

Design and Analysis of Wideband U-T shaped Slotted patch Antenna for WLAN & Wi-Fi Applications

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Abstract— A wideband U-T Shaped Slotted patch antenna is presented in this paper for WiMAX and S-band applications. The antenna presents more gain and wide bandwidth enhancement when compared to a conventional microstrip patch. The proposed antenna comprises a rectangular patch and combination of U-T-slot in center of patch and apart from this it also consists 8mm air gap bet patch and gnd to provide wideband performance. The antenna has been designed on FR4 substrate with an overall dimension of 70mm*70mm*1.6mm. The substrate has dielectric constant of 4.4 and thickness of 1.6 mm. The simulated results shows that the proposed antenna achieves excellent impedance matching an operating bandwidth of 1.96–2.69 GHz (29.18%). Thus it covers WiFi 2.4GHz band, WiMAX 2.5GHz band and LTE 2.5-2.69 GHz band. The gain of this antenna is around 4.3dBi for most of the frequency band and therefore the proposed antenna is suitable for wireless communication applications. In addition, effects of different slot like U, F, E in patch and air gap are examined and discussed in detail. The radiation pattern, directivity, return loss, VSWR and Bandwidth of the proposed antenna are described and simulated using HFSS software package.

Key words: Rectangular MSA (RMSA), U-slot, U-T slot, E slot, F slot, HFSS simulation

I. INTRODUCTION

The first concept to understand regarding antennas is that they are passive devices. To operate, they require no supply voltage. They do not alter nor do process RF signals and they not amplify RF energy. If they are 100% efficient, they cannot radiate more total power than is delivered to their input terminal. The basic properties that are used to describe the performance of an antenna include impedance and VSWR (Voltage Standing Wave Ratio), amplitude radiation patterns, 3 dB beam width, directivity, gain, polarization, and finally, bandwidth. These properties and their impact on system performance are discussed in this paper. U slot shape has been extensively used to increase bandwidth of antenna. In its most basic form, a Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to

design a compact Microstrip patch antenna, higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a compromise must be reached between antenna dimensions and antenna performance.

A. Feeding Technique

Feeding technique used for proposed paper is Coaxial Feed. The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. Another parameter which affects the design is the feed position. The feed location is moved from the center of the geometry to get the best possible impedance match and radiation characteristics for the antenna. It is seen that offset of feed position from the center controls the center and width of the operational band.

II. ANTENNA PARAMETERS AND ITS DESIGN

The first concept to understand regarding antennas is that they are passive devices. To operate, they require no supply voltage. They do not alter nor do process RF signals and they not amplify RF energy. If they are 100% efficient, they cannot radiate more total power than is delivered to their input terminal. The basic properties that are used to describe the performance of an antenna include impedance and VSWR (Voltage Standing Wave Ratio), amplitude radiation patterns, 3 dB beam width, directivity, gain, polarization, and finally, bandwidth. These properties and their impact on system performance are discussed here.

The three essential parameters for the design of a rectangular Microstrip Patch Antenna are:

- Frequency of operation (f_o): The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for design is 2.4 GHz.
- Dielectric constant of the substrate (ϵ_r): The dielectric material selected for design is FR4 epoxy which has a dielectric constant of 4.4.
- Height of dielectric substrate (h): For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6 mm.

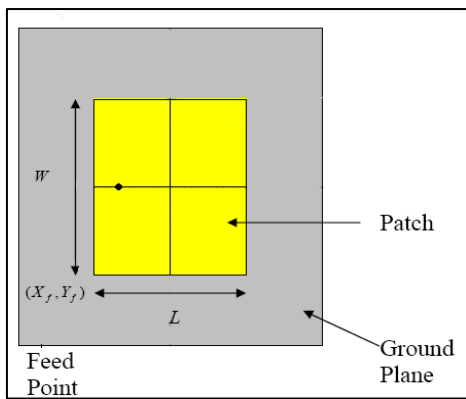


Fig. 1: Rectangular microstrip antenna

The initial calculation starts from finding the width of the patch which is given as:

A. Geometry band U-slot patch antenna

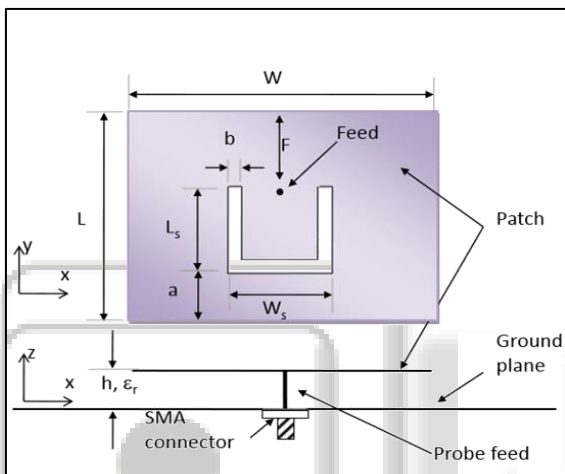


Fig. 2:

B. Output Parameters Calculations:

$$\lambda = c/f = 3 \times 10^8 / 2.4 \times 10^9 = 125 \text{ mm at } 2.4$$

1) Step a): Calculation of the width of Patch (W)-
The width of the Microstrip patch antenna is given as

$$W = \frac{c}{2f_o \sqrt{\frac{\epsilon_r + 1}{2}}}$$

For $c = 3 \times 10^8 \text{ m/s}$, $f_o = 2.4 \text{ GHz}$, $\epsilon_r = 4.4$
We get $W = 38.22 \text{ mm}$.

2) Step b): Calculation of effective dielectric const-
Fringing makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant is introduced, given as:

$$\epsilon_{r_{eff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1/2}$$

For $\epsilon_r = 4.4$, $h = 1.6 \text{ mm}$, $W = 38 \text{ mm}$
We get $\epsilon_{r_{eff}} = 3.99$

3) Step c): Calculation of Length of Patch(L)-
The effective length due to fringing is given as:

$$L_{eff} = \frac{c}{2f_o \sqrt{\epsilon_{r_{eff}}}}$$

For $c = 3 \times 10^{11} \text{ mm/s}$, $\epsilon_{r_{eff}} = 3.99$, $f_o = 2.4 \text{ GHz}$

We get $L_{eff} = 30.25 \text{ mm}$

Due to fringing the dimension of the patch as increased by ΔL on both the sides, given by:

$$\Delta L = 0.412h \frac{(\epsilon_{r_{eff}} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{r_{eff}} - 0.258) \left(\frac{W}{h} + 0.8 \right)}$$

For $W = 36.4 \text{ mm}$, $h = 1.53 \text{ mm}$, $\epsilon_{r_{eff}} = 3.99$

We get $\Delta L = 0.70 \text{ mm}$

Hence the length of the patch is:

$$L = L_{eff} - 2\Delta L = 28.4 \text{ mm}$$

4) Step d): Calculation of Substrate dimension-

For this design this substrate dimension would be

$$L_s = L + 2 * 6h = 28 + 2 * 9.6 = 49 \text{ mm}$$

$$L_s = 49 \text{ mm}$$

$$W_s = W + 2 * 6h = 38 + 2 * 9.6$$

$$W_s = 58 \text{ mm}$$

5) Step e): Calculation of feed point-

For this feed would be given $L/4$ distance. i.e 7.5mm.

Calculated Parameters table-

Sr.No	Parameters	Calculated Dimensions(mm)
1.	L	28.4
2.	W	38.0
3.	Ls	49.0
4.	Ws	58.0
5.	y0	7.0

6) Return loss:

It indicates the amount of power that is lost to load and does not return as reflection. Return loss is a parameter similar to VSWR to indicate how well the matching between transmitter and antenna has taken place.

III. RESULT AND ANALYSIS

A. U-slot Patch Antenna

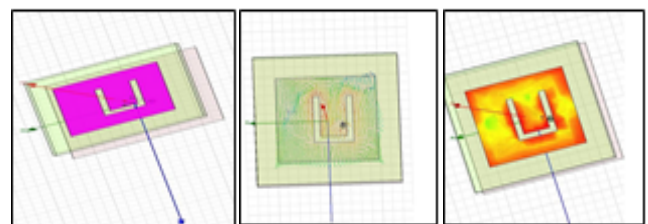


Fig. (a)

Fig. (b)

Fig. (c)

Fig. 3: (a)-Geometry of U-slot patch antenna, Fig(b) and Fig(c)-Current density vector.

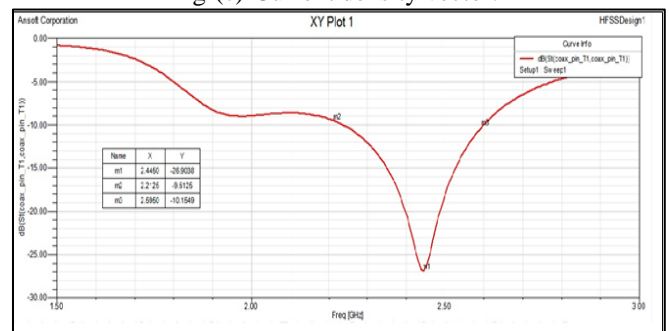


Fig. 4: (d) -Simulated return loss of the U-slot RMSA
From simulation for U slot RMSA we got the return loss of -26.9038dB .

NAME	X(GHZ)	Y(dB)
M1	2.4450	-26.9038
M2	2.2125	-9.5125
M3	2.5950	-10.1549

Fo = 2.4450GHz

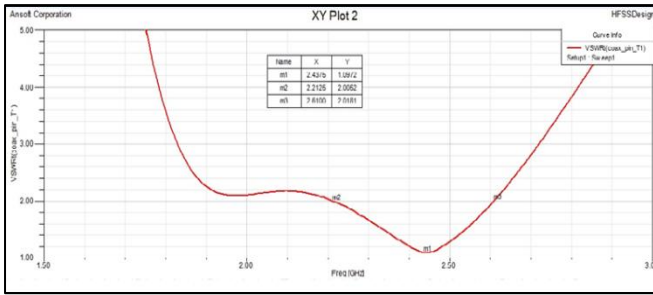


Fig. 5: (e) –Simulated VSWR of the U-slot RMSA

The ideal value of vswr is in between 0-1,in proposed project we got VSWR 1.09 The VSWR provides an indication of how closely the impedance of an antenna matches the impedance of the connecting transmission line. If an impedance mismatch exists, a reflected wave will be created towards the energy source. This reflected wave reduces the level of forward energy transferred from the transmission line to the antenna. This effectively reduces the total level of energy available for radiation thus reducing the effective gain of the antenna.

NAME	X(GHZ)	Y
M1	2.4375	1.0975
M2	2.2125	2.0052
M3	2.6100	2.0181

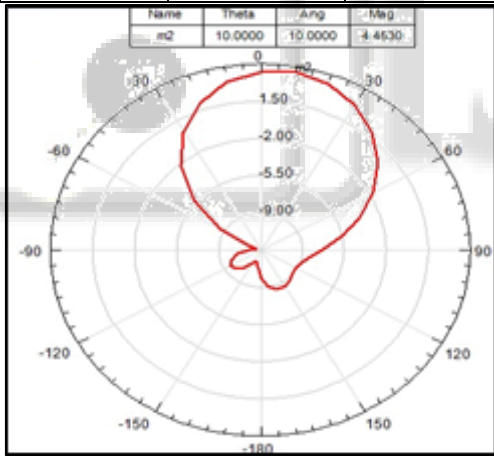


Fig. 6: (f) Radiation pattern of U slot RMSA AS Shown in above fig (f)–we got directivity of 4.4dB

Name	Theta	Angle	Magnitude
M2	10.0000	10.0000	4.4530

B. RMSA E-slot

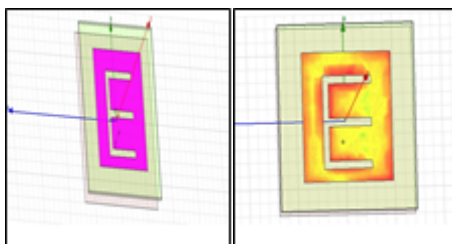


Fig. 7: (G)Geometry of E-slot patch antenna, Current density vector

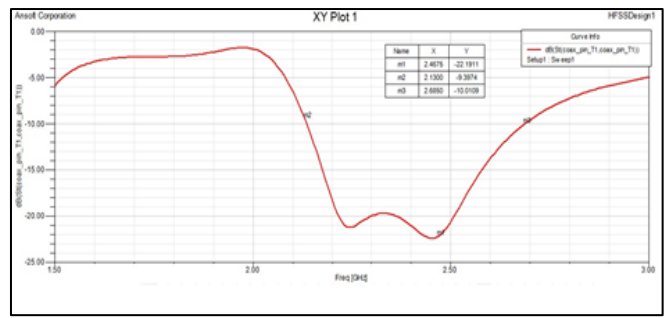


Fig. 8: (H) -Simulated return loss of the E-slot RMSA. Fo = 2.4675GHz

NAME	X(GHZ)	Y(db)
M1	2.4675	-22.1911
M2	2.1300	-9.3974
M3	2.6850	-10.0109

From simulation for U slot RMSA we got the return loss of -22.1911dB.

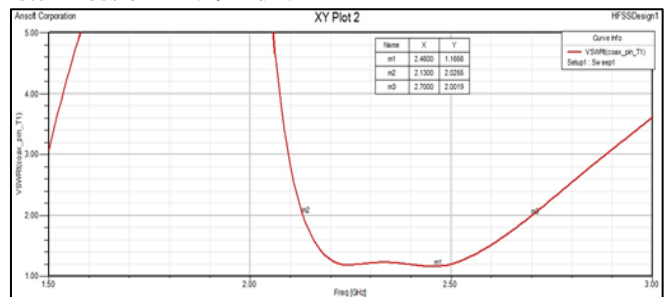
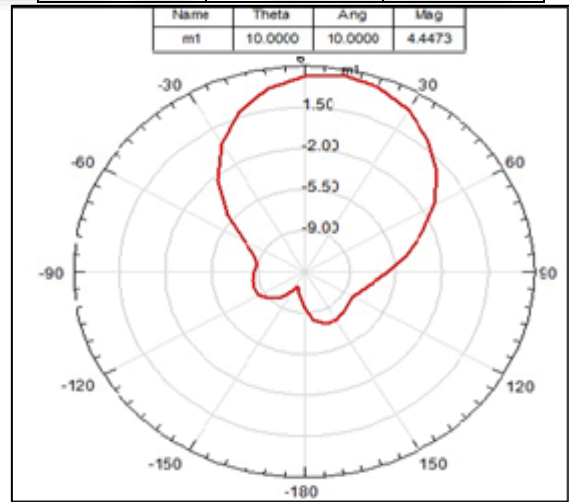


Fig. 9: (I) –Simulated VSWR of the E-slot RMSA

The ideal value of vswr is in between 0-1,in proposed project we got VSWR 1.16

NAME	X(GHZ)	Y
M1	2.4600	1.1656
M2	2.1300	2.0255
M3	2.7000	2.0019



AS Shown in above fig. 10: (J) –we got directivity of 4.3db Fig –(J) Radiation pattern of E slot RMSA.

Name	Theta	Angle	Magnitude
M2	10.0000	10.0000	4.1973

C. RMSA U & T slot

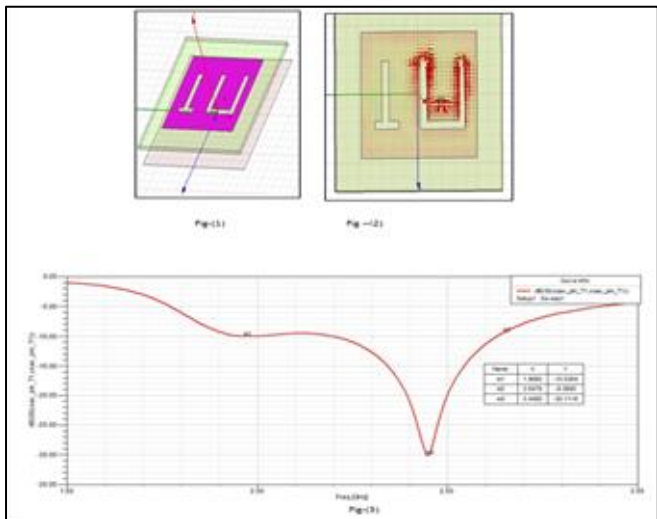


Fig. 11: (3) -Simulated return loss of the U AND T-slot RMSA

From simulation for U slot RMSA we got the return loss of -10.0364dB.

Fo =1.9600 GHz

NAME	X(GHZ)	Y(db)
M1	1.9660	-10.0364
M2	2.6475	-9.3865
M3	2.4450	-30.1118

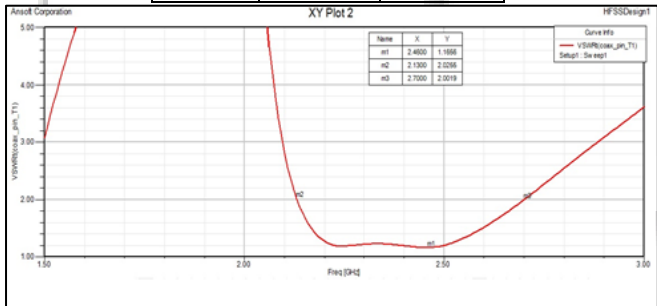


Fig. 12: (4) –Simulated VSWR of the U AND T-slot RMSA in proposed project we got VSWR 1.06

NAME	X(GHZ)	Y
M1	2.4450	1.0644
M2	1.9200	1.9815
M3	2.6400	1.9868

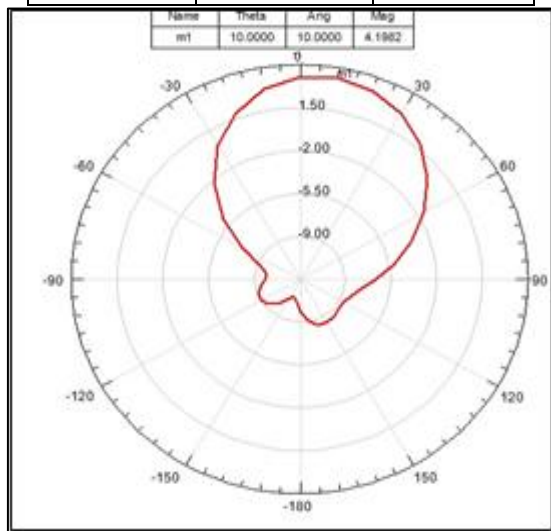


Fig. 13: (5) Radiation Pattern of U AND T Slot RMSA

AS Shown in above fig (5) –we got directivity of 4.19db

Name	Theta	Angle	Magnitude
M2	10.0000	10.0000	4.1982

IV. CONCLUSION

U-T-slotted patch antenna has been proposed to operate in the frequency band of WLAN 2.4-2.48 GHz and Wi-Fi 2.4-2.5Ghz.The simulated return loss is -30.91 dB and the antenna presents a good highly directional radiation pattern with wideband performance.

In this paper, we proposed design of U-T slot microstrip patch antenna with and without suspended techniques where the with suspended techniques bandwidth increase of proposed antenna as compared to simple patch antenna. In this design we get a maximum bandwidth is approximately 700 MHz at U-T Shape slot, gain 4.3dB and VSWR is equal 1.05. These properties of proposed antenna show that it could be successfully used for WiFi, and WLAN application.

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