

# **Bandwidth Enhancement of a Slotted Ultra Wideband Antenna Using Defected Ground Structures**

Jasdeep Kaur<sup>1</sup>

Assistant Professor, Department of Electronics Technology, Guru Nanak Dev University, Amritsar, Punjab, India<sup>1</sup>

**ABSTRACT:** In this paper, we propose various defected ground structures (DGS) for improving the return loss and impedance bandwidth of an ultra wideband antenna. A comparative parametric analysis has been made on the basis of return loss, gain, radiation pattern characteristics and impedance bandwidth. Simulation results are analyzed and presented for an ultra wideband antenna with four slots in its radiating patch considering three types of DGS configurations.

**KEYWORDS:** Ultra Wideband, Microstrip Patch Antenna, Defected Ground Structure, DGS

## **I. INTRODUCTION**

A widely accepted definition of Ultra-Wideband (UWB) technology is any wireless transmission scheme that occupies a bandwidth in excess of 25% of a centre frequency [1]. Ultra-wideband antenna are employed to transmit and/or receive very short time durations of electromagnetic energy consequent to which traditional antenna design is less than adequate for UWB systems [2].

When considering patch antenna design for ultra-wideband applications, defected ground structures present a novel technique for modifying the characteristics of the microwave device[3][4]. These have been studied in detailed by Weng et. al. [5] and the equivalent circuit models can be used to simulate the behaviour of the same.

In this paper, the use of defected ground structures is discussed for the enhancement of bandwidth of a UWB slot antenna. Three different types of defected structures employed in the ground plane are [5,6,9]:

1. Inverted T-Shaped Notch
2. Square Notch
3. Corner Notches

The notches in the ground plane control the impedance bandwidth and return loss levels by modifying the capacitance between the patch and the ground plane. Additionally, the size and placement of these notches are the most critical parameter since they determine the upper and lower UWB frequencies. This is because they help reduce the lower frequency and improve the upper frequency, hence contributing to bandwidth enhancement [5]. The requirements necessary for the characterization of UWB antennas are summarized in table 1.1 [8]:

As per the fundamental definition of UWB, the designed antenna must be fully operable in the entire frequency range i.e., 3.1 – 10.6 GHz which implies having an impedance bandwidth of 7.5 GHz [8]. Also due to properties of low transmission power and low power spectral density, the antenna must have high radiating efficiency. Thus, the return loss and dielectrics need to be as low as possible. Another parameter of concern is the group delay. By group delay here we mean to say amount to which the UWB signal gets dispersed during communication. And the requirement is of a constant group delay for a communication to be said as distortion-less over the entire operable UWB bandwidth.

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Physical profile	Less weight and volume, cheap
Frequency band	3.1 – 10.6 GHz
Return loss	$S_{11} < -10$ dB
Radiation pattern	Highly directional and stable for operable band
Directivity/ gain	High
Group Delay	Constant over entire bandwidth
VSWR	Less than 2 for the entire band

Table 1.1: Design Requirements for an UWB Antenna

## II. RELATED WORK

Dalia Nashaat et. al. (2009) [12] came up with the use of metamaterial structures for enhancing the UWB bandwidth of an antenna. The prototype antenna was a semicircular microstrip monopole antenna with a modified ground plane. This geometry thus produced an impedance bandwidth greater than 29 GHz. Also for improving antenna's performance metamaterials like metallo-electromagnetic band gap structure (MEBG) and spiral artificial magnetic conductors (SAMC) were used which helped to brought about the radiation efficiency ( $\eta$ ) nearly 0.92 and the gain to 7 dBi.

You-Zhi Cai et. al. (2014) [13] presented the configuration of a compact and multiband UWB antenna fed by a Microstrip line. The prototype consisted of a double-fed monopole antenna and a truncated ground plane. A square slot is etched in the feed line to produce the required band notched characteristics in the WLAN, WiMAX and ITU band. These characteristics are carefully investigated and controlled through rigorous parametric analysis of the slots embedded along the length of the feed line.

Ghyda'a M Al-Maani et. al. (2014) [14] proposed a new method for improving the parameters of a slot antenna. The performance was improved by introducing a rotated slot in the ground plane accompanied by an E-shaped patch in its center. Various parametric analysis were made for the proposed antenna such as E-patch dimensions; the length, width and position of the slit; and the effects of slot length and position of the feed line on antenna parameters. Simulations concluded that the proposed antenna is capable of operating in all WiMAX bands, HIPERLAN 1 & 2 and WLAN band also.

N. Prombutr et. al. (2009) [15] reported a bandwidth enhancing technique for a microstrip fed planar circular disc shaped monopole antenna. The prototype modified the rectangular ground plane to a T-shaped one by making diagonal cuts at the top corners and rectangular slots in the body. The simulated results showed that by modifying the ground plane the bandwidth gets improved to nearly 28.67 % more than the one allocated by the FCC.

Lee Chia Ping (2015) [16] presented a slotted UWB antenna characterized by bandwidth enhancement for portable wireless devices applications. The paper presented an edge-fed microstrip patch antenna with impedance bandwidth from 3.3 to 19.53 GHz. The geometry comprised of a larger patch with square shaped slot and two steps were used at the bottom part. Again truncated ground plane was used with a notch cut at the center. Excellent UWB characteristics were exhibited even by the fabricated prototype of the same.

K.Praveen Kumar et. al. (2015) [17] studied the effect of a number of EBG rows surrounding a rectangular microstrip patch antenna (MPA). These structures basically cause two effects; firstly is multiple resonances which lead to bandwidth improvement and secondly the cavity effect which causes a bit of reduction in the bandwidth. The parametric study was based on mushroom-like EBG structures.

Jalaj Sharma et. al. (2013) [18] triangular lattice shaped electromagnetic band gap (EBG) structures in the ground plane for the bandwidth enhancement of a triangular microstrip patch antenna (TMPA). The EBG structures not only widen the impedance bandwidth but also cause reduction in the surface wave generation in a microstrip antenna.

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The simulations showed an increased bandwidth of about 16.76 GHz with ETMPA array with EBG compared to a bandwidth of only 2.46 GHz without EBG.

Nagendra Kushwaha et. al. (2014) [19] proposed different EBG structures for the purpose of bandwidth enhancements in single as well as dual band. These structures characteristics were analyzed with those of conventional mushroom type EBG's in terms of their unit element's dimensions, the distance between them and the effect of the diameter of via on the transmission parameters. The results indicated that proposed EBG's led to an increase in antenna gain and bandwidth, enhancing the signal integrity, reduction in filter noise, minimize mutual coupling in antenna arrays and eliminating noise in high speed switches.

Shiva Chauhan et. al. (2014)[20] studied and made a comparative analysis of different types of EBG structures on the parametric features of an antenna. Instead of 3D structures the analysis was based on planar structures viz., fractal type, the fork type and the spiral shaped EBG structures. And these proposed structures were suitable for improving gain and bandwidth, and also for minimizing surface waves and mutual coupling.

Sabzar Ahmad Bhat (2015) [21] proposed a low profile Ultra Wideband (UWB) antenna incorporating EBG structures of square shape on the both sides of the dielectric and to reduce the effect of mutual coupling the substrate is drilled with cylinders. Also in order to enhance the radiation efficiency, semicircular ground plane was used. Thus, the proposed prototype was found to be suitable for WLAN applications as it achieved bandwidth of 2.5 GHz in this range and acceptable return loss and voltage standing wave ratio (VSWR).

### III. ANTENNA CONFIGURATION

For designing an antenna structure different materials used are: Perfect Electric Conductor (PEC) for the partial ground plane and the radiating patch, FR4 for the dielectric substrate having relative permittivity of 4.4 and Air for radiation box [4]. The ground plane is assigned as PEC so as to obtain a monopole radiation pattern for the designed antenna. The patch dimension is  $W \text{ mm} \times L \text{ mm}$  with a substrate height of 1.6 mm. Here microstrip feed line is used which is represented by the smaller patch, having feed length as 'F' mm and feed width as 'H' mm. Also a partial ground of size  $16 \text{ mm} \times 4 \text{ mm}$  is utilized. A notch of size 'S' is cut at the bottom corners of the main patch. The detailed dimensions of the proposed antenna are listed in table 1.2. The three DGS configurations considered for comparative analysis are shown in fig 1.2 to 1.4.

BASIC CONFIGURATION	VARIABLE	DIMENSION (mm)
SUBSTRATE	W	16
	L	18
PATCH	M	7
	N	11
SLOT	P	2
	Q	1
DISTANCE BETWEEN SLOTS	R	2
PATCH'S NOTCH	S	1 × 2
FEED LINE	F	6
FEED WIDTH	H	2
GROUND PLANE	W	16
	G	4

Table 1.2: Antenna Parameters

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## IV. COMPARATIVE PARAMETRIC ANALYSIS

The parametric study is performed using HFSS at a solution frequency of 3.5 GHz[10] for all the different defected ground structures on the basis of parameters discussed in subsequent sub-sections.

### 1. Return Loss Characteristics

The following fig 1.5 shows the obtained return loss characteristics at solution frequency 3.5 GHz for different DGS configurations. The different notches employed here have led to reduction in the lower frequency and improvement in the upper frequency thus, causing an increase in impedance bandwidth. Also it is important to note here that we obtain two resonating frequencies in the return loss plots instead of one due to the resonating property of the notch structures deployed in the ground plane [11].

From our analysis of return loss plots we observe that the corner notch configuration in the ground plane has effectively reduced the lowermost frequency to 3.6 GHz compared to 3.7045 GHz for T-shaped notch and 3.6212 GHz for square notch. In case of upper frequency also, the corner notch configuration has improved it to the maximum i.e., 15.359 GHz compared to 15.2549 GHz for T-shaped notch and 15.2758 GHz for square notch.

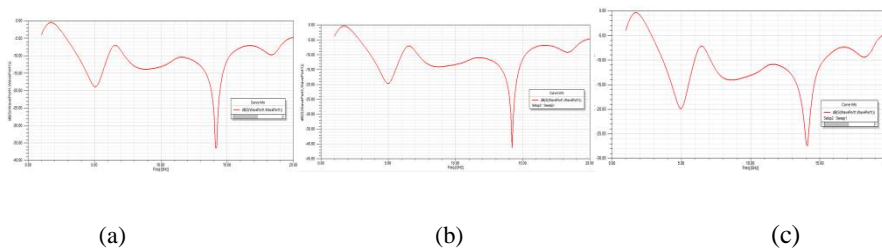


Fig 1.5: Return Loss Plot for Antenna with (a) Inverted T-Shaped Notch (b) Square Notch (c) Corner Notches in the Ground

The table 1.3 below represents the obtained values of  $S_{11}$  (in dB) and the resonant frequencies (in GHz) for the three DGS configurations simulated at an operating frequency of 5 GHz. It can be noticed from the table below that we get the improved value of  $S_{11}$  for the Square slot DGS configuration, i.e., -41.3135 dB compared to other obtained values.

TYPE OF DGS CONFIGURATION	RETURN LOSS OR $S_{11}$ (in dB)	RESONANT FREQUENCIES (in GHz)
T-SHAPED SLOT	-36.3884	5.0100/ 14.11
SQUARE SLOT	-41.3135	4.9000/14.205
CORNER SLOTS	-27.4018	4.9499/14.11

Table 1.3: Obtained Return Loss Values and Resonant Frequency for Different DGS Configurations

## V. RADIATION PATTERN CHARACTERISTICS

After the return loss we will investigate our next parameter, i.e., radiation pattern and obtained gain values for these DGS configurations. Figure 1.8 depicts the far field plots of radiation patterns while the gain values are indicated in table 1.4. From figure 1.8 (c), it is clear that the antenna with corner slot DGS configuration attains the perfectly omnidirectional radiation pattern and the maximum gain value compared to other configurations.

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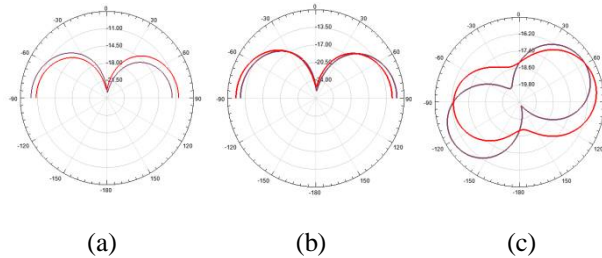


Fig 1.6: Radiation Pattern Plot for Antenna with (a) Inverted T-Shaped Notch (b) Square Notch (c) Corner Notches in the Ground

TYPE OF DGS CONFIGURATION	GAIN (in dB)
T-SHAPED SLOT	6.4607
SQUARE SLOT	3.6775
CORNER SLOTS	8.5215

Table 1.4: Obtained Gain Values from Radiation Patterns for Different DGS Configurations

## VI. IMPEDANCE AND PERCENTAGE BANDWIDTH

The impedance bandwidth, percentage bandwidth and center frequency are calculated respectively as per the following equations (1.1) to (1.3) [12]. The upper and lower frequencies that is,  $f_H$  and  $f_L$  are calculated from the return loss plots shown in fig 1.5 at the 10 dB line. The table 1.5 below shows the calculated values for different antennas corresponding to the best obtained return loss values above.

$$BW_{(UWB)} = f_H - f_L \quad (1.1)$$

$$\% BW = [(f_H - f_L) / f_C] \times 100 \quad (1.2)$$

$$f_C = (f_H + f_L) / 2 \quad (1.3)$$

PARAMETER	T-SHAPED SLOT DGS	SQUARE SLOT DGS	CORNER SLOT DGS
UPPER FREQUENCY, $f_H$ (GHz)	15.2549	15.2758	15.359
LOWER FREQUENCY, $f_L$ (GHz)	3.7045	3.6212	3.6004
CENTER FREQUENCY, $f_C$ (GHz)	9.4797	9.4485	9.4797
IMPEDANCE BANDWIDTH, $BW_{(UWB)}$ (GHz)	11.5504	11.6546	11.7586
PERCENTAGE BANDWIDTH, % BW (%age)	121.84	123.34	124.039

Table 1.5: Calculated Values for Impedance and Percentage Bandwidth

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From the table 1.5 above it is clear that the impedance bandwidth has maximum value of 11.7586 GHz for corner cut DGS configuration in comparison to others accompanied with the maximum attained percentage bandwidth of 124.039%.

## VII. CONCLUSION

In this paper, an analysis of three defected ground structures is presented. Of these three, the corner notch defected structure was calculated to have a maximum impedance bandwidth of 11.7586 GHz, a percentage bandwidth of 124.039 % and return loss value of -27.4018 dB making them the better candidate for UWB applications. Additionally it was observed to have the best reduction and enhancement features in the lowermost and uppermost frequency that is 3.6004 GHz and 15.359 GHz respectively compared to other DGS configurations, which further strengthens its case amongst the three.

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