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Broadband rectangular patch microstrip antenna with rhombus shaped slot for WLAN applications

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Abstract: The paper presents best matching between simulated and measured results of broadband Rectangular Patch Microstrip Antenna with Rhombus Shaped Slot (RPMARSS) for the WLAN 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 of this antenna are optimized by varying position, length and width of the Rhombus shaped slot. The simulated and measured results indicate that the designed structure resonate at various closely spaced frequencies which lying between frequency band allocation for WLAN application [WLAN (Wireless Local Area Network) has been allocated (IEEE 802.11a5) frequency band, (5.15 to 5.825 GHz)] and offers much improved simulated bandwidth 16.09% at central resonance frequency 5.66GHz and measured bandwidth is 15.06% at central frequency 5.51GHz, This is five times higher than that in a conventional rectangular patch antenna (Bandwidth = 3%) with same dimensions.

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 the attention from the 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 rhombus shaped slot. The simulation analysis of these antennas is carried out by applying Zeeland IE3D simulation software.

II. Antenna Geometry and Results

The conventional rectangular patch antenna is designed on a 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 2.5cm x 4cm is considered in the present work. The rectangular patch antenna without slot mainly resonates at a frequency 5.5GHz as shown in figure 1.

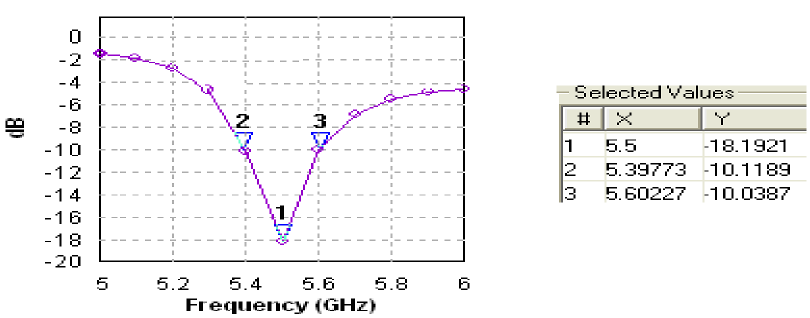

Fig. 1: Variations of reflection coefficient of conventional rectangular patch microstrip antenna with frequency

Since it was designed on a high permittivity substrate having a high loss tangent, antenna radiation efficiency is found (27.28%) while low bandwidth around 3.6% corresponding to 5.5GHz. In order to increase the impedance bandwidth, extensive optimizations in slot dimensions are made.

The rectangular patch antenna with optimized slot dimension (L=W=2.83mm) at the center of the patch (X=12.5mm, Y=20mm). When the impedance bandwidth for these geometries were obtained and compared, it was found that due to the variation of rhombus slot dimension, impedance bandwidth first increases and attains its highest value. The impedance bandwidth of antenna geometry starts decreasing as we increased the slot dimensions greater than 2.83mm. These variations are carried out in the slot dimension, length and width as shown in Table-I. The antenna is mainly resonates at a frequency 5.69GHz. Since it was designed on a high permittivity substrate having a high loss tangent, antenna radiation efficiency is found (25.4%) and the bandwidth is around 13.7%, corresponding to 5.69GHz. But the gain of this antenna is negative.

Further in order to increase more impedance bandwidth and the enhancement of the antenna gain, the variation of the slot location on the patch are made. By using slot dimension L = W = 2.83mm, the simulated impedance bandwidth of an antenna attains the maximum value 16.09% at central frequency 5.65 GHz. This central frequency lies in a band (5.15 to 5.825 GHz) of WLAN (Wireless Local Area Network). So the antenna geometry is a useful geometry for future generation wireless systems. The directivity of an antenna is more or less equal in all antenna geometries. The Rectangular Patch Microstrip Antenna with Rhombus Shaped Slot (RPMASRS) geometry used in this paper is shown in figure-2.

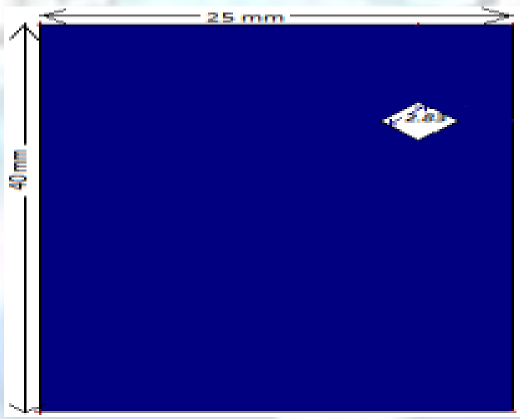

Fig. 2: Designed Rectangular Patch Microstrip Antenna with Shifted Rhombus Slot (RPMASRS) antenna using IE3D software

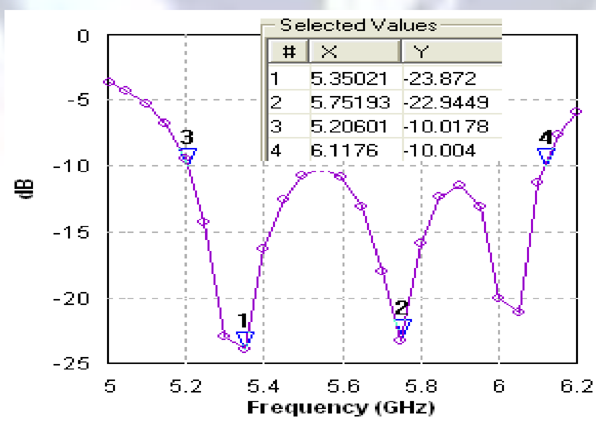

Fig. 3: Variations of Simulated Reflection Coefficient with Frequency of RPMASRS for frequency range 5GHz-6.2GHz

Based on this analysis, we decided to study the performance of this antenna structure in detail. This antenna is designed and fabricated on a glass epoxy FR4 substrate having a 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 2.5cm x 4cm and patch is modified by cutting rhombus slot (having slot length L and slot width W = 2.83mm) located at coordinates X=20mm and Y=30mm.

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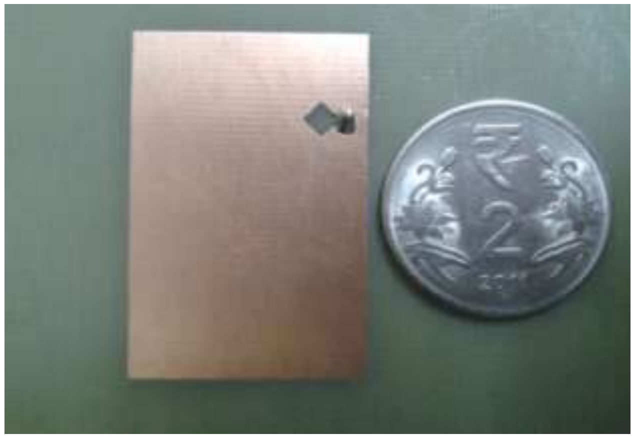

Fig. 4: Fabricated Rectangular Patch Microstrip Antenna with Shifted Rhombus Slot (RPMASRS)

The fabricated rectangular patch antenna geometry with rhombus slot is shown in figure- 4. The analysis of measured antenna is carried out by vector network analyzer. We find the best matching between simulated and measured results. The simulation analysis reveals that the antenna is resonating at two resonating frequencies 5.35GHz and 5.75GHz corresponds to two measured resonance frequencies 5.37GHz and 5.72GHz as shown in figure -3 and figure 5, with feed location (22.2mm, 30mm). Resonating frequencies 5.35GHz and 5.75GHz are close to each other and lie in 5.15GHz to 5.825 GHz allocated for high band of WLAN communication systems. The simulated impedance bandwidths obtained in present condition are 16.09% with respect to central frequency 5.65GHz. The measured result shows that impedance bandwidth corresponding to central frequency 5.509GHz is 15.06%. This is five times higher than that in a conventional rectangular patch antenna (Bandwidth = 3%) respectively with same dimensions. The measured variations of reflection coefficient of antenna as a function of frequency in the considered band are shown in figures 5.

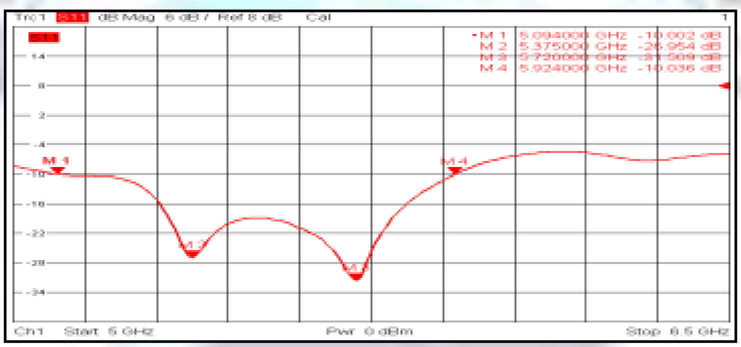

Fig. 5: Variations of Measured Reflection Coefficient with Frequency of RPMASRS for frequency range 5GHz-6.5GHz

The simulated input impedances corresponding to two resonance frequencies 5.35GHz and 5.75GHz are (44.65 - j 3.62) ohm and (52.06 -j 6.78) ohm respectively which are close to 50 ohm impedance of the feed line considered in the present work.

Fig. 6: Variation of input impedance of with frequency of RPMASRS for frequency range 5GHz-6.2GHz

The measured input impedances corresponding to two resonance frequencies 5.37GHz and 5.72GHz are (53.32 - j 3.2) ohm and (48.19 – j 1.85)ohm respectively as shown in figure 7. This shows the excellent matching between the antenna and feed network system.

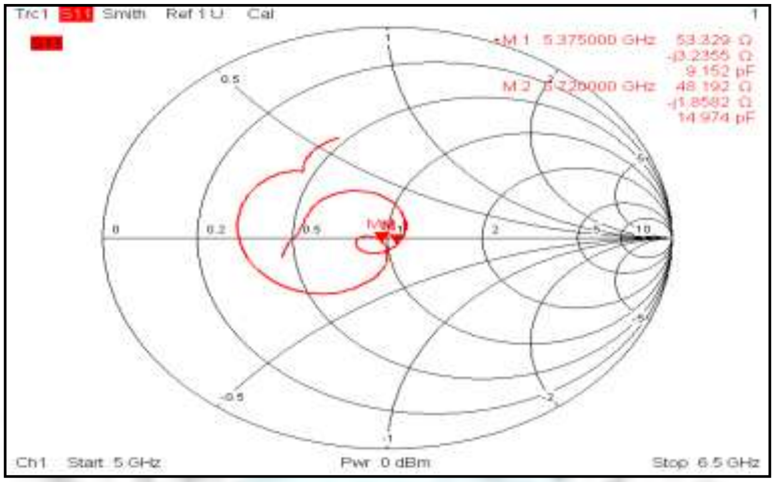

Fig. 7: Variation of measured input impedance with frequency of RPMASRS for frequency range 5GHz-6.5GHz

The Simulated VSWR for this antenna geometry corresponding to resonance frequencies 5.35GHz and 5.75GHz are as shown in figure 8. The measured VSWR values of this modified antenna as a function of frequency at feed location are shown in figure 9 for the band under consideration. The simulated and measured VSWR values with respect to the resonance frequencies 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.

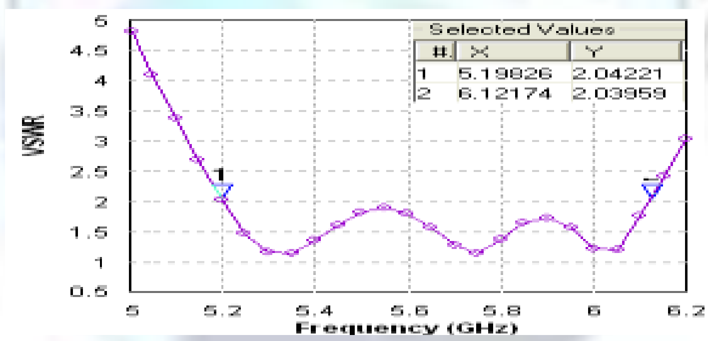

Fig. 8: Variation of VSWR of antenna with frequency for RPMASRS for frequency range 5GHz to 6.2GHz

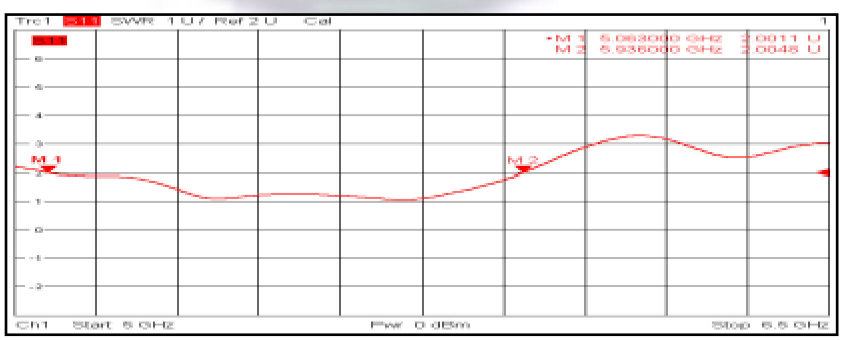

Fig. 9 Variation of measured VSWR with frequency for RPMARSS for frequency range 5GHz-6.5GHz

The radiation efficiency of antenna is 24.12% for 5.35GHz and 16.37% for 5.75GHz frequency as shown in figure 10.

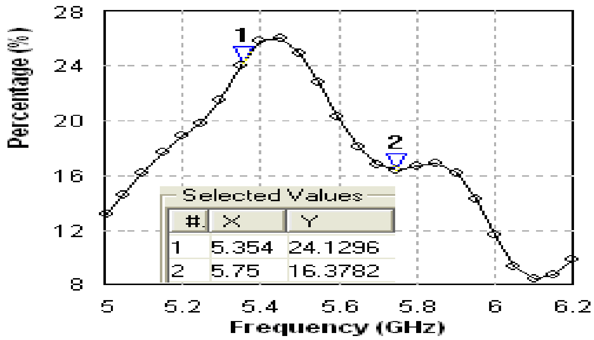

Fig.10: Variation of radiation efficiency for RPMASRS with frequency for RPMARSS

The Directivity of this antenna is around 8.62dBi and 10.56dBi for the corresponding frequencies respectively. It is shown in figure-11.

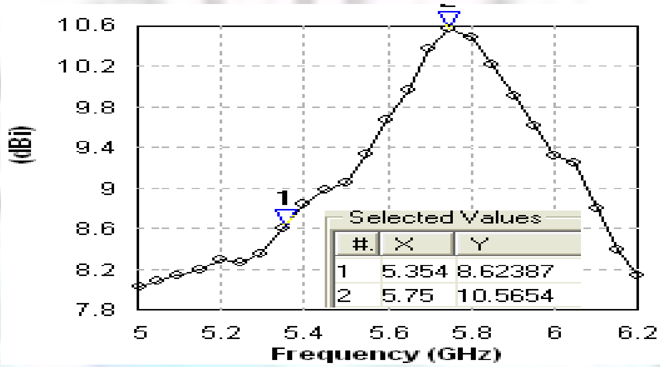

Fig.11: Variation of directivity of antenna with frequency for RPMASRS for frequency range 5GHz to 6.2GHz

The gain of antenna has now approached to 2.42dBi for 5.35GHz and 2.68dBi for 5.75GHz frequencies as shown in figure-12, which is not so much higher than that obtained in earlier case reported in this paper.

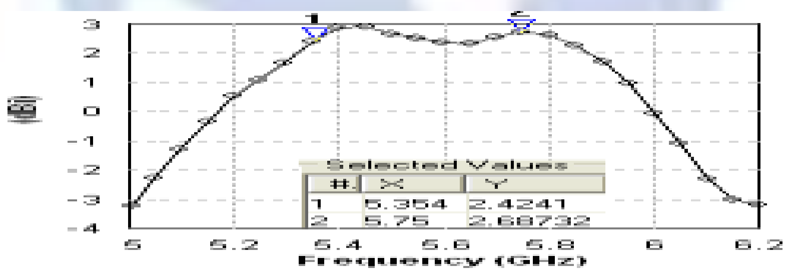

Fig-12: Variation of gain of antenna with frequency for RPMASRS for frequency range 5GHz to 6.2GHz

III. CONCLUSIONS

The paper presents best matching between simulated and measured results of broadband antenna for the communication systems for WLAN Application as shown in table -III. The analysis is carried out by considering a substrate material with the higher loss tangent value; still the reported simulation results are very encouraging. The bandwidth of modified antenna is 16.09% at central resonance frequency 5.66GHz.This is five times higher than that in a conventional rectangular patch antenna (Bandwidth = 3%) with the same dimensions. The gain is 2.68dBi. The higher gain may be achieved further with the application of low loss materials. We have carried out this analysis by considering parameters of glass epoxy FR-4 substrate due to the availability of this material with our group. The work requires extensive experimentation before reaching any possible thought for its application. At present these antennas are tested and the experimental results are available for the validation and matched with the simulation results.

VI. ACKNOWLEDGEMENT

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Table I: Variation of antenna parameters with respect to the various dimensions of the rhombus slot (RPMASRS) at the center (X=12.5mm,Y=20mm) of the rectangular patch

S.No	Type of Antennas	Length & Width of slot (mm)	Resonance Frequency (GHz)	Radiation Efficiency (%)	Directivity (dBi)	Gain (dBi)	Band Width (%)
1	Rectangular Patch with Slot	L=W=√2=1.414	5.35 5.75	20.12 14.57	8.53 10.48	1.4 1.7	6.99 9.34
2	Rectangular Patch with slot	L=W=2√2=2.83	5.69	25.4	8.5	-6.0	13.7
3	Rectangular Patch with slot	L=W= 4√2=5.66	5.1 5.49	24.12 28.5	9.9 8.7	3.4 2.1	4.1 2.3
4	Rectangular Patch with slot	L=W= 6√2=8.48	5.1 5.6	27.1 17.2	9.8 9	3.2 1.6	5.12 2.1

Table II: Comparison of Antenna Parameters of Rectangular Patch Antenna and Rectangular Patch Microstrip Antenna With Shifted Rhombus Shaped slot (The slot having dimension L=W=2.83mm and it is located at X=20mm, Y=30mm)

S.No	Type of Antennas	Feed Location (mm)	Resonance Frequency (GHz)	Radiation Efficiency (%)	Directivity (dBi)	Gain (dBi)	Band Width (%)
1	Rectangular Patch	X = 12.5 Y = 20	5.5	27.28	8.99	3.26	3.6
2	Rectangular Patch Microstrip Antenna with Shifted Rhombus Shaped	X = 22.2 Y = 30	5.35 5.75	24.12 16.37	8.62 10.56	2.42 2.68	16.09

Table III: Comparison of Simulated and Measured results of Rectangular Patch Microstrip Antenna with Shifted Rhombus Slot

S.No	Type of final Antenna	Feed Location (mm)	Resonance Frequency (GHz)		Band Width (%)	
			Simulated Results	Measured Results	Simulated Results	Measured Results
1	Rectangular Patch Microstrip Antenna with Shifted Rhombus Shaped Slot	X = 22.2 Y = 30	5.35 5.75	5.37 5.72	16.09	15.06