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Split-ground Compact Ultra-wide Band Patch Antenna for Wireless LTE/UMTS Operations

Deepthi Chamkur V, C R Byrareddy, Saleem Ulla Shariff

Abstract*: *The lower band and mid band '5G' are known to use the frequencies in the range of 600 MHz – 6 GHz worldwide, especially 3.5GHz to 4.2GHz. A new modified multi slot compact planar ultra-wideband Microstrip patch antenna with a split ground plane has been proposed in this paper. The size of the antenna occupies volume of 34x30x1.7 (1734 mm^3) which has been designed on a FR4 epoxy substrate with dielectric constant of 4.4. In order to provide dual wideband characteristics, a 'T and G 'shaped slots with split ground plane using line feeding structure has been used. The effects on the return losses v/s frequency for the antenna using different substrates with varying dielectric constants for the same dimensions has been studied in this paper. The proposed antenna operates in dual band with first band being a narrow band ranging from 1.92GHz to 2.06GHz and the second band is an ultra-wide band which ranges from 3.40 GHz to 9.6 GHz. The split ground plane and slot size variations in the T and G slot geometry helps in retrieving the dual bands. The proposed antenna is covering applications from LTE band No 40, UMTS IMT-2000, Wimax (3.5/5.55GHz), ISM WLAN 5.2/5.8GHz and RFID etc. The direct line feeding method which uses a 50Ω line with width of W=3mm has been used for the micro-strip line. With split ground plane, coupling between the slots plays role for achieving the good bandwidth. The analysis of return loss (dB), bandwidth, VSWR (Voltage Standing Wave Ratio) of patch antenna with different substrates and variation of the sizes of slots in shapes has been performed using HFSS tool [12] and results has been studied in this paper.

Keywords **: Dual bands, *Line fed; Split Ground Plane ; patch antenna; Wireless; '5G' shaped; Multi Slot; Microstrip ; FR4 epoxy ; Glass; Wi-Fi; LTE; ISM; RFID; Radio altimeters ;Rogers.***

I. INTRODUCTION

In recent times, the focus & interest in research for the ultra-wide band (UWB) communication systems such as the wireless personal area network (WPAN) which is covering frequency band from 3GHz to 10GHz has seen the rapid growth. This growth can be attributed to their many advantages including the low-spectral-density radiated power and the potential for accommodation of the higher data rates [1]. With the rapid development and advancement in the wireless communication technology, the need and demand for the multi bands and ultra-wide band antennas are great. For the scholars, it is a known fact about the Micro-strip Patch antennas that they usually have narrow bandwidth which creates a hindrance for them to be opted for use in modern wireless [9] applications [10]. Due to these facts, there is a factual increase in demand for further research on the micro-strip antennas with low-profile low cost for obtaining ultra-wide band antennas so that they can be easily integrated within the advanced communication systems of today's generation [9]. The current generation emerging applications in wireless operations expect good antenna characteristics [13] and due to their low profile, light weight, ease of fabrication micro-strip antenna draws much attention from researchers. Due to various drawbacks ranging from narrow bandwidth to low gain, the need for research to overcome limitations of narrow impedance bandwidth there is need for depth study of the same. The bandwidth enhancement and size reduction are important design considerations to be considered while looking for the improvement of one of the characteristics with care to lower the degradation of the other parameters [13]. Many authors have proposed techniques and investigated the same like slotted patch antennas [1]–[6] feeding techniques [6]–[7] to achieve ultra-wide bands for modern wireless devices. This paper is being discussed and aimed at describing the design and realization of a compact planar UWB antenna suitable for use in the LTE/UMTS and various other wireless applications. The proposed design has a planar and simple structure to make it easy to design & fabricate & has a better probability to achieve a low Q-factor for the effective increase in the bandwidth with insertion of slots into the patch and the ground plane [1]. With the proper selection of the shape and dimensions of the slots as well as the splitting of the ground plane, a better impedance bandwidth and good radiation characteristics for the wireless applications can be achieved[1]. The effects of cutting and miniaturization, embedding of the 'T' and 'G' slots to the designed patch on resonance have been studied with the effects of use of various different substrate types on the bandwidth.

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The dual band or multi band patch antennas have aroused much of the attention in modern mobile communication systems as they can provide double transmission channels in a frequency-reuse communication system for instance, Universal Mobile Telecommunications Service (UMTS) and Worldwide Interoperability for Microwave Access (WiMAX) with respect to combating the multipath fading problem [3].

In the typical conventional patch antennas, the structure of the ground plane is complete[2] but to achieve desired frequency response and excite the new resonances, the splitting of the ground plane with desired shapes are employed in [see Fig. 2(b)]. The typical ‘T-shaped’ and ‘G-shaped’ slots with a suitable height is used inside the radiating patch [see Fig. 2(a)] to help in achieving the generation of the additional current paths on the patch and the new coupling paths between the slotted radiating patch and split ground plane[2].

II. PROPOSED ANTENNA DESIGN

The Fig. 2(a) and Fig. 2(b) presents the configuration of the proposed split ground compact UWB antenna with the antenna constructed by printing it on a 1.6mm thick FR4 epoxy substrate with relative dielectric constant εr = 4.4 and the area of 34x30x1.7 (1734 mm^3) . The length size and width size of the rectangular split ground of the antenna is 34mm and 30 mm. In the radiating patch design, the two slots of T-shaped & G-shaped slots along the centerlines are embedded in the patches on the radiating patch. The antenna has been fed by a Microstrip line of W=3mm width with 50ohm direct line feed that has been placed along the centerline of the radiating patch and is located in mid or the center of the patch.

The proposed antenna consists of a ‘T-shaped’ and ‘G-shaped’ slots along with rectangular shapes etched out on the radiating patch with a partially itched ground plane which is sandwiched between the FR4 epoxy substrate [4]. The proposed antenna consists of patch & ground plane composed of a conducting material such as copper with εr = 1 and the substrate made of a FR4 epoxy material with εr = 4.4[5].

The substrate used in antenna can consists of a dielectric material which is made using various types of materials [4], these materials can give varying dielectric constants and it can range between 2.2 to 12. The well-known dielectric materials used as a substrate by the researchers are Rogers RT /duroid 6006 (6.15), FR4 (Flame resistant-4) (4.4), etc. In the proposed design the effects related to use of different di-electric materials has been studied. Table-2 details out the effects on the bandwidth and the return losses. The applications for which the variation of the substrates, the bands produce can be seen in the same table.

Table- I: The proposed Antenna dimensions specifications.

Parameter	Specifications	Dimensions (mm)
Patch	T- Slot	2x8 horizontal 5.68 x2 Vertical
	G-Slot	8x2 Vertical
Ground Plane	Partial itching	14.4x28x0.05
	Split ground	4x13x0.05 & 30x3x0.05
Feeding	Line feeding	15.075x3
Substrate	FR4(εr = 4.4)	34x30x1.6

From the fig 2(a), the structure of the split ground can be discussed. The split ground has three structures of rectangular shapes with the first rectangular shape overlapping the feeding line having sizes of 14.35X15mm and the other structures have rectangular shapes of sizes 4x10 mm and 34x3mm. The figure 2(b) describes the radiating patch with dimensions which is mounted on a substrate of 34x30mm. Without the etching of the slots & rectangular shapes, the radiating patch will have dimensions of LxW as 15.5x21mm. The dimensions of the etched out rectangular shapes in the radiating patch have sizes of R1=2.5X3mm, R2=2X3mm, R3=5X2.5mm and R4=4.5X2.5mm. The mentioned Table-1 quotes the antenna dimension specifications used while designing and selection of the final structure which gives us an optimum result.

The figure-3 shown displays the comparison of the various shapes before arriving at the final structure for discussion. There are six designs as shown in the figure. In Design-1 shown in fig.3, the ground plane is not split but has a rectangular shape of 14.4x28x0.05mm. In Design-2 , the size of the substrate has been increased to 34x30x1.6mm size. The ground plane has been split into rectangular shapes of 14.4x17mm and 6x11mm and 31x2mm. The radiating patch dimensions can be referred from the figure 3, design-2.The variation in the sizes and shapes can be studied in the figure-3, and analyze them.

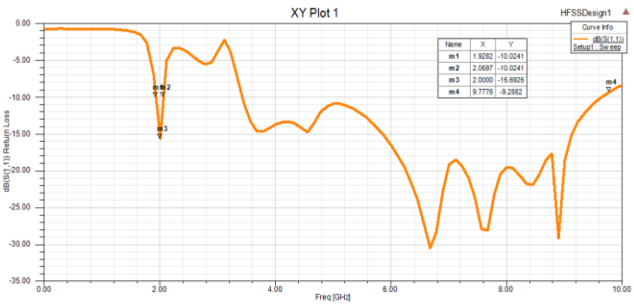

Fig. 1. 2D simulated graph of Return loss v/s Frequency from HFSS.

(a) (b)

Fig. 2. The proposed split ground Microstrip patch antenna with dimensions on FR-4 substrate (a) Split Ground. (b) Radiating Patch.

III. RESULTS AND DISCUSSION

The proposed 'Split-ground Compact Ultra-wide Band Patch Antenna' uses the High Frequency Structure Simulation (HFSS) [8] full-wave simulation software to design and obtain the simulation data, and the proposed antenna's prototype has been etched out on a FR4 substrate. The parameters such as return loss patterns, gain, VSWR, radiation patterns, current & electric field density plots are simulated and extracted from HFSS software design tool [8] and have been plotted in the respective figures in up-coming sections. From the analysis of the results plotted as shown in fig-1, there are two bands obtained in return loss v/s frequency plot. The proposed antenna has achieved a -10dB return loss bandwidth of 1.92–2.06 GHz for the first band which is suitable for UMTS applications [3] with a peak resonance at 2GHz having -15.7 dB return loss. Similarly the second band has -10 dB return loss with continuity of VSWR=2 from 3.6GHz up to 9.78 GHz bandwidth range. If the VSWR is taken with a reference point of 2.5, then the bandwidth coverage will increase enormously. Fig.4 shows the Graph of Return loss v/s frequency comparisons for the variations in the shapes with respect to the changes in the sizes in the shape by varying the structure. As like the proposed design, designed with the FR4 epoxy substrate (4.4), with the same specifications and same dimensions, if we change the substrate FR4 with Glass or other substrates the variation in the VSWR & return loss happens which has been shown in the table-II below.

Table-II: Bandwidth comparison for different substrates for the proposed design with same dimensions

Substrate Name	Dielectric Constant	Useful Band Range with Bandwidth	Applications
FR-4	εr =4.4	Narrow Band : 1.92GHZ- 2.06GHz (BW= 140MHz) Wide Band: 3.40 GHz - 9.60GHZ (BW= 6.2 GHz)	UMTS / WCDMA/ IMT-2000 (1.92 to 2.17 GHz), LTE Band No 40 UWB, ISM : WLAN 5.2 GHz/5.8 GHz RFID - 5.75- 5.85 GHz Radio altimeters(4.2 - 4.4 GHz) Satellite radio uplink (7.05GHz- 7.075GHz) WiMAX(3.5GHz , 5.55GHz) 5G - (600MHz to 6GHz)
Glass	εr =5.5	3.2280 GHz - 8.78 GHz (BW= 5.55GHz)	
Rogers TMM 3 (tm)	εr =3.27	3.78GHz - 10GHz (BW = 6.22 GHz)	
Rogers RT/duroid 6006(tm)	εr =6.15	3.1746GHz -4.639 GHz(BW= 1.464GHz) 5.19GHz - 7.6296 GHz(BW= 2.44GHz) 8.28GHz - 8.75GHz(BW= 470MHz)	

Fig. 3. The proposed split ground plane 'T' and 'G' shaped slotted wide band Microstrip patch antenna structure comparisons with the variations of length and widths.

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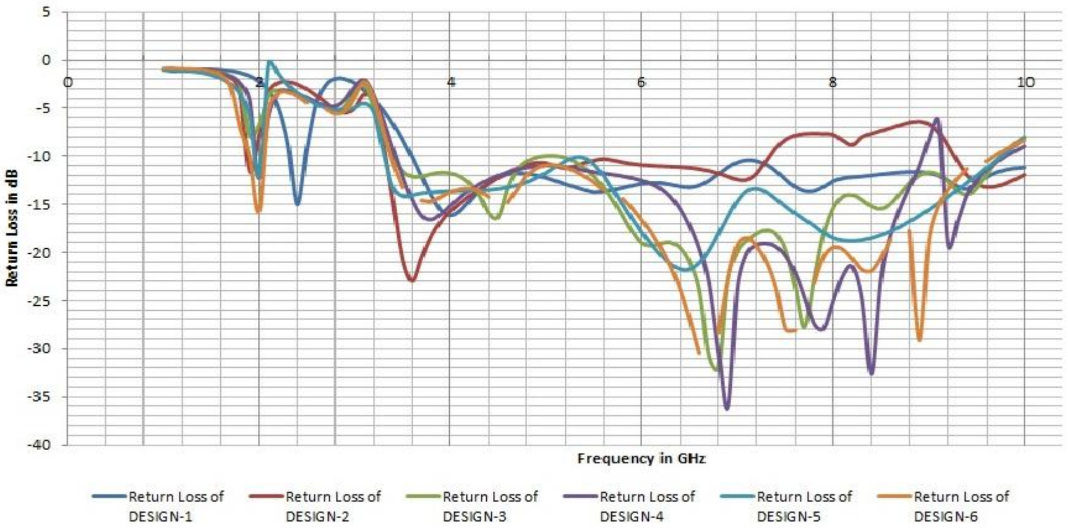

Fig. 4. Graph of Return loss v/s frequency comparisons for the variations in the shapes.

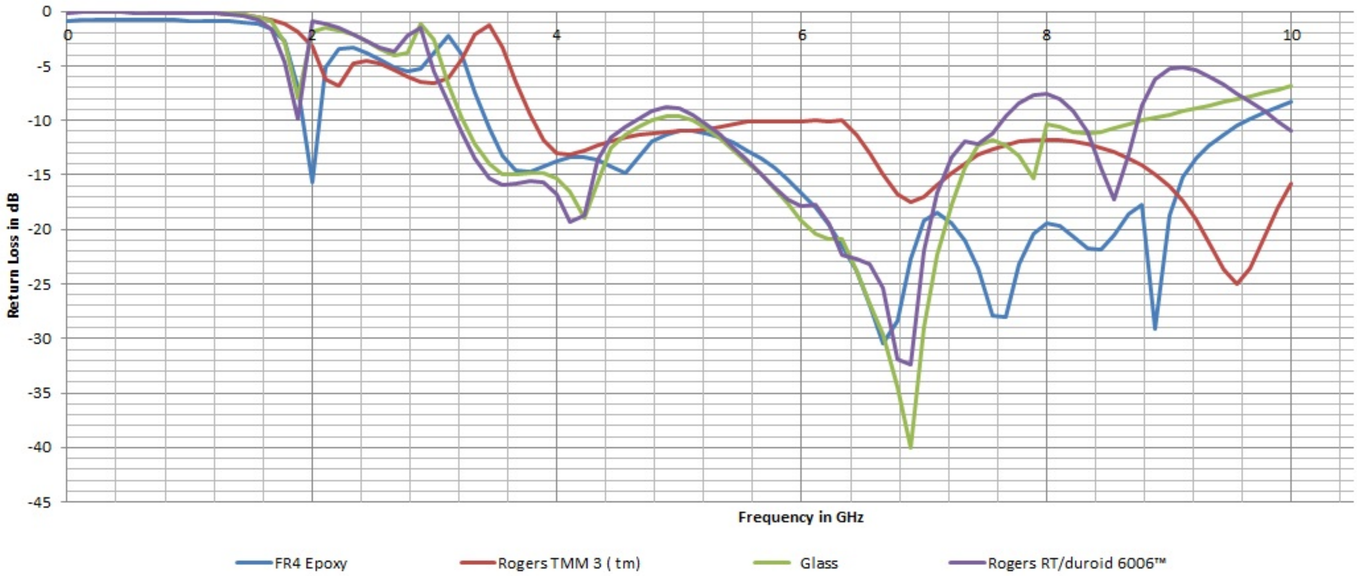

Fig. 5. Comparison of Return loss for different substrates for the proposed design.

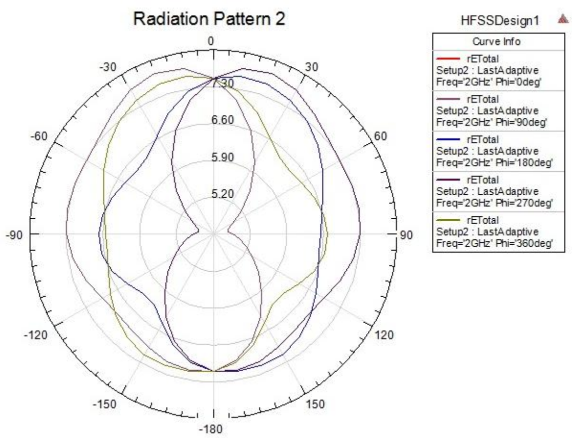

Fig 6. Graph displaying the Radiation pattern at 2 GHz at phi = 0, 90,180 and 270 deg.

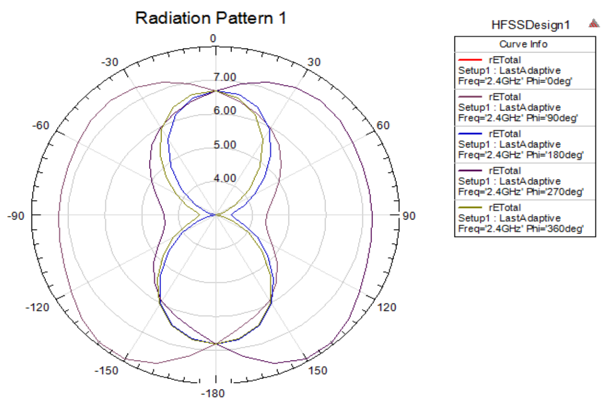

Fig. 7. Graph displaying the Radiation pattern at 2.4GHz at phi = 0, 90,180 and 270 deg.

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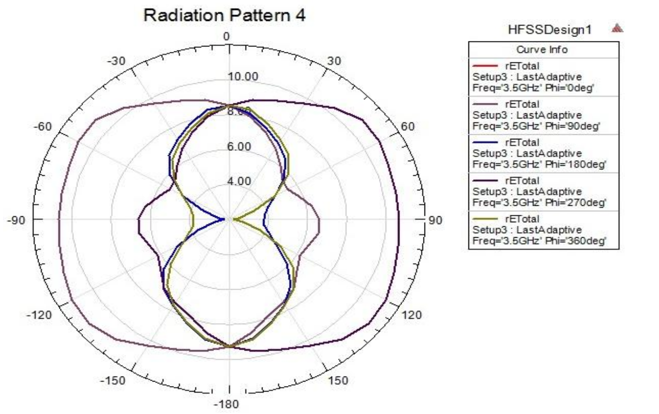

Fig. 8. Graph displaying the Radiation pattern at 3.5 GHz at phi = 0, 90,180 and 270 deg

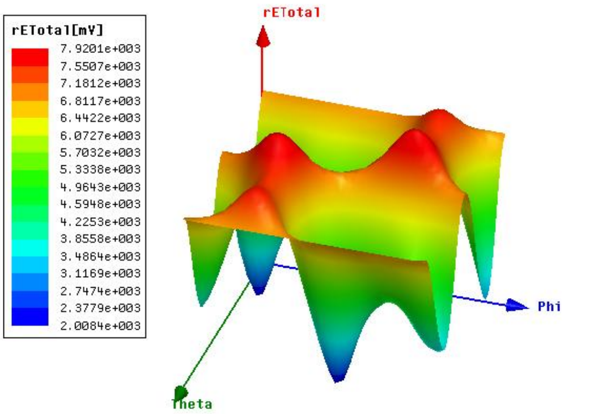

Fig. 9. plot for the simulated 3D Rectangular pattern

The Fig.5 shows the comparison graph for the return loss v/s frequency plots between the different used substrates in HFSS tool while simulation with same dimensions used for final structure as shown in fig.2 (a-b) as reference. As per Fig.6, Fig.7 and Fig.8 the plot of radiation patterns can be studied which have been simulated in the E-plane and H- plane in HFSS tool [8] at 2 GHz, 2.4 GHz and 3.5 GHz frequencies at phi=0,90,180,270 degrees respectively [4]. From these plots, it can be observed that the radiation patterns are almost omnidirectional. The plots pertaining to the 3D rectangular patterns have been shown in fig.9, and it has depicted a very good polarization for proposed split ground plane 'T-shaped' and 'G-shaped' slots shaped ultra wide band antenna.

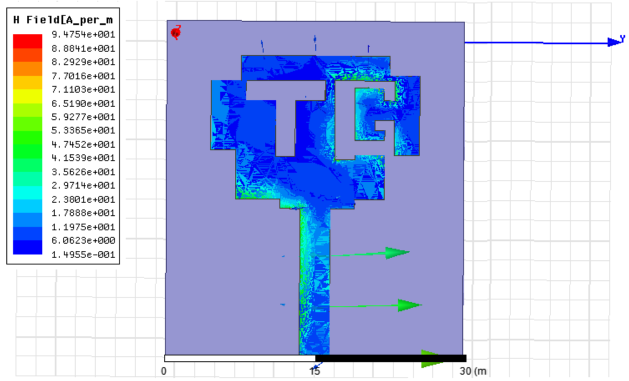

Fig. 10. Graph of Vector Magnetic field distribution

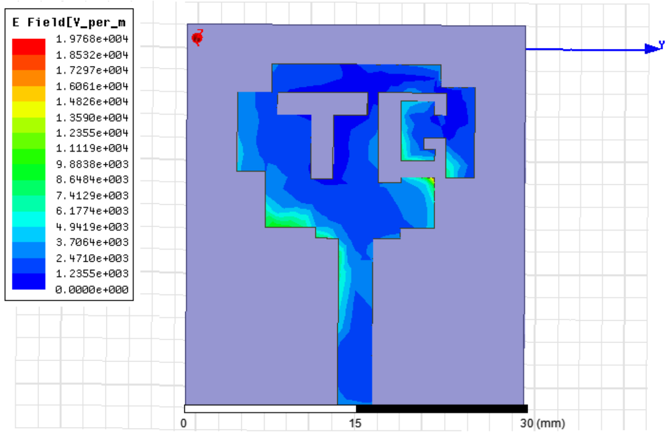

Fig. 11. Graph of Electric field distribution

In HFSS tool, the surface current density, electric field and magnetic field distribution plots have been simulated for the proposed split ground 'T-shaped' and 'G-shaped' slotted ultra-wide band antenna for various frequencies of operation such as 3.5GHz etc., are shown in Fig. 10, 11 and 12. It can be easily noted from the Fig.12 that the surface current density for the antenna is maximum at the edges of the radiating patch whereas low or minimal at the center. Fig.13 plots the simulated results for the VSWR (Voltage Standing Wave Ratio), VSWR value is very important in determination of the antenna return loss. As shown in the fig.13, we can note that the VSWR for the proposed split ground 'T-shaped' and 'G-shaped' slotted micro-strip patch antenna is less than the 2, which is one of the important conditions to satisfy to obtain the bandwidth requirement for specified frequency ranges [4]. The overall VSWR is better than 2.5 throughout and this makes the available bandwidth to cover the maximum requirement of an UWB frequency of operation. Fig.14 is the plot for the simulated stacked gain obtained from the HFSS for the proposed antenna for 3.5 GHz at phi= 0, 90, 180, 270 and 360 degrees.

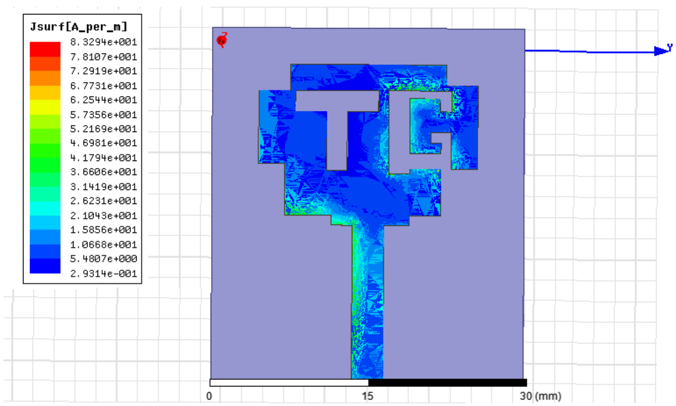

Fig. 12. Graph of surface Current density distribution.

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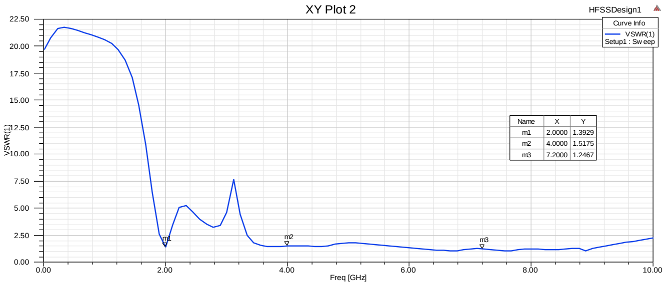

Fig. 13. Graph of simulated VSWR v/s frequency for the antenna.

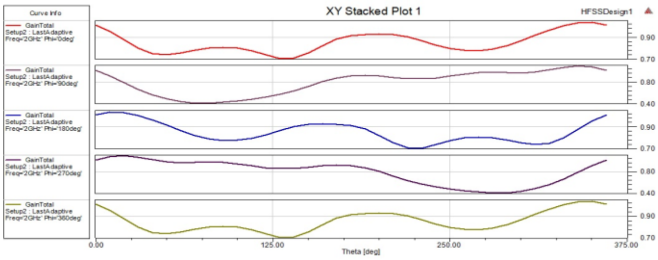

Fig. 14. Graph of simulated stacked gain v/s frequency at 2 GHz.

IV. CONCLUSION

The 'Split-ground Compact Ultra-wide Band Patch Antenna for Wireless LTE/UMTS Operations' paper discusses about analysis of the effects of the variation in the sizes of the slots and use of different substrates on the return loss & bandwidth. The paper discusses about, how the proposed antenna can be harnessed for various wireless applications such as UMTS, Wi-Fi, RFID, Radio altimeter and WLAN/Wimax LTE applications [7]. The overall VSWR is better than 2.5 throughout and this makes the whole available bandwidth to cover the requirement of an UWB frequency of operation.

In this paper, the proposed design uses the typical split ground plane with 'T-shaped' and 'G-shaped' slots on the radiating patch elements with the etched out rectangular slots etched on the copper plated radiating patch having a compact volume . The variations of the length and width of the etched slots and their effects have been studied with the help of simulation with the use of Ansoft HFSS [8] tool. With an antenna size of volume of 34x30x1.7 (1734 mm^3), the HFSS software has been used for validation of the parameters such as VSWR, radiation patterns; return loss, Gain, Current & Electric field distribution for the designed split ground UWB antenna with the help of simulation. .

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