Design of Ultra-Wide Band Hexagonal Patch and Defective Ground Structure Microstrip Antenna

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***Abstract*: The objective of this work is to cover continuous S, C and X band ultra-wideband operation from the designed microstrip antenna. The antenna should meet these parameters as Very high return loss bandwidth, Very high impedance bandwidth, VSWR should be close to 1, and Input impedance should be close to 50 ohms and Omni-directional radiation pattern. The designed antenna works for the frequency range of 3.5 GHz – 7.5 GHz and impedance bandwidth is approximately 100% which makes the proposed antenna ultra-wideband.**

***Index Terms*: Ultra Wide Band (UWB), Defected ground structure, Omnidirectional antenna, VSWR, Return Loss, Antenna Impedance.**

I. INTRODUCTION

A microstrip antenna is a patch antenna that fabricated using microstrip techniques on a printed circuit board. It is a kind of low profile antenna since it is printed over a surface.

A microstrip antenna consists of a patch or metal foil of different shapes on the surface of a printed circuit board, with a metal ground plane on the other side of the board. Due to these properties, like thin planar profile which can be unified into the surfaces of consumer products like aircraft, and missiles; their ease of fabrication using printed circuit techniques, Microstrip antennas have become popular in current decades.

II. DEFECTED GROUND STRUCTURE (DGS)

Defected Ground Structure (DGS) is one of the methods, which are used to miniaturize the size of microstrip antennas, DGS consist etching of a simple shape in the ground plane, or sometimes by a complicated shape for the better performance. The DGS can be modeled by an equivalent L-C resonator circuit. The value of the inductance and capacitance depends on the area and the size of the shape. By varying the various dimensions of the etched shape, the desired resonance frequency can be achieved. [1].

III. ANTENNA GEOMETRY

The proposed design is a 'Hexagon shaped' Microstrip antenna meant to operate at wide band ranging from 2.5 to 7.5 GHz. This antenna has a ground plane with a slot of hexagon shape bigger than the hexagon of the patch. Since there is no ground plane beneath the hexagonal patch, this antenna radiates both above and below the x-y plane.

This antenna belongs to the category of monopole with defected ground plane. Foot print of the antenna is 40mm×40mm. Very cheap quality substrate (FR4 Epoxy) is used with relative permittivity εr =4.4 is used. Thickness of the substrate is 1.5 mm. The radiating patch is fed by a microstrip line of length 6.34mm (approx.) and width 4.9mm.

Table 1 Dimensions of Proposed Antenna

Denotations	Dimensions (mm)
L	40
W	40
R1	9
R2	15
L1	14.5
L2	20
W_F	2.9
h	1.5

The frequency band of 3.1 GHz-10.6 GHz was assigned by Federal communication commission for commercial applications. In these applications generally monopole antenna is used for its large bandwidth but the drawback with conventional monopole is that it is not compact and requires large ground plane perpendicular to the radiating element. Research carried out on reducing the size of the antenna lead to development of UWB printed antennas using partial ground plane. Many researchers are working on UWB monopole antennas with slots in patch and slots even in ground plane. These antennas are gaining attraction because of high speed data rate, low power consumption, low complexity, low cost, compact in size, less in weight and large bandwidth.

When slot is cut on the patch it effects the current distribution. By varying the slot position current distribution on the ground plane varies. The longest electrical path for the currents generated on the surface of the monopole is dependent on the lower limit of operating frequency. The shape of the slot and its dimensions play an important role in achieving UWB characteristics. Normally the current is concentrated in the bottom as well as at the left and right hand edges of the monopole. So to improve UWB characteristics sometimes slots are made on the lower edges of the patch beside the feed line. The ground plane of the antenna is also a part of radiating configuration and the current distribution on radiating element. The gap between ground plane and patch play a crucial role in achieving wide band characteristics. For UWB characteristics with the monopole antenna defective ground structure is used. To get good matching and impedance band width hexagonal slot is made on the ground plane. The performance is investigated for frequency band of 2.5 – 7.5 GHz. To investigate the performance of these arrangements return loss, VSWR, antenna impedance and radiation pattern are evaluated. The antenna is designed and tested using HFSS software.

Table 1 shows the dimensions and Fig. 1 show the top view of the proposed antenna.

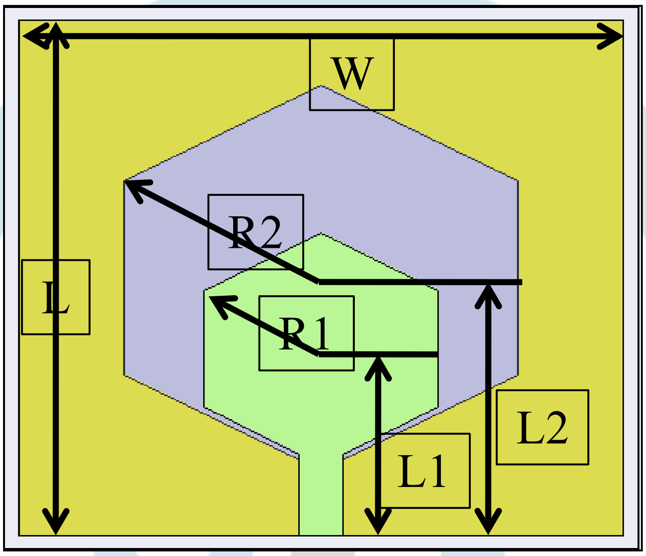


Fig. 1 Hexagonal Shape Monopole Antenna

The hexagonal patch has the radius of 9 mm and the hexagonal slot on the other side of the substrate has 15 mm radius. The center of the hexagonal patch and hexagonal slot on ground are 14.5 mm and 20 mm away from the bottom edge of the substrate respectively.

IV. Simulation Results

Following table shows the results of the proposed antenna

Table 2 Consolidated Parameters

Antenna Parameters	**Values**
Operating Frequency Range	2.5 GHz to 7.5 GHz
Bandwidth	5 GHz
Max Gain	2 dB
Minimum Return Loss	-24 dB approx.
Radiation Pattern	Egg Shaped (Broadside)
Minimum VSWR	1.1374 at 3.44 GHz

V. Radiation Pattern

The radiation pattern of antenna is the most important output. It tells where the antenna can be used. Radiation pattern is broadside with two nulls on the horizontal plane. The radiation pattern is horizontally polarized. Figure 2 shows 3D radiation pattern. It can be seen that the radiation pattern is Omni-directional in YZ plane. The nulls are located at +X and –X directions. Figure 3 shows 2D radiation pattern at 3 GHz, 4GHz, 5 GHz, 6 GHz and 7 GHz. All the radiation patterns are nearly same and as expected the patterns get distorted at higher frequencies.

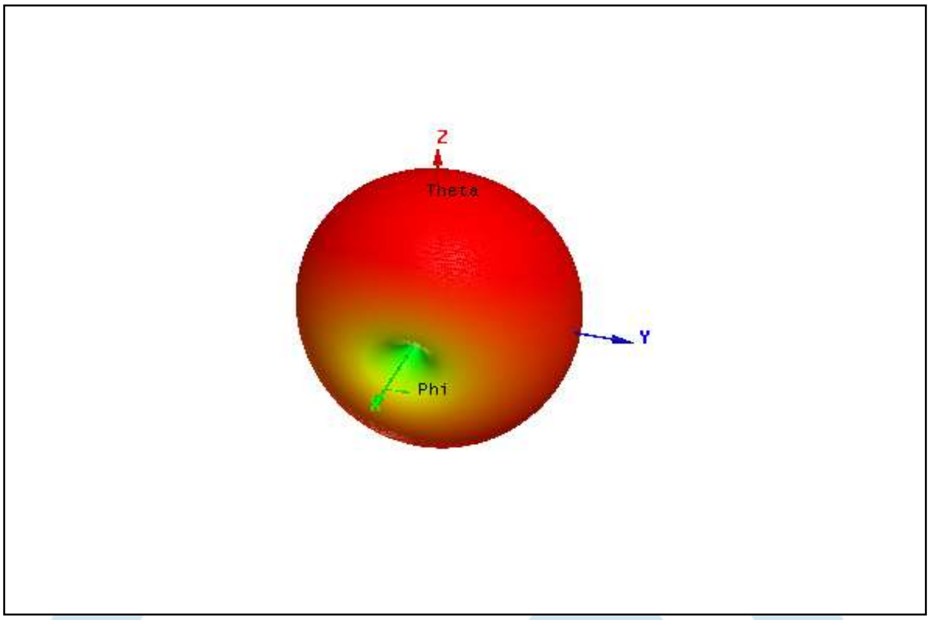
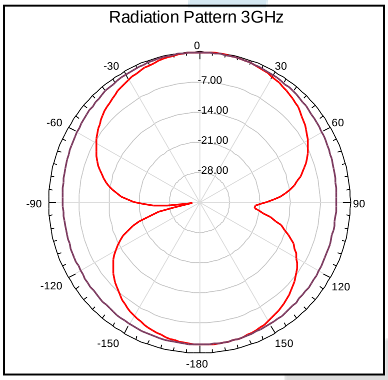
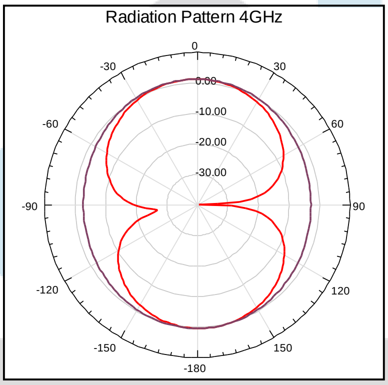


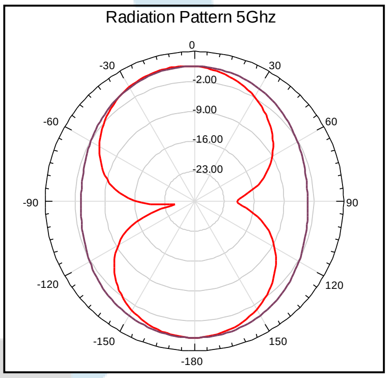
Fig. 2 Radiation Pattern



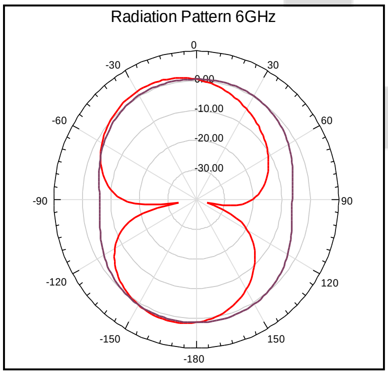
(a) 3 GHz



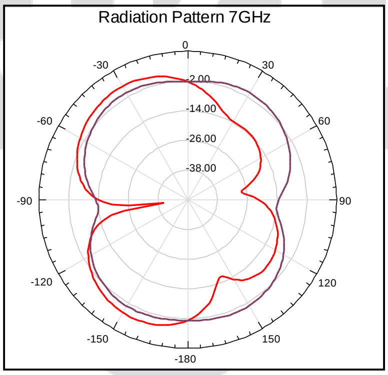
(b) 4 GHz



(c) 5 GHz



(d) 6 GHz



(e) 7 GHz

Fig. 3 Radiation Pattern at Different Frequencies

VI. Bandwidth And Operating Frequency

The antenna works between 2.5 GHz to 7.5 GHz. This frequency band is mostly used in small distance high bandwidth communication. Proposed antenna has a bandwidth of 5 GHz which is very high. The percentage bandwidth of the antenna is 100% that is why it is called Ultra-Wideband Antenna.

Percentage Bandwidth can be calculated from the equation below

$$BW\ \% = \frac{f_2 - f_1}{f_c} \times 100$$

$$BW\ \% = \frac{7.5 - 2.5}{5} \times 100 = 100\%$$

f_1 and f_2 are obtained by taking -10 dB reference.

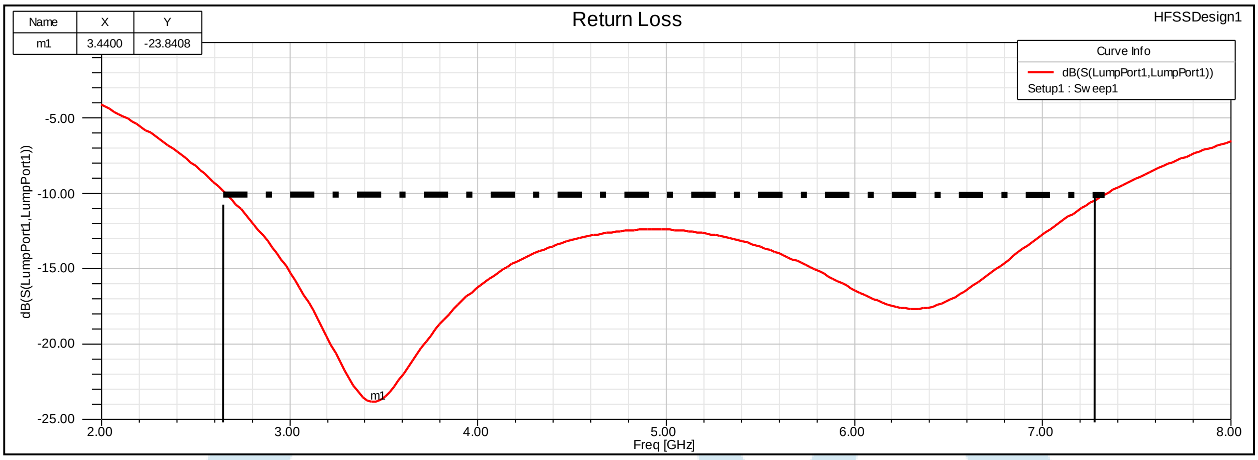


Fig. 4 Bandwidth & Operating Frequency Range

VII. Return Loss

Return loss is one of the scattering parameters also known as S11. The value of return loss tells us the amount of power that is returned back from a load connected through a transmission line. This in turn tells the expected efficiency of the load. The load in this case is an antenna. Simulation results show that the proposed antenna achieves a minimum return loss of about -24 dB at 3.34 GHz. Fig 4 shows the return loss graph.

VIII. VSWR

VSWR stands for Voltage Standing Wave Ratio. It is the ratio of maximum voltage and the minimum voltage of a transmission line feeding a load. VSWR tells the impedance matching qualities of the antenna. Ideal value of VSWR is 1 and practical value must be less than 2 and our antenna has VSWR below 2 for the given operating range. Fig 5 shows the VSWR of proposed antenna.

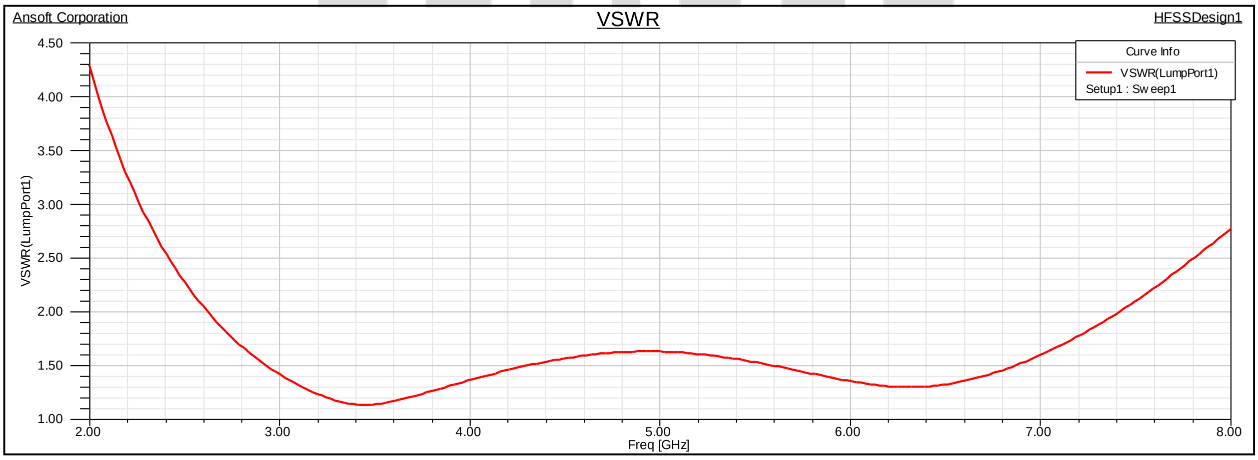


Fig. 5 VSWR

IX. Antenna Impedance

The input impedance of the proposed antenna fluctuates near to 50 ohms at operating frequency range. The advantage of having 50 ohms input impedance is that we can connect it to a coaxial wire. It can be seen that the antenna impedance does not change drastically from 50 ohms for the complete bandwidth. Thus impedance bandwidth is very good. Fig 6 shows the graph of antenna impedance.

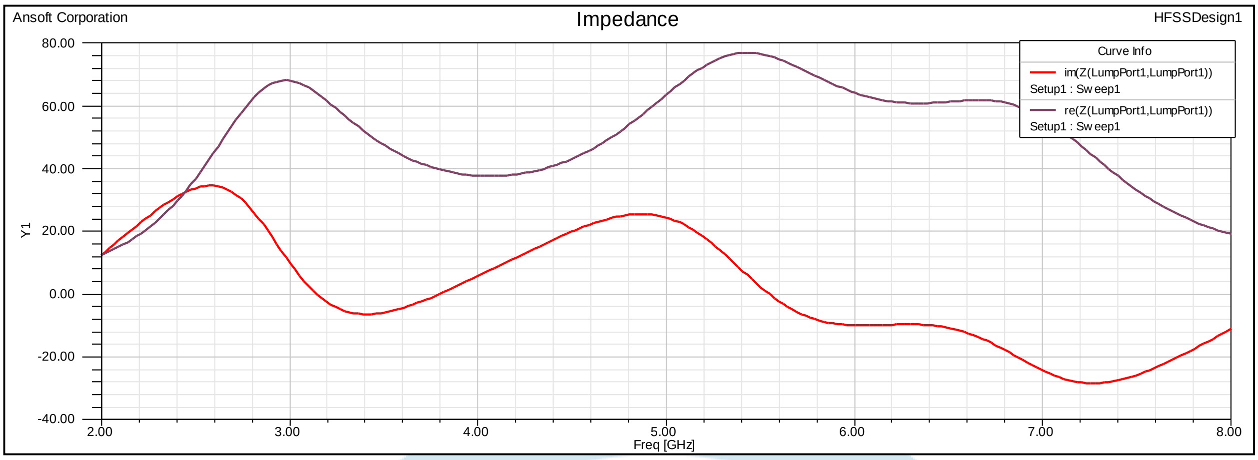
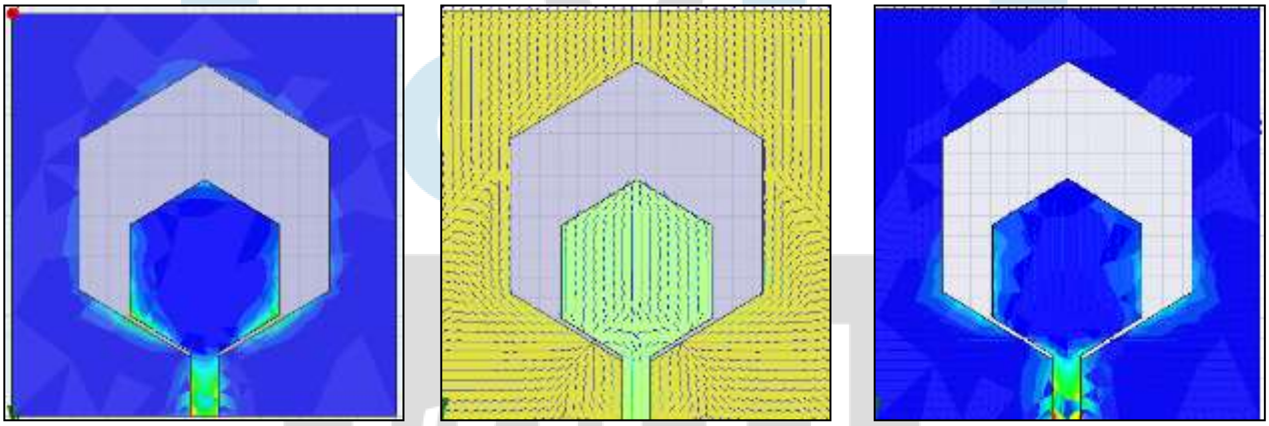


Fig. 6 Input Impedance

X. SURFACE DISTRIBUTION

Figure 7(a) shows the electric field distribution, Figure 7(c) shows the magnetic field distribution and Figure 7(b) shows the surface current distribution. Maximum electric field and magnetic field distribution is at the base of the hexagonal monopole. Surface current also evenly on the patch and ground plane. The distance between the patch and the ground plane plays a major role in antenna performance. Electric field/Magnetic field distribution of a Microstrip antenna show that how far the electric field/current could travel from the feed point. Since Microstrip antenna is a resonant antenna, it is customary that the electric field and magnetic field will be at its maximum near the port and keep on reducing as the structure moves away.



(a) Electric Field Distribution (b) Surface Current Distribution (c) Magnetic field Distribution

Fig. 7 Surface Distributions

XI. CONCLUSION

A UWB hexagonal monopole with hexagonal slotted ground is presented in this paper. The designed antenna works for the frequency range of 3.5 GHz – 7.5 GHz. Omnidirectional vertically polarized radiation pattern is obtained. Minimum return loss obtained is approximately -24 dB. Impedance bandwidth is approximately 100% which makes the proposed antenna ultra-wideband.

Hexagonal shape has 6 sides all having different orientations with respect to the supply line. This results in the antenna resonating at various close frequencies and when these frequencies are close enough they all combine and make a wide band response.

The antenna's radiation pattern is tested for various frequencies of the operating bandwidth and the radiation pattern nearly remains the same for the complete frequency range.

VSWR of the antenna is below 2 for the complete frequency range which makes the antenna reliable under any frequency within operating range. For the frequency range observed in the simulation results (2 to 8 GHz) the impedance of the antenna remains between 20 ohms to 80 ohms and mostly moves around 50 ohms. It means that a 50 ohms cable can be connected to this antenna for supply without worrying about impedance mismatch losses if the frequency is tuned between 2-8 GHz.

XII. ACKNOWLEDGMENT

Many people contributed towards the completion of this work. I would like to thank my mentor for guiding me throughout till the completion of this work. I also want to thank my institution for providing me resources to complete my research. I also thank my family and friends to support me morally when the work was under progress. Finally, I thank everyone who was directly or indirectly involved in completion of this work.

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