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Research Article

Design of a Planar Ultra Wide Band Antenna Structure using Stepped Contours

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Abstract**—**When US-FCC has given approval to license free usage of low power short range antenna then only the researchers have starting to explore the Ultra Wide Band (UWB) antenna. The approval date of this usage was 14 February, 2002. A UWB antenna structure of planar geometry is propounded in this paper. Simulation of this structure is carried by Computer Simulation Technology (CST) Microwave Studio - 2016 software tool. In the designing of the proposed structure a rectangular microstrip patch antenna, partial ground plane, stepped contours and microstrip line feed is utilized. In addition to this the substrate used was a FR-4 substance with height of 1.6 millimeter. The dimensions of the structure taken as a whole are 27 x 36 x 1.6 mm^3. This structure functions in entire specified frequency range for UWB and beyond up to 11.67 GHz giving the fractional bandwidth of more than 116 %. For the entire said operating frequency range the VSWR is always lees than 2. The essence of this design is its simple and conformal structure. The peak return loss is obtain at 6.84 GHz of about S_{11}= -44 dB. The Peak Gain (IEEE) of about 5.83 dB at 9.5 GHz. The proposed structure can be commonly used for 3.5 GHz and 5.7 GHz which are specified bands for WiMax and WLAN respectively. The other applications for which the structure cam be utilized are ARN (4.55 GHz), ITU-8 (8.8 GHz), XSCS (7.8 GHz), RLS (3.4 GHz), ITS (5.9 GHz), etc.

Keywords**—**Ultra Wide Band (UWB) antenna, Microstrip Patch Antenna (MPA), fractional bandwidth.

I. INTRODUCTION

By virtue of quick advancement in the wireless communication systems, it requires the technologies with add-on features and therefore the Ultra Wide Band (UWB) technology have been extensively exploited to provide additional features [1-3]. Now a days, mobile companies like apple, Samsung, etc. are manufacturing UWB enabled chips in mobile phones which they are utilized the benefits and additional features of UWB technology [4, 6-8]. The UWB technology can be utilized without the need of any license for low power and short range applications. The authorizing body was US-FCC and the approval for this type of usage approved on 14 February, 2002. The frequency allocated for this license free usage was from 3.1 GHz to 10.6 GHz with -41.3 dBm / MHz value of EIRP [5, 9-10]. This approval has opened a new chapter of research and it requires an antenna structure which can be utilized from said frequency band termed as Ultra Wide Band (UWB) antennas. Generally, the UWB antennas was designed with the help of microstrip patch antenna because of its less size, planar structure, conformal nature, easy to fabricate, ruggedness, low cost, etc [11]. Above all the main advantage of planar structure is that they can be placed or mounted on nearly any place as and when needed as per the application [12-14].

Most of the researchers have used slotting, stacking, shorting pin, fractal design, EBG structures, partial ground, modified ground, inserting protruded stripes, slits and stubs in order to enhance and improve bandwidth [15-19]. The structures of the design are so that enhanced electro-magnetic coupling between the top and bottom and coupling between the feed and patch should be more on the higher level.

II. CONFIGURATIONS OF THE ANTENNA STRUCTURE

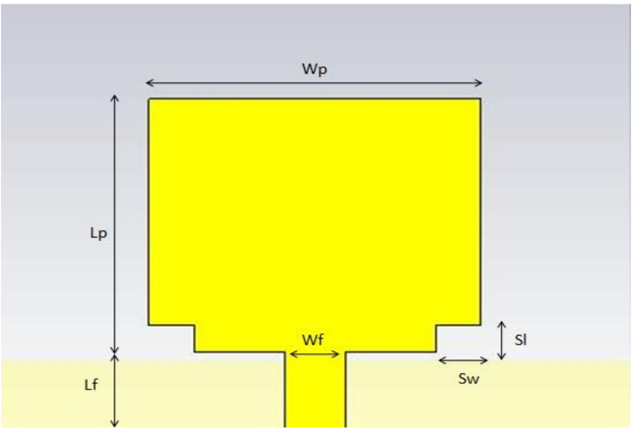

Fig. 1: Front side of the UWB design.

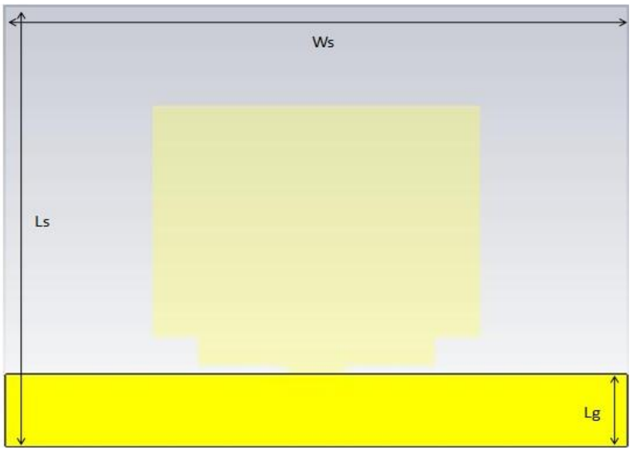

Fig. 2: Back side of the UWB design.

The substrate chosen to design this structure is FR-4 (Flame Retardant) with permittivity of substrate as 4.3 and tan δ of 0.025. Loss tangent is the parameter by virtue of which one can have an idea of how much of energy fed to the antenna structure will be converted into radiations (EM waves). Indirectly, its value will depend on how much portion of fed energy to the structure will actually be converted into losses in form of heat. In this structure the thickness of copper (annealed) is taken as 0.035 mm or 35 µm. The remaining parameters of this optimized stricture are revealed in the table 1 given below.

TABLE 1

Optimized dimension of parameters chosen in this structure

Parameter Description	**Parameter**	**Dimension (mm)**
Substrate Length	L_S	27.00
Substrate Width	W_S	36.00
Patch Length	L_P	16.00
Patch Width	W_P	19.00
Ground Length	L_G	4.45
Ground Width	W_G	36.00
Height of the Substrate	h	1.60

Thickness of Copper (Annealed)	mt	0.035
Microstrip Line Feed Length	L_F	5.00
Microstrip Line Feed Width	W_F	3.50
Stepped Contours Length	S_L	1.70
Stepped Contours Width	W_L	2.60

III. DEVELOPMENT OF THE DESIGN

In the evolution of the design, the antenna was developed in 3 stages which are shown in figure 3 given below. In this evolution process Computer Simulation Technology (CST) Microwave Studeio-2016 is utilized as a software tool. In the first stage, by utilizing the standard design equations of rectangular microstrip patch antenna, the antenna was design to resonate at 5 GHz. Microstrip line feed was utilized for this structure and the dimensions of the same are chosen so as to match the impedance of 50 Ω and for enhanced bandwidth. In this stage the antenna was radiating efficiently from 3.30 GHz to 7.25 GHz with the bandwidth of 3.95 GHz. In the first stage, the fractional bandwidth was calculated as 74.88 %. The dimension of all the parameters was optimized by parameter variation method so as to achieve large and enhanced bandwidth.

In the second stage, a stepped contour was inserted on the lower left side of patch. The stepped contour was used to make the design operative with specified range for UWB. The dimensions of both length and width of stepped contour were optimized by parametric study. In this stage, the design was working for 3.23 GHz - 9.56 GHz giving bandwidth of about 6.33 GHz. In this stage, the bandwidth was enhanced by 2.38 GHz. The fractional bandwidth for this ate was calculated as 99 %.

In the last stage, an identical stepped contour was inserted on the lower right side of the patch. The parametric study was again carried out to obtain the optimized results. After the last stage, structure was functioning for 3.09 GHz - 11.68 GHz giving bandwidth of 8.59 GHz. The bandwidth in the last stage was enhanced by 2.26 GHz. The fractional bandwidth of the optimized structure was calculated as 116.32 %.

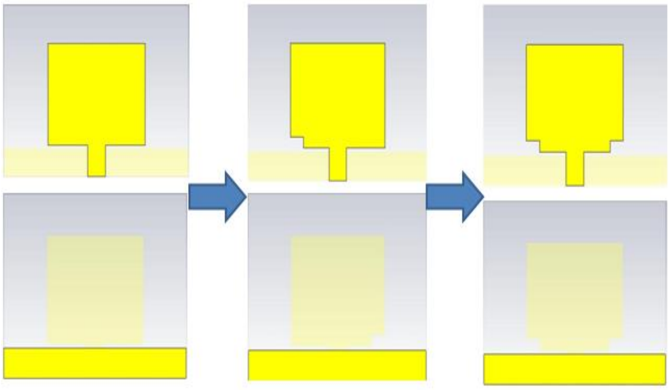

Fig. 3: Stage wise evolution of the design.

IV. PARAMETRIC STUDY

Optimization of the design parameters is the must to do task in all the designing processes to achieve best results. This proposed structure is also optimized by utilized the parameter sweep method applied on nearly all design parameters. The parametric study of three design parameters is shown below in figure 4, 5 and 6 respectively.

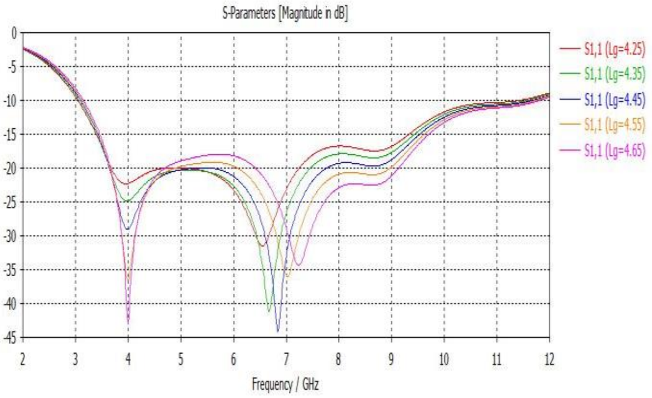

Fig. 4: Parametric study of ground length ‘L_G’.

Many researchers have used partial ground plane to enhance or boost the bandwidth of the design. While performing the parametric study of the parameter ‘L_G’ denoting the length of the ground it was found that the bandwidth of the antenna increases immensely by virtue of partial ground plane which can be seen in figure 4. If the ground length is increased, the entire S_{11} plot moves to higher frequencies and maximum return loss at 4GHz also increases. On the other hand, second peak at higher frequency (at nearly 7 GHz) shifts to higher side and the peak first increases then decreases. Therefore, keeping the balance at both lower and higher frequencies the middle value of ‘L_G’ was chosen.

The deviation in the length of both stepped contours was analyzed and can be seen from figure 5 given below. It was found that the bandwidth increases with the incremental change in the length of the stepped contours. After a certain value the peak starts to decrease. The maximum value of S_{11} plot on the higher frequency also improves by increasing the length of the stepped contours. The middle value of this variation was chosen in this case also as at the mid frequencies the return loss is decreasing.

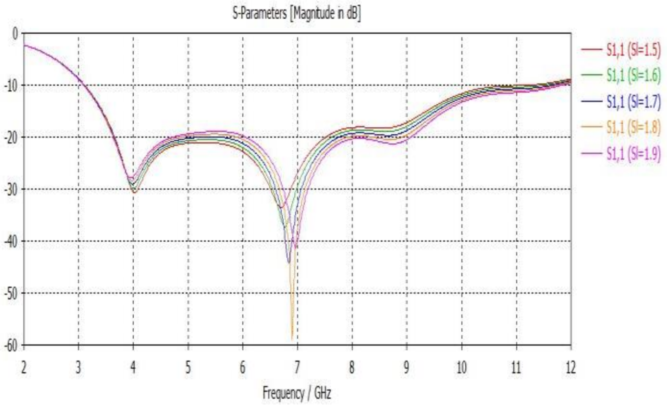

Fig. 5: Parameter variation of ground length ‘S_L’.

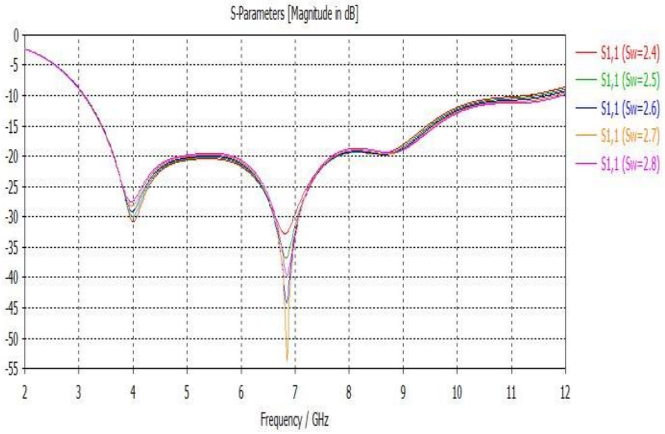

Fig. 6: Parameter variation of ground length ‘S_W’.

Figure 6 shows the parametric variation of the design parameter named ‘S_W’. This denotes the width of the stepped contours on the radiating patch antenna. The measurement of both side i.e. widthwise and length wise of the stepped contours are the variables for the function in enhancing the bandwidth and improving the peak S_{11} plot. As the value of this parameter increases the return at lower frequency decreases. On the other hand, it first increases then decreases with the increasing value of stepped contours width. Therefore, the mid value of this parameter was chosen so as to have large bandwidth, peak return loss and curve well below the 10 dB.

V. RESULTS AND DISCUSSION

Figure 7 reveals the S_{11} plot of proposed structure. The structure has a bandwidth of 8.59 GHz and fractional bandwidth of about 116.32 %. The peak return loss obtain at 6.84 GHz is 44.19 dB. The curve shows that the structure can operate in the entire UWB as per US-FCC.

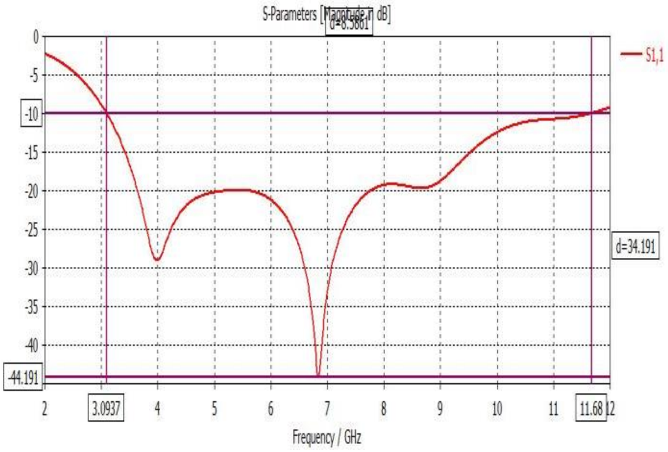

Fig. 7: Return Loss (S_{11}) plot of structure.

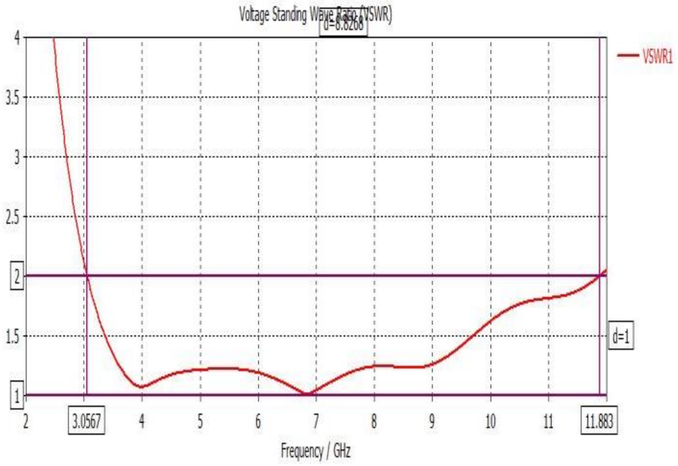

Fig. 8: VSWR plot of structure.

The VSWR curve of the proposed structure is shown in figure 8. The curve shows good matching of impedance as the curve is lower than 2 for the specified band for UWB of the structure.

Figure 9 shows gain v/s frequency plot of the structure. Proposed design exhibits a piecewise constant gain v/s frequency plot. 5.83 dB is reported as the peak gain at 9.5 GHz. The gain performance is satisfactory for the whole proposed range.

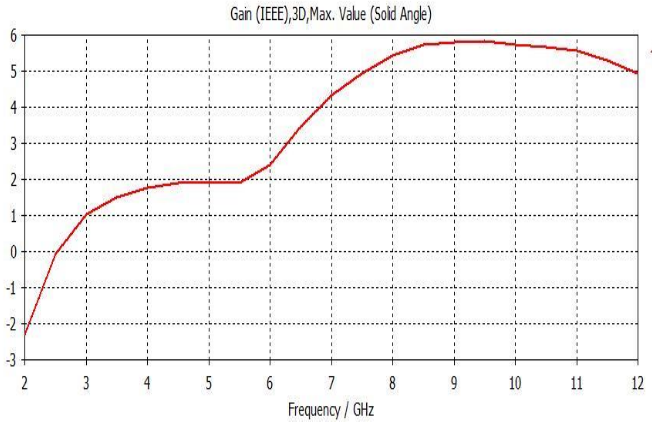

Fig. 9: Gain v/s frequency plot of the structure.

The radiation patterns are revealed in fig. 10, 11 and 12 respectively. It is noticeable that for the first two frequency the pattern is bidirectional whereas it is somewhere between bidirectional and omnidirectional in the last case.

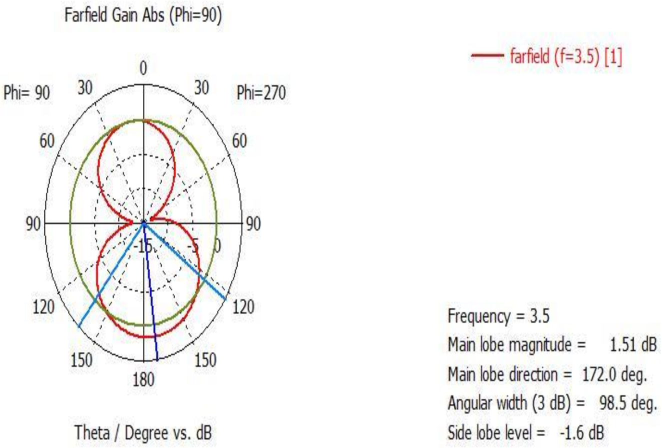

Fig. 10: Far field of the antenna at 3.5 GHz.

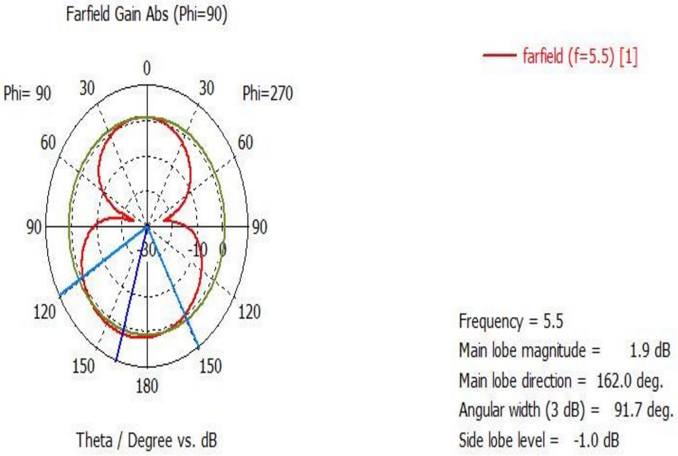

Fig. 11: Far field of the antenna at 5.5 GHz.

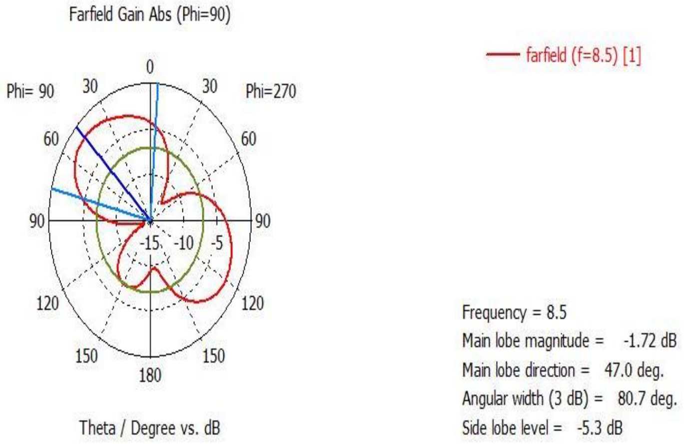

Fig. 12: Far field of the antenna at 8.5 GHz.

VI. CONLCLUSION

This paper reveals a design of a planar rectangular ultra wide band antenna by inserting stepped contours on the lower two sides of the patch. The key feature of this structure is that it can function in the complete ultra wide band as specified by US-FCC ranging from 3.1 GHz to 10.6 GHz. The structure functions in entire specified frequency range for UWB and beyond up to 11.67 GHz giving the fractional bandwidth of more than 116 %. The said structure can be utilized for the usages like ARN (4.55 GHz), ITU-8 (8.8 GHz), XSCS (7.8 GHz), RLS (3.4 GHz), ITS (5.9 GHz), etc. The other commonly used applications are for WiMAX and WLAN which are operating at frequency of 3.5 GHz and 5.7 GHz respectively.

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