PERFORMANCE EVALUATION OF SPATULA SHAPE UWB ANTENNA USING PARAMETRIC ANALYSIS APPROACH ON THE DIMENSIONS OF INVERTED T-SLOT AND STUB GEOMETRY

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***Abstract*- An ultra-wideband (UWB) antenna with a multiband UWB antenna is presented. The antenna has been fabricated on an FR4 substrate and occupies an area of only 25 × 25 mm2. The study is extended for geometry reduction and better performance evaluation with a parametric analysis approach The proposed antenna is designed to operate from 2 to 12 GHz. It consists of a spatula shape patch with a partial ground plane to form an antenna. The antenna results are found much better with T slot and stub. Details of the proposed antenna design and measured results are presented and discussed.**

Keywords:- Circular disc monopole, microstripline feed, parametric approach, inverted T, Ultra wideband (UWB).

I INTRODUCTION

In recent years, more interests have been put into WPAN technology. The future WPAN aims to provide reliable wireless connections between computers, portable devices and consumer electronics within a short range. Furthermore, fast data storage and exchange between these devices will also be accomplished. The UWB concept is especially attractive since it facilitates the optimal Sharing of a given bandwidth between different systems and applications. This caused an UWB technology is a promising technology for High data rate devices.

II SPATULA SHAPE MONOPOLE PRINTED UWB ANTENNA

The band-notch function is desirable in the UWB system to reduce the interferences with the IEEE802.11a and HIPERLAN/2 WLAN systems operating in the 5-6GHz band..Generally, the design concept of the notch function is to adjust the total length of the slot to be approximately half-wavelength at the desired notched frequency, which makes the input impedance singular at the slot-resonant frequency. To implement it, a narrow-band resonant structure is added to the original wideband antenna area. The inverted T slot is taken for study. The dimensions of the band notched design can be postulated as

$$F_{notch} = \frac{c}{2L\sqrt{\varepsilon eff}} \qquad (1)$$

Where L is the total length of the slot, *εeff* is the effective dielectric constant and c is the speed of the light. We can take (eq 1) into account in obtaining the total length of the slits at the very beginning of the design and adjust the geometry of the final design. The single band notched UWB antenna successfully blocks out the 5-6GHz band and still performs good impedance matching at other frequencies in the UWB band. The antenna gain in the entire UWB band is presented in Figure.5 (b). This shows a sharp gain decrease in the 5-6GHz band and good performance at other frequencies in the UWB band. The impedance nearby the feed-point changes acutely making a large reflection of the desired notched frequency; this causes the antenna to be unresponsive at that frequency.

III ANTENNA DESIGN AND PERFORMANCE

The geometry of the designed dual band-notched UWB antenna is shown in Fig1, the antenna is fabricated on a low-cost FR4 substrate with the thickness of 1.6 mm and the dielectric constant of 4.4. The radiator is a spatula shape patch with radius=9mm..

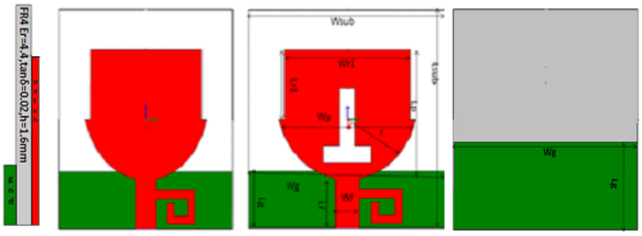

Figure 1:- Geometries of designed Spa tuna shape UWB antenna

The parametric study is carried out using the Ansoft HFSS Software. Simulation results on S11 and VSWR with different values of Lg are shown in Fig2 and Fig 3 respectively. From the figures we can see that the resonant frequency varies with Lg. This property provides a great freedom to the designers to select the proper value of Lg. One of the drawbacks with this design is, it is not a good dual band antenna. To have a perfect dual band design, it must suppress some narrow band at the lower end of UWB. To overcome this problem parametric approach is used in geometry of inverted T and stub.

A The Effect of the Dimension of the ground plane length

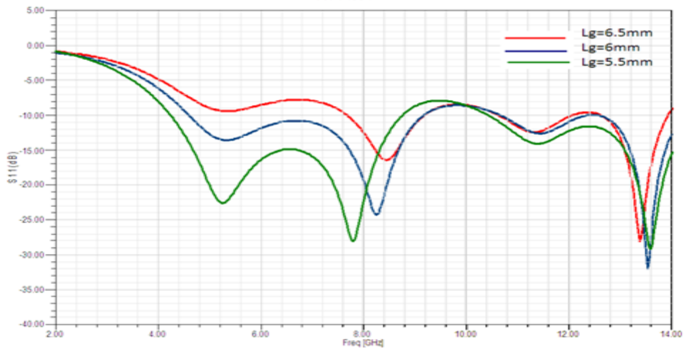

Fig.2:- Simulated return loss curves for antenna designs shown in fig1.

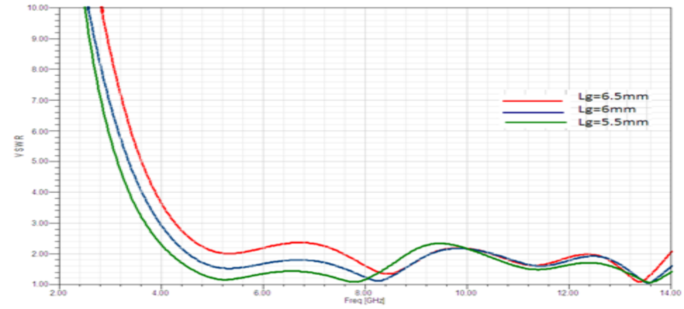

Figure 3:- Simulated VSWR curves for the antenna designs shown in 1a

B Improved Design with slot and Stub for WPAN Application

It is shown that the achieved bandwidths of these antennas cannot cover the whole FCC defined UWB frequency band from 3.1GHz to 10.6GHz. Besides, the sizes of the antennas are not very small. The novel designs of printed spatula shape antenna with inverted slot and the stub is considered for analysis.

C Evolution of spatula shape UWB antenna with slot and stub

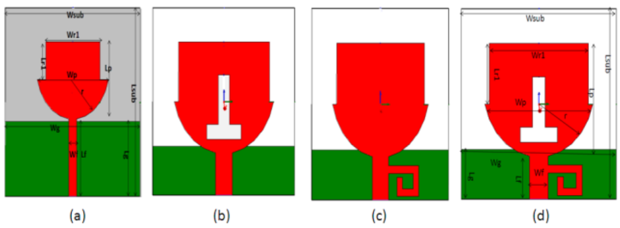

Figure4:-Geometry of improved DMP UWB antenna (25mm×25mm×1.6mm) with slot and stub.

A spiral shaped tuning stub is introduced to enhance the coupling between the slot and the feed line so as to broaden the operating bandwidth of the antenna. Enhancement can be achieved by adjusting the length of the ground plane. The antenna structures considered in this section offer omnidirectional radiation pattern over UWB. The antennas are designed using a low cost, easily available FR4 substrate. The antenna structures offer many attractive advantages such as low cost, light weight, high efficiency, ease of fabrication; stable gain, small group delay variation and their radiation patterns indicate their suitability for UWB applications. The structure offers low cross polarization and less than 3dB gain difference along the transverse axes., within the designated bandwidth of UWB systems. There are some narrowband services that already occupy frequencies in the UWB band, such as WiMAX [IEEE 802.16] operating in the 3.3 to 3.7 GHz, C band satellite communication in the 3.7 to 4.2 GHz and WLANs [IEEE 802.11a and HIPERLAN/2] operating in the 5.15–5.825 GHz band..Figure 6 shows the designed antenna structure with slot and stub. This study will investigate the effect of inverted T slot and stub. The rectangular ground plane is used for impedance matching. The radiator is fed by a microstrip line of 3 mm width. On the front surface of the substrate, a rectangular patch with a size of 16 mm x 9 mm is printed. The distance between the rectangular patch to ground plane printed on the back surface substrate is1 mm, and the length of the truncated ground plane of 6 mm. The excitation is a 50 Ω microstrip line printed on the partial grounded substrate. The Inverted T slot and spiral stub result novelty structure of spatula shape UWB antennas,.

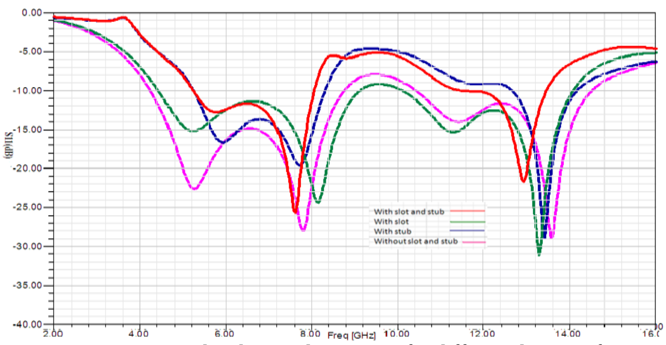

Figure 5.- Simulated return loss curves for different designs of DMP

IV ANTENNA GEOMETRY

The designed UWB antenna is a variation of the circular monopole antenna. Initially a circular monopole antenna of radius `r' is designed and optimized to achieve the desired UWB response. Since the current is mainly concentrated along the periphery of the circular monopole antenna, therefore, Upper portion of the circular monopole of radius `r' can be removed with negligible effect on impedance bandwidth or radiation characteristics and resulting in a semicircular ring monopole antenna. Thereafter rectangle shape monopole antenna adds to it without affecting the UWB impedance bandwidth. The additional space available in the central portion of the monopoly provides design accessibility. To reduce the interferences from the WiMAX systems, the band-notched function is desirable in the UWB system. By etching the inverted T and inserting a spiral shaped λ/4 open stub in the microstrip feed line, the frequency band notch for WiMAX and WLAN is created.

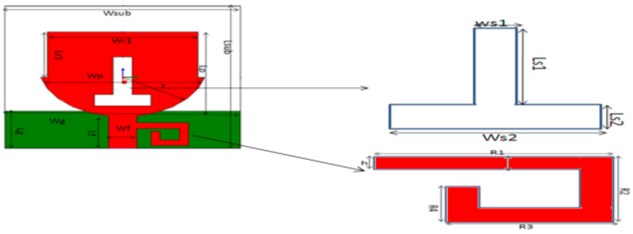

Figure6:-Geometry of improved spatula UWB antenna (25mm×25mm×1.6mm) with slot and stub

Table 1:-Dimensions (in mm) of a designed Spatula shape UWB antenna

Wsub	Lsub	Wp	Lp	Wg	Lg	Wf	Lf	Wr1	Lr1	r
25	25	18	16	25	7	3	6	16	9	9
Ws1	Ls1	Ws2	Ls2	R1	R2	R3	R4	-----	----	--
2	7	5	2	6	4	4	3	-----	----	--

A Effect of the dimension of Inverted T slot

The optimized dimensions of the proposed structure with slot and stub are tabulated in Table 1 Fig 6 shows the geometry and configuration of proposed printed dual band-notched donut shape UWB antenna.The High frequency structure simulator software is used for design,simulation and optimization. To reduce the interferences from the WiMAX systems, the band-notched function is desirable in the UWB system and to find out the proper band rejection following equations are used.

$$f_{WLAN\text{-}notch} = \frac{c}{4(L+2\Delta L)\sqrt{\epsilon_{eff}}} \text{ GHz} \quad (2)$$

$$\varepsilon eff = \frac{(\varepsilon r+1)}{2} + \frac{(\varepsilon r-1)}{2}\left(\sqrt{1+\frac{12H}{Wg}}\right)^{-1} \quad (3)$$

$$\Delta l = \frac{0.412H(\varepsilon eff+0.3)\left(\frac{Wg}{H}+0.262\right)}{(\varepsilon eff-0.258)\left(\frac{Wg}{H}+0.813\right)} \text{CM} \quad (4)$$

whereL= [(Ws2+Ls1)-(Ws1+Ls2)] is the total length of the Inverted T slot and H is the substrate height in cm, "εeff and"εr are the effective and relative dielectric constants respectively.The physical length of Inverted T-shaped slot at central notched frequency of 7.5 GHz is calculated using Equations (5.2), (5.3) and (5.4), εeff = 3*:*3, Δ*l* = 0.753 mm and *L* = 8 mm.The length of the Inverted T-shaped slot is equal to L= [(Ws2+Ls1)-(Ws1+Ls2)]=[(5+7)-(2+2)]=8mm which is close to the calculated value.The ground plane is beveled which results in a smooth transition from one resonant mode to another and ensures good impedance match over a broad frequency range. The dimensions of quarter-wave resonating (Inverted T shaped) slot at central band-notched frequency can be postulated.

B Effect of the dimension of spiral stub

The physical length of spiral shaped open stub at a central notched frequency of 7.5 GHz is calculated using Equations (5.2) and (5.4), εeff= 3.3,and wg=25 mm. The length of the spiral stub using design is equal to w= [R1+R2+R3+R4] = 17 mm value.

$$f_{wimax\text{-}notch} = \frac{c}{4w\sqrt{\varepsilon eff}} \text{ Ghz} \quad (5)$$

where w=[R1+R2+R3+R4] is the total length of the spiral stub, "εeff is the effective dielectric constant, and c is the speed of light (= 3×10^8m/s)

C Effect of the Antenna Parameters on its Performance

During the parametric study, one parameter varies while all other parameters are kept fixed. The optimized antenna parameters are: wsub=25mm, Lsub=25mm, Lg=7mm, Wp=18mm, Lp=16mm, Lf=6mm and Wf=3mm.The width of the feed Wf, the maximum achieved impedance bandwidth is determined.The Inverted T slot inside the radiating patch acts as an impedance matching element which controls the antenna impedance matching as well as the antenna impedance bandwidth. Also, the slot in the radiating patch can be used for miniaturizing the monopole antenna. The optimum values for Lg, slot length and stub length 6.5, 8 and 17 mm, respectively. Cutting out inverted T slot from the patch to reduce the overall metallic area and hence reduce the antenna copper losses without affecting the antenna operation or disturbing the current distribution of the antenna is a challenging task. From the electric field distributions, it is noticed that the monopole antenna supports multiple resonant modes. It can be seen that the current distribution is mainly located close to the radiating patch edges rather than in the center.

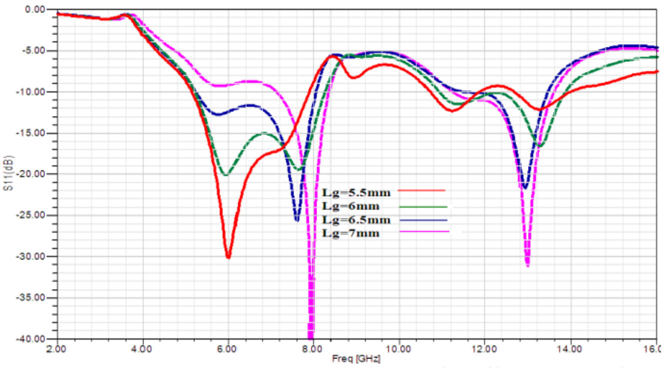

Figure7:- Simulated return loss curves for different values of Lg

For increasing the maximum achieved impedance bandwidth, the lower resonant frequency should be decreased. This can be done by increasing the antenna perimeter which directly affects lower resonant frequency and then the antenna impedance bandwidth.To increase the antenna perimeter, cutting out steps from the radiating patch are used.This is simply because the surface current will take longer path when the antenna perimeter P is larger and the new antenna with larger perimeter P appears to be like a longer length monopole antenna and then the lowest resonance frequency Fl will be decreased according to [63]. Near the feed point, the current is mainly distributed on the Upper edge along the y-direction. That means the portion of the ground plane close to the feed line acts as the part of the radiating structure. Consequently, the performance of the antenna is critically dependent on the width of the ground plane Wg.. The simulated effect of feed width is shown in fig 8.

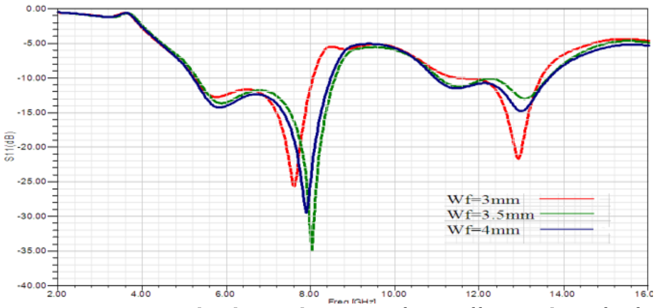

Figure8:- Simulated return loss curves for Different values of Wf

D Radiation Patterns and Gain

The antenna exhibits a stable omnidirectional radiation over UWB bands except in notched frequency bands. At higher frequencies, the radiation pattern deteriorates because the equivalent radiating area changes with frequency over UWB..The proposed antenna has a nearly omnidirectional radiation characteristic in the *H* plane and a figure of eight radiation pattern in the *E* plane over the desired band. The proposed antenna provides more than 90% radiation efficiency except at the notched frequency bands.

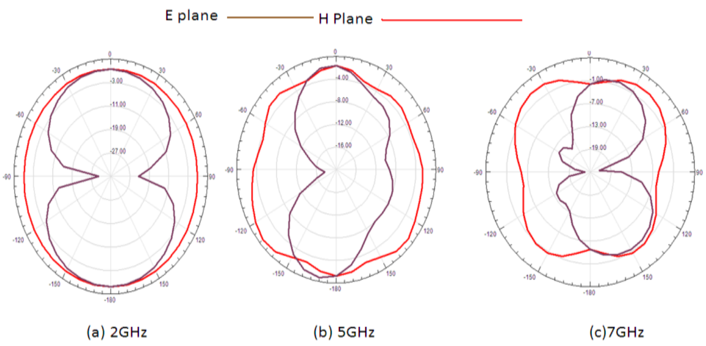

Figure 9:- Radiation pattern of designed antenna at 2, 5 and 7 GHz frequencies.

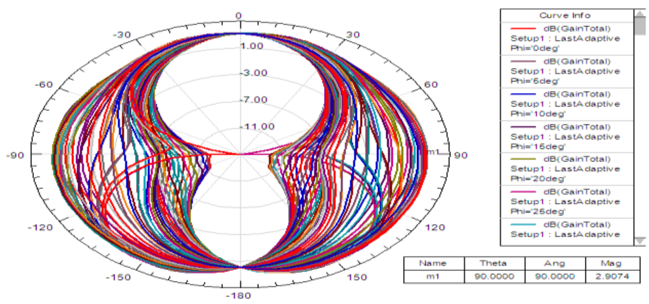

Figure10:- simulated Gain of designing DMP UWB antenna at $\Phi=0^0$to 360^o and $\theta=90^0$, Gain =2.90dB at 8GHz

V. CONCLUSION

A simple, low cost and compact printed spatula shaped dual band antenna is proposed. This microstrip line fed antenna can be easily integrated.. The dimensions of the central rectangle govern the Bluetooth band while the dimensions of semicircle-shaped monopole govern the UWB band. The dimensions of stub and inverted T controlled to minimize the potential interferences between the UWB. The proposed antenna provides more than 80% antenna efficiency and moderate gain. The radiation patterns are nearly omnidirectional over the desired bands except in the WLAN notched band. The proposed antenna is a good candidate for integrated UWB application.

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