DESIGN AND OPTIMIZED ANALYSIS OF T- SLOTTED TRAPEZIUM SHAPED MICROSTRIP PATCH ANTENNA

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Abstract - A Trapezium shaped microstrip patch antenna with T- slot is presented in this paper. To design Trapezium shaped patch antenna, FR4 substrate are used. The relative permittivity of substrate is 4.4 and loss tangent is 0.0013. The substrate has thickness of 1.6 mm, on which a patch of Trapezium shape is designed and T- slot is etched. The **antenna is fed by 50 Ω coaxial probe feed. The** designed is simulated using IE3D software. We optimized the design of proposed antenna by varying the dimension of T-slot and obtain a broad band width 67.25% (2.38 GHz – 4.79 GHz), and the resonant frequency 4.45GHz. The feed is provided at point (5, 5) which gives a good match for impedance. Thus proposed antenna can be used in the Wi-max (2.2-3.4 GHz), WLAN (2.40–2.48 GHz), and UMTS II (2.50–2.69 GHz) frequency bands.

Keyword: T- slot, Wide band, Microstrip patch antenna, Co-axial probe feed.

INTRODUCTION

Due to day by day advancement in wireless communication there is always unprecedented demand to create compact or even electrically small antennas that are compatible with modern technology, which will operate on a small handheld ground plane, and satisfy the performance specifications, particularly with respect to bandwidth and efficiency [4].

Hence for the above purpose microstrip antennas are more attractive due to their light weight, conformability, low cost and ease of fabrication [1].These antennas can be integrated with printed strip-line feed networks and active devices. In its most fundamental form, a microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. For a rectangular patch, the length of the patch is usually $0.3333\lambda_0 < L < 0.5\lambda_0$, where λ_0 is the free space wavelength. The patch is selected to be very thin such that $t \ll \lambda_0$ (where t is patch thickness).The height 'h' of the dielectric substrate is usually $0.003\lambda_0 \leq h \leq 0.05\lambda_0$ .The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$ [9].

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 [3-7].However such a configuration leads to a larger antenna size. To design a wideband microstrip patch antenna, substrate having higher dielectric constant is used, which is less efficient. This results narrow bandwidth. Hence a trade-off must be realized between the antenna dimensions and it's performance. However the major disadvantage of the microstrip patch antenna is its inherently narrow impedance bandwidth. Much intensive research has been done and going on to enhance the bandwidth and techniques. These techniques include the utilization of thick substrate with low dielectric constant and slotted patch also [1].

By the use of different feeding techniques one can get better performance results. In this paper we use 50 Ω co-axial probe feed.

ANTENNA DESIGN

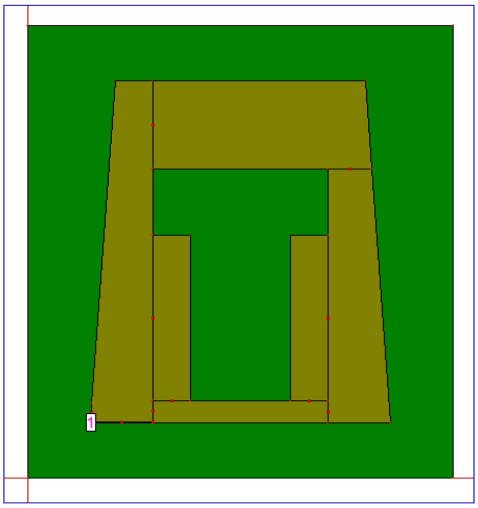

Figure 1: Proposed Antenna

The first step in the design is to choose a suitable dielectric substrate of appropriate thickness (t), dielectric constant and loss tangent. A thicker substrate, besides being mechanically strong it will increase the radiated power, reduce the conductor loss and improve impedance bandwidth [3].

A larger patch width increases the radiated power, bandwidth and radiation efficiency and decreases resonant resistance. It has been suggested that the inequality 1< W/L< 2 must be satisfied for better performance. In case of microstrip antenna, it is proportional to its quality factor Q [9].

The dielectric material selected for this design is FR4 substrate, which has a dielectric constant ε_r=4.4, loss tangent tanδ=0.0013, the height of the dielectric substrate is h = 1.6 mm. The Wi-Fi applications use the frequency range from (2.38-4.79) GHz. Some frequency bands applications are also available named Wi-max (2.2-3.4 GHz), WLAN (2.40–2.48 GHz), and UMTS II (2.50–2.69 GHz) frequency bands. Here the design frequency (f_o) is selected 2.9 GHz.

The Design parameters of proposed MSA antenna is given in Table1.

TABLE 1: ANTENNA DESIGN PARAMETERS

Parameter	Value	Parameter	Value
H	1.6mm	Feed point 1	(5,5)mm
ε_r	4.4 GHz	L_1	20 mm
f_o	2.9GHz	L_2	14 mm
Lg	34mm	L_3	8 mm
Wg	41mm	W_1	15 mm
L	24 mm	W_2	6 mm
W	31mm		

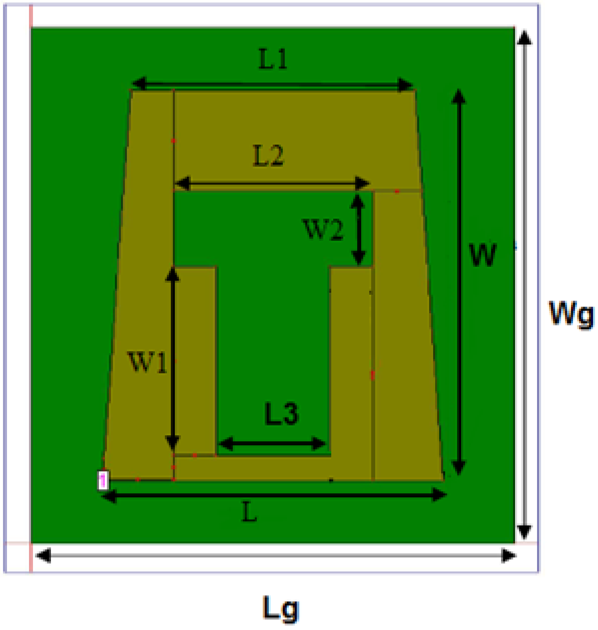

Figure 2: Proposed Antenna Geometry

Figure 1 shows the layout of a coaxial probe-fed trapezium patch antenna. First the ground plane of Length Lg and Width Wg is made and then a trapezium patch of given dimensions as mentioned in table 1, is printed above the ground plane of microstrip antenna which is at a height of 1.6mm(in case of FR4 material) from the ground. Feed is provided by co-axial probe of 50 Ω at point (5, 5) and doing this the bandwidth has enhancedupto67.25% in frequency range (2.38-4.79) GHz with resonant frequency (f_r) 4.45 GHz.

In the process of designing microstrip patch antenna, the size of the radiation patch and ground plane can be similar to the following formulas.

Width of radiating patch [12]:

$$W = \left(\frac{c}{2f_r}\right)\left(\frac{\varepsilon_r + 1}{2}\right)^{-0.5} \quad (1)$$

The effective dielectric constant [4]:

$$\varepsilon_{reff} = \left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\left(1 + \frac{12W}{H}\right)^{-0.5} \quad (2)$$

Length of radiating patch [12]:

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta l \quad (3)$$

The length extension [9, 10]:

$$\Delta L = 0.412H\left(\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258}\right)\left(\frac{\left(\frac{W}{H}\right) + 0.264}{\left(\frac{W}{H}\right) + 0.8}\right) \quad (4)$$

Length formula for ground plane [15]:

$W_g = 6H + W$.

Width formula for ground plane [15]:

$L_g = 6H + L$.

Where f is the resonant frequency, c is the free space velocity of the light, L is the actual length of the current, ε_r is the effective dielectric constant of the substrate and Δl is the length of equivalent radiation gap.

The far electric fields of the trapezium patch are as follows:

$$E_\theta = \frac{Ke^{-jor}}{r}\cos\left(k_0 h\sqrt{\varepsilon_r}\cos\theta\right)\frac{\sin\left(\frac{\pi W}{\lambda_0}Sin\theta Sin\varphi\right)Cos\left(\frac{\pi L}{\lambda_0}Sin\theta\cos\varphi\right)\cos\varphi}{Sin\theta Sin\varphi}$$

……………… (5)

$$E_\varphi = \frac{-Ke^{-jkr_0}}{r}Cos\left(k_0 h\sqrt{\varepsilon_r}Cos\theta\right)\frac{Sin\left(\frac{\pi W}{\lambda_0}Sin\theta Sin\varphi\right)Cos\left(\frac{\pi L}{\lambda_0}Sin\theta Cos\varphi\right)\cos\varphi}{Sin\theta Sin\varphi}$$

…………………… **(6)**

Equations 5 & 6 enables one to plot the radiation pattern for every mode of the trapezium micro strip patch antenna.

RESULT AND DISCUSSION

Figure 3 shows the return loss of a coaxial probe-fed trapezium patch with T slot microstrip antenna which resonates at frequency 4.45 GHz, and obtained a wide impedance bandwidth of 67.25%.Hence it is more suitable to use proposed antenna for wide band applications named as Wi-max (2.2-3.4 GHz), WLAN (2.40–2.48 GHz), and UMTS II (2.50–2.69 GHz) frequency bands.

Figure 4 shows the smith chart. Figure 5 shows the VSWR (VSWR<2) curve which is of wide band microstrip antenna obtained from IE3D.The proposed microstrip antenna have better antenna efficiency and good radiation efficiency of about 89.55% and 94% respectively. Figure 6 shows 3D radiation pattern & elevation pattern at 4.48GHz.

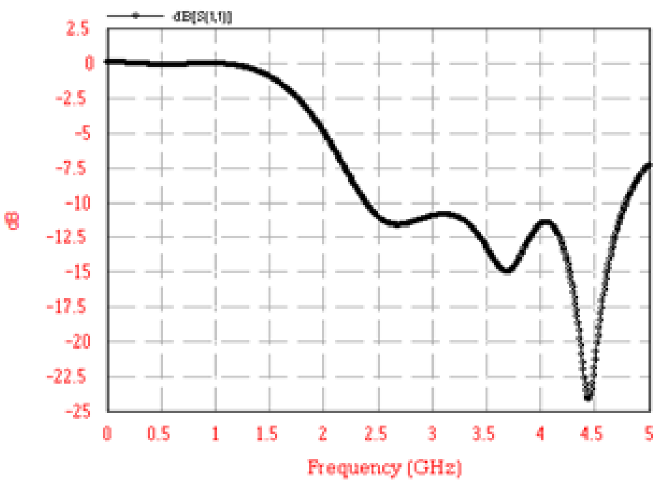

Figure3: Simulated Return loss of proposed MSA

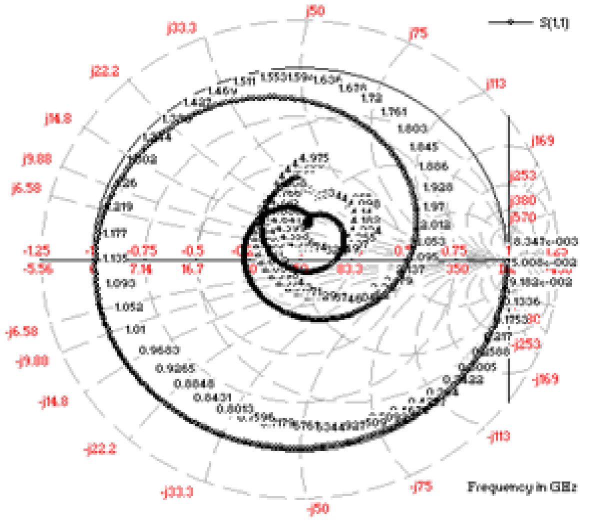

Figure4: Smith chart plot of proposed microstrip antenna

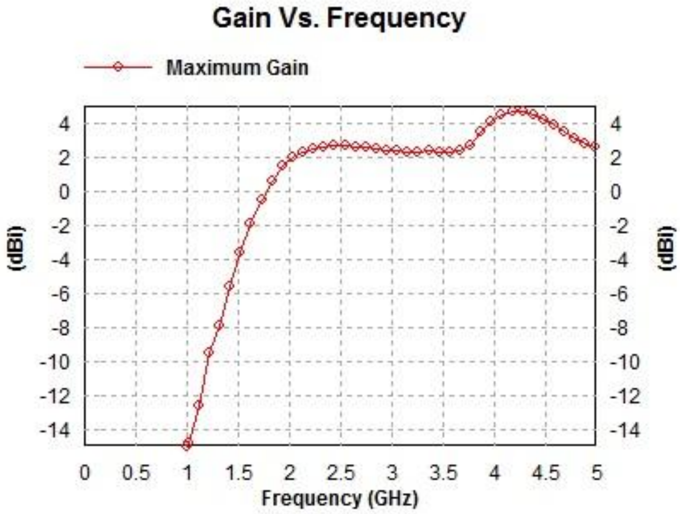

Figure7: Gain of proposed microstrip antenna

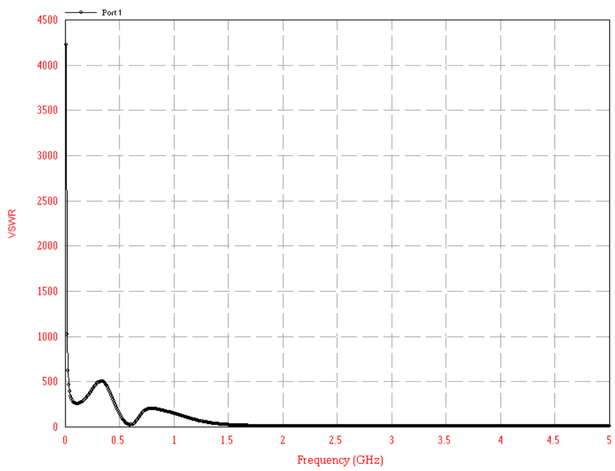

Figure5: VSWR Vs frequency of proposed micro strip antenna

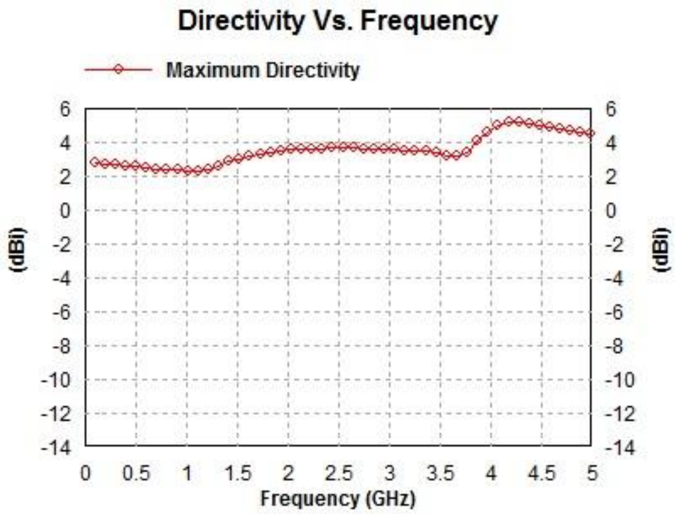

Figure8: Directivity of proposed microstrip antenna

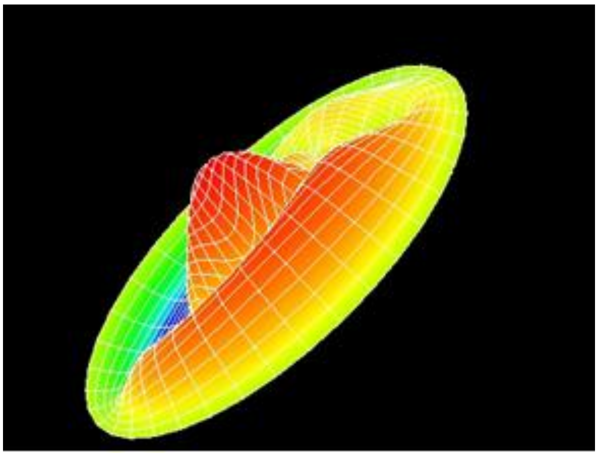

Figure6: Radiation pattern of proposed microstrip antenna

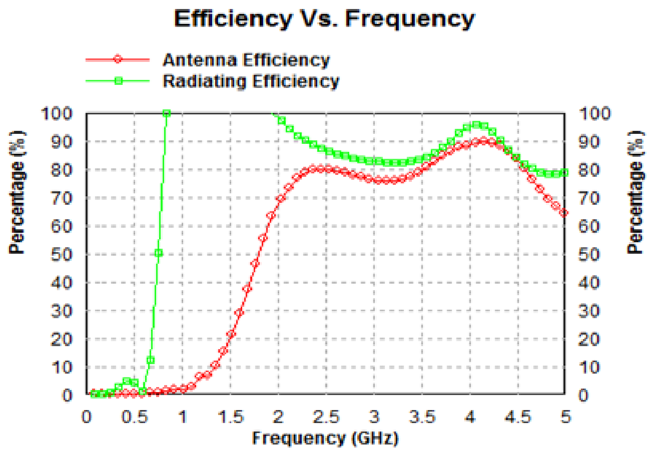

Figure9: Efficiency Vs frequency of proposed microstrip antenna

ANALYSIS FOR OPTIMIZATION

A numerical analysis has been done to understand the effects of variation in dimension of T-slot and to optimize the performance of the proposed antenna. The results show that the enhancement in bandwidth largely depends on the slot length L3. The effect of variation in L3 on impedance bandwidth is studied to obtain optimized structure for achieving higher bandwidth.

The comparison of the simulated return loss for different values of L3 is shown in figure 10. The impedance bandwidths versus variations in L3 are summarized in table II. The optimum value of L3 is 8 mm and feed position of probe is (5, 5).

TABLE 2: THE SIMULATED BANDWIDTHS FOR DIFFERENT VALUES OF L3

L3 (mm)	F_L(GHz)	F_H(GHz)	BW(%)	Gain	R_L
7	2.62	4.83	68.68	4.3	-23.78
8	2.38	4.79	67.25	4.68	-24.20
9	2.404	4.76	66	4.46	-25.20
10	2.429	4.725	64.18	2.6	-26.89
11	2.462	4.69	62.32	2.8	-31.60
12	2.496	4.65	60.44	4.45	-49.98

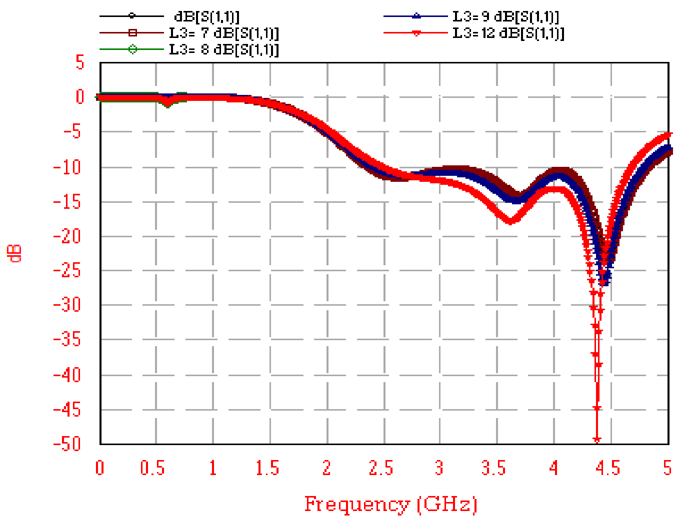

Fig. 10: Simulated Return Loss of Proposed Antenna with Different Size of Slots L3.

TABLE 2: THE OPTIMIZED RESULT

Resonance Frequency	4.45GHz
Gain	4.68 dB
Directivity	5.16 dB
Bandwidth	67.25%
Frequency Range	2.38 GHz - 4.79 GHz
Return Loss	-24.2dB
VSWR	1.132
Radiation efficiency	94 %
Antenna efficiency	89.55 %

CONCLUSION

In this analysis, a new design of linearly polarized trapezium shaped microstrip patch antenna with T- slot is designed for wireless application and result shows the achievement of a wide impedance bandwidth of 67.25% at -10 dB return loss, in the frequency range 2.38GHz – 4.79GHz.

In my design, the antenna is fed by co-axial probe feed of 50 Ω at point (5, 5). So I have achieved enhanced bandwidth of 67.25%, gain of 4.68 dBi, directivity of 5.16 dBi, and radiation efficiency of 94%, and antenna sufficiency of 89.55%as shown in figure 3, 7, 8 and 9 respectively.

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BIOGRAPHIES

Mr. Kaushal Prasad is an Assistant Professor in the Department of Electronics and Communication Engineering, S.R. Group of Institutions Jhansi, India. He has 2 years of experience in teaching, research and administrative work and 2 years industrial experience. He has specialization in communication field. He has published one paper in IEEE 2nd international journal conference on Communication and Signal Processing (ICCSP-2013), 2 papers in international conference on Advanced Information Communication Technology in Engineering (ICAICTE-2K13), 1 paper in international conference on Recent Trends in Engineering Sciences, 1 paper in international scientific journal on science engineering and technology (ISJSET), 1 paper in IJSR and also published one paper in national conference on challenges of efficient energy technology for clear energy. Thus he has published 6 international and 1 national research paper. His current area of research includes MSA for wide band and ultra-wide band applications.

Mr.. Manoj Kumar was born in India on 05 October 1987. He has pass out B.Tech. in 2010 and. My branch is Electronics and Communication Engineering from Krishna institute of engineering & Technology, Ghaziabad. He has analysis a paper in broad band MSA in 2011.Currently he is large working on WMAX microstrip patch antenna & circular polarized MSA in BIET, Jhansi for wireless applications.

Dr. D. K. Srivastava is an Associate Professor in the Department of Electronics and Communication Engineering, Bundelkhand Institute of Engineering and Technology Jhansi, India. He has more than 15 years of experience in teaching, research and administrative work. His current area of research includes Microwaves and Optical communication. He has published around 20 papers in referred journals and more than 30 research articles in international and national conferences.

