Bandwidth Enhancement of Patch Antenna For Ultra Wideband Applications

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Abstract - *Wireless technology is one of the main areas of research in the world of communication systems today and a study of communication systems is incomplete without an understanding of the operation and fabrication of antennas. This was the main reason for our selecting a project focusing on this field. In this project a simple structure of Ultra Wideband (UWB) antenna is proposed. The antenna offers excellent performance for UWB system, ranging from 3 GHz to 10 GHz. The antenna exhibits a 10 dB return loss bandwidth over the entire frequency band. The antenna is designed on FR4 substrate and fed with 50 ohms micro-strip line. This antenna is composed of a modified shaped patch with a partial slot ground plane and a height of 1.6 mm that shields the low-cost substrate material FR-4 with a relative permittivity of 4.4 and loss tangent of 0.002 that makes it suitable for UWB operations. 50Ω micro-strip transmission line used as feed current and observe the simulated results in HFSS software. With a decent impedance match and constant radiation pattern the presented antenna has comprehensive bandwidth of 14 GHz (0.96 GHz to 15 GHz) which makes the antenna appropriate for various ultra-wideband applications. It is found that the frequency band depends on the width of the partial ground width, the width of the feed line and position of the feed line.*

I. INTRODUCTION

In 2002, the Federal Communications Commission (FCC) allotted the spectrum bandwidth for ultra-wideband system with the frequency bandwidth from 3.1 to 10.6 GHz including EIRP of -41.3 dB m / MHz as an effective isotropic radiated power [1]. The micro-strip UWB antennas have lots of good features such as negligible power consumption, simple structure, cost effective, maximum data rate, omnidirectional, easy to fabricate with maximum accuracy. Therefore, UWB antennas become most promising research area for result of modern communications and it attracts lot of researcher's concentration for the development and to improve the performance of UWB antenna. While in designing, micro-strip UWB antennas also face some challenges like small in size, electromagnetic interference and good impedance matching, channel capacity [2]. Due to the limited bandwidth and high usage, it is necessary to use a single antenna for radiation more than one frequency bands [3-8]. IEEE 802.15.3a (TG3a) provides the solution for UWB technology [9]. The micro-strip antenna contains of patch, ground and substrate materials. The radiating patch is designed on the upper surface of substrate and that of ground plane is on the lower surface of the substrate [10]. To design UWB antennas working in 3.1 – 10.6 GHz bandwidth, different types of antennas have been designed and the shaped of radiating patch is also different such as planar square, disc antenna, diamond shape antenna, shape, rectangular, circular, and elliptical [11-15]. The discussed different shape of antennas are used to achieved larger impedance bandwidth using several radiating patch structure.

II. ANTENNA DESIGN AND CONFIGURATION

The idea of micro-strip antenna was first proposed by Deschamps in 1953 and a patent in 1955. However, the first antenna was developed and fabricated during the 1970's when good substrates became available. Micro-strip antenna is also referred as a patch antenna. Micro-strip patch antenna consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side as shown in Figure 2.1. The patch is generally made of a conducting material such as copper or gold and can take any possible shape. There are several shapes that can be used as the radiating patch. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular, combination.

Design Procedure

Using the design specifications along with the equations obtained from transmission line model of

analysis, the dimensions of the micro-strip patch antenna can be calculated as explained below:
Step 1: For efficient radiation, the width is given as: W = c/(2f0√((€r +1)/2)) = 30.4 mm.

Step 2: Calculation of effective dielectric constant. €reff = ((€reff +1)/2) + [((€reff-1)/2) (1 + 12 h/W)$^{-1/2}$]= 4.03.

Step 3: Calculation of effective length of the patch: Leff = c/(2f0√€reff) =23.43 mm.

Step 4: Calculation of length extension: ΔL = 0.412h [((€reff+0.3)(W/h+0.264))/ ((€reff-0.258) (W/h+ 0.8))] = 0.0736mm.

Step 5 : Calculation of line length and line width:Z_o = 50Ω from this value we can calculate line width
Z_o=[(1/√4.03)(120π/[(w/0.16+1.393+0.667ln(w/0.16+1.444)]
W_L = 3.058mm
L_L = λ/4 = 13.699mm.

Step 6: Calculation of ground plane dimensions: The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery.

Table 1 Design parameters of patch antenna

Parameter	Values
Input Impedance(Z0)	50Ω
Frequency(F0)	3GHz
Dielectric Constant(Er)	4.4
Height of substrate(H)	1.6mm

Table 2 Calculated parameters for patch

Parameter	Values
Patch Width (Wp)	30.4mm
Patch Length(Lp)	23.43mm
Dielectric Constant(ε_{reff})	4.03
Length Extension(ΔL)	0.0736mm

Table 3 Calculated parameters for line

Parameter	Values
Line Width (Wl)	3.058mm
Line Length(Ll)	13.699mm

Table 4 Antenna design parameters and dimensions

Parameters	Value(mm)
Patch L	23.43mm
Patch W	30mm
Height of Substrate	1.6mm
Dielectric constant	4.4
Substrate Length	41mm
Defected Ground Length	11.7mm
Slot in defected ground	2.7mm*3.3mm
Ground corner cut	1mm*1mm
Patch corner cut	2.8mm*4.4mm

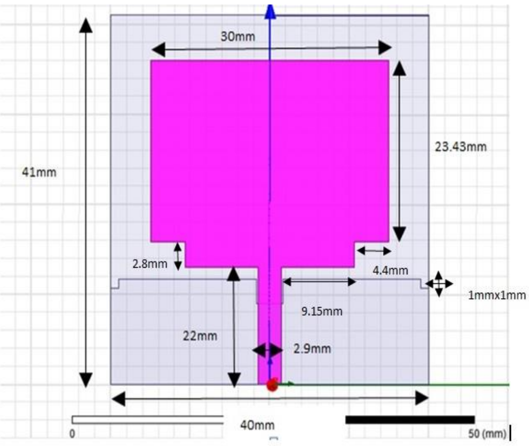

Fig.1. Design parameters and dimensions of proposed antenna

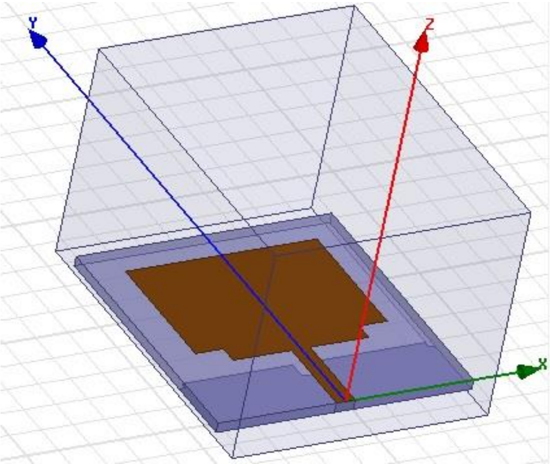

Fig.2. HFSS design of proposed antenna

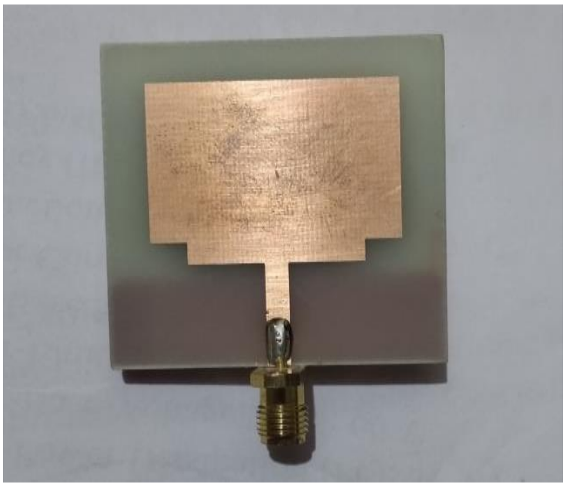

Fig.3. Front view of fabricated antenna

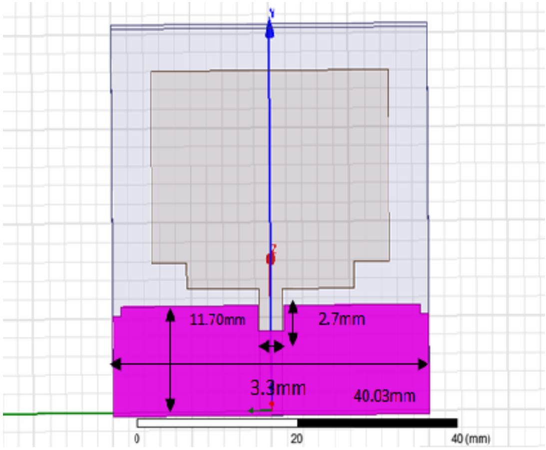

Fig.4. Modified ground of simulated antenna

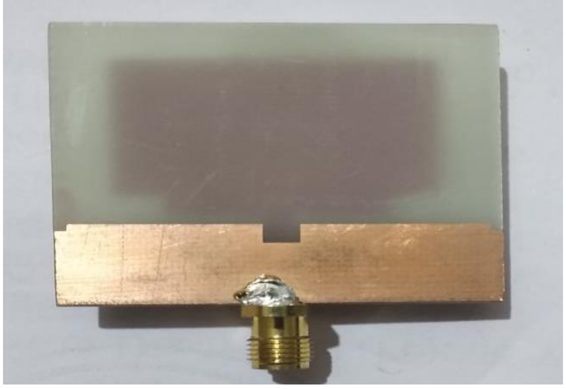

Fig.5. Modified ground of fabricated antenna

III. RESULT AND DISCUSSION

Return loss

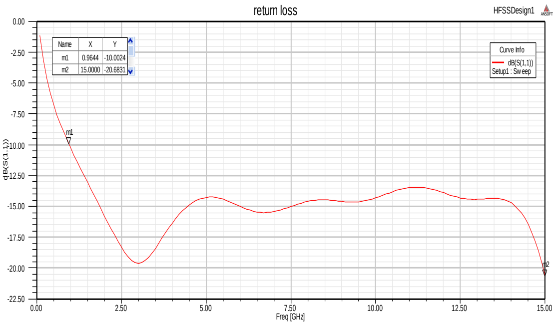

Fig.5. Simulated return loss vs frequency

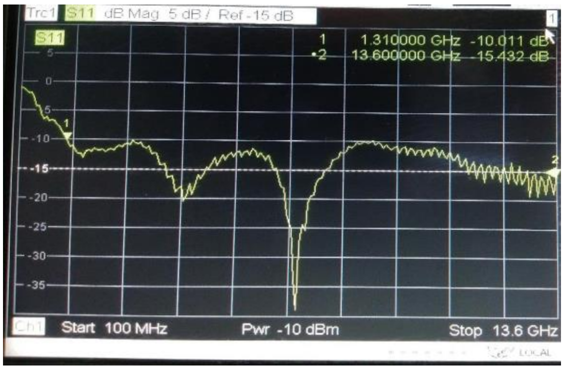

Fig.6. Actual return loss vs frequency

Fig.5 shows simulated results of the proposed linearly polarized micro-strip antenna resonating at 0.965 GHz with a return loss of -10.0065dB and having bandwidth of 13.535(14.5-0.965GHz). From fig.6 we have starting frequency at 1.31GHz with return loss of -10.011dB, covering frequency up to 13.6GHz.

VSWR

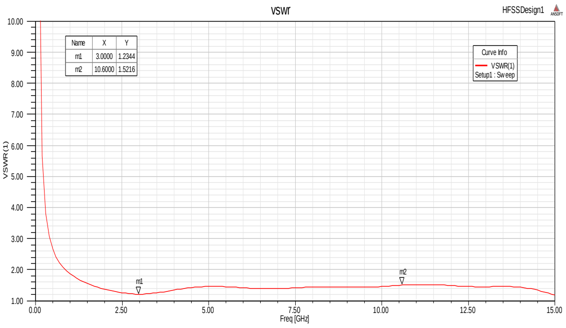

Fig.6. Simulated voltage standing wave ratio

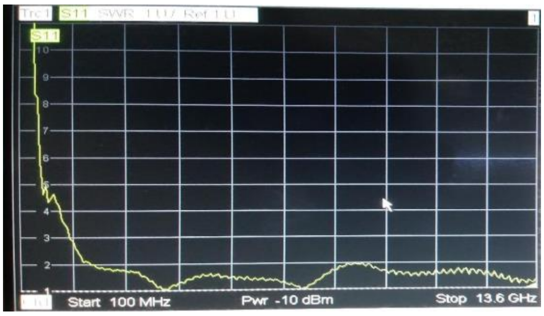

Fig.7. Actual voltage standing wave ratio

Fig.6. Shows simulated results of VSWR, and the value measured varies around 1.2309 to 1.5217 for frequency 3-15 GHz. Fig.7 shows actual VSWR plot which is below 2 for frequency 1-13.6GHz. The measured value below 2 shows that antenna is transmitting more than 70 percent of its received power and if it is above then antenna will transmit less than 70 percent of its received power.

Impedance

The input impedance of an antenna is the impedance presented by the antenna at its terminals. Input power is dissipated due to ohmic/dielectric losses, power radiated into free space.

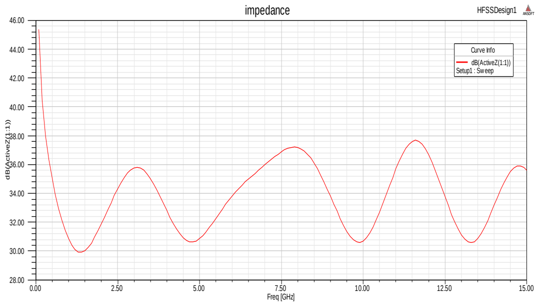

Fig.8. Simulated impedance plot of antenna

Fig. 8 shows the input impedance of an antenna which is varying between 35 to 60 ohm among frequency range of 0 to 15GHz.

Axial Ratio

The axial ratio is the ratio of orthogonal components of an E-field. A circularly polarized field is made up of two orthogonal E-field components of equal amplitude (and 90 degrees out of phase). Because the components are of equal magnitude, the axial ratio is 1 (or 0 dB). The axial ratio for pure linear polarization is infinite, because the orthogonal components of the field are zero.

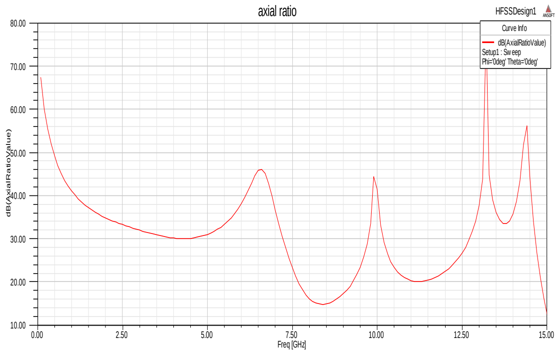

Fig.9. Simulated axial ratio of an antenna

Fig .9 shows simulated axial ratio above 3dB which shows proposed antenna having linear polarization.

Radiation pattern

Radiation pattern is defined as the power radiated or received by an antenna in a function of the angular position and radial distance from the antenna. It describes how the antenna directs the energy it radiates.

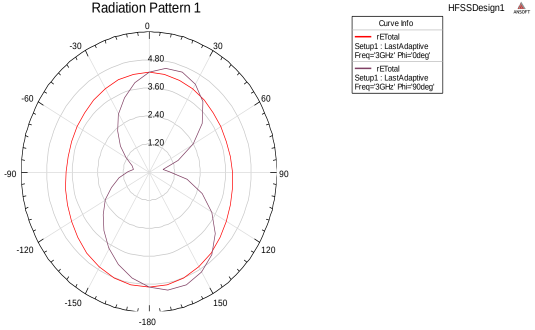

Fig.10.Simulated Radiation pattern of an antenna

Fig.10 shows experimental radiation pattern of proposed antenna for 3GHz frequency which is nearer to figure of eight for E plane and omnidirectional in H plane. The polarization of proposed antenna is linearly polarized. The radiation pattern is maximum to perpendicular to plane of antenna.

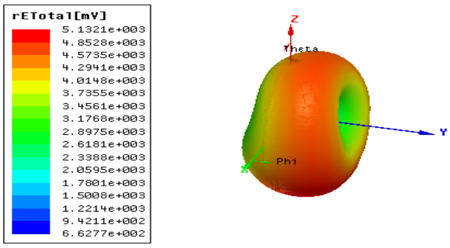

Fig.11. Simulated 3D polar polt of an antenna

Current density

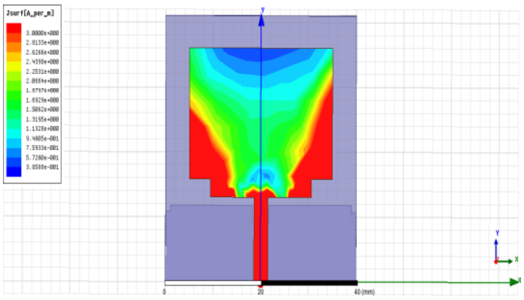

Fig.12. Simulated surface current density on patch.

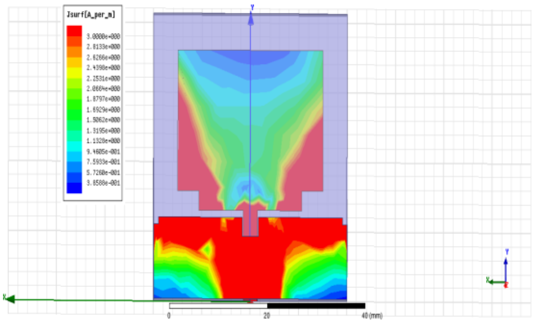

Fig.13 Simulated surface current density on ground plane.

Fig.12 shows current density for patch, it can be observed that current density is high near the edge of patch. Fig.13 shows current density for modified ground structure which is high at middle portion and upper edges.

Table 5 Different Antenna parameters

Quantity	Value
Incident Power	1(W)
Radiated Power	0.941682(W)
Accepted Power	0.988998(W)
Max U	0.0349323(W/sr)
Radiation Efficiency	0.952158

IV. CONCLUSION

From this work conducted on Micro-strip patch antenna for ultra wide band frequency we studied and analyzed different antenna parameters and noted their behavior under different conditions.

The proposed antenna is a low profile antenna thus it is very compact, easy to fabricate and is fed by a micro-strip feed line which makes it an attractive structure for current as well as future WLAN, Wi-Fi, 4G, Wi-MAX, 5G applications.

Simulations were performed using HFSS. In this, both ground plane and radiating patch are modified to obtain desired performance. The Selection of antenna parameters like bandwidth, VSWR, efficiency, radiation pattern of the antenna. UWB antenna has low profile, small size & low manufacturing cost, hence the UWB antenna has been found to be significant demand for wireless applications. The designed multiband antenna is very sensitive to changes in dimension of the structure including the ground plane. Ground plane of the antenna is used as a radiator resulting in overall size reduction & improvement in the operating bandwidth. Well suited for high speed, short range WPAN.

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