A Miniaturized Ultra Wideband Slot Antenna with Band Notched Characteristic

Akkala. Subbarao*, Dr.S.Raghavan
Department of Electronics and Communication Engineering, National Institute of Technology, Tiruchirappalli-620015, India.
Tel: +91-9489830942; Fax: +91 431 2500133; E-mail: subbarao_ka@yahoo.co.in

Abstract- A Compact planar slot antenna is proposed and developed for Ultra Wideband Applications. The antenna has compact size of 28 x 31 x 0.8 mm\(^3\). The antenna is fabricated with FR4 substrate and it is fed by Coplanar Wave Guide. The antenna is investigated experimentally to obtain required return loss, gain and radiation pattern characteristics. The antenna operates over a band between 3.1 GHz and 11 GHz for return loss < -10 dB, removing the undesired band of 5.1- 5.85 GHz to avoid interference with WLAN and HIPERLAN/2. The design and analysis of the proposed antenna is made on the method of moments based IE3D Electromagnetic solver. The antenna has stable Omni directional pattern in E-plane and bi-directional radiation pattern in H-plane. The group delay of the antenna is less than 1 ns in operating bandwidth.

Index Terms- UWB antenna, group delay, VSWR, radiation pattern, gain, coplanar waveguide (CPW).

I. INTRODUCTION

Development of Ultra Wideband (UWB) antennas became popular because of high data transmission rate, simple hardware configuration and low power consumption. Large bandwidth, high transmission rate in UWB enable short range, low power consumption, Omni directional radiation pattern, constant gain for UWB Antenna. Since Federal Communication Commission (FCC) approved UWB for commercial usage in 2002, design of UWB antenna became a research topic in both industry and academy of communications. These antennas have applications in data transmission, radar, location tracking and sensor networks. Many UWB Antennas which meet above requirements were reported in literature [1-3]. One major factor in designing UWB antenna is of compact size and wideband antenna [4]. Recently planar slot antennas [5-6] became popular in designing UWB antennas because of small size, simple configuration, stable radiation pattern and ease of fabrication. These antennas can be fed by transmission lines like microstrip line or coplanar waveguides etc. Since coplanar wave guides offer low profile and wide bandwidth, they are very useful in millimeter and microwave applications. Coplanar waveguides have less dispersion and low radiation leakage Compared to microstrip line.

UWB Communication systems use 3.1-10.6 GHz frequency band. This band includes HIPERLAN/2 bands (5.15-5.35 and 5.470-5.725 GHz) and IEEE 802.11a WLAN bands (5.15-5.35 and 5.725-5.825 GHz). Because of this, the UWB systems may interfere with WLAN and HIPERLAN/2 bands. To avoid this interference, band notch filter in UWB system is required. But, this increases complexity of overall UWB Communication system. Various other techniques have been used to avoid the interference between UWB and WLAN, HIPERLAN/2. Conventional methods to avoid interference are cutting U slot [7], inverted U slot [8] in patch or embedding a quarter wavelength stub with in big slot on patch [9] or slit in either the ground plane or radiating patch[10-11]. Parasitic elements [12] can also be placed near the printed monopole which play role as filter to reject undesired narrow bands.

In this paper, we have proposed a compact planar slot antenna for wideband applications. The antenna has pot shaped patch and is fed by
copolanar waveguide. A C-shaped slot was carved inside the patch to avoid interference from WLAN and HIPERLAN/2. The paper is organized in the following manner. The structure of antenna and its details are presented in Section II. The simulated and measured results of antenna are explained in Section III. Conclusions are given in Section IV.

II. ANTENNA CONFIGURATION

![Fig. 1. Geometry of Proposed antenna](image)

Fig. 1 shows the structure of the proposed antenna. The antenna has small size of 28 x 31 x 0.8 mm³ and simple structure. The antenna is printed on FR4 substrate with relative permittivity of ε_r = 4.4 and thickness of h = 0.8 mm and is fed by Coplanar Waveguide line with 50Ω characteristic impedance. The CPW line is having signal strip width of W_2 = 2.8 mm and gap between ground plane and signal strip width is g = 0.45 mm. The antenna has pot shaped patch at the centre with its different widths (W_5, W_6, W_7), heights (L_5, L_6, L_7) and radius 'r' which provide UWB bandwidth. A C-shaped slot was carved in the pot shaped patch to avoid the potential interference with WLAN and HIPERLAN/2.

![Table 1: Parameters of the proposed antenna (in mm)](table)

<table>
<thead>
<tr>
<th>Parameter</th>
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<td>W_4</td>
<td>5</td>
<td>W_5</td>
<td>7</td>
</tr>
<tr>
<td>W_6</td>
<td>5</td>
<td>W_7</td>
<td>13.8</td>
<td>W_8</td>
<td>2.3</td>
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<td>L_8</td>
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<td>4.2</td>
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</tr>
<tr>
<td>r</td>
<td>5.5</td>
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</table>

By considering the length of slot nearly equal to half wavelength at notch frequency, destructive interference takes place due to defects in unequivalent LC components and leads to rejection of WLAN and HIPERLAN/2. The fabricated antenna is shown in Fig. 2. The commercial Zeland IE3D tool is used to design and optimize antenna parameters. The various optimal configuration parameters of antenna are mentioned in Table1.

![Fig. 2. Fabricated Antenna](image)

![Fig. 3. Proposed antenna returns loss vs. frequency](image)
III. RESULTS AND DISCUSSION

Fig. 3 shows measured and simulated return losses versus frequency for the proposed antenna. The measured results exhibit operating impedance bandwidth of 7.2 GHz, starting from 3.1 GHz to 11 GHz except notched band. The notched frequency band is from 5.1 to 5.9 GHz. There is reasonable agreement between measured and simulate results except at 4.8 GHz and higher frequencies. This might be the effect of fabrication tolerance or soldering the SMA connector.

A. Effects of different geometrical parameters on antenna performance

To analyze the wideband width of the antenna, the effects of varying antenna parameters are investigated. Every geometrical parameter has different effect on performance of the antenna. The effects of three different parameters \( L_2, L_{10}, r \) on the antenna have been observed and discussed.

i. The effect of radius of the patch \((r)\)

As \( r \) increases from 5 to 6 mm, better impedance matching is obtained at higher frequencies as shown in Fig. 4. Increase in \( r \) leads to better impedance matching at higher frequencies and increase in impedance bandwidth. This also decreases notched bandwidth and at \( r = 6 \) mm, the notched bandwidth does not fully avoid WLAN, HIPERLAN/2. From this simulation analysis, better notched band and ultra wideband is obtained at optimized value of \( r = 5.5 \) mm.

ii. The effect of intrusion depth \((L_2)\)

Fig. 5 illustrates the return loss of antenna as a function of frequency for different values of \( L_2 \) keeping all other parameters constant. It is noticed that impedance bandwidth decreases at higher frequencies. This is mainly due to inductive and capacitance effects obtained by electromagnetic coupling between ground and bottom part of the notch. Since the parameter has significant effect on antenna at higher frequencies, it plays an important role in impedance matching.

iii. The effect of the distance from top of the ground plane to the lower end of the C shaped slot \((L_{10})\)

Fig. 6 shows the effect of the length \( L_{10} \) on the antenna performance is studied by keeping all other parameters fixed. As \( L_{10} \) decreases from 4.3 mm to 2.3 mm, the operating bandwidth decreases from 7.4 GHz to 5.2 GHz and notched
frequency bandwidth increases from 0.6 GHz to 1.6 GHz. The entire UWB band along with rejection of WLAN, HIPERLAN/2 are obtained at $L_{t0} = 3.3$ mm. The highest resonant frequency is significantly affected whereas lowest resonant frequency slightly changes. It can be concluded that this parameter has significant effect on notched band and operating bandwidth.

![Fig. 6](image)

**Fig. 6.** Return loss vs. frequency for proposed antenna with $L_{t0} = 2.3, 3.3, 4.3$ mm

B. Radiation Pattern and Gain

Fig. 7 and 8 show E and H plane radiation patterns. The radiation pattern is Omni directional at lower frequencies in H plane and nearly Omni directional at higher frequencies. In E-plane, radiation pattern is bidirectional. The cross polarization levels are minimum compared to co-polarization levels. Fig 9 shows measured and simulation gain of the antenna as a function of the frequency. It shows that antenna gain ranges from 3 to 5.1 dBi in operating bandwidth except for notched band from 5 to 5.9 GHz. In notched frequency band, the gain falls to -8 dB. The sharp decrease of antenna gain in the notched band is a good sign for elimination of narrow bands. It also indicates that the antenna has good performance at all frequencies in operating band width of 7.2 GHz and it is non dispersive and fairly stable.

![Fig. 7](image)

**Fig. 7.** Measured E-plane radiation pattern at (a) 3.51 GHz (b) 6.2 GHz (c) 9 GHz.
Fig. 8. Measured H-plane radiation pattern at (a) 3.51 GHz (b) 6.2 GHz (c) 9 GHz.

Fig. 9. Measured and simulated gain of the antenna

C. Group Delay

Fig. 10. Measured Group delay of proposed antenna vs. frequency

In UWB communication, UWB signals are transferred into impulse or non sinusoidal signals with very short pulse in terms of nanoseconds. These signals vary rapidly in time domain. Accordingly, data transmission can be done as fast as hundreds of Megabits per seconds. In UWB, it is desirable to measure the pulse distortion by the antenna. Ideally, a linear phase response i.e. constant group delay is required. In this UWB antenna, the group delay is measured between two identical antennas, which are placed face to face orientation. The distance between two identical antennas is 0.3 m. From fig. 10, it is observed that variation of group delay is less than 1 nano seconds except in
the notched band. At notched band, group delay variation is nearly 3 nano seconds, which deteriorates phase linearity. But, in unnotched band, group delay variations are small indicating reasonably good linear phase response and good time domain characteristics. The nearly constant group delay also indicates that the antenna has good pulse handling capability as required in modern communication systems.

IV. CONCLUSION

A compact CPW fed slot antenna is presented for UWB Applications. The antenna contains pot shaped radiating patch and notched frequency band is achieved by carving C shaped slot in the patch to avoid interference from WLAN, HIPERLAN/2. The UWB antenna is simulated and experimentally verified. The antenna has reasonably good radiation pattern and almost constant gain in the operating band. The group delay variation is less than 1 ns in operating region and more than 3 ns in notched band which indicate that the antenna has good time domain characteristics. The measured results indicate that the antenna is a good solution for UWB Communication applications.

REFERENCES