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Design of Compact Printed Ultra Wideband antenna with notch band characteristic

By

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Abstract: The research thesis is aimed towards the designing of a compact printed ultra wideband antenna (UWB) with dual band notched characteristics. It is a planar monopole micro-strip fed designed antenna structure. The radiating patch is rectangular in shape with a partial ground plane. The 3.0 GHz Wi-max band is rejected in addition to the 5.0 band used in Wireless Local Area networks (WLAN's). Simulation is done using the "High Frequency Structure Simulator" and the measured values are analyzed. The results obtained after using the optimized parameters depict UWB characteristics while rejecting the two bands frequencies.

Introduction & Literature Review

This chapter presents the introduction to the antennas and various concepts pertaining to the designing and implementation of the proposed schemes with historical perspective in picture.

- Introduction & Background

The Federal Communication Commission in early 2002 allowed the commercial use of the frequency band falling in the range between 3.1-10.6 Giga Hertz (GHz). This led to a lot of development and research work in the designing of the ultra-wideband antennas across the globe. The best think about these antennas was there very compact size with lesser weight and their easy interconnection with the radio frequency circuits with much lower costs.

It is noted that the following two narrowband technologies are in place which are close to the ultra-wide band:

(a) Wimax Standard (IEEE 802.11a)

(b) Wireless Local Area Network (WLAN)/HyperLAN2

The 802.11a standard uses the 5 Giga Hertz band covering roughly 5.1 to 5.3 GHz & 5.7 to 5.8 Ghz. Similarly the "High Performance LAN" (HyperLAN2) is a Wireless Local Area network Standard which provides speeds up to 54 Mbps in the 5 Giga Hertz bands (HyperLAN1 provides speeds equal to 20Mbps). Hence there is a need to counter or mitigate the effects of these narrowband systems on the UWB through designing the band-notched antenna systems. The beauty of the band notched antenna is that it significantly suppresses interferences from the nearby existing communication systems using almost the same frequency bands.

The advancement/research in the field of UWB antenna designing led to many developments and structures, some of them are;

- Bell Shaped patch (staircase structure)
- Arc shaped Slot (elliptical shaped patch)
- Rectangular Tuning Stub
- L-Shaped Slot
- E-Shaped Slot
- C-Shaped Parasitic Strip

The above different type of antennas all have good performance but the challenge of the antenna designers is to come up with new designs and parametric changes so that a more reliable/efficient antenna can be designed. With simple micro strip patch antennas, the efficiency is generally low. However in case of U shaped antennas, the efficiency is high with fair costing and less size. It cannot be said with certainty which antenna design is better than the other as every manufactured units tend to improve its performance with versatile approaches.

- Designing approach

In order to deal with the issue, a dynamic approach is needed. For this, a monopole micro strip planer UWB line fed dual band antenna with notched characteristics (3-5 GHz) is simulated. A monopole antenna consists of a straight rod shaped conducting element (rectangular radiating patch), mounted on a conducting surface (slotted partial ground plane). The signal from the transmitter is applied. One end of the antenna has the feed line and the other end is attached to the ground plane.

Dual band notched characteristics (wideband matching) can be achieved by the embedding of the U-Shaped (inverted + non-inverted) slot resonators in the feed-line for the rejection of 3/5 GHz frequencies and using stair cased rectangular radiating element. The adjustment of the notched frequencies can be achieved by changing the length of the U-Shaped slots. This is done to adjust to the notched frequency thus helping in a way to achieve appropriate gain and acceptable radiation patterns.

It should be noted that the simulated/proposed antennas are in reality printed on a FR4 is a composite material comprising of epoxy resin and woven fiber glass cloth. It is flame resistant with self-extinguishing properties.

Parameter	Value
Specific gravity/density	1.850 g/cm³ (3,118 lb/cu yd)
Water absorption	−0.125 in < 0.10%
Temperature index	140 °C (284 °F)
Thermal conductivity, through-plane	0.29 W/m·K,[1] 0.343 W/m·K[2]
Thermal conductivity, in-plane	0.81 W/m·K,[1] 1.059 W/m·K[2]
Rockwell hardness	110 M scale
Bond strength	> 1,000 kg (2,200 lb)
Flexural strength (A; 0.125 in) - LW	> 440 MPa (64,000 psi)
Flexural strength (A; 0.125 in) - CW	> 345 MPa (50,000 psi)
Tensile strength (0.125 in) LW	> 310 MPa (45,000 psi)
Izod impact strength - LW	> 54 J/m (10 ft·lb/in)
Izod impact strength - CW	> 44 J/m (8 ft·lb/in)
Compressive strength - flatwise	> 415 MPa (60,200 psi)
Dielectric breakdown (A)	> 50 kV
Dielectric breakdown (D48/50)	> 50 kV
Dielectric strength	20 MV/m
Relative permittivity (A)	4.8
Relative permittivity (D24/23)	4.8
Dissipation factor (A)	0.017
Dissipation factor (D24/23)	0.018
Dielectric constant permittivity	4.70 max., 4.35 @ 500 MHz, 4.34 @ 1 GHz
Glass transition temperature	Can vary, but is over 120 °C
Young's modulus - LW	3.5×10^6 psi (24 GPa)
Young's modulus - CW	3.0×10^6 psi (21 GPa)
Coefficient of thermal expansion - x-axis	1.4×10^{-5} K^{-1}
Coefficient of thermal expansion - y-axis	1.2×10^{-5} K^{-1}
Coefficient of thermal expansion - z-axis	7.0×10^{-5} K^{-1}
Poisson's ratio - LW	0.136
Poisson's ratio - CW	0.118
LW sound speed	3602 m/s
SW sound speed	3369 m/s
LW Acoustic impedance	6.64 MRayl

Table 1.1: Physical/Electrical properties of FR4
(Source: http://en.wikipedia.org/wiki/FR-4)

High Frequency Structure Simulator (HFSSS) is used for simulation/optimization through the use of optimized parameters/values.

Similarly notch filters/characteristics also need to be understood. These filters are generally compact and have VSWR which is low with fewer losses. Some of the available notch filters are tabulated below;

Notch Filters						
Passbands (MHz)	Model Number	Loss(dB)	VSWR	Rejection (dB)	Stopband (MHz)	Size (inches)
0 to 2170, 3000 to12000	BRM50701	see pdf data sheet	2.0:1	50	2400 to 2500	1.0 x 0.98 x 0.51
0 to 2170, 3000 to 18000	BRM50702	2.0	2.0:1	50	2400 to 2500	1.0 x 0.98 x 0.51
0 to 4950, 5550 to 11000	BRC50703	2.0	1.7:1	45	5150 to 5350	3.48 x 0.87 x 0.53
0 to 5250, 5950 to 12000	BRC50704	2.0	1.7:1	45	5470 to 5725	3.33 x 0.87 x 0.54
0 to 5550, 6050 to 12000	BRC50705	2.0	1.7:1	45	5725 to 5875	3.28 x 0.87 x 0.53
0 to 550, 1300 to 6000	BRM50706	1.5	2.0:1	50	800 to 1000	1.0 x 0.98 x 0.51
0 to 1250, 2600 to 9000	BRM50707	1.5	2.0:1	50	1800 to 2000	1.0 x 0.98 x 0.51
0 to 3200, 3800 to 9000	BRC50708	1.5	2.0:1	45	3400 to 3600	4.50 x 0.99 x 0.70
0 to 2000, 3200 to 18000	BRM50709	1.5	2.0:1	50	2495 to 2690	1.0 x 0.98 x 0.51
0 to 1900, 3000 to 18000	BRM50710	1.5	2.0:1	50	2300 to 2400	1.0 x 0.98 x 0.51
0 to 2800, 4400 to 18000	BRM50711	1.5	2.0:1	40	3400 to 3800	1.25 x 0.48 x 0.40
750 to 1500, 1650 to 2500	BRC50712	1.0	1.5:1	50	1573.92 to 1576.92	4.70 x 2.30 x 1.20
0 to 1260, 2240 to 9000	BRM50713	1.5	2.0:1	45	1710 to 1785	1.00 x 0.98 x 0.51
0 to 1600, 2160 to 9000	BRM50714	1.5	2.0:1	40	1850 to 1970	1.00 x 0.98 x 0.51
0 to 1770, 2130 to 9000	BRM50715	1.5	2.0:1	30	1922 to 1978	1.00 x 0.98 x 0.51
0 to 4550, 6400 to 18000	BRM50716	1.5	2.0:1	40	5150 to 5880	1.25 x 0.48 x 0.40
0 to 800, 875 to 2000	BRC50717	1.5	1.5:1	50	825 to 850	7.80 x 2.25 x 2.50
0 to 850, 940 to 2000	BRC50718	1.5	1.5:1	50	880 to 915	7.80 x 2.25 x 2.50
0 to 1660, 1835 to 4000	BRC50719	1.5	1.5:1	50	1710 to 1785	10.0 x 1.60 x 1.14
0 to 1800, 1960 to 3500	BRC50720	1.5	1.5:1	50	1850 to 1910	9.53 x 1.65 x 1.14
0 to 1870, 2030 to 4200	BRC50721	1.5	1.5:1	50	1920 to 1980	9.53 x 1.65 x 1.14
0 to 880, 950 to 1500	BRC50722	1.5	1.5:1	50	902 to 928	7.80 x 2.25 x 2.50
0 to 2000, 2400 to 18000	BRM50723	2.0	2.0:1	40	2110 to 2170	1.0 x 0.98 x 0.51

Table 1.2: Notch Filters
(Source:http://www.microtronics.net/Notch.html)

- literature Review & Framework

The “Band notch UWB planar monopole with two parasitic patches” was first introduced by Kim, K.H., Cho, Y.J., Hwang, S.H., and Park. This was followed by future developments which led to the introduction of “Planar ultra-wideband antenna with a frequency notch characteristic” by Huang, and Hsia. As the work to further come up with new designs continued, Lee, Baik, and Kim came up with a new design “A coplanar waveguide fed monopole ultra-wideband antenna having band-notched frequency function by two folded-strip lines”. This was followed by “A compact ultra-wideband slot antenna with multiple notch frequency bands”.

Keeping in picture the above narrated research works, my research aims to focus on the simple and compact Micro strip-fed antenna covering the UWB operation band with notched-band. This will be followed by the details of the antenna design and its performance measurements. UWB antennas with band-notch characteristic have been studied in [1–4]. However, most of the antennas were designed with only one notched frequency band e.g. [1–3]. In [4] authors proposed a dual band notch antenna, their design is based on making use of a two split resonant rings (SRR). Moreover, within the proposed design the two rejected bands cannot be tuned respectively.

An extensive work undertaken in the field of “antenna and propagation” was presented in the 14th Biennial international Symposium [5]. This

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is a collection of hundreds of papers pertaining to the research undertaken as of 2014.

- Research Drive

With the extensive use of Wimax Standard (IEEE 802.11a) & Wireless Local Area Network (WLAN)/HyperLAN2 standards, the newly commercialized UWB needs to be used for which there is an extensive need to look at mechanisms in which the interference from dual bands can be mitigated. This will further lead to the designing/fabrication of compact sized, micro strip, light weight efficient antennas.

Furthermore, Micro strip antennas are used extensively in varied range of applications which include radars, biomedical systems, mobile/satellite Communications etc. As UWB systems work over ultra-wide frequency (spectrum) which overlaps with the existing wireless infrastructures i.e. Global Positioning System (GPS), and the IEEE 802.11 WLAN, hence the notch band UWB printed antenna is one of the ways to counter this problem. Notch band will be used as a band stop filter in order to mitigate the interference with the existing wireless systems.

Standard	Technology	Features
802.11	Wi-Fi	Wireless LAN Media Access Control and Physical Layer specification. 802.11a,b,g,etc. are amendments to the original 802.11 standard. Products that implement 802.11 standards must pass tests and are referred to as "Wi-Fi certified."
802.11a		Specifies a PHY that operates in the 5 GHz U-NII band in the US - initially 5.15-5.35 AND 5.725-5.85 - since expanded to additional frequencies • Uses Orthogonal Frequency-Division Multiplexing • Enhanced data speed to 54 Mbps • Ratified after 802.11b

Table 1.3: IEEE 802.11 & 802.11a standard

Standard	Technology	Features
HyperLAN	WLAN	HiperLAN/2 functional specification was accomplished February 2000. Version 2 is designed as a fast wireless connection for many kinds of networks. Those are UMTS back bone network, ATM and IP networks. Also it works as a network at home like HiperLAN/1. HiperLAN/2 uses the 5 GHz band and up to 54 Mbit/s data rate. The physical layer of HiperLAN/2 is very similar to IEEE 802.11a wireless local area networks. However, the media access control (the multiple access protocol) is Dynamic TDMA in HiperLAN/2, while CSMA/CA is used in 802.11a/n. Basic services in HiperLAN/2 are data, sound, and video transmission. The emphasis is in the quality of these services (QoS). The standard covers Physical, Data Link Control and Convergence layers. Convergence layer takes care of service dependent functionality between DLC and Network layer (OSI 3). Convergence sublayers can be used also on the physical layer to connect IP, ATM or UMTS networks. This feature makes HiperLAN/2 suitable for the wireless connection of various networks. On the physical layer BPSK, QPSK, 16QAM or 64QAM modulations are used. HiperLAN/2 offers security measures. The data are secured with DES or Triple DES algorithms. The wireless access point and the wireless terminal can authenticate each other.

Table 1.4: HyperLAN standard

Basis of Research

- Research Problem

Ultra-wideband (UWB) system design and application have become the focus of wireless communication. The problem with the wireless system is that it is already crowded with a number of narrowband standards being in operation which include the WLAN & WIMAX in particular. Hence the fallout is the availability of the vacant UWB. His problem can be overcome by overlaying of the UWB over existing (partially-vacant-spectrum) in such a dynamic way so that the ultra-wide band must not use the existing occupied effective part of the spectrum.

There can be several techniques which can be used to achieve this goal. Researchers have used band stop filters in the path of transmit and receive signals in the allowed part of the spectrum. However the problem with using the band stop filters is that they are the active filters and their power consumption and complexity further complicates things. Another more progressive and innovative approach relates to using notch antennas which only transmit & receive energy in the allowed bands. This intended research will focus on investigating and proposing antennas with notch band characteristics.

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- **Aims and Objectives**

The main objectives of the research are:

- To design a compact ultra-wideband Micro strip-fed planar antenna with dual band-notch. Frequencies of 3GHz (range 3.4-3.7GHz) & 5GHz (5.1-5.8GHz) will be investigated/simulated.

- To validate/simulate the proposed design by using HFSS (High Frequency Structure Simulator) environment.

- **Research Methodology**

- A Patch antenna having dual band-notch function will be designed for UWB applications.

- A basic mathematical model of the proposed antenna will be applied for achieving dual-stop-band.

- Proposed antenna will be implemented within HFSS, a simulation tool.

- By using simulations, proposed design will be analyzed and fine-tuned.

- Through HFSS Software (High Frequency Structure Simulator) different radiating patterns will be produced.

Antenna Design & Simulator

- **Antenna Design**

Before we discuss the design of our proposed antenna, it is important to understand few defining principles pertaining to antenna design. Antenna designing involves selecting dimensions, patterns and the materials which are used for the building of the antenna system. Voltage standing wave ratio, impedance matching, radiation patterns/efficiency, dispersion and delays are some of the parameters which need proper dimensioning for antenna designing. In case of ultra-wide band systems, these parameters greatly affect the performance; which certainly is not the case of narrowband antenna's where these values are constant.

The following parameters require special care for UWB designing;

- Bandwidth
- Group Delay
- Dispersion
- Antenna Directivity
- Antenna gain
- Radiation Efficiency
- Impedance Matching
  - Voltage Standing wave Ratio (VSWR)

In addition to the above, certain other design requirements include;

- Operation in the UWB frequency range
- Avoiding Return Loss
- Linear phase
- Constant Group Delay
- Reduced dispersion of pulses
- Omni-Directional Radiation pattern
- Minimum antenna gain
- Low power spectral density
- High radiation efficiency
- Reduced conductor and dielectric losses
- Compact Physical Size
- Robust

The earlier developments in the designing of micro strip antennas started in seventies. However major developments took place in eighties. The micro strip antenna has a radiating patch, made of a grounded substrate. A metallic strip which is very thin in size is placed on the grounded substrate. Following are the parameters which define the shapes/sizes of the antennas;

Length = L
Width = W
Substrate Thickness = h
Thickness of the Patch = t

The antenna dimension is diagrammatically depicted in figure 3.1.

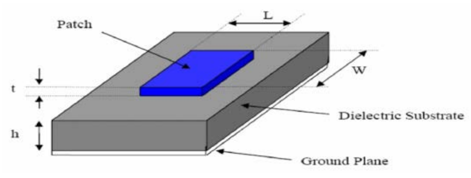

Fig 3.1: Antenna dimensions

Higher the thickness of the substrate and lower the dielectric constant, the performance can be enhanced. The dielectric constant's (εr) preferred range should be between 2.2 $\leq$ Dielectric Constant $\leq$ 12.

Similarly we have many different shapes for the radiating patch shown in figure 3.2.

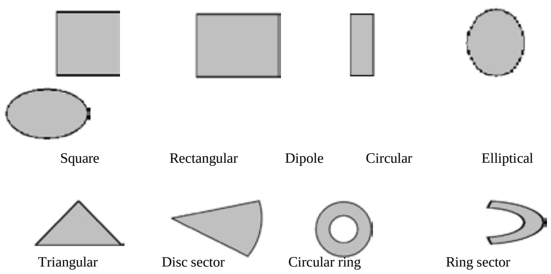

Fig 3.2: Radiating Patches Shapes

Lastly we have the feeding of the transmission line mechanism which includes feeding the radiating patch through a strip made of a conducting material and by attaching it directly to the edge of the patch. The same is shown I figure 3.3.

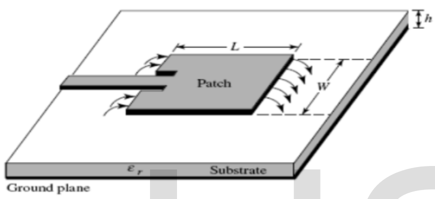

Fig 3.3: Transmission line (feeding mechanism)

Keeping the above factors in mind, the simulated antenna will be fed with a fifty ohms micro strip-line. The proposed fabrication is to be done on the FR4substrate. The thickness of the substrate is generally taken as 1.60 mm. As mentioned above, for the substrate, generally the relative permittivity is set. The relative permittivity of the materials is its dielectric permittivity which is a ratio relative to that of the permittivity in the vacuum ($\varepsilon 0 = 8.85 \times 10^{-12}$ F/m). The relative permittivity of 4.4 is suggested (range: $2.2 \leq$ Dielectric Constant ≤ 12).

Figures-3.4 through 3.7 shows the geometry of the proposed simulated antenna. Rectangle shape radiating element (fed with 50Ω micro strip transmission line) is used with a stair cased symmetric structures at the bottom corners of the rectangular radiating element.

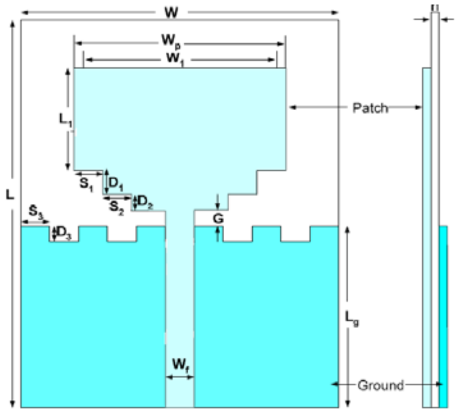

Fig 3.4: Antenna Design (Ground, Patch & rectangular radiating line)

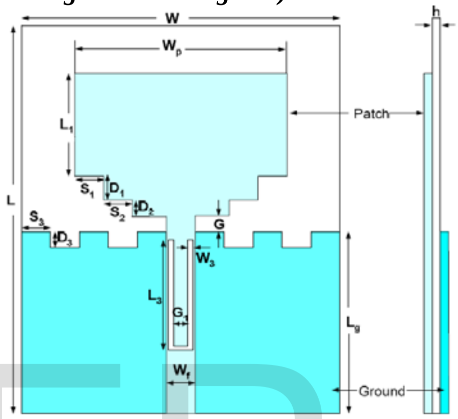

Fig 3.5: Antenna Design (U-Shaped Patch)

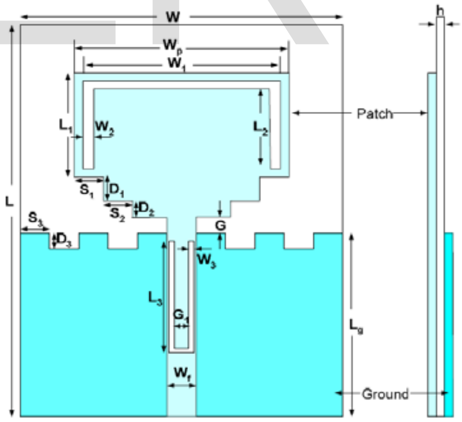

Fig 3.6: Antenna Design (U-Shaped & Inverted U-shaped Patch)

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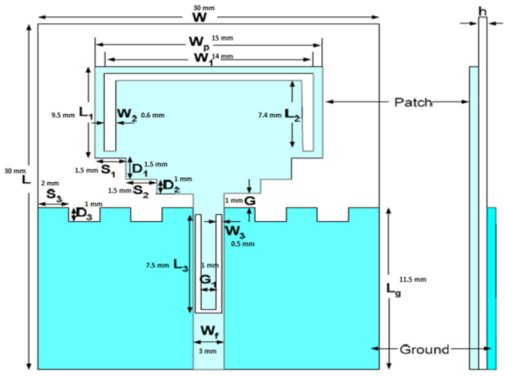

Fig 3.7: Proposed Designed Antenna with dimensions

Table-3.1 lists the other physical dimensions of the proposed/simulated antenna;

Description	Details/Dimens
Radiating element	Fed by 50Ω strip transmissio
Micro strip transmission line center width (terminated with a sub miniature connector for the measurement purpose)	Wf = 3mm
Partial Ground Plane	W × Lg
Each Slot Size	2 mm × 1 mm
Gap between radiating patch and ground plane	G = 1mm
G1	1mm
W	30mm
Wp	15mm
W1	14mm
W2	0.6mm
W3	0.5mm
Wf	3mm
L	30mm
Lg	11.5mm
L1	9.5mm
L2	7.4mm
L3	7.5mm
S1	1.5mm
S2	1.5mm
S3	2mm
D1	1.5mm
D2	1mm
D 3	1mm

Table-3.1: Antenna Dimensions

Fig 3.8: Proposed Antenna (prototype/visualization)

- **High Frequency Structure Simulator (HFSS)**

High Frequency Structure Simulator (HFSS) is used. It is a very authentic commercially used tool used for the antenna designing. The various steps required for simulation can be described as:

1. Open or Make new project
2. Draw objects
3. Assign material property
4. Define boundary conditions
5. Solve
6. Display result

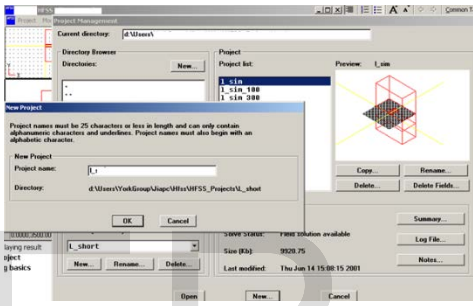

Fig 3.9: HFSS Simulator (sample)

Analysis & Simulations

- **Voltage Standing Wave Ratio (VSWR)**

Voltage Standing Wave Ratio is the term extensively used in the radio communications and is the measure of the impedance matching of the loads to the impedance of the transmission line. For the Transmitters or receivers in case of Radio Transmission, in order to ensure that the power is delivered to the antenna, the impedance of the radio and the transmission line has to be well matched to the impedance of the antenna. Hence the Voltage Standing wave Ratio is a numerical representation of how well the matching has been achieved. VSWR in turn is a function of the coefficient of reflection which describes the reflected power from the antenna.

Impedance is basically the ratio between the magnetic and the electric fields. As electric and magnetic fields are generally not in phase, hence we see a complex value when the impedance is specified. Hence e.g. if the transmission line has an impedance represented by Z1 and the impedance of the antenna is denoted by Z2 and

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if they are not the same, it will result in a mismatch which will further lead to the incident signal being reflected back to the source. Reflection Coefficient depicts this reflection in mathematical terms.

Reflection Coefficient = Reflected Voltage / Transmitted Voltage

Or

(Z2 - Z1) / (Z2 + Z1)

So in order to achieve perfect impedance matching, the concept of VSWR comes in to play. It is the ratio of peak voltage maximum to the peak voltage minimum.

If,

VSWR = 1 (No reflection/Return loss)

However this ideal condition is extremely difficult to achieve in the real scenarios.

Hence if,

VSWR < 2, we consider it a good acceptable matching.

In order to have a clear understanding, VSWR of a typical ultra-wide band antenna which has no slots is studied. Figure 4.1 depicts the results;

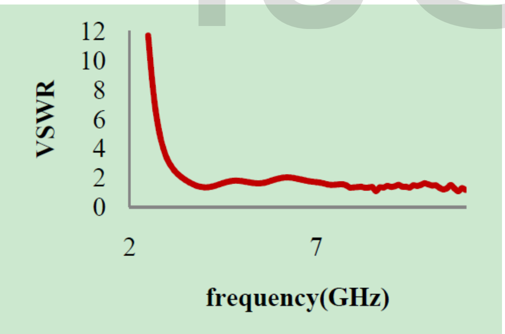

Fig 4.1: UWB antenna (VSWR vs frequency)

It is to be noted that in case of the old antennas, the voltage standing wave ratio between the frequency ranges of 3.1 – 11.8 GHz, is ≤ 2. What we see here is a reasonable perfect impedance matching (both between micro strip transmission line and the stair cased radiating element). This structure greatly improves the impedance matching along with the bandwidth.

What has been observed that IEEE 802.11a & HiperLAN/2 WLAN systems also operate with the ultra-wide band spectrum; hence an eminent threat of interference is introduced. The implementation of the band-notch scheme becomes more relevant to cancel the effects from the interference from these mentioned narrow bands.

Say, if we remove (a) inverted U-shaped slot (b) U-shaped slot, the dual band notch function is observed. The frequency (rejected) can be calculated as:

$$f_{notch} = \frac{c}{2L_{slot}\sqrt{\varepsilon_{eff}}} \quad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} \quad (2)$$

(Source: International Journal of Computer Theory and Engineering, Vol. 3, No. 6, December 2011)

Where;

Length of the Slot = L_{slot}

Effective Dielectric = ε_{eff}

Speed of Light = 3 x 10^8 m/s

Dielectric constant of substrate = ε_r

The length of the slot resonator can easily be calculated by using the above two equations. With the varying of the length of the slots, the band-notch frequencies can be adjusted for optimization. Here it should also be kept in mind that if we can vary the width of the slots, it will also have a substantial effect on the bandwidth of the notched band.

- **Simulations**

Let's now look at our proposed antenna. First of all we will vary the length of the inverted U shaped slot by varying length L2.

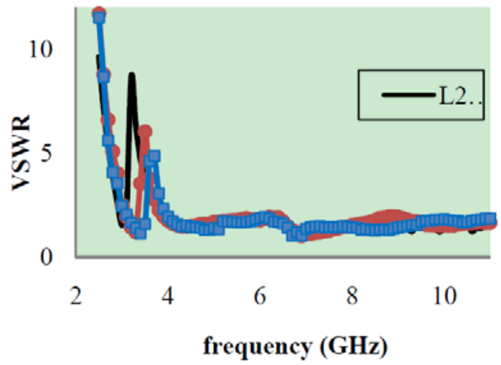

Fig 4.2: L2 Variation effects

The effects of varying length are summarized in Table-4.1(a) & (b).

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L2 Variation	Notch band Shift	VSWR
Total Length of Inverted U-Shaped Slot		2L2 + W1
Decreasing from 7.4 mm to 5.4 mm	Shift from 3.2 GHz to 3.7 GHz	Drops from 8.64 to 4.85

Table-4.1(a): Inverted U-Shaped slot (length variations)

2L2 + W1 = (2 X 7.4) + 14 = 28.8

VSWR = 8.64

Notch Band frequency = 3.2 GHz

Now if;

L2 = 5.4

2L2 + W1 = (2 X 5.4) + 14 = 24.8

VSWR = 4.85

Notch Band frequency = 3.7 GHz

Now if we vary L2, for different vales, we will get the following results;

L2 (mm)	Frequency (GHz)	VSWR
7.4	3.2	8.64
7.0	3.3	5.10
6.6	3.4	5.70
6.2	3.5	3.57
5.8	3.6	2.50
5.4	3.7	4.85

Table-4.1(b): Different values of L2

Let's now look at the U-Shaped Slot. The simulation is shown in Fig-4.3.

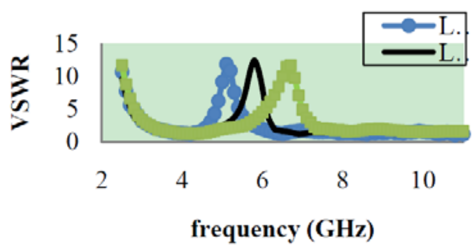

Fig 4.3: L3 Variation effects

The effects of varying length are summarized in Table-4.2(a) & (b).

L3 Variation	Notch band Shift
Total Length of Inverted U-Shaped Slot = 2L3 + G1	
Decreasing from 8.5 mm to 6.5 mm	Shift from 5.1 GHz to 6.7 GHz

Table-4.2(a): U-Shaped slot (length variations)

L3 mm	Frequency GHz	VSWR
8.5	5.10	2.9
8	5.55	5.2
7.5	6.00	12.1
7	6.45	5.1
6.5	6.70	1.3

Table-4.2(b): L3 Variations

- **Analysis**

By varying the lengths L2 & L3, our proposed antenna maintained the wideband performance; the overall antenna response is summarized in Table-4.3.

Performance	It is observed that the proposed antenna provides the band-notch in the frequency range of 3 – 4 GHz with a VSWR value of about 9 & 5 – 6 GHz with a VSWR value of about 11, which maintains wideband performance from 3.1 – 11.8 GHz for VSWR ≤ 2, covering the entire UWB frequency band.
Impedance	The simulated impedance of the proposed antenna shows that the high VSWR in the WiMAX and WLAN bands result from low input impedances at 3.2 GHz and 5.8 GHz.

Table-4.3: Proposed Antenna Simulation (Performance/impedance)

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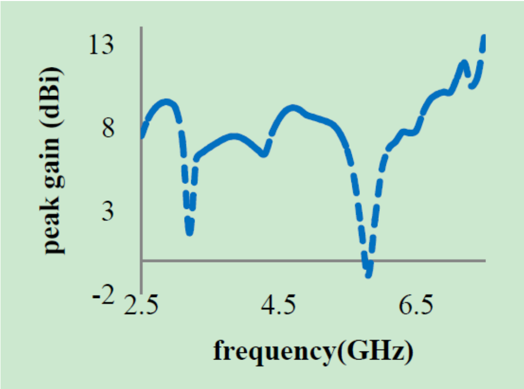
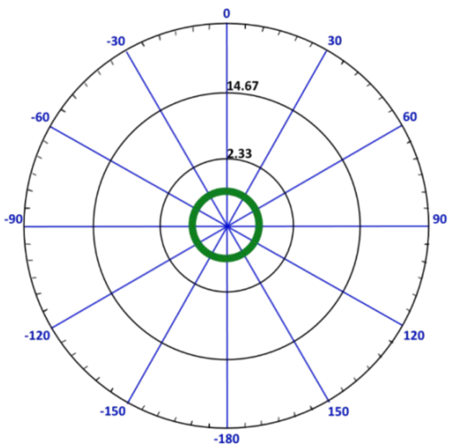


F (GHz)	G (dBi)
3.2	1.5
3.5	7.0
4.5	9.2
5.5	7.4
5.8	-1.3
6.5	8.1
7.5	13

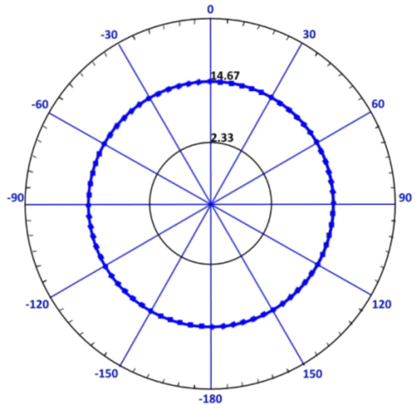
Fig 4.4: Frequency vs Peak Gain

Similarly we looked at the peak gain of the proposed antenna. We have simulated the peak gain results for a frequency range starting from 2.5 GHz to 7.5 GHz. At 2.5 GHz, the corresponding gain is very high i.e. 8 dbi. However we observe a major decrease in the antenna gain at frequency of 3.20 GHz. Similarly at 5.80 GHz, we see a very obvious effect of the band stop characteristics.

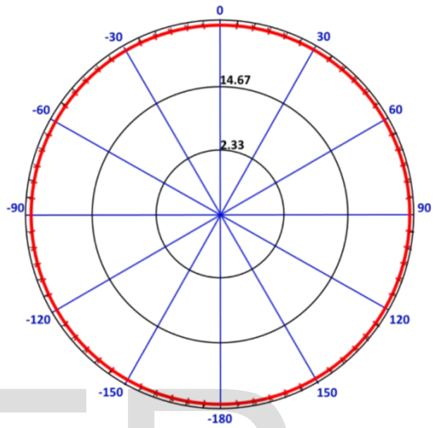
It is also important at this stage to have a look at the radiation patterns of the proposed antenna at different frequencies. Figure-4.5 shows patterns in the yz plane with respective frequencies shown in different colors.



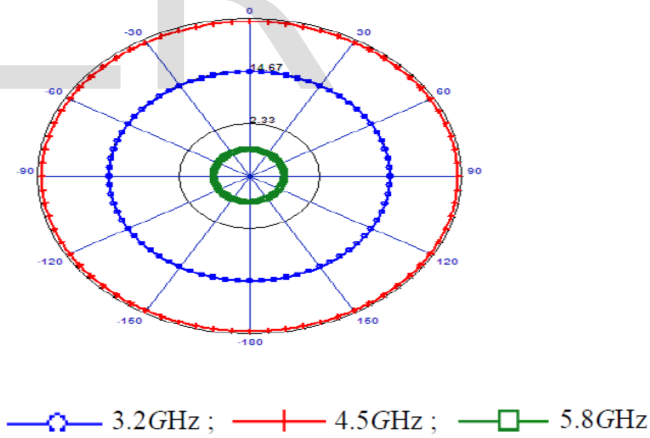
(a) 5.8 Ghz



(b) 3.2 GHz



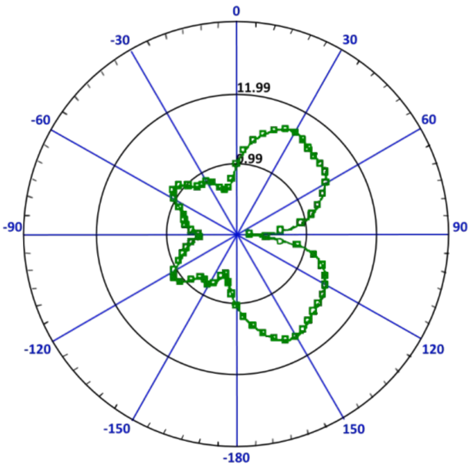
(c) 4.5 Ghz



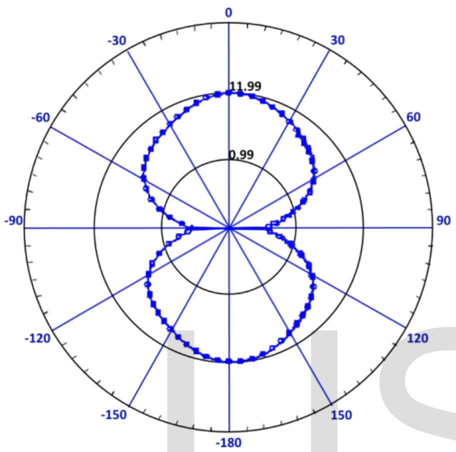
(d) 5.8, 3.2 & 4.5 GHz

Fig 4.5: Radiation Pattern (yz plane)

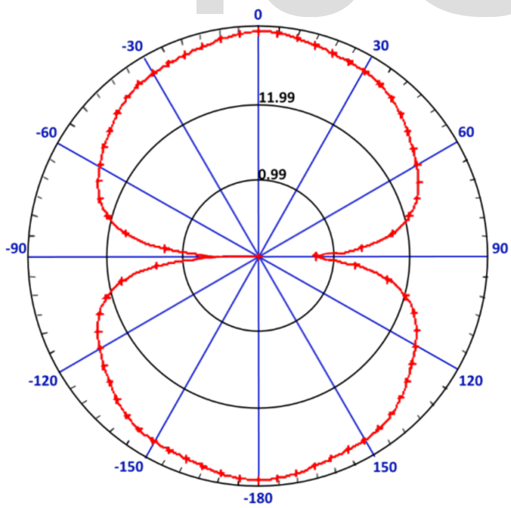
A close look at all the frequencies will depict that we are getting omnidirectional patterns at all the simulated frequencies. In case of omnidirectional antennas, the signals are sent/received equally in all directions.



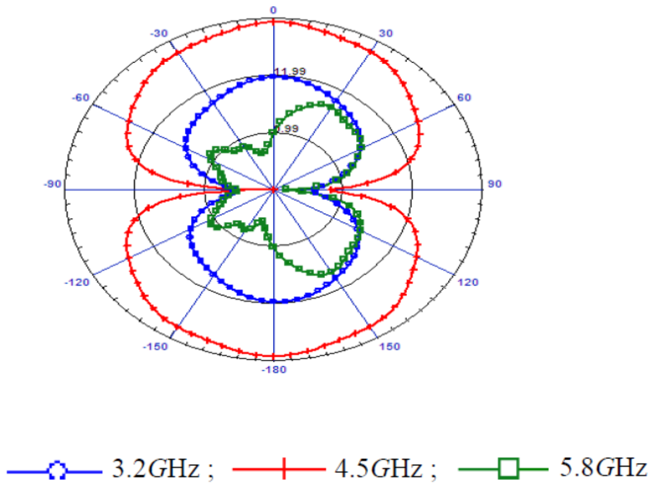
(a) 5.8 Ghz



(b) 3.2 GHz



(c) 4.5 Ghz



(d) 5.8, 3.2 & 4.5 GHz

Fig 4.6: Radiation Pattern (xy plane)

However in the xy plane (Figure-4.6), we observe the characteristics of a dipole antenna with a radiation pattern which is bidirectional. But as we move towards the higher frequency, we observe distortion. Resultantly, the efficiency in the stop bands is much lesser than those of the pass band. The radiation efficiency of the proposed antenna is more than ninety percent in the pass band and less than twenty percent in the stop band.

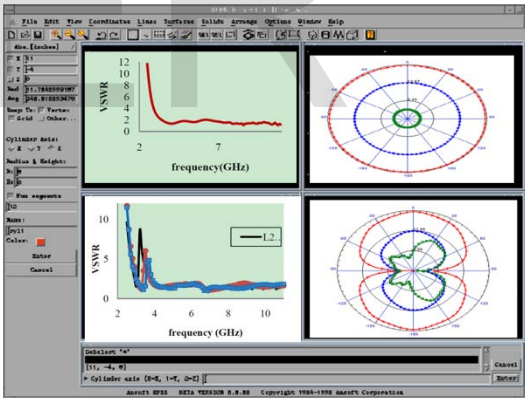


Fig 4.7: HFSS Snapshot

Conclusions/Recommendations

- Conclusion

Based on our simulations, the following drawn conclusions:

- In this study, a compact (less weight) micro-strip Ultra wide Band (UWB) antenna is proposed.
- The proposed antenna is stair cased.
- It has a rectangular radiating patch
- The proposed antenna is monopole.
- After defining various important parameters, the simulation was done.

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- One of the important aspect of designing the antenna was the matching of the impedance, especially in the case of wideband. In order to achieve that, the following two steps were taken;
    - At the radiating element, a stair cased structure was introduced.
    - At the ground plane, many rectangular slots were incorporated.
- In order to avoid the interference from the WiMaz and the WLAN (narrowband), the following U-Shaped Slots were introduced;
    - Inverted
    - Non-Inverted
- The above mentioned U-Shaped slots helped in the aim of the rejection of the bands.
- The simulated results show the following;
    - Dual notched band characteristics (over the UWB)
    - Radiating patterns were of reasonable good quality.
- Looking at the radiating patterns, the proposed antenna can be easily integrated with radio frequency (RF).
- The antenna can be integrated with microwave Systems
- The manufacturing cost is low.
- Supports various UWB applications.

- **Future Work**

While enhancing this work, I will use the Network Analyzer and will do PCB Design and fabrication of UWB Micro strip Patch Antenna. The prototype can be fabricated and by measuring the actual results using the network analyzer, the simulated results can be verified.

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