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Dual band and Broadband Rectangular Patch Mircostrip Antenna with T Shaped Slot for WiMax Application

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Abstract—The paper presents the good matching between simulated and measured results of dual band and broad band rectangular patch mircostrip antenna with T shaped slot (RPMATSS) for the WiMax Application. This antenna is designed on glass epoxy FR-4 substrate. The performance of this antenna is also compared with that of a simple rectangular patch antenna. The simulated results for this antenna are optimized by varying position, length and width of T shaped slot. The Simulated and measured results indicate that the designed structure resonate at various closely spaced frequencies which lying between two different frequency bands (median and higher) allocation for WiMax application [WiMAX (Worldwide Interoperability for Microwave Access) has been allocated (IEEE 802.16) frequency bands, which will be called the median band (3.25 to 3.85 GHz) and the high band (5.25 to 5.85 GHz), respectively] and offers much improved bandwidth 8.9% at central resonance frequency 3.55GHz and 12.53% at central resonance frequency 5.84GHz in comparison to an rectangular patch antenna (having band width 3.27%). The directivity and gain of antenna also improves significantly at some of the resonance frequencies.

Keywords—Microstrip antenna, dual band, broadband, impedance bandwidth, gain.

I. INTRODUCTION

Microstrip antennas consist of a very thin metallic strip (patch) on a grounded substrate found extensive applications in different fields due to their attractive features. These antennas are low profile, light weight, compact and conformable structure and easy to fabricate [1]. These antennas have drawn attentions of scientific community over the past decades. These antennas may easily be put easily on any surface and may be easily coupled with MIC components [2]. However their low bandwidth and gain values restrict their commercial applications. Now a day, the scientific community is deeply involved in improving their performance so that these may replace other antenna structures in modern communication systems [3,4]. In the present communication we have presented a rectangular patch antenna with T shaped slot. The two rectangular slots of different dimensions are designed on two edges of rectangle as shown in figure-1. The simulation analysis of these antennas is carried out by applying Zeeland IE3D simulation software.

II. ANTENNA GEOMETRY AND RESULTS

The antenna geometry used in this paper is shown in figure-2. The antenna is designed on glass epoxy FR4 substrate having substrate thickness h=0.159cm, relative dielectric constant ε_r=4.4 and substrate loss tangent= 0.025 with copper as its ground plane. The patch size of 6cm x 5cm is considered for the present work. The rectangular patch antenna without slot mainly resonates at a two frequencies 3.75GHz and 5.6GHz. Since it was designed on a high permittivity substrate having high loss tangent, antenna efficiencies is found low (10.23%) while bandwidth is around 2.4% and 2.3% corresponding to 3.75GHz and 5.6GHz respectively. In order to increase the impedance bandwidth and to make this antenna suitable for dual band operations, extensive optimizations in slot dimensions and slot location on patch are made as shown in table-1. These variations are carried out in the slot size between length and width 5mm to 13mm as shown in figure 3. When the impedance bandwidth for these geometries were obtained and compared, it was found that on increasing the size of T shaped slot, impedance bandwidth first increases and attains its highest value when length & width of vertical and horizontal arms are equal to 9mm. Gain of antenna in this case is positive and after increasing slot dimensions further, impedance bandwidth of antenna geometry start decreasing as shown in table 1.

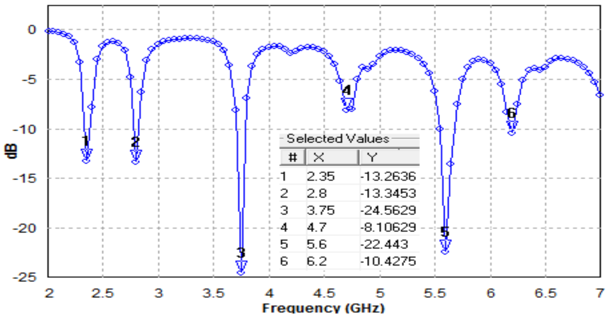

Fig. 1 Variation of reflection coefficient of simple rectangular patch microstrip antenna with frequency

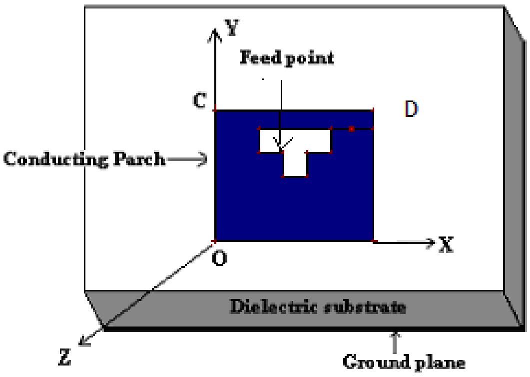

Fig. 2 Geometry of RPMATSS structure with coordinate system

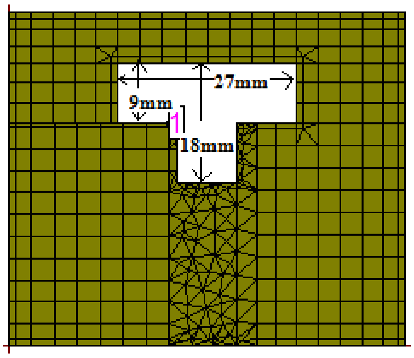

Fig. 3 Meshing structure geometry of RPMATSS structure

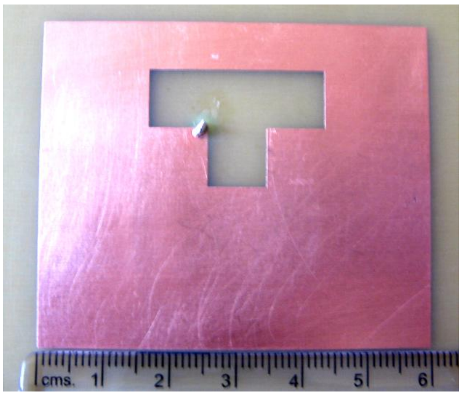

Fig. 4 Fabricated rectangular patch mircostrip antenna with T shaped slot (RPMATSS) antenna

Based on this analysis, we decided to study the performance of this antenna structure in detail. This antenna is again designed on glass epoxy FR4 substrate having substrate thickness h = 0.159cm, relative dielectric constant $\varepsilon_r = 4.4$ and substrate loss tangent = 0.025 with copper as its ground plane. The patch size is still of 6cm x 5cm and patch is modified by cutting T shaped slot (having slot length L=9mm and slot width W = 9mm) at coordinates X=30mm and Y=38mm. On making L = W = 9mm of slots, impedance band width of antenna attains maximum value 8.9% at central frequency 3.56 GHz. The bandwidth of second band is 12.53% at central frequency 5.86 GHz. Both these central frequencies lies in medium band (3.25 to 3.85 GHz) and upper band (5.25 to 5.85 GHz) of WiMAX (Worldwide Interoperability for Microwave Access) respectively. In this way, this antenna geometry is a useful geometry for future generation wireless systems. The directivity of antenna is more or less equal in all antenna geometries. This indicates that the variation of slot size do not affect the directivity of antenna geometry.

The fabricated rectangular patch antenna geometry with T shaped slot is shown in figure 4. The size of T slot is optimized (as shown in table 1) to achieve best performance with this antenna. The simulation analysis of this antenna is carried out by applying IE3D simulation software. The simulation analysis reveals that antenna is resonating at a four resonance frequencies 3.46GHz, 3.66GHz, 5.68GHz and 6.02GHz as shown in figure 5a and 5b. Resonating frequencies 3.46GHz and 3.66GHz are close to each other and lie in 3.25GHz to 3.85GHz allocated for median band of Wi-MAX communication systems. Other two resonating frequencies 5.68GHz and 6.02GHz are close to each other and lie in 5.25GHz to 5.85 GHz allocated for high band of Wi-MAX communication systems. Although resonance frequency 6.02GHz does not lie within this range but it is close to it. The simulated impedance bandwidths obtained in present condition are 8.9% with respect to central frequency 3.56GHz and 12.53% with respect to central frequency 5.86GHz.

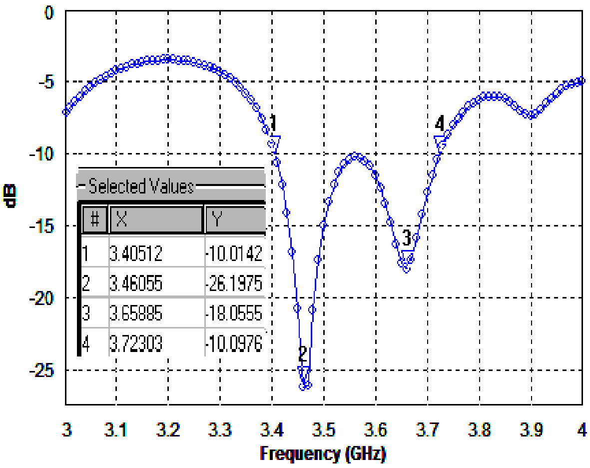

Fig. 5a Variation of simulated reflection coefficient with frequency of RPMATSS for frequency range 3GHz-4GHz

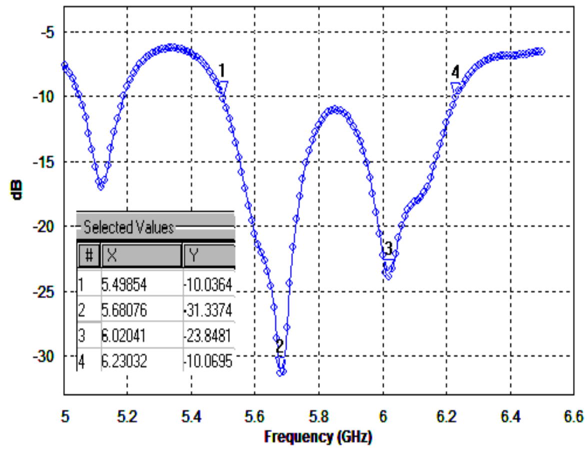

Fig. 5b Variation of Simulated Reflection Coefficient with Frequency of RPMATSS for freq. range 5GHz-6.6GHz

The measured result shows that impedance bandwidth corresponding to central frequency 3.57GHz and 5.91GHz are 8.68% and 14.72% respectively. This is 5.78 and 9.81 times higher than that in a conventional rectangular patch antenna (measured band width = 1.5%) respectively with same dimensions. The measured variations of input impedance of antenna as a function of frequency in the two considered bands are shown in figures 6a and 6b respectively.

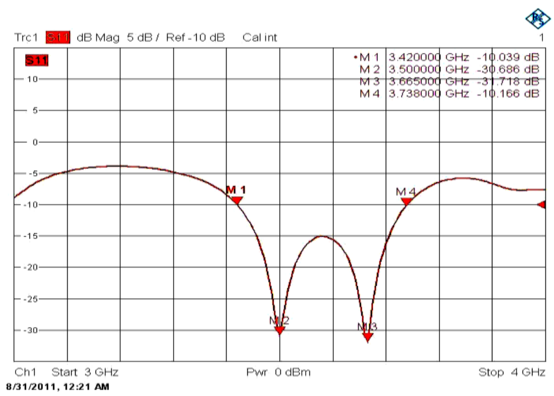

Fig.6a Variation of measured reflection coefficient with frequency of RPMATSS for frequency range 3GHz-4GHz

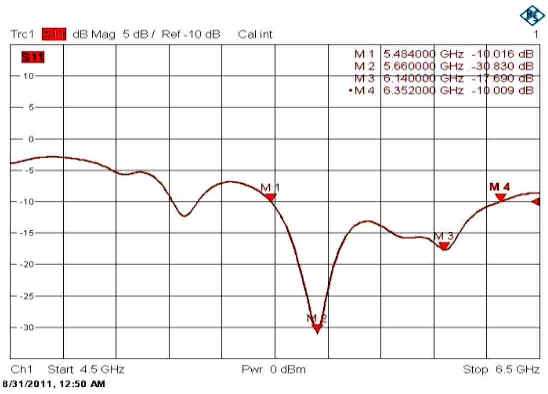

Fig. 6b Variation of measured reflection coefficient with frequency of RPMATSS for frequency range 4GHz-6.6GHz

The simulated input impedances corresponding to four resonance frequencies 3.46GHz, 3.656GHz,5.68GHz and 6.02GHz are (48.04 - j 4.3) ohm, (50.74 – j13.3) ohm, (47.99 - j 1.65) ohm and (50.65 -j 6.42) ohm respectively which are close to 50 ohm impedance of the feed line considered for the present work.

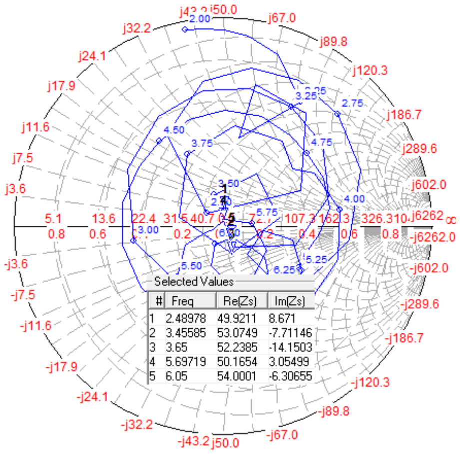

Fig. 7 Variation of input impedance of with frequency of RPMATSS for frequency range 3GHz-6.6GHz

The measured input impedances corresponding to three resonance frequencies 3.50GHz, 3.66 GHz, 5.66GHz and 6.14GHz are (47.18 + j 3.2) ohm, (48.5 - j 2.08)ohm,(52.82-j8.71)ohm and (55.35-j12.7)ohm respectively as shown in figure 8a and 8b for the two considered bands.

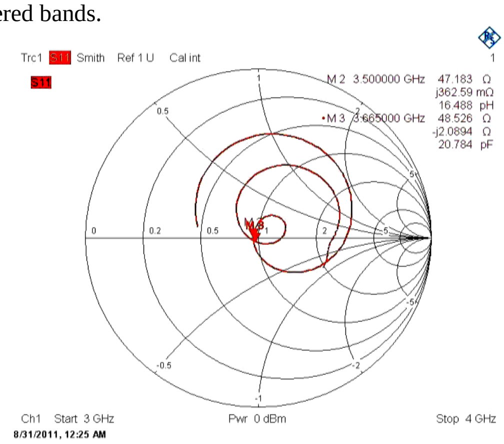

Fig.8a Variation of measured input impedance with frequency of RPMATSS for frequency range 3GHz-4GHz

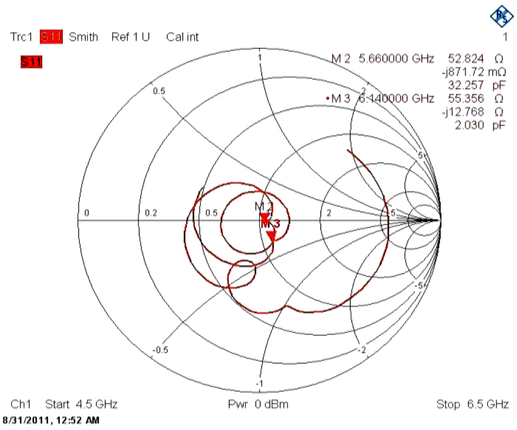

Fig. 8b Variation of measured input impedance with frequency of RPMATSS for frequency range 4.5GHz-6.5GHz

The measured VSWR values of this modified antenna as a function of frequency at feed location are shown in figures 10a and 10b respectively for the two bands under consideration. Simulated VSWR for this antenna geometry corresponding to resonance frequencies 3.46GHz, 3.66GHz, 5.68GHz and 6.02GHz are 1.10, 1.28, 1.05 and 1.13 respectively as shown in figures 9, while the measured VSWR values with respect to the resonance frequencies 3.50GHz, 3.66GHz, 5.66GHz and 6.14GHz are 1.06, 1.053,1.059 and 1.3 respectively which are close to unity and indicate that simulated and fabricated antennas are nicely matched with the feed line and very little reflections are taking place at the feed location.

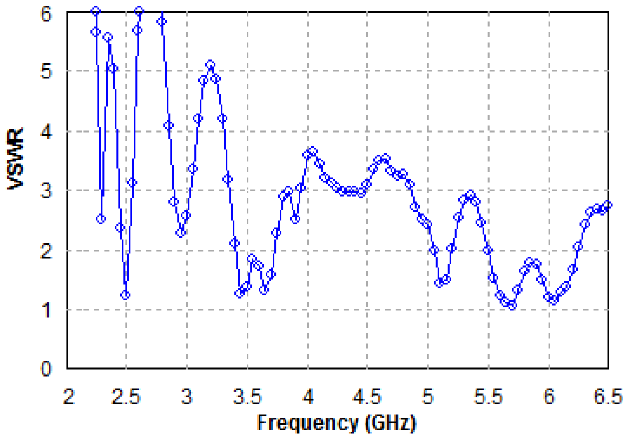

Fig. 9 Variation of VSWR of antenna with frequency for RPMATSS for frequency range 2GHz to 6.5GHz

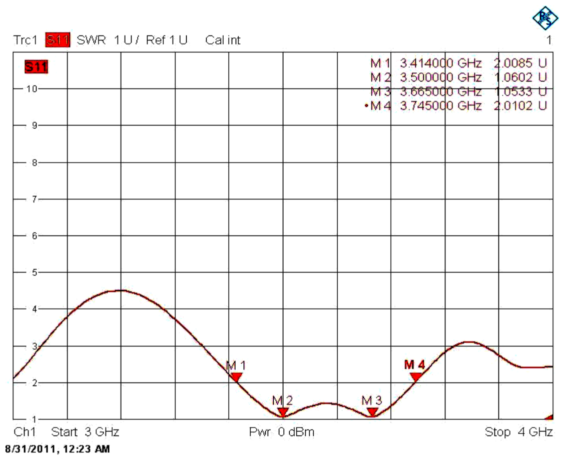

Fig. 10a Variation of measured VSWR with frequency for RPMATSS for frequency range 3GHz-4GHz

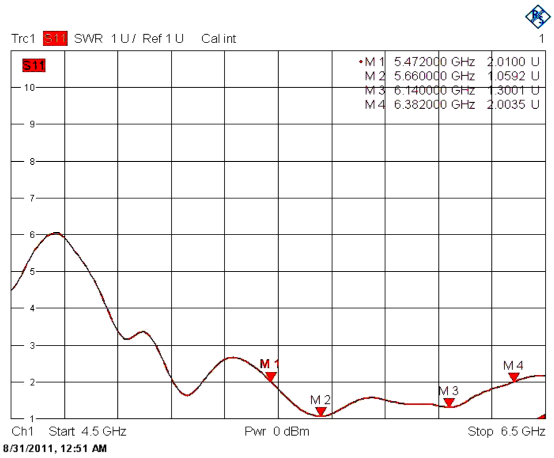

Fig. 10b Variation of measured VSWR with frequency for RPMATSS for frequency range 4.5GHz-6.5GHz

The radiation efficiency of antenna is now approached to 24.05% for 3.45GHz frequency, 14.63% for 3.65GHz, 18.94% for 5.68GHz and 14.72% for 6.05GHz frequency as shown in figures 11.

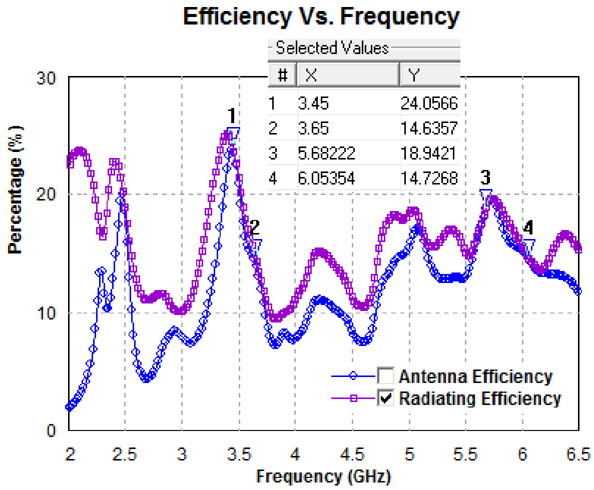

Fig.11 Variation of radiation efficiency for RPMATSS with frequency for RPMATSS

The Directivity of this antenna is around 9.35dBi, 6.77dBi 8.92dBi and 8.86dbi for the corresponding frequencies respectively. It is shown in figure-12.

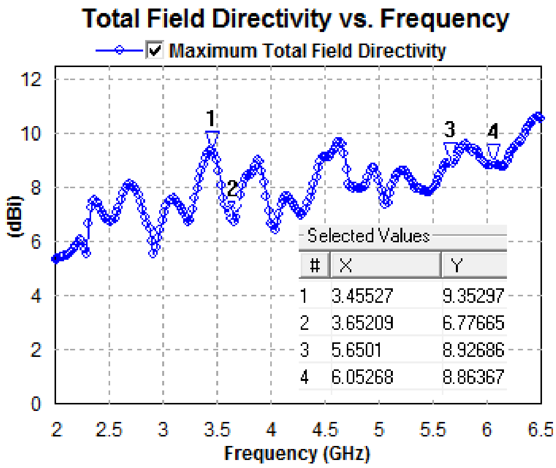

Fig.12 Variation of directivity of antenna with frequency for RPMATSS for frequency range 2GHz to 6.5GHz

The gain of antenna is now approached to 3.08dBi for 3.45GHz frequency, 1.83dBi for 5.699GHz and 0.521dBi for 6.05GHz frequency as shown in figure-8, which is not so much higher than that obtained in earlier cases reported in this paper.

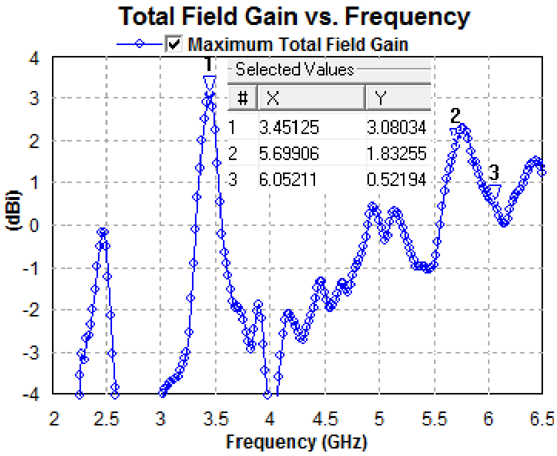

Fig-13 Variation of gain of antenna with frequency for RPMATSS for frequency range 2GHz to 6.5GHz

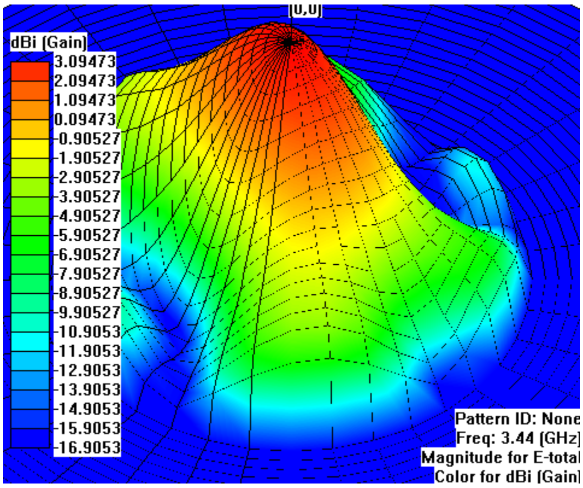

Fig.14 3D Radiation Pattern of rectangular patch mircostrip antenna with T shaped slot (RPMATSS)

III. CONCLUSIONS

The paper presents the good matching between simulated and measured results of dual band and broad band antenna for the communication systems for WiMax Application. The analysis is carried out by considering a substrate material with higher loss tangent value still reported simulation results are very encouraging. The antenna bandwidth is high, 8.9% at central resonance frequency 3.55GHz and 12.53% at central resonance frequency 5.87GHz in comparison to a rectangular patch antenna (having band width 3.27%). The directivity up to 9.35dBi may be achieved. These values may be increased further with application of low loss materials. We have carried out this analysis by considering parameters of glass epoxy FR-4 substrate due to availability of this material with our group.

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Table 1: Comparison of antenna parameters having various dimensions of shifted T shaped slot (RPMATSS) [Center of T shaped slot at (30mm, 38mm)] of rectangular antenna

Type of Antenna	Size of Vertical & arm (mm)	Size of Horizontal arm (mm)	Resonance Frequency (GHz)	Radiation Efficiency (%)	Directivity (dBi)	Gain (dBi)	Bandwidth (%)
Rectangular Patch Antenna	Without slot	Without slot	5.63	23.74	8.16	1.78	2.3
Rectangular Patch Mircostrip Antenna No-1 with T shaped slot	L=7 W=7	L=7 W=7	3.46	20.83	9.48	2.67	6.79
			3.57	12.97	7.48	-1.37	
			5.61	13.02	7.55	-1.29	14.86
			6.02	16.92	9.66	1.94	
			5.74	20.07	8.93	1.949	
			6.02	15.38	9.19	.98	
Rectangular Patch Mircostrip Antenna No2 with T shaped slot	L=9 W=9	L=9 W=9	3.46	23.57	9.37	2.33	8.9
			3.66	14.09	6.71	5.01	
			5.68	19.00	8.85	0.99	12.53
			6.02	14.91	8.93	0.79	
Rectangular Patch Mircostrip Antenna No-3 with T shaped slot	L=11 W=11	L=11 W=11	3.38	24.33	8.85	2.628	3.08
			3.7	17.08	6.61	-1.078	2.94
			5.78	20.25	7.67	0.59	6.73
			5.98	20.28	9.53	2.58	