. For verification of the simulation results, the antenna is fabricated using photolithography process and tested using Vector Network Analyzer (VNA).
obtained results like reflection coefficient or S11 curve, radiation pattern, VSWR and bandwidth are presented in the paper.

2. ANTENNA DESIGN

The designed slot antennas with four bands is illustrated in Figure 1, which consists of a rectangular slot dimensions $L_1 \times W_1 = 48 \times 18$ mm$^2$ with triangular cuts on four corners of the slot to achieve better impedance matching. The rectangular slot with triangular cuts is included with a M-shaped stub and two C-shaped stubs on the right and left sides of the slot. A T-shaped microstrip feed patch is used to feed the rectangular slot. A feed line of width $W_f = 1.76$mm is used to achieve an impedance of 50Ω. The antenna is designed using FR-4 substrate with a relative permittivity of $\varepsilon_r = 4.4$, a thickness of about 0.8mm and a loss tangent of 0.025. This material is known to retain its high mechanical and electrical strength and also available at low cost. The antenna is fabricated using photolithography process and tested using vector network analyzer.

![Fig.1. Designed Antenna (a) top view; (b) bottom view](image)

The rectangular slot with chamfered edges with W-shaped stub with bending generates band 1 at about 1.57GHz. The two C-shaped stubs generate band 2 at about 2.5GHz for IEEE 802.11 b&g standard. Due to the coupling of the T-shaped feed patch and W-shaped stub generates band 3 at about 3.5GHz for WiMAX applications. The T-shaped feed patch in the higher mode generates band 4 at 5.3GHz for IEEE standard 802.11a WLAN. The concluding dimensions of the designed multiband antenna are illustrated in Table 1.

| L   | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ |
|-----|-------|-------|-------|-------|-------|
| 56  | 48    | 6     | 15    | 12.5  | 29    |
| $L_6$ | $L_7$ | $L_8$ | $W$   | $W_1$ | $W_2$ |
| 5.5 | 3.6   | 1     | 44    | 18    | 21.6  |
| $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_7$ | $W_8$ |
| 2   | 2     | 12    | 1     | 0.5   | 1.3   |
| h   | $W_f$ |
| 0.8 | 1.76  |
3. RESULTS

The designed antenna with a rectangular slot of dimensions 48 × 18 mm$^2$ is shown in the Fig.1. The antenna is designed and simulated in CST studio suite and the antenna should maintain the input-output relationship between ports which is described by return loss curve or S11 curve. S11 represents how much power is reflected from the antenna. For a better antenna performance, S11 should always be less than -10dB. Fig.2 depicts the S11 curve for the four bands.

Voltage standing wave ratio (VSWR) is a quantity that tells how best the impedance of antenna is matched. Smaller the VSWR, better the impedance matched. For better performance, VSWR reading should be near to 1. Fig.3 depicts the VSWR curve for the four bands of the antenna.

The designed antenna shows an uniform radiation pattern which is one of the advantageous properties of the antenna.
Figures 4, 5, 6, and 7 represent the 2D radiation patterns of GPS, WLAN IEEE 802.11 b&g, WiMAX, and WLAN IEEE 802.11a respectively. It is observed that the radiation patterns are in the form of 8, which represents better radiation pattern.

The antenna is fabricated using photolithographic process. Fig. 8 represents the fabricated antenna. After the fabrication, the antenna is tested using a vector analyzer. Fig. 9 represents the testing of the antenna in a vector network analyzer.

Fig. 8. Fabricated antenna

Fig. 9. Testing in VNA

Fig. 10 and Fig. 11 represent the S11 and VSWR curves respectively of the fabricated antenna in a vector network analyzer.

Fig. 10. S11 curve in VNA

Fig. 11. VSWR curve in VNA

Simulated vs. Measured results of the antenna i.e. S11 and VSWR are shown in Fig. 12 and Fig. 13.

Fig. 12. Simulated vs Measured S11

Fig. 13. Simulated vs Measured VSWR
Tables 2, 3, 4 and 5 describe the Simulated vs Measured results for GPS, WLAN at 2.5GHz, WiMAX and WLAN at 5.3GHz. There is an improvement in the measured return loss S11 at 1.57GHz, 3.5GHz, 5.3GHz as compared to Simulated Return loss S11.

Table 2: Simulated vs measured results for GPS at 1.57GHz

| Parameter | Simulated | Measured |
|-----------|-----------|----------|
| VSWR      | 1.0611    | 1.069    |
| S-parameter | -31.591  | -29.65   |

Table 3: Simulated vs measured results for WLAN IEEE 802.11 b&g at 2.5GHz

| Parameter | Simulated | Measured |
|-----------|-----------|----------|
| VSWR      | 1.097     | 1.093    |
| S-parameter | -29.382  | -20.00   |

Table 4: Simulated vs measured results for WiMAX at 3.5GHz

| Parameter | Simulated | Measured |
|-----------|-----------|----------|
| VSWR      | 1.0682    | 1.0633   |
| S-parameter | -29.455  | -39.95   |

Table 5: Simulated vs Measured results for IEEE 802.11a WLAN at 5.3GHz

| Parameter | Simulated | Measured |
|-----------|-----------|----------|
| VSWR      | 1.3849    | 1.3722   |
| S-parameter | -15.865  | -21.22   |

4. CONCLUSION

In this paper, a multiband slot antenna for GPS at 1.57GHz, IEEE 802.11 b & g WLAN at 2.5GHz, WiMAX at 3.5GHz and IEEE 802.11a WLAN at 5.3GHz is designed and simulated using CST microwave studio software and achieved very low return loss and excellent voltage standing wave ratio. The antenna has been observed to provide better impedance matching, exceptional VSWR readings, S11 parameters and uniform radiation pattern. Hence, as per the characteristics observed above, the antenna can be used for many applications such as GPS/ WiMAX and WLAN systems as it resonates at multiple bands of frequencies.

5. FUTURE SCOPE

The antenna can also be extended to resonate at some more frequencies for various applications. With the increase in the number of frequencies, impedance gets mismatched, to reduce the impedance mismatch various feeding techniques can be adopted.
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