A Compact Multiband Rectangular Microstrip Antenna for UWB Applications

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Abstract. This manuscript develops the design of rectangular patch antenna with loaded on defected ground structure (DGS), which covers the entire range of ultra-wideband (UWB). The area of proposed antenna 33x35 mm² and is printed on FR-4 plane substrate, its permittivity (Ɛr) 4.2 and loss tangent (tanδ) is 0.02 at entire frequency range. Proposed structure renders wider impedance bandwidth extended from 2 GHz to 10.7 GHz at < -10 dB return loss (VSWR< 2) with multi-bands. The UWB antenna suitable for UMTS 2.1 GHz, WLAN 3.5 GHz, WiMAX 5.8 GHz, and X-band 7.5 GHz applications. The parameters of antenna such as loss of return are reduced, and width of band, as well as gain in VSWR, is improved to an acceptable limit with reasonable radiation pattern by means of CST V.17 EM simulator. The results from simulation and experiment results are almost similar to acceptable limit.

1. Introduction
The increasing expansion of the wireless network and several far-reaching types of wireless applications like GSM/UMTS/ DCS/PCS/IMT, Bluetooth, ISM, Wi-MAX, and WLAN etc. raises the demand to cover a wide frequency range and design an antenna with broadband. In wireless communication, the patch antennas have played an important role and to be used as multi-band applications due to its smart profile, and lesser power consumption capabilities. The size reductions of antenna gain and impedance bandwidth enhancement are the major approaches for practical applications of patch antennas. The different shapes can be applied developed a patch antenna, that has been used for achieving as much as wide impedance bandwidth and gain of antenna. Satellite and wireless communication often require antenna with conveniently small size, ease of fabrication and capable of operating multi-band of frequencies [1–6].

In 2002, a US Federal Communications Commission (FCC) permitted a (3.1 - 10.6) GHz unlicensed radio spectrum of band designated by used as an ultra-wideband (UWB). UWB is generally applied because of its lower cost, lower power spectral density and low capacity of channel [7]. The design of UWB patch antennas compared to narrowband antennas has more complex and challenging due to the large bandwidth and linearity requirements [8].

A simple and compact UWB defected ground structure (DGS) antenna is proposed and investigated for achieving the gain and bandwidth enhancements for multiband operation [9–13]. The dimensions of patch antenna have a small and operate an entire frequency range 2.0 - 10.7 GHz and suitable for UMTS 2.1 GHz, WLAN 3.5 GHz, Wi-MAX 5.8 GHz, and X-band 7.5 GHz applications. The remainder of this paper is structured into three parts. The geometrical parameters of antenna are described in section 2. The analysis of results of UWB antenna is presented in part 3 and summarized in section 4.
Table 1. Impedance bandwidth comparison of UWB with other antennas

| Reference | Area [mm²] | UWB (3.1 - 10.6 GHz) Notch frequencies (fN) |
|-----------|------------|-------------------------------------------|
| [5]       | 25×40      | 3-10.6 GHz (fN=3.4, 6.3, and 8.9 GHz)      |
| [6]       | 40×40      | 2.9-19.2 GHz (fN=3.7, 5.7, and 9.5 GHz)    |
| [7]       | 57×77      | 3-10 GHz (fN=4, 7, and 10 GHz)             |
| [8]       | 42×24      | 2.3-2.5 GHz, 3.1-12 GHz (fN=2.45, 3.5, 6.5, 8.5 GHz) |
| [9]       | 60×60      | 2.67-13 GHz (fN=5.12, 5.73, and 6.42 GHz)   |
| [10]      | 40×35      | 2.62-15.45 GHz (fN=3.4, 6.8, and 8.9 GHz)   |
| Proposed  | 33×35      | 2.0 - 10.7 GHz (fN=2.1, 3.5, 5.8, and 7.3 GHz) |

2. Structure of Antenna

The structure and dimensions of the UWB multiband antenna is shown in Fig 1. The radiating patch of the antenna is loaded on FR-4 material. With the entire range of frequency, its loss tangent (tanδ) is 1.2 and permittivity (E_r) 4.4. The area (W_sub×L_sub) of the substrate is 33×35 mm² and thickness 1.6 mm respectively. By etching a radiating patch (W_p×L_p) 15.7×15.8 mm² on the substrate plane and connected to a 50Ω feed line (W_f= 2.8 mm) on same plane. The UWB antenna and its radiating tuning stub are tuned empirically to find the performance of the antenna in terms of enhanced bandwidth impedance with stable radiation pattern to entire operating bandwidth. The parameters related to design UWB antenna are mentioned in Table 2. To optimize the design parameters for the multiband application, simulation is carried out.

Table 2. Optimal unit value of the antenna shown in Fig. 1

| Parameters | L_sub | W_sub | L_p | W_p | L_f | W_f | L_slot |
|------------|-------|-------|-----|-----|-----|-----|--------|
| Unit (mm)  | 35    | 33    | 15.8| 15.7| 10.25| 2.8 | 24.75  |

Fig. 1. Configuration of the UWB antenna
3. Result Discussions
The simulated performances of antenna have been used (CST V.17 EM) simulator, and experimental results of the proposed design had measured with vector network analyzer. The different structural parametric results are carried out and presented, after analysis, which is inevitable for any UWB antennas. The optimization results are best performance characteristic of the antenna to suit for bandwidth impedance, VSWR, gain and radiation pattern demonstrated in Fig. 3. The optimal unit values of the antenna structure are given in Table 2.

Fig. 2. Fabricated antenna (i) Front, (ii) Backimage

(i)

(ii)
3.1. Parametric Results Analysis

The antenna simulations process is carried out for the parametric geometry studies and conducted by to investigate the design technique and optimization methods. For the same geometry, only one parameter is all the owed to change during any one period while remaining parameters remained same. A parametric analysis of dimensions such as Wg, Wp, Lp, Wf and gap is carried out.

3.1.1. Impact of Wg variation

A width of ground strip (Wg) shown in Fig. 1. The width of ground strip is varied from 0 mm to 2 mm. The deviation of notch frequency is pragmatic in term of reflection coefficient. When Wg = 0 mm, the optimum desired result is achieved, and loss of return is stable at a low and high frequency of operation presented in Fig. 4.

![Simulated characteristics of proposed antenna](image)

(iii)

(iv)

**Fig. 3.** Simulated characteristics of proposed antenna
(i) Reflection coefficient, S_{11}<-10 dB,(ii) Gain of antenna
(iii) Radiation pattern E/H at 3.5 GHz,(iv) Radiation pattern E/H at 5.8 GHz
3.1.2. Impact of Wp variation
The parametric variations of radiating patch width (Wp) are done to study effect on reflection coefficient characteristic of proposed antenna. Reflection coefficient notch frequency is observed, when Wp =14.8 mm, 15.8 mm and 16.8 mm respectively are shown in Fig. 5. We can see that the optimized result has been observed at Wp = 15.8 mm with large bandwidth and good reflection coefficient.

3.1.3. Variation Effect of Parameter (Lp)
As it can be analyzed in Figure 6, which shown that at the radiating patch length (Lp) from 14.8 mm to 16.8 mm, we achieve a satisfied UWB characteristic of proposed antenna and good reflection coefficient. The optimum desired result has been observed at Lp =15.7 mm.
3.1.4. Impact of Feed Line Width Parameter ($W_f$) Variation
The feed line width is varies from 2.7 mm to 2.9 mm as shown in Fig. 7. When $W_f = 2.8$ mm, the reflection coefficient achieved desired level as compared to others feed line width. But when $W_f$ is 2.7 mm and 2.9 mm, very minor changes in notch frequency.

![Fig. 7. Reflection coefficient with variable $W_f$](image)

3.1.5. Impact of Ground Gap Variation
The impact of variation in ‘ground gap’ on the coefficient of reflection and performance of UWB is presented in Fig. 8. If gap 0.2, 1.2, and 2.2 mm, achieved a stable multi-deep notch frequency bands of wireless communication.

![Fig. 8. Reflection coefficient with variable gap](image)

4. Experimental Results and Discussion
A vector network analyzer (N5230A) has been applied to find characteristics performance of the developed design of antenna in terms of bandwidth impedance and VSWR. Fig. 9 presents the deliberated and simulated results such as return loss and VSWR of a compact multiband rectangular micro-strip antenna. The return loss is measured and plotted to indicate that it covers UWB of 8.7 GHz (2 to 10.7 GHz). Good agreements between the simulated and measured results are achieved as shown in Fig. 9.

![Fig. 9. Experimental results and simulated results](image)
5. Conclusion

The proposed UWB antenna have covered the bandwidth 8.7 GHz from 2.0 GHz to 10.7 GHz in which it shown four distinct notch frequency, first 2.1GHz, second 3.5GHz, third 5.8GHz and fourth 7.3GHz respectively, which covers frequency bands of UMTS (1.9 - 2.17) GHz, Wi-MAX (3 - 4) GHz, WLAN (5.2 - 6.5) GHz and X-band (7.1 - 7.9) GHz respectively with a return loss < -10 dB and VSWR < 2 at the specified operating bands. The antenna also showed desired flat gain (close to 5dB), better directivity and good radiation patterns in the desired frequency bands all possible because of the proposed geometry. This type of antenna might prove to be a useful structure for modern wireless communication systems, including devices like- UMTS, WLAN, Wi-MAX and lower band of UWB communication systems.

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