Design and Analysis of Compact Planar Microstrip Patch Antenna for Ultra-Wideband Applications

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Abstract*— In this paper, the design, and performance analysis of an Ultra-Wideband Antenna (UWB) is proposed. The Ultra-Wideband Antenna is found capable enough of working over an UWB range as allocated by Federal Communications Commissions (FCC) with good antenna properties over the frequency range. The antenna has been designed using Flame Retardant 4(FR4) substrate of dielectric constant, ε_r=4.4 and height of dielectric substrate, h=0.1566 cm. A microstrip line fed rectangular patch antenna is made to undergo several slot cuts to ensure that it has better Return Loss S11 < -10dB, Peak Gain, Efficiency, and Radiation Pattern. This staircase-shaped design with a Defective Ground Surface (DGS) has wide impedance bandwidth measured at about 9.95 GHz (3.22 GHz-13.17 GHz), bandwidth ratio about 1:4, VSWR less than 2. The antenna structure is flat, and its design is simple and straightforward geometrically small, hence embedded easily in various applications like Medical Imaging and Point-to-Point (P2P) Microwave Radio Links. The simulation and analysis were done using High Frequency Structure Simulator (HFSS).

Index Terms— *Defective Ground Surface, Planar Antenna, UWB.*

I. INTRODUCTION

The word "Ultra-Wideband" (UWB) usually refers to signals or systems that either have large relative bandwidth or large absolute bandwidth. The Ultra-Wideband systems are widely used in large number of applications such as medical imaging, radar, collision detection systems in automobiles, etc. [1-2] These systems have various advantages such as potentially low complexity, very low cost when compared to other systems, low average transmission power, low power consumption, good noise immune system, and it resists serving multipath and jamming, large throughput, covertness, coexistence with current radio services allowing for location and tracking applications, high transmission speed and has very broad frequency bandwidth.

The main advantage of this technology over other technologies is having robust characteristics to multipath environments, very low degree of interference with other systems, and use of expended spectrum techniques at low power levels. In the world of miniaturization and specifically in wireless hand-held devices, it is essential to integrate more than one communication band in a single antenna. In the year 2002, the Federal Communications Commission (FCC) officially released the unlicensed use of UWB frequency spectrum from 3.1-10.6 GHz. Since then, the design of wideband antennas, especially ultra-wideband antennas has become an attractive and challenging area in the research of the system design.

The resolution characteristics and good penetration properties has made the Ultra-wideband (UWB) microwave imaging a promising method to detect cancer. The underlying principle of UWB cancer detection is a significant contrast in dielectric properties, which is estimated to be greater than 2:1 between normal and cancerous tissue. UWB imaging systems have shown positive results in the detection of tumors during early stages of breast-cancer.

II. ANTENNA STRUCTURE DESIGN

Both the views of the antenna which shows the patch and the slots on the top and the defective ground structure at the bottom of the antenna is shown in Figure.1 and Figure.2 respectively. The planar micro strip patch antenna dimensions are designed by taking into considerations the standard antenna equations. The geometry of the proposed antenna is considered as such that its operable frequency works for Wireless Body Networks and most importantly for Wireless Medical Imaging Applications. For a rectangular patch, the length L of the element is usually between the range $\lambda 0 / 3 < L < \lambda 0 / 2$. The different types of feeds also plays an important role in determining the antenna parameters and keeping this in mind, the micro strip line feed is selected for this proposed antenna. The defective ground surface is considered just in case to perfectly match the impedance of the antenna at exactly the operable frequency of the antenna. The design parameters of the rectangular patch antenna are given in Table 1.

The two slots are introduced into rectangular patch. Slots or defects integrated on the ground plane of microwave planar circuits are referred to as Defected Ground Surface (DGS). DGS is adopted as a new technique to improve the various parameters of microwave circuits, that is, very narrow bandwidth, cross-polarization, and so forth. The return loss of the antenna is dependent and is directly proportional to the slot dimensions.

Table 1: Design parameters of rectangular patch antenna.

Sl.No	Parameter	Value (Units)
1	Di-electric constant (ε_r)	4.4
2	Height of the substrate	0.1566 mm
3	Operating Frequency	7.5GHz
4	Length of the Patch	13.5 mm
5	Width of the Patch	3.05 mm
6	Characteristic Impedance	50 Ω
7	Length of the Ground Plane	12.5 mm
8	Width of Ground Plane	30 mm

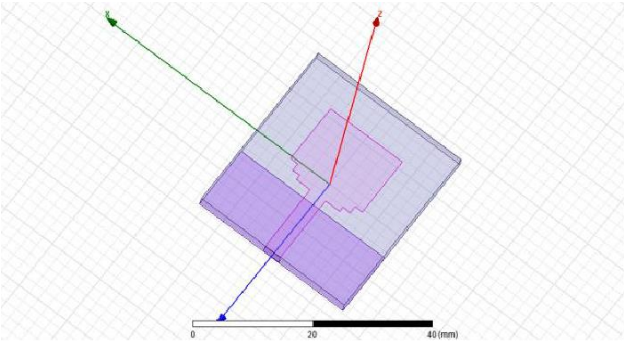

Figure.1 Design – Top View of proposed antenna

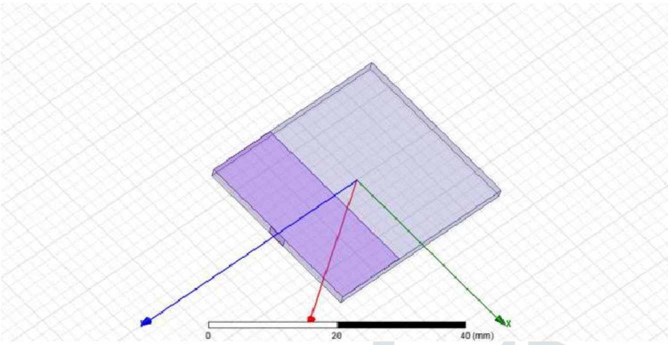

Figure.2 Design – Bottom View proposed antenna

III. RESULTS AND DISCUSSION

The performance of the proposed antenna is studied using the High Frequency Simulator Software (HFSS) tool. The antenna possesses good return loss (S11), -49dB and -28.5dB at 3.88GHz and 11.2GHz respectively. The first slot will make the antenna work under UWB range, and the second slot will make the antenna work as dual bandpass antenna where good return loss (S11) i.e., -19.8dB at 7.64GHz is obtained as shown in Figure.3. The obtained return loss at 7.64GHz can be used extensively for the applications under WBAN such as Wireless Medical Imaging.

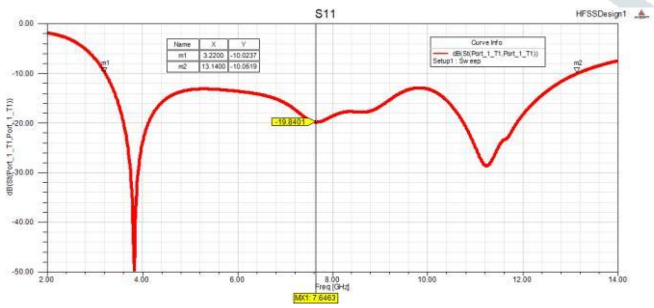

Figure.3 Return Loss (S11, dB)

The 3D Gain pattern of the proposed antenna is plotted and the total gain of the antenna is 4.8dB as shown in Figure.4. Voltage Standing Wave Ratio (VSWR) of the design is also plotted and is found to be following the regulations of the UWB given by FCC. The VSWR plot is shown in Figure.5.

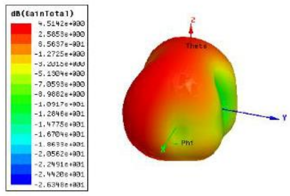

Figure.4 Gain

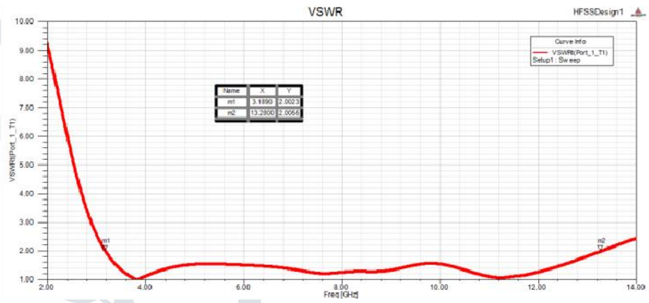

Figure.5 Voltage Standing Wave Ratio (VSWR)

The Radiation Efficiency of the given proposed design is monitored and is shown in Figure.6. The ground plane is designed in such a way that it is matched for all frequencies.

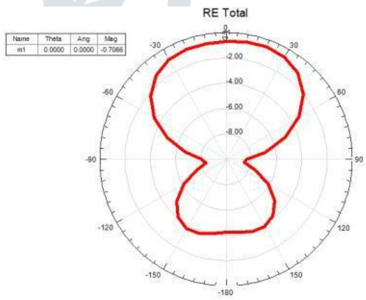

Figure.6 Radiation Pattern

The various antenna parameters such as Peak Directivity, Axial Ratio, and Specific Absorption Rate (SAR) etc. are also monitored and is said to be in bounds within the specified range, given by FCC.

Reducing the size and complexity of the antennas has been the primary objective of recent antenna research and many of the medical applications like microwave imaging, medical implants, hyperthermia treatments, and wireless wellness monitoring still use bulky antenna systems which prevents their high efficiency.

IV.CONCLUSIONS

The compact planar ultra-wideband antenna working for applications under ultra-wideband range is designed and the simulated results are obtained through HFSS tool. The measured results of the proposed antenna satisfy the -10dB return-loss requirement for UWB as defined by the FCC. The antenna structure is compact and less power dissipation occurs across the antenna. Results have shown that the antenna has approximately omnidirectional radiation patterns and possess high gain total.

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