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Slotted T shaped ultra wideband microstrip patch antenna for wireless applications

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Abstract: Miniaturized slotted T shaped ultra wideband microstrip patch antenna is presented in this paper for wireless applications. The proposed antenna consists of a variable sized T shaped radiating patch with four rectangular slots etched on the plane of the patch as well as on the ground plane. Slots are taken on the patch for wideband characteristics. The designed antenna also uses the concept of fractal geometry for wideband characteristics and partial ground for impedance matching. The proposed antenna design is analyzed using different substrates like FR-4, Duroid and Glass. The optimal results are obtained with the FR-4 substrate with dielectric constant 4.4. The proposed antenna is fabricated on FR-4 epoxy (ε_r=4.4) substrate of thickness 1.6 mm and tangent loss δ=0.01. The feeding to the antenna is by 50 Ω microstrip line feeding. The antenna satisfies the ultra wideband characteristics and can be useful in many wireless applications. The slotted T shape is obtained from the basic rectangular patch antenna of size 17 x 15 x 1.6 mm^3. The slotted antenna has been simulated using HFSS v.15 Software, fabricated on FR-4 substrate and the parameters like return loss, VSWR, gain and radiation pattern are measured using network analyzer and anechoic antenna measuring unit. The measured and simulated results are very much similar in all responses. The simulation results show that the antenna resonates at 4.35 GHz, ranging from 2.75 GHz to 10.65 GHz and hence suitable for wideband applications. Many wireless devices such as 3.6/4.9/5/5.9 GHz WiFi, 3.41/3.49 LTE, 3.5/5.5 GHZ WiMAX, 4.2-4.4 GHz Radio Altimeter, 5.2/5.8 GHz WLAN, 7.05-7.075 GHz Satellite Radio Uplink, 5.15-5.35 GHz HiperLAN, 3.7-4.2 GHz C-Band, 8.5-10.68 GHz X-Band and 3.3/3.4 GHz proposed 5G applications can use this proposed antenna. The radiation patterns and return loss are omnidirectional with moderate gain. The size reduction of the antenna is by etching of slots on the patch and partial ground concept. The overall antenna size is reduced around 41.33%. The simulation and measured results are closely related to each other.

Keywords: T shaped, Slotted antenna, Ultra wideband, Partial ground, Return loss, FR-4 epoxy.

I. INTRODUCTION

The ultra wideband (UWB) communication system is much essential for wireless communication to cover the frequency band of wireless devices. High data rates and low power consumption are the main features of UWB communication system, used for short-range indoor communications. Hence there is a huge demand for small, low profile with broadside radiation pattern antennas for UWB communications to integrate multiple wireless devices [1]. Slotted microstrip patch antennas are the comfortable choice for UWB wireless applications because of their high radiation efficiency, easy integration and low dispersion [2]. In the design of UWB antennas care should be taken for high impedance bandwidth, radiation pattern stability, reduction in size along with low manufacturing cost. The UWB spectrum allocated by US federal communications ranging from 3.1 to 10.6 GHz for the commercial purpose [3]. Slotted microstrip patch antennas with the partial ground are the researching interest in this proposed design because of their adaptability for small wireless communication devices. Microstrip patch antennas have some disadvantages like narrow bandwidth and low gain [16]. So the researchers of the microstrip patch antenna have proposed various methods to increase the bandwidth such as employing a good dielectric substrate with low dielectric constant, creating slots on the patch, use of the partial ground plane and with suitable feeding techniques [4]. A small slotted T shaped patch antenna for ultra wideband applications are presented in this article. Slotted patch provides multi-resonance characteristics and the resonance overlapping results in wideband characteristics [5]. A 50-ohm microstrip line feeding is used to feed the input. The proposed antenna is simulated for the results such as return loss, bandwidth, gain and VSWR using high-frequency structure simulator (HFSS) Software. HFSS (High-frequency Structure simulator) is a software build on the principle of Finite Integration Technique (FIT) [6].

Nasrin Tasouji et al [2] proposed a novel printed UWB slot antenna with reconfigurable band notch characteristics covers a wide band of 3.12 GHz to 12.51 GHz with -10 dB return loss having a bandwidth of 120%.

Jun-Won Kim et al [1] presented a compact multiband microstrip antenna using inverted L and T shaped parasitic elements shows three bands include LTE TDD No. 34 (2.0175 GHz), WLAN (2.45 GHz), and WiMAX (3.5 GHz).

Bashar B et al [8] explains the design of broadband circular patch microstrip antenna for KU-band satellite communication applications achieved an impedance bandwidth of 40.95% from 11.36 GHz to 17.21 GHz at -29.18 dB with VSWR less than 2.

The UWB slotted T shaped microstrip patch antenna is developed on FR-4 substrate with slots on the patch. Four rectangular shaped slots are taken on the initial rectangular patch of dimension 17 x 15 x 1.6 mm3. The variation of the results due to slot size variations are analyzed step by step and the best result is obtained in this proposed design. The results of the proposed structure are simulated using HFSS v.15 software, fabricated using mechanical milling method, measured using network analyzer and antenna testing unit. The simulated and measured results are validated and found closely following each other.

II. Proposed Antenna Design

The proposed antenna shape is developed on the fundamental rectangular patch of size 17 x 15 x 1.6 mm3. Slots on the patch surface are etched systematically to introduce multi resonance characteristics and hence resonance overlapping takes place to yield wide band characteristics. Slots on the ground plane will not significantly vary the resonances but helps in impedance matching [19]. Formation of the proposed antenna is carried out in four simulative iterations as represented in the figure 1. The detailed slot size variation analysis is used in optimizing the antenna to obtain enhanced results. The corresponding results for each step are analysed using HFSS simulator to obtain the proposed antenna with UWB characteristics.

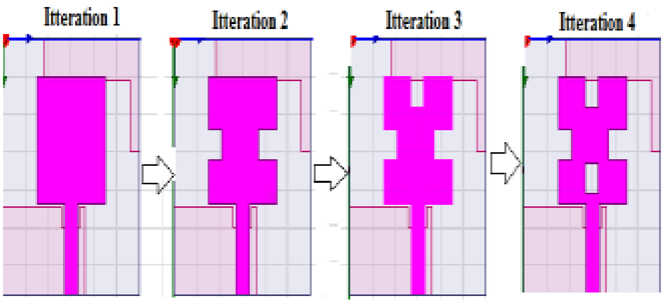

Figure1. Successive iterations to design proposed antenna

The patch and ground view of the proposed slotted T shaped microstrip patch antenna is represented in figure 2 and 3. Table 1 shows the complete dimensions of the microstrip patch antenna and the percentage of size reduction. The proposed antenna is simulated using different substrates like FR-4(εr=4.4), duroid(εr=2.2) and Glass(εr=5.5). A graph of return loss in dB v/s frequency in GHz is plotted and shown in figure 4 for different substrates like FR-4, duroid and glass. Table 2 shows the comparison of S11 parameters in three substrates. In FR-4 substrate antenna exhibits the frequency band ranging from 2.78 to 10.65 GHz with a bandwidth of 7.87 GHz. Duroid exhibits two bands, band 1 is from 3.1 to 5.25 GHz (2.15 GHz bandwidth) and band 2 ranging from 7.1 to 11 GHz (3.9 GHz bandwidth). Finally, the glass substrate has a band of 2.75 to 9.5 GHz (bandwidth 6.75 GHz). Among these substrates, the antenna results were more attractive in FR-4; also it is cheap and widely used. Hence the designed antenna structure is fabricated on FR-4 substrate of size 34 x 30 x 1.6 mm. The partial or defected ground is on the other side of the patch. The results of the proposed antenna such as return loss, Voltage Standing Wave Ratio (VSWR), Gain, Radiation pattern are plotted and analyzed. Also, the designed antenna is analyzed using two different types of feedings like probe feeding and line feeding. The results of the antenna are appreciating in microstrip line feeding. Hence the feeding to the antenna is by 50 Ω microstrip line feeding. The antenna shows UWB characteristic ranging from 2.78 GHz to 10.65 GHz with a bandwidth of 7.87 GHz. The obtained UWB finds useful for wireless devices like WLAN, WiMAX, and WiFi. The compactness of the antenna is achieved by etching slots on the patch as well as the ground plane. The size of the slots on the patch is varied and the corresponding return loss is plotted. The corresponding return loss is analyzed to get the best value of UWB characteristics. Once the simulated results found to be UWB characteristics the same is fabricated on FR-4 substrate using photolithography or mechanical milling machine method. The optimized structure of the proposed design gives the ultra wideband from 2.78 GHz to 10.65 GHz with a bandwidth of 7.87 GHz.

III. Proposed Work

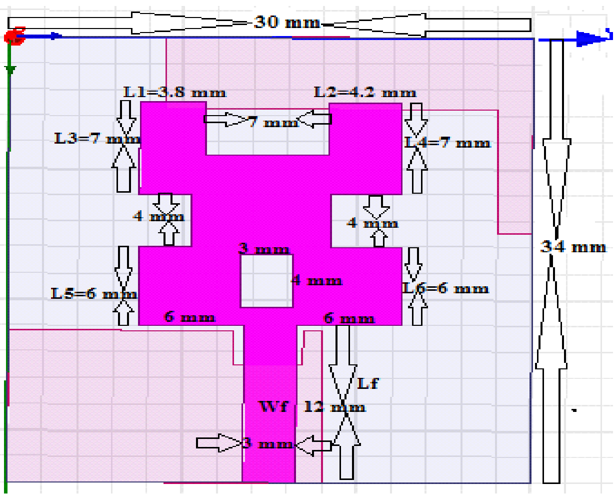

Figure2. Proposed antenna (patch view)

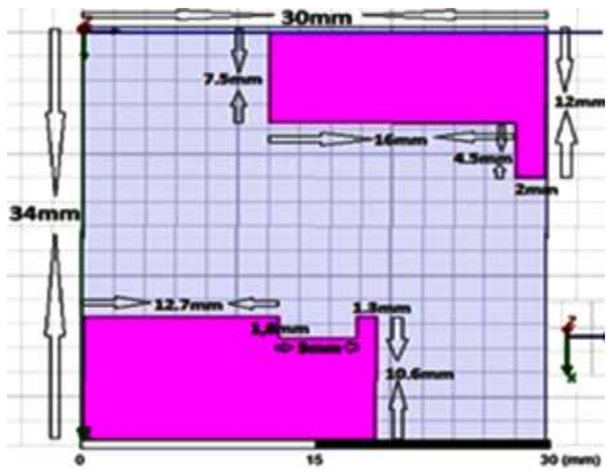

Figure3. Proposed antenna (ground view)

Table1. Dimensions of the proposed antenna

Parameter	Specifications	Dimensions (mm)
Patch	Rectangle (Basic Patch) Four Rectangular Slots on the Patch	15 x 17 Slot 1= 7 x 4 Slot 2= 3 x 4 Slot 3= 4 x 3 Slot 4= 3 x 4
Feed	Microstrip Line Feeding	3 x 2
Substrate	FR-4(ε_r = 4.4, δ=0.01)	30 x 34 x 1.6
Ground (Partial)	G_1 (Metal Part) G2(Metal Removed Part)	30 x 34 686.66 mm^2
Actual Size Slotted Size	1257 mm^2 506.34 mm^2	Reduction in Size 41.33%

Table2. Bandwidth comparison for different substrates

Substrate	Dielectric Constant	Useful Band Range (%Band width)
FR-4	4.4	2.78-10.65 GHz (104%)
Duroid	2.2	3.1-5.25 GHz (28%) and 7.1-11 GHz (52%)
Glass	5.5	2.75-9.5 GHz (90%)

The fabricated antenna is tested using the network analyzer and microwave antenna testing chamber for practical measurement of the results of the proposed design.

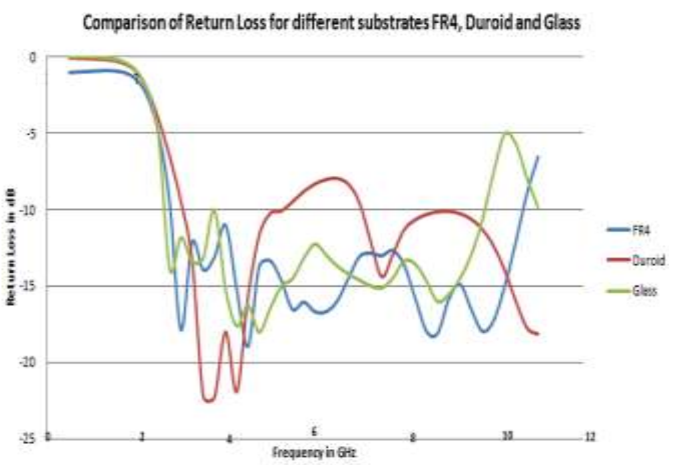

Figure4. Return loss for different substrates FR-4, Duroid and Glass

IV. RESULTS AND DISCUSSIONS

Return loss V/s frequency simulated result of the proposed antenna is shown in figure 5 represents the wide band from 2.77 to 10.65 GHz is useful in WiFi (3.6/5.9 GHz), Radio Altimeters (4.2 GHz to 4.4 GHz), WLAN (5.8 GHz), WiMAX (5.5 GHz) and Satellite Radio Uplink (7.05 GHz). This band ranges from 2.77 GHz to 10.65 GHz maintains the required value of gain at -10 dB and the acceptable VSWR at 2:1. Thus the UWB spectrum of 3.1 GHz to 10.6 GHz for commercial purpose is covered with this proposed design. Figure 6 depicts 3-D simulated return loss plots for proposed antenna. The antenna resonates at 4.35 GHz and we selected the response at the point where it shows the return loss of -10 dB. VSWR characteristics are shown in figure 7 gives less than 2:1. Figure 8 shown below is the gain of the proposed antenna at 3 GHz. Simulation results of radiation pattern at 5.2 GHz and 5.8 GHz are shown in figures 9 and 10. The proposed slotted T shaped ultra wideband microstrip patch antenna satisfies omnidirectional radiation patterns in the complete range of frequency band. Figures 13, 14 and 15 give the simulated electric field distribution (E), magnetic field distribution (H) and Surface Current density distributions (J).

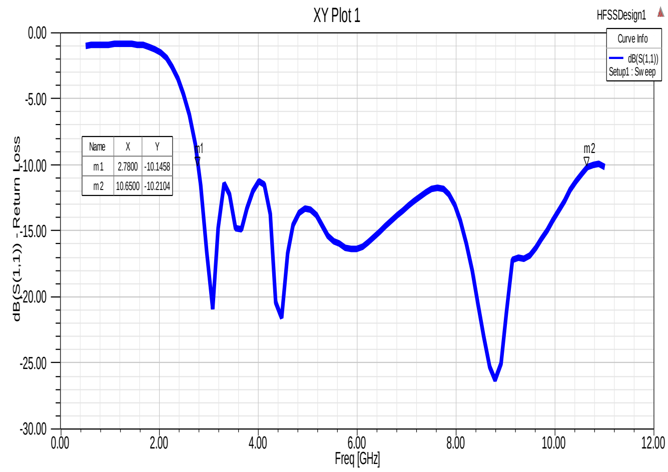

Figure5. Simulated return loss(dB) vs frequency(GHz)

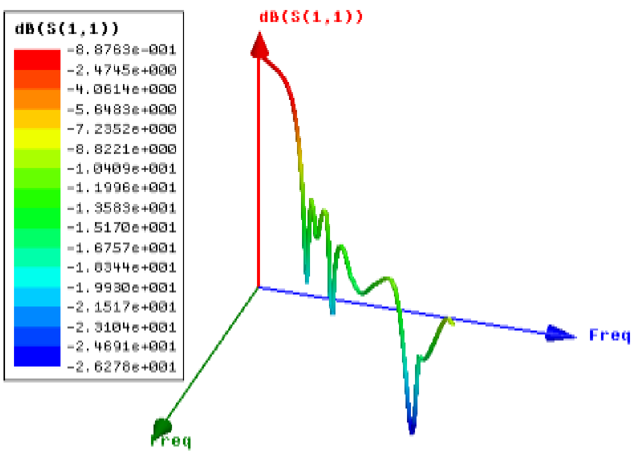

Figure6. 3-D plot of return loss vs frequency

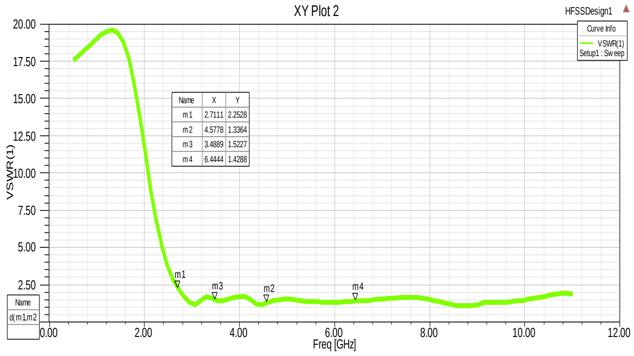

Figure7. Graph of VSWR v/s frequency

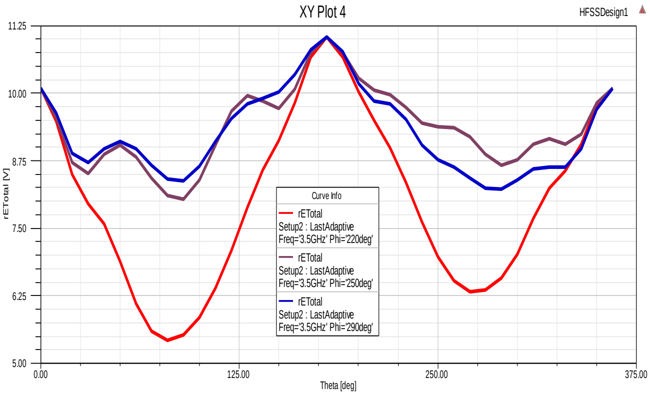

Figure8. Graph of gain at 3 GHz

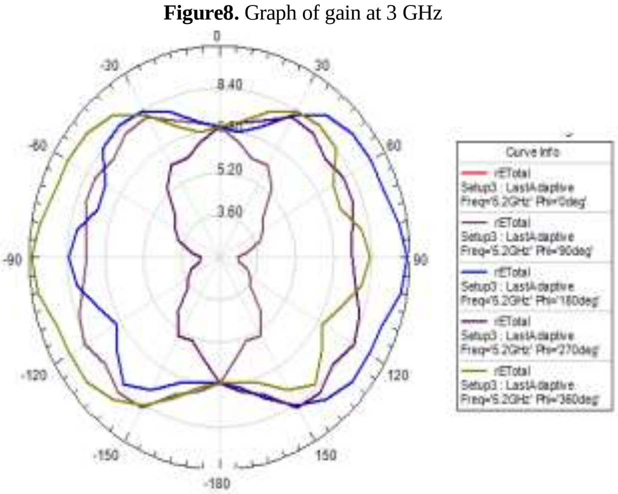

Figure9. Graph of radiation pattern at 5.2 GHz

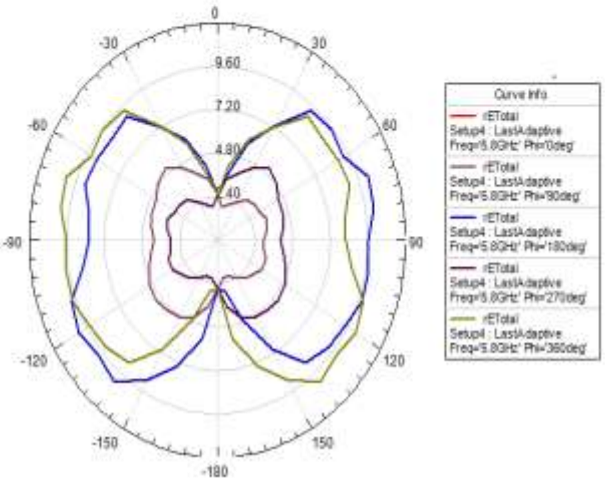

Figure10. Graph of radiation pattern at 5.8 GHz

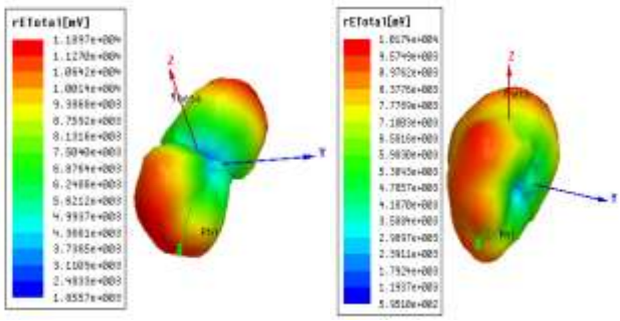

Figure11. Simulated 3-D polar radiation pattern at 5.2 GHz and 5.8 GHz

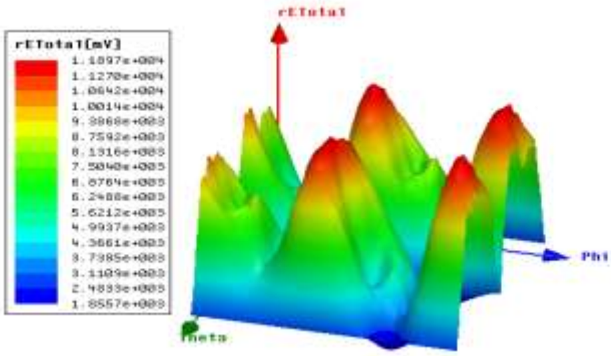

Figure12. Simulated 3-D rectangular radiation pattern at 5.8 GHz

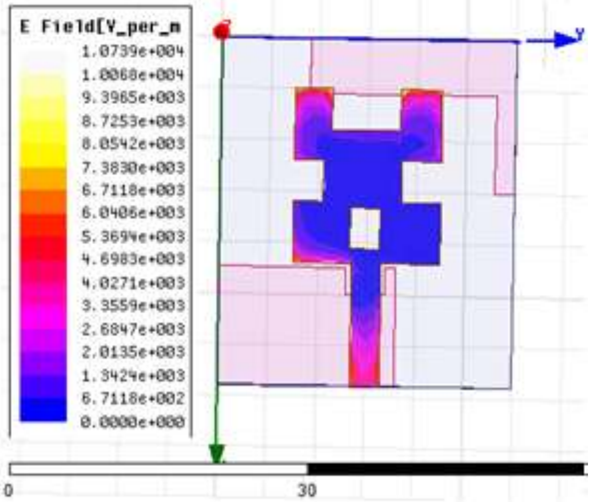

Figure13. Simulated electric field distribution

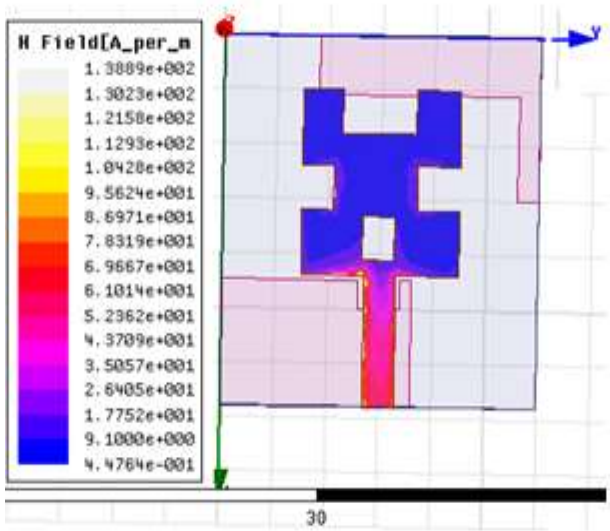

Figure14. Simulated magnetic field distribution

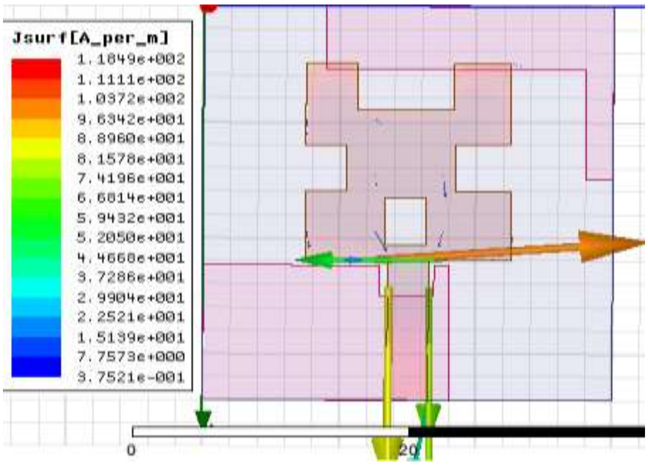

Figure15. Simulated surface current density

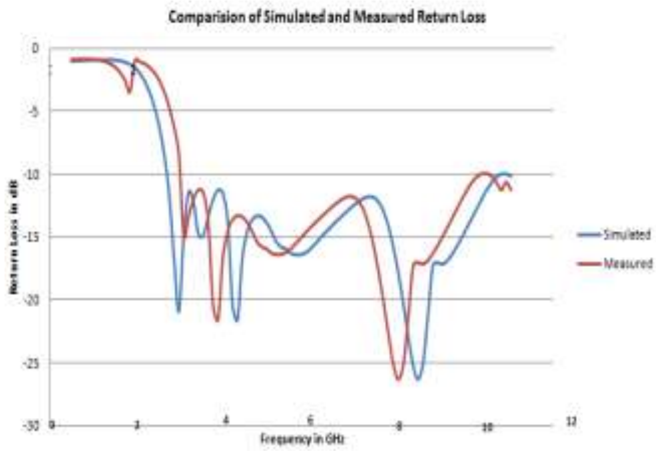

Figure18. Comparision of measured and simulated return loss v/s frequency

Once the simulation of the proposed antenna gives the expected results in all respects the proposed antenna is fabricated using FR-4 substrate for the final prototype model. Mechanical milling method of fabrication is employed here. The same can be carried by using chemical lithiography method. The practical fabricated model is tested using Agilent E8362B vector network analyzer [22] and an isolated anechoic chamber [23] to measure all the parameters of the antenna as shown in figures 16 and 17. The simulated and measured results are closely matching each other which are shown in figure 18. The practical fabricated model of the proposed antenna is shown in figure 19 and 20.

Figure16. Agilent E8362B vector network analyzer to measure the return loss and VSWR

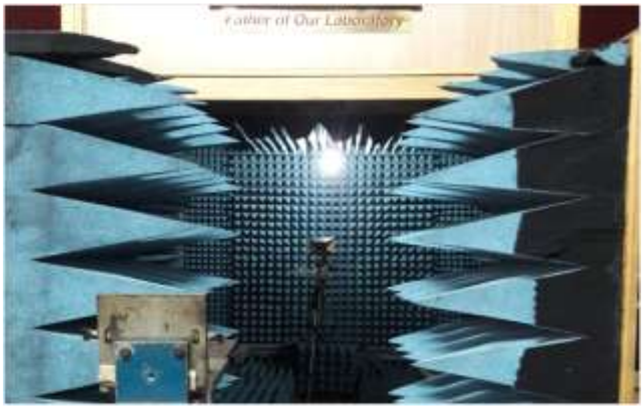

Figure17. Isolated anechoic chamber to measure radiation pattern and gain

Figure19. Fabricated patch view of the antenna

Figure20. Fabricated ground view of the antenna

V. CONCLUSION

The miniaturized slotted T shaped ultra wideband microstrip patch antenna for wireless devices like WLAN, WiFi and WiMAX are been explained in this paper. Results of the presented antenna like return loss; VSWR, gain, radiation pattern etc are simulated using HFSS v15 simulator fabricated on FR-4 substrate and measured using the network analyzer and microwave measuring unit. The antenna exhibits good UWB spectrum ranging from 2.75 GHz to 10.65 GHz with a wide bandwidth of 7.9 GHz. The slotted patch and the partial ground plane are used to introduce multi-resonance [10] behavior and also reduce the size of the antenna. The designed antenna maintains good return loss, radiation patterns with the acceptable value of gain (-10 dB) and VSWR<2. With all these specifications the antenna can be adopted for 3.6/4.9/5/5.9 GHz WiFi, 3.41/3.49 LTE, 3.5/5.5 GHZ WiMAX, 4.2-4.4 GHz Radio Altimeter, 5.2/5.8 GHz WLAN, 7.05-7.075 GHz Satellite Radio Uplink, 5.15-5.35 GHz HiperLAN, 3.7-4.2 GHz C-Band, 8.5-10.68 GHz X-Band and 3.3/3.4 GHz proposed 5G applications. The simulated and measured results are closely following each other.

Suggestion for Future Work

The designed antenna band ranges from 2.77 GHz to 10.6 GHz. The important need of the antenna design is to achieve high gain suitable for densely populated areas. The design is verified and measured in an isolated lossless anechoic environment which can be useful for in-house wireless applications. But the same will suffer much fading effect in urban lossy environments. So for such environments the same design can be verified with array structure of multiple inputs multiple outputs (MIMO) to increase the gain.

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