Coplanar Waveguide-fed RectangularSlotAntennafor Ultra-Wideband Application

P N Shinde
Department of E & TC,Sinhgad Academy of Engineering,Pune,India.

B KMishra
Thakur College of Engineering & Technology Mumbai, India

J P Shinde
Department of E & TC, Sinhgad Academy of Engineering,Pune,India.

ABSTRACT
This study describes a tunable coplanar waveguide fed (CPW) rectangularslot antenna to work within ultra wide band (UWB) for the future communication systems. This slot antenna of area $30*20mm^2$ is designed on a FR4 substrate and its operation was tested in terms of return loss and gain. The developed antenna shows VSWR ≤ 2 bandwidth of 800MHz in 0.7-1.51GHzband as well as bandwidth of 6.06GHz in the UWB band of 2.76-8.83GHz with near omni-directional characteristics and good radiation efficiency of more than 92% for the major band spectrum and a gain of 2dBi and 4.2 dBi for the centre frequency of 1.1GHz and 6.06GHz respectively.

General Terms
Measurement,Performance,Design,Experimentation, Verification.

Keywords
Rectangular aperture slot, pentagonal tuning stub, CPW feed, ultra- wide band (UWB)

1. INTRODUCTION
In 2002 Federal Communications commission (FCC) have given the approval for the commercial use of ultra wide band. A frequency band of 7.5GHz from 3.1 GHz to 10.6GHz is legally authorized by FCC as unlicensed band to be used for UWB technology as it has become the most promising candidate for short range high speed wireless indoor data communication [1]. The compact antenna for such UWB system offers many design aspects like the type of feed, shape of slot and tuning stub for 50Ω impedance match[2],[5].UWB antenna can be achieved with microstrip line feed or coplanar waveguide (CPW) feed but CPW feed antenna attains UWB characteristics [9]. The advantages of slot antenna fed by CPW are broad bandwidth performance, low manufacturing cost and easy compatibility with radio frequency as well as with microwave integrated circuits. Due to its planar simple structure radiation leakage and dispersion is very low.

In the designing of UWB antenna the issues like impedance matching, radiation stability and low power emission over entire UWB operating frequency range with compact size are at prior interest. Many researchers have reported rectangular slot UWB antenna design with various tuning stub shapes like fork, rectangular, circular and U-shaped etc., to achieve the broad bandwidth [2-7]. The tuning parameters of these antennas are more critical to have bandwidth enhancement.

In this paper a CPW fed rectangular e slot antenna with pentagonal shaped tuning stub is proposed. An attempt is made that the antenna has less tuning parameters and simple tuning stub structure with a band of 7GHz approximately. These design features of antenna helps to achieve a dual band, one is of bandwidth 800MHz and second is UWB of bandwidth 6.06GHz from 0.7-1.51GHz and 2.76-8.83GHz respectively, with simple alteration in basic tuning stub. This gives more design tolerance during fabrication and testing of antenna.

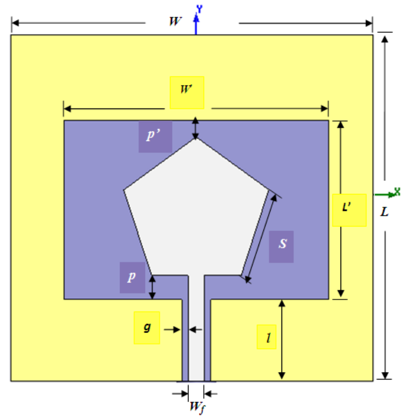

Figure 1.Structureofrectangular slot pentagonal stub of side length *S*, CPW fed antenna.

2. ANTENNA DESIGN
The configuration of the proposed dual band rectangular slot antenna without an additional band rejecting structure is shown in figure1. The antenna is designed on a low cost FR4 substrate having dielectric constant of ε_r = 4.3 having dimension of 39*41 mm^2, thickness *h*= 1.6mm and dielectric loss tangent tanδ =0.02. A CPW transmission line with 50Ω match impedance is used to feed the simple pentagon stub at its side length *s*. The CPW feed has a width W_f of 1.8mm and length L_f of 9.2+*p* mm. The spacing between pentagonal stub and CPW ground *p* is 2.55mm and gap width *g* between CPW feed line and CPW ground is 0.75 mm. The CPW waveguide coupling slot provides good impedance matching [8] to achieve UWB operation. The other side of the substrate does not use any radiating electromagnetically coupled structure or slot to enhance bandwidth. The antenna is designed for guide wavelength λ_g = 36.85mm with design frequency of approximately 5GHz, effective dielectric constant ε_{eff} = $(\varepsilon_r+1)/2$=2.65[10] and velocity of light c = $3*10^8$ m/s. The proposed antenna resonates at 1.2GHz and 4.4GHz with simple pentagon tuning stub. Rectangular slot is kept in close proximity to the radiating patch with distance *p* and *p'* to achieve input impedance matching for wideband characteristics. To design a suitable dual band antenna the parameters under consideration are tabulated in Table I.

Table 1. Structural parameters and optimized values of the proposed dual band CPW fed rectangular slot antenna

Parameters	Notations	Dimensions(mm)
Width of substrate	*W*	42
Length of substrate	*L*	39
Rectangular aperture width	*W'*	30
Rectangular aperture length	*L'*	20.2
CPW feed width	W_f	1.8
CPW feed length	L_f	11.75
CPW feed coupling gap	*g*	0.75
Spacing between lower apex of pentagon and CPW ground	*p*	3.7
Spacing between upper vertex of pentagon and CPW ground	*p'*	2.05
Pentagon side length	*s*	9.95

3. PARAMETRIC STUDY OF ANTENNA

In this paper the commercial electromagnetic simulation tool Ansoft HFSS version11 is employed to analyse and optimize the proposed structure. The current distribution along the side length of pentagonal stub is of interest to obtain the wide dual band characteristics. Thus the optimization of side length *s* and two parasitic parameters *p* and *p'* decides the inherent notching to generate dual band having good resonance and less than 10dB impedance gain. The S_{11} sensitivity with variation in *s*, *p* and *p'* is shown in figure2.

Figure2 shows the comparison of S_{11}(dB) for three values of *s* 8.47mm, 9.15mm and 9.95mm at constant values of W_f = 1.8mm, *g* = 0.85mm and L_f = (9.2+*p*)mm which is a parasitic variable which changes with respect to *s*. From the comparison it is found that by increasing the pentagonal stub length *s*, there is a significant chance in the variations of resonating frequencies and the 10dB impedance bands for both of the GSM and UWB bands. At the optimum value of*s* = 9.95mm, *p* = 3.7mm and *p'* = 2.05mm, S_{11} at 1.245GHz is improved from -22.66dB to -32dB in the lower band and for UWB it is improved from -21.48dB to -37dB, also there is increase in 10dB impedance bandwidth from5.47GHz to 6.1824GHz for UWB in comparison with when *s* = 8.47mm.

By selecting this optimum value of *s*= 9.95mm as constant, gives *p*=2.55mm and *p'* = 2.71mm. For *g* = 0.85mm and L_f = 11.75mm, further the optimizations are done on this antenna by changing its CPW feed line width W_f from 1mm to 3mm. Figure3 shows a comparison of S_{11}(dB) for the three values of W_f of 1.8mm,2mm and 2.4mm. The optimized value of W_f is chosen to be of 1.8mm since this shows a better S_{11} graph in comparison to the other two. In the first lower band the antenna resonates at the centre frequency of 1.2744GHz with a 10dB impedance band of 876MHz while the UWB has a 10dB impedance band of 6.2736GHz with respect to the centre frequency of 5.7624GHz.

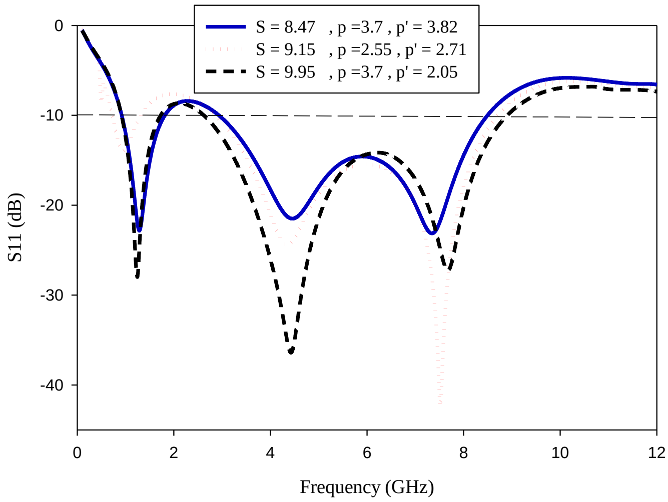

Figure 2. Variation in pentagon side length withW_f = 1.8mm,L_f=9.2+*p* and*g* = 0.85mm

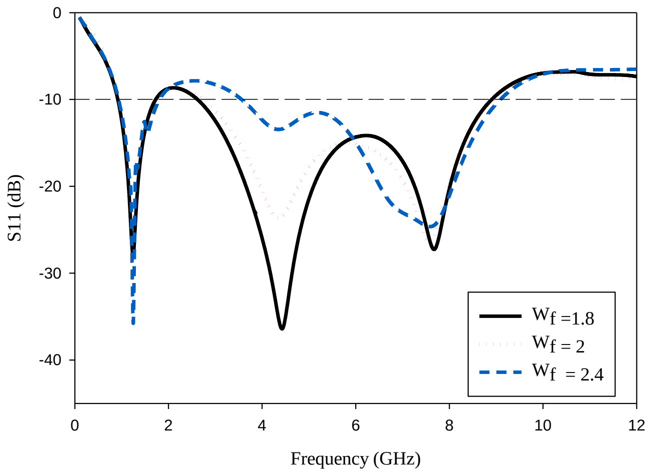

Figure3.Variation in feed width W_f at *s*= 9.95mm,L_f= 11.75,*p'*=2.71mm,*g* = 0.85mm

By selecting the optimized value of W_f = 1.8mm, L_f = 11.75mm and *s* = 9.95mm, the CPW feed coupling gap *g* is necessary to be optimized critically, since this is an important parameter to decide the maximum coupling between the CPW feed line and the tunable pentagonal stub for optimum impedance matching in the UWB bands. The results of S_{11}(dB) for the values of g of 0.35mm, 0.5mm, 0.65mm and 0.75mm is shown in figure4. For *g*=0.75mm is chosen to be an optimized value with respect to the other ones since this antenna resonates at the centre frequency of 1.1GHz with a 10dB impedance band of 800MHz in the first lower band while the second UWB has a 10dB impedance band of 6.06GHz with respect to the centre frequency of 5.8GHz.

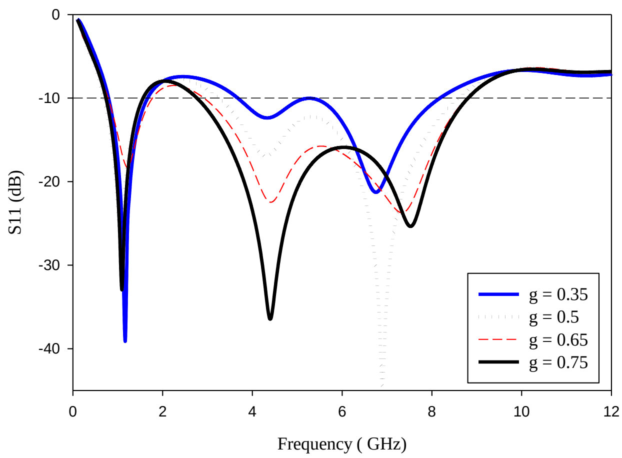

Figure 4. Variation in fed gap '*g*' at W_f=1.8mm, *s*= 9.95mm; L_f=11.75 and *p*'=2.71mm

Hence this proposed antenna is fabricated whose S_{11} is measured on VNA with the parameters as given in Table I. The good impedance bandwidth is achieved for g = 0.75mm and W_f = 1.8mm. Figure5 shows S_{11} (dB) graph and from this it is observed that there are three resonant frequencies at 1.1GHz, 4.42 GHz and 7.6GHz. The $S_{11} \leq 10$ band is controlled mainly by the side length of pentagon if it is fed at its side length.

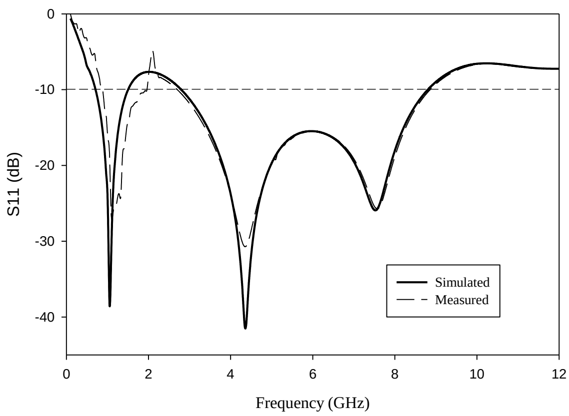

Figure5. Comparison between measured and simulated result of proposed antenna:*s*= 9.95, W_f =1.8, L_f=11.75 and g= 0.75

4. CONCLUSION

In this paper, a simple method for designing compact rectangular slot antenna with pentagonal shaped tuning stub has been presented. For this proposed antenna the pentagonal tuning stub is used for tuning the inputimpedance in the two bands one for personal communication system (PCS) bandand other for UWB band by properly tuning the stub's side length, spacing between stub and CPW ground, length and width of CPW feed line and gap coupling between the CPW feed line and CPW ground to improve the antenna performance. The proposed CPW feed slot antenna has been manufactured using the inexpensive FR4 substrate of dielectric constant ε_r = 4.3. The designed antenna cover the PCS band from 0.7-1.51GHz as well as fall within the UWB band from 2.76- 8.83 GHz, giving 10dB impedance bands of 800MHz and 6.06GHz respectively which finds application for PCS and UWB in integrity for future communication systems.

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