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Compact CPW Ultra Wideband F Slotted Microstrip Antenna for Wireless Applications

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***Abstract*—In this paper, a novel F slotted shaped Ultra Wideband (UWB) microstip antenna simulated on FR_4 Epoxy substrate. The proposed antenna is a very compact design since it can be fabricated on a board with patch dimensions only 20.3×17 mm^2, while the two linear segments that comprise the F-shaped Slots in microstrip provide a direct control on antenna matching. The proposed antenna is operating from 2.2 GHz to 11.5 GHz and by using HFSS 13.0 (High Frequency Strucutral Simulator) presents very consistent omni directional patterns throughout the UWB frequency range. The simplicity of this topology, with the easily controllable return loss, allows for its easy implementation for various UWB sub-band designs, just by building suitable microstrip versions, for which the only difference is the length of the two linear segment.**

***Index Terms*— F slotted antenna, Compact antenna, FR_4 Epoxy antenna, F-shaped stub, UWB, UWB microstrip patch antenna etc.**

I. INTRODUCTION

Since the FCC [1] regulated the 3.1–10.6 GHz band for UWB applications, a significant amount of research activity has been recorded in the area of the design and implementation of UWB antennas. Depending on the application, the requirements for antenna designing may vary significantly, however, for wireless applications, especially for mobile handheld devices, the small size and the omni-directional pattern are highly demanded. For the omni-directional pattern requirements the solution of the printed microstip antenna has been proven very popular and adequately efficient.

UWB antennas design is preferred due to its applications in portable electronics and mobile communications. The conventional UWB antenna is not suited well for normal requirements. For different requirements such as size, gain and radiation patterns, many design approach of antennas have been proposed like Slotted type UWB Antennas, Biconical, Bowtie and Monopole Antennas, Fractal UWB Antennas and Tapered Slot UWB Antennas.

Slotted antennas are commonly used in ultra-wideband (UWB) systems due to the attractive advantages such as low profile, lighter weight, fabrication ease and wide frequency bandwidth. The antenna consists of the ground-plane with rectangular slot and microstip feeding line with a tuning stub. Its measured bandwidth covers the UWB band of 2.5 GHz to 11.3 GHz i.e 127 % fractional bandwidth of S11 < -10dB.. A circular disk microstip antenna proposed in [2-3] provides consistent omni-directional pattern, however it does not provide any control on the return loss that would potentially allow the operation of the antenna in desired UWB sub-bands (lower and higher). A direct control on the return loss and therefore on the radiated frequencies is achieved by the CPW-fed hexagonal antenna presented in [4] and the composite right/left-handed (DCRLH) transmission line loaded antenna [5], which are used for multi-band applications. CPW-fed microstip antenna and electromagnetic band-gap (EBG) combination antenna that features multi-band and wideband behavior is introduced in [6-7], while CPW-fed microstip antenna with parasitic circular-hat patch is used for the broadband operation in [8] and the L-shaped microstip antenna with hexagonal slot is demonstrated in [9]. However, none of the aforementioned antennas covers the whole UWB range. Microstrip line fed Fork-shaped [10], U-shaped [11], pentagon-shaped [12] and CPW-fed bowled-shaped [13] planar microstip antennas that cover the whole UWB range have been presented in recent years, however all of these antennas are almost two times the size of the proposed F shaped microstip antenna.

In this paper, a compact F shaped slotted-shaped microstip UWB antenna is designed and simulated. The presented prototype has board overall dimensions, 25 x 26.2 mm^2, is fabricated on low FR4_Epoxy (ε_r=4.4) dielectric material, presents consistent omni-directional patterns in *H*-plane, and allows direct control on the return loss.

II. ANTENNA DESIGN PARAMETERS

The proposed antenna is designed by two F shaped slots on the top of the patch with same dimensions than other as shown in Fig. 1. Due to cutting of these slots in antenna increases the current path results in increased current density due to which efficiency is also enhance. In this research first a rectangular micro-strip patch antenna is designed based on standard design procedure is to calculate the length (L) and width (W) for resonance frequency. The resonance frequency and the size of the radiation patch can be found out by using these following formulas. After the selection of three parameters based on application, i.e. frequency of operation, height of substrate and permittivity of dielectric material, next step is to calculate width and length of the patch.

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Step 1: Calculation of Width (W)

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

where, μ_0 is the free permeability, ε_0 is the free space permittivity and ε_r is relative permittivity.

Step 2: Calculation of Effective Dielectric Coefficient (ε_{reff}) the effective dielectric constant is

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{1/2} \quad (2)$$

Step 3: Calculation of Effective Length (Leff)

The effective length is

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3)$$

Step 4: Calculation of Length Extension (ΔL)

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{rff}-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

Step 5: Calculation of Length of Patch (L)

The actual length of radiating patch is obtained by

$$L = L_{eff} - 2\Delta L \quad (5)$$

Step 6: Calculation of Ground Dimensions (Lg, Wg)

$$L_g = 6h + L\ ,\ W_g = 6h + W \quad (6)$$

where *f* is the resonant frequency of the antenna, *c* is the free space speed of the EM waves equal to speed of light, L is the actual length of the current element, ε_r is the effective dielectric constant of the substrate material and ΔL is the length of equivalent radiation parameter.

The F shaped slotted antenna was fabricated on (ε_r=4.4, tanδ=0.06) with overall patch dimensions 20.3×17 mm^2. The designed and simulated prototype is presented in Fig. 1

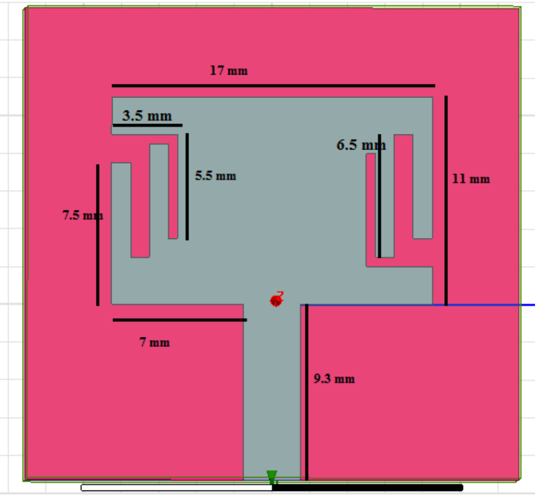


Fig 1. F slotted UWB microstrip Antenna

The antenna consists of a CPW line with a linearly tapered broadband transition terminated with a rectangular resonator. Two uneven linear segments are extended from both sides patch, along the direction of the feed line. In a transmission line equivalent circuit, the tapered segment with the F shaped slotted-shaped radiator can be considered as a broadband load that terminates a typical CPW line with length H=9.3 mm. If the equivalent load at the end of the CPW line was equal to the characteristic impedance of the line throughout the whole frequency band of operation, the H length would make no difference in the resulted return loss.

Fig 2 (a)Ground Plane

However, since the impedance of the load changes over frequency, the dimension H is critical in order to achieve good matching. A linearly tapered segment is used as a transition between the CPW line and the radiator. This size of the slotted F segment was chosen after a parametric sweep analysis was conducted, in order to achieve the best matching behavior between the CPW line and the ring. From the bottom part of the annular segment, a circular sector is created resulting in a circle of radius 5.5 mm. Since the most important parameter is the length of each stub, the width of the central stub was chosen to be narrower than the width of the side stubs, aiming to increase the distance and therefore reduce the coupling between the neighboring stubs. The overall dimensions of the fabricated antenna are only 25×26.2 mm^2.

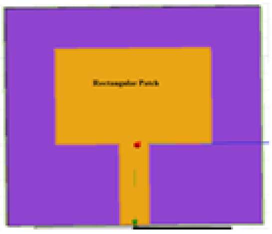


Fig 2 (b) Basic Patch Antenna

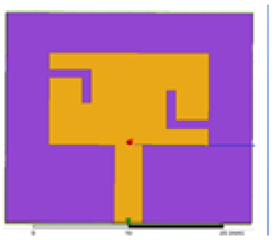


Fig 2 (c) L Slotted I

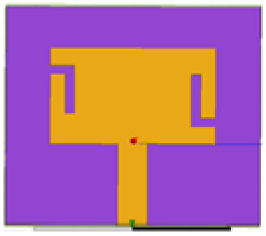


Fig 2 (d) L Slotted II

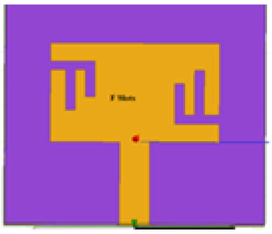


Fig 2 (e) F Slotted Patch

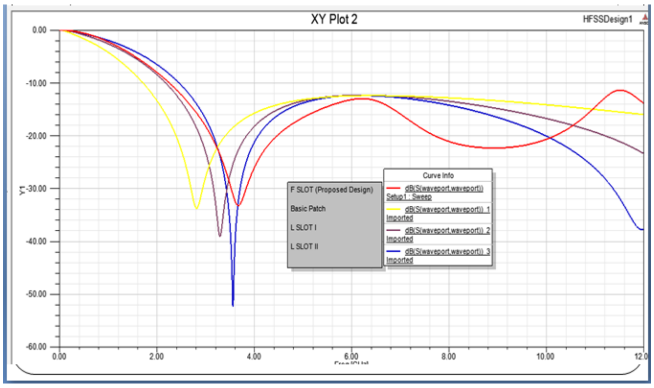


Fig 2 (b),(c),(d),(e)Return Losses UWB

III. SIMULATION AND RESULTS

The bandwidth of the circular planar microstip antennas is larger than any other planar microstip antenna configuration [14]. The main advantage of the circular planar microstip antenna over the rectangular planar microstip antenna can be interpreted in terms of its various resonant modes that are closely spaced, hence supportive for wideband operations like UWB. For a planar 3D microstip antenna, surrounded by air and operating in free space, the lower resonant frequency can be approximately calculated by equating its area $L_{\text{microstip antenna}} \times W_{\text{microstip antenna}}$.

The electromagnetic waves solver, Ansoft HFSS, is used to investigate and optimize the proposed antennas configuration. Fig. 3, shows the simulated return loss of the proposed antenna with the iteration optimized parameters. Obviously, the simulation results the ultra wideband of frequency for which the antenna designed is optimized i.e., 2.2 to 11.5 GHz with S_{11} value beyond -10 dB and the range of frequencies as per the results shows it has a wider bandwidth as compared to other microstrip antenna..Comparative results are mention in Table I.

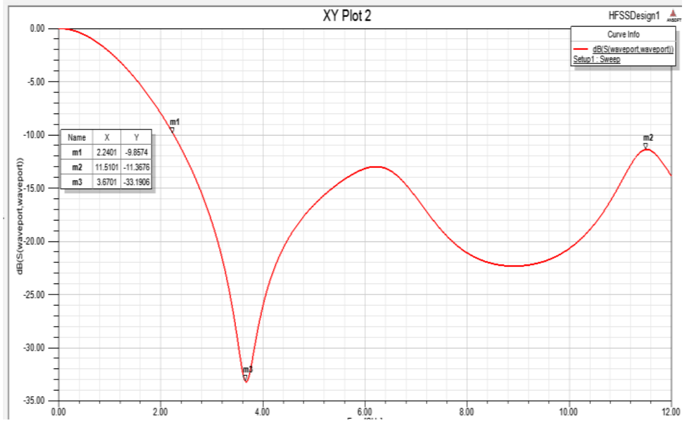


Fig 3(a) Return Loss Vs Frequency Plot

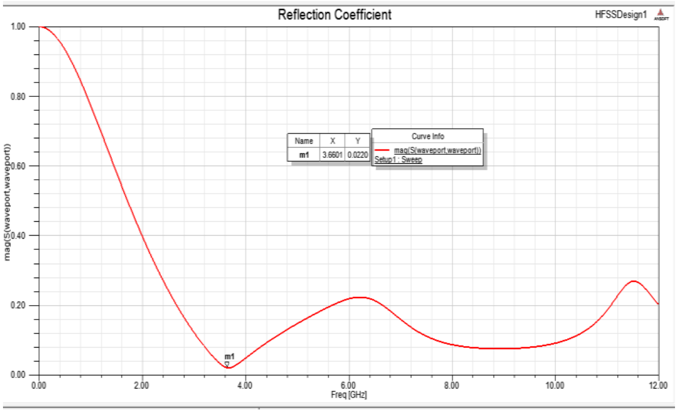
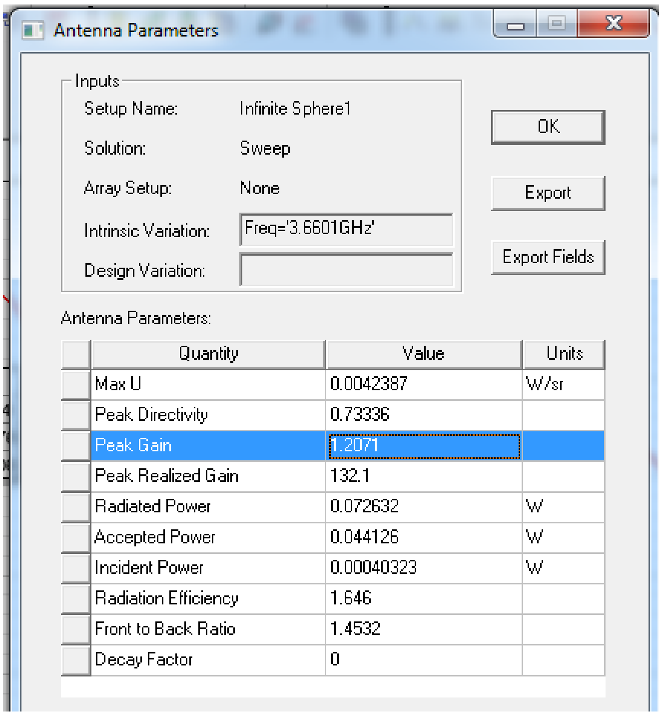


Fig 3 (b) Result for Reflection Coefficient Vs Frequency Plot.



Inputs

Setup Name: Infinite Sphere1
Solution: Sweep
Array Setup: None
Intrinsic Variation: Freq='3.6601GHz'
Design Variation:

Antenna Parameters:

Quantity	Value	Units
Max U	0.0042387	W/sr
Peak Directivity	0.73336	
Peak Gain	1.2071	
Peak Realized Gain	132.1	
Radiated Power	0.072632	W
Accepted Power	0.044126	W
Incident Power	0.00040323	W
Radiation Efficiency	1.646	
Front to Back Ratio	1.4532	
Decay Factor	0	

Fig 4 Antenna Results Window

Table I

Freq (GHz)	S_{11} (dB)	VSWR	Gain	Bandwidth (GHz)
3.66 GHz	-33 dB	1.2	1.2 dB	9.2 GHz

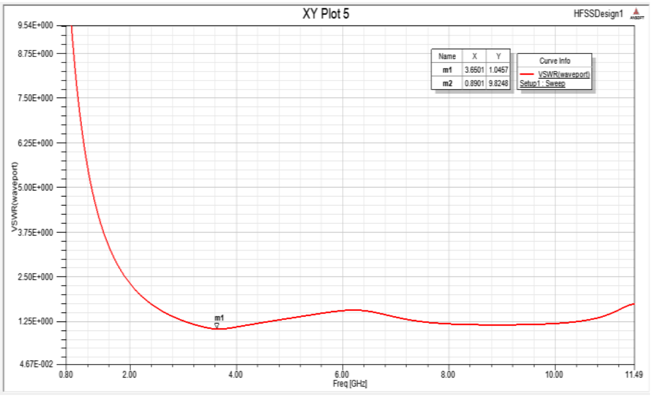


Fig 5 VSWR Vs Frequency Plot

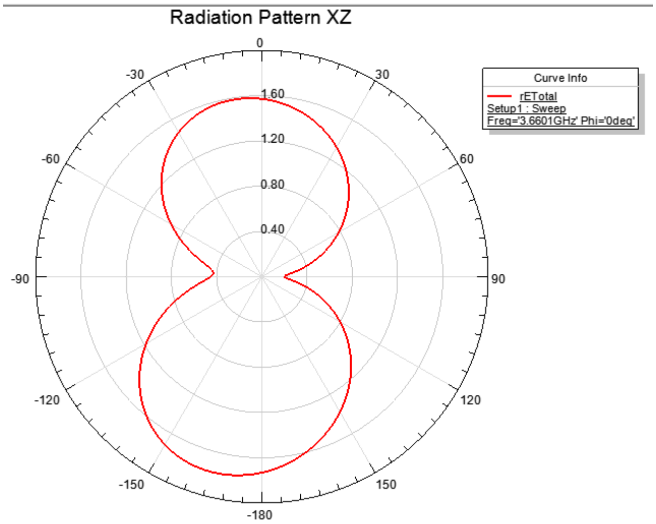


Fig 6 (a) XZ Radiation Pattern

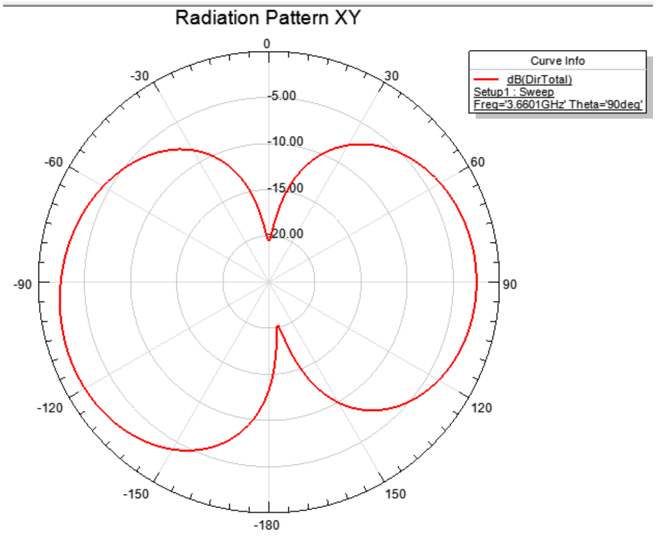


Fig 6 (b) XY Radiation Pattern

Fig. 6 (a) and (b) presents the comparison of simulated and normalized radiation patterns in both E and H-planes at 3.66 GHz. Based on the antenna orientation described in Fig. 6 x-z and x-y planes represent E and H-planes respectively. It is evident from the radiation patterns that the antenna is exhibiting, close to typical microstip antenna radiation patterns, in resonating frequency of 3.66 GHz, and in both planes, as well. The plots also confirm the sustainability in radiation performance of the F shaped slotted-shaped antenna throughout the UWB frequency range. Radiation patterns are in good agreement with the simulated predictions, validating the performance of the prototype. Although the antenna is not symmetrical, the presented radiation patterns are almost symmetrical. The expected asymmetry in the radiation patterns should be reflected on x-y plane cuts, however the measured patterns are presented only in x-z plane.

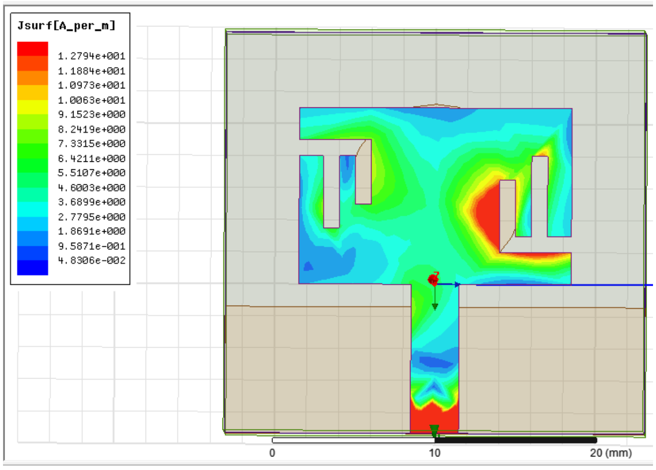


Fig 7 Resultant Current Density at 3.66 GHz for Proposed design.

The gain of the antenna grows linearly with respect to frequency and the overall gain remains within 1.2 dB range. The very consistent omnidirectional radiation patterns of the antenna, in H-plane, is the reason that maximum gain is kept low as can be deduced from Table II The consistent omni-directional patters in combination with the compact size of the F shaped slotted-shaped microstip antenna make the proposed antenna a good candidate for most UWB applications.

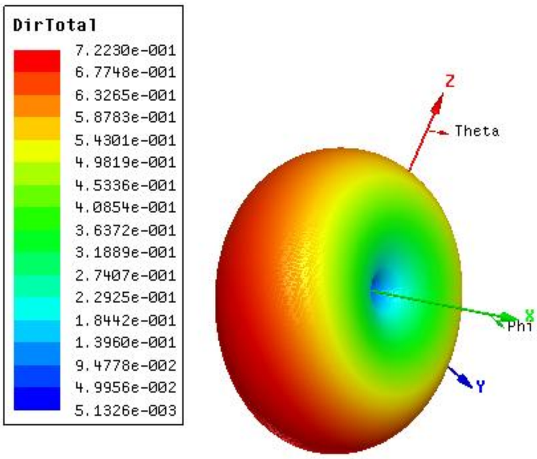


Fig 8. 3-D Radiation Pattern at 3.66 GHz for Proposed design

Table II Concluded Results

Operating Frequencies (GHz)	**VSWR**	**Radiation Efficiency**	**Gain (dBi)**	**Overall Bandwidth**	**Patch Dimension**
2.2 - 11.5	1.04	1.64	1.14	9.3 GHz	20.3 x 17 mm2

IV. CONCLUSION

A novel CPW fed, compact, F shaped slotted-shaped microstip antenna is presented. The radiation mechanism of the antenna, depends on three radiating stubs, connected to a semi-annular ring creating a F shaped slotted shape radiator. The resonances of the antenna were initially predicted with an analytical formula using classical theory of CPW line-fed, semi-annular, and rectangular, radiators. Full wave EM simulator was further used to optimize the performance of the antenna to exhibit good impedance matching throughout the whole UWB frequency range. The lengths of the three radiating stubs control the position and depth of $|S_{11}|$ resonances, hence allow a direct control on the return loss and therefore on the antenna matching. Slot insertion causes size reduction which increases bandwidth and return loss (RL) as well. This feature allows a readjustment of the antenna characteristics to focus on different UWB sub-bands, making the presented antenna a potential candidate for next generation UWB transceivers, which may operate in designated sub-bands, depending upon the specifications of the desired application.

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