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A New Patch Antenna Design for X Band Applications

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***Abstract*—**in the last years the rapid development in the satellite communication and broadcasting systems require to develop a low cost, light Wight, easiness in movement and in usage antennas. That's capable of high performance at the same time. In this paper X-band micro-strip antenna has been discussed and designed which could be used for many applications and it is consist of radiating patch on a Roger RO4003C substrate with a ground patch, and the micro-strip feeding line to the patch is set on 50 Ohm. And it will give us 8.45 dB peak gain in X-band Frequency range and wide Impedance Bandwidth (IBW) range from 5.8 GHz till 12 GHz.

Keywords: patch antenna, X-band.

I. INTRODUCTION:

These days the rapid development in the wireless communication

n systems and the importance of providing high quality multimedia services for our daily life activities requires to keep developing antennas that's easy to use and easy to fabricate at the same time. The huge demands on the satellites communication services require us to develop our systems and antennas as it will receive and send the electromagnetic waves to be able to use every possible range of frequency [1]. The range of X-Band is (8-12) GHz this band is mainly used by the military especially in radar applications but also the X-band is used in civil, and government applications such as television broadcasting, weather forecast, and for air traffic control and vehicle speed detection. And it has many advantages like not been affected by weather conditions and its high throughput which make it very suitable to be used to send High Definition HD videos, voice and data [2]. The micro-strip antenna is made of a radiated metallic piece (patch) which is printed or

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attached on a dielectric material [3]. Also it's called as dielectric substrate and on the bottom side of the dielectric substrate attached a ground patch that will be separated from the upper patch with the dielectric substrate, this radiated patch could be designed into many configurations and shapes, the most used shapes are the circular and the rectangular patch [4].

The aim of this letter is to present a single element patch antenna that will be operate on x-band frequency and that have a rectangle holes in the ground slot to increase the return lose value and a pair of notches had been made on the lower corner of the patch to achieve maximum impedance matching [5]. The antenna design and simulation done by using Computer Simulation Technology (CST) studio software.

II. Antenna Desigen:

The micro-strip antenna substrate is build using Rogers RO4003C material which is a glass reinforced hydrocarbon/ ceramic laminates designed for high volume commercial application and this material is designed to offer a superior high frequency range performance. Also, comparing to the FR4 material the RO4003C has a low dielectric tolerance and loss which gave it the excellent performance in the high frequencies. Its relative permittivity **εr** = 3.55, and the dielectric loss tangent is **δ** = 0.0027 [6]. The size of our designed antenna is 40*38*1.524 mm^3 which means that the width of the antenna is 40 mm and the length is 38 mm and the antenna thickness of the substrate is 1.524 mm. The patch will consist of main rectangular part adjoined by smaller rectangular parts to form two notches from both sides on upper face of the substrate to operate effectively on the higher estimated frequency and to give us mush enhanced impedance bandwidth [7]. While on the ground face of the substrate we have a rectangle patch and a rectangular slot had been cut from in addition that the width of the ground slot is not equal to the upper patch to give more stability and wider bandwidth response in X-band frequency range. The radiating patch will be feed with 50Ω. The antenna feeding done by a using the feed line method where the feed line will be attached to the patch on the upper face of the antenna [8] and that will provide a planer structure. So, the fabrication will be easier. The antenna design with its first step and the last refined design is shown in figure 1 and figure 2 respectively.

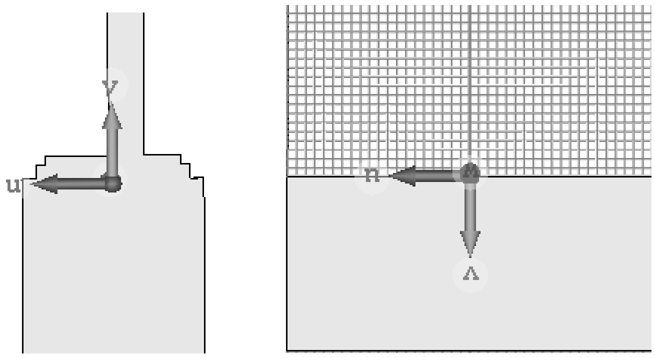

Figure 1. The first step of the desgined antenna

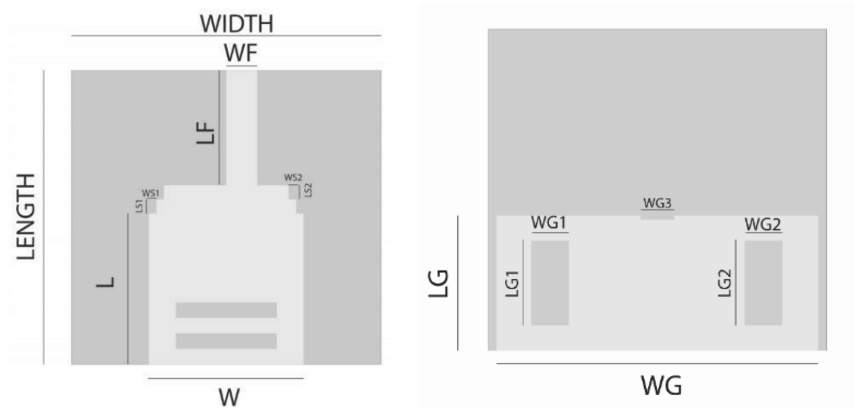

Figure 2. The final design of the antenna

Table 1. The Designed Antenna Dimension

Parameters	Values (mm)	Parameters	Value (mm)
Sub Width	40	WF	4
Sub Length	38	LF	16
Sub high	1.524	WS1	1.5
W	20	LS1	1.5
L	19.5	WS2	1
WC	3.8	LS2	1
LC	2.7	Mt	0.1
LS3	2	WS3	13
LS4	2	WS4	13
WG	38	LG	16
WG1	4.5	LG1	10
WG2	4.5	LG2	10
WG3	4	LG3	0.5

III. ANTENNA SIMULATICON AND RESULTS:

This paper aims to present a single element patch antenna to be used in the X-band frequency applications and to check our antenna efficiency within this frequency range. The results will be studied and observed of the following antenna parameters.

A. Return Lose and VSWR:

The return loss (S11) shows how good is the matching between the transmission line and the antenna [9]. At first, we had the good value only on a very narrow bandwidth; by cutting the side edge from the ground slot we got enhanced S11 on much wider bandwidth. Because these cuts helped to improve the electromagnetic coupling between the upper patch and the ground slot [10], as it shows in the figure 3 that in the first stage the good value of S11 was just close to 9.8 GHz with very narrow band while the value was very low for the other frequency range. On the other hand, when the ground slot had been refined the S11 value improved to had good value from 5.8 GHz till 11.8 GHz. Moreover, the return loss result should be less than -10 DB for an effective antenna [11]. Figure 4 illustrate the value of S11 in our design. The antenna reference impedance is constant on 50 Ohm.

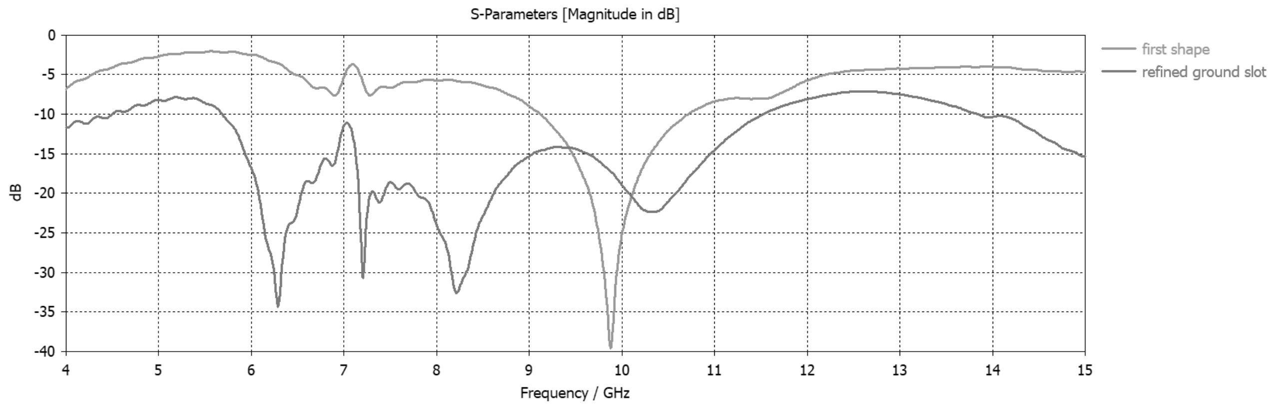

Figure 3 The designed antenna S11 comparison with the result of the same design before the ground slots refining.

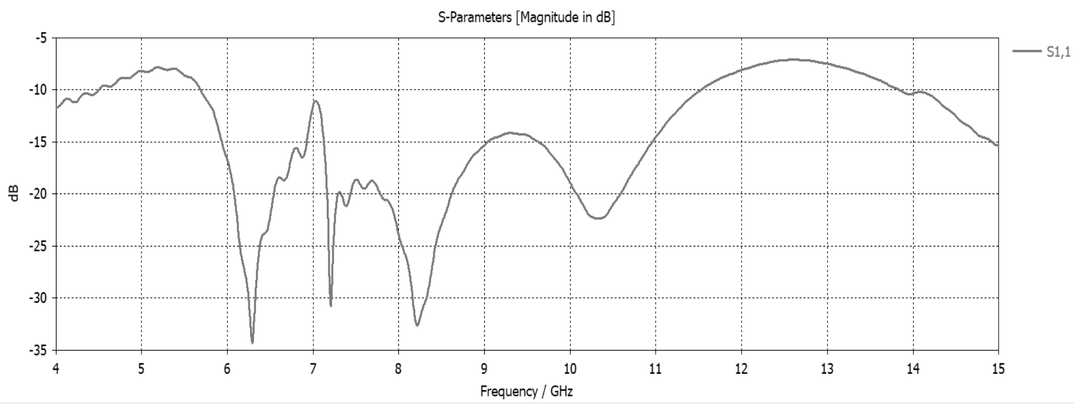

Figure 4 The designed antenna S11 Diagram

As S11 of the designed antenna had been analyzed let's compare VSWR results in the main step of our antenna design with the final shape as we can see in the figure 4 that in the beginning before refining the design of the ground slot we had a narrow bandwidth impedance which was between 9-11 GHz and this small range will not allow us to use our antenna in many X Band application but after the cut of the Ground slot the bandwidth impedance has been improved and we gained a wider bandwidth. Ground slot the bandwidth impedance has been improved and we gained a wider bandwidth from 5.7 till almost 11.8 GHz.

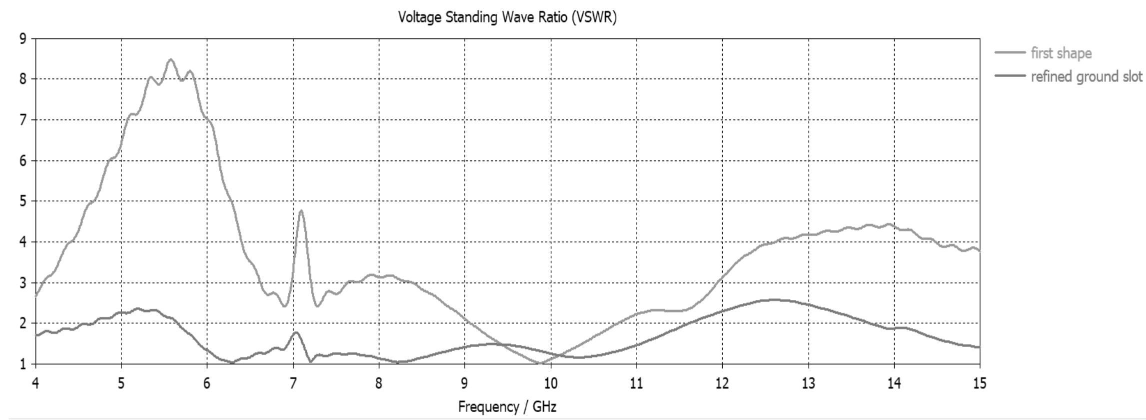

Figure 5 The designed antenna VSWR comparison with the result of the same design before the ground slots refining.

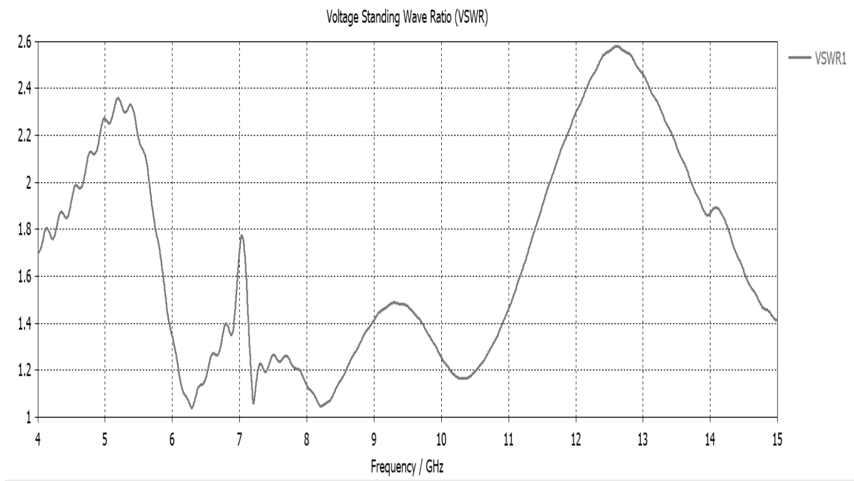

Figure 6 The Designed antenna VSWR

B. Radiation Pattern and Antenna Efficencey :

In the figure 7 the 1-D radiation pattern for our final design of the antenna has been shown as it illustrate the statistics of the ideal main lobe value to the side lobe value.

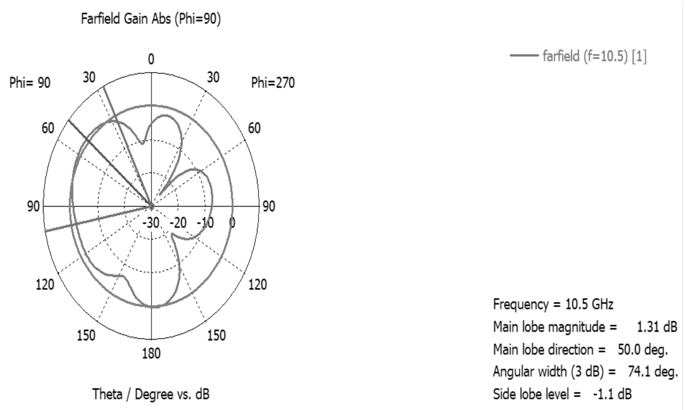

Figure 7 the Antenna 1-D radiation pattern

The designed antenna directivity and Gain has been analyzed to see that good values has been achieved as it shown in the figure 8 of the 3-D radiation pattern that our antenna peak gain is 8.49 dB while we can see that the Directivity is equal to 8.72 dBi.

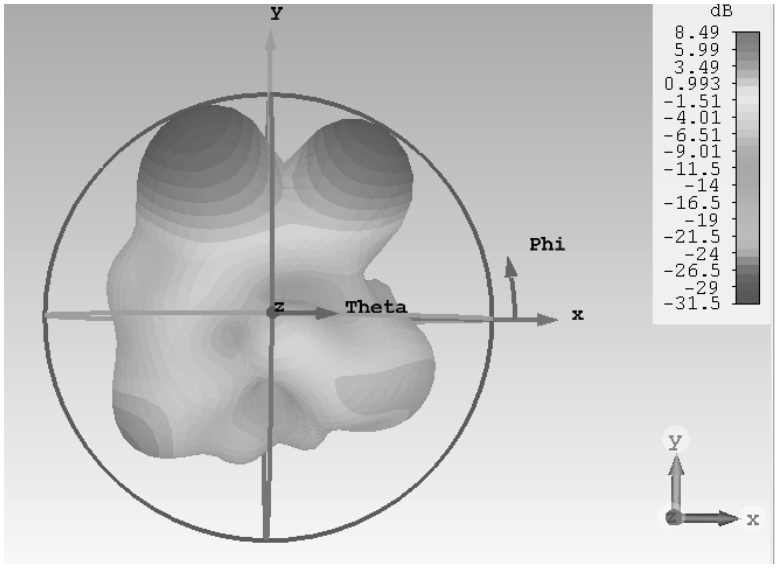

Figure 8 The antenna gain and 3-D radiation pattern

The antenna efficiency is the ratio of the power that delivered to the antenna to the power that been radiated from the antenna, we say that the antenna has a high efficiency when most of the power that been delivered to the antenna input is been radiated away. The antenna efficiency is a number between 0-1 or could be described as a % percentage. Figure 9 shows the designed antenna efficiency percentage and that it reach around 0.958 of radiation efficiency.

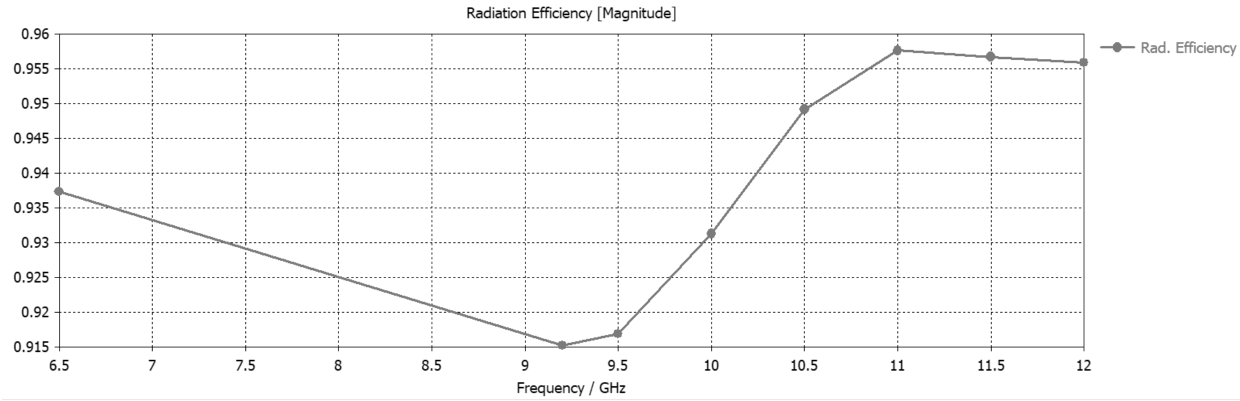

Figure 9 The antenna Radiation efficency

C. Surface Current Distribution:

The last study that had been done on the antenna is the Surface current distribution, to see the antenna behavior in the final design. Figure 10 illustrate the importance of the distance that had been done between the upper patch and the ground patch which created a current intensity in addition to that in the feedline the current is intensely located and finally the rectangle cuts in the upper face and in the lower face helped with improving the current flow on the patch surface.

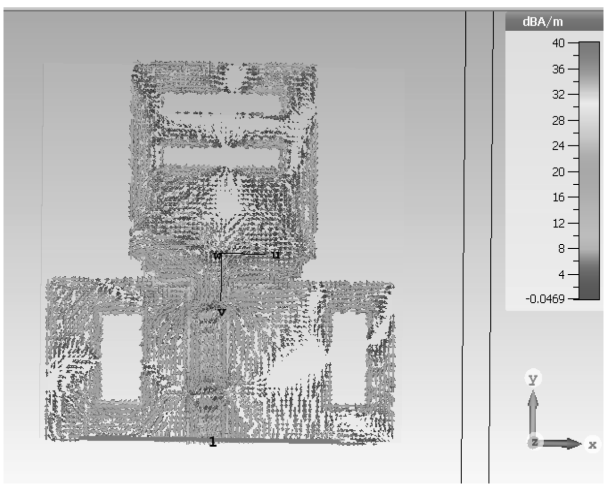

Figure 10 The Designed antenna Surface current distribution

At last the proposed antenna had been compared in terms of dimensions gain frequency range and S11 values with some of other antenna designs, and this references numbers and values are mentioned in the table

Table 2 Comparison between the designed antenna and the references antennas

REF NO	Dimensions (mm)	Center Frequency (GHZ)	Substrate material	Peak GAIN (DB)	S11 (DB)	Disadvantage
[12]	12*18*1.6	10.5	FR4	6.25	-18	
[13]	33.10*16.84*1.57	8.2	FR4	8.6	-58.2	VSWR BW is very narrow
[14]	9.12*7.44*1.6	9.49	FR4	4.31	-23.87	Low gain value
[15]	21.17*21.17*1.535	9.36	RT5880	7.622	-18.81	-
[16]	17.79*21.96*1.588	8.9	RT Duriod	8.15	-16.10	-
[17]	14*16*1.544	9.1	FR4	4.6	-28	Low gain value
[18]	30*30*3	9.5	FR4	4.6	-18	Low gain value
The proposed antenna	40*38*1.524	10.5	RO4003C	8.49	-23	

IV. CONCLUSIONS AND FUTHUER WORK:

In this paper, antenna designing to be used for X-band frequency application had been done by using RT 4003C as a substrate material because of its efficiency results on our desired range of frequencies, then compared that result that we had with the result that we will got if we used the FR4 common material, and found out that the RT 4003C will give better results and stability of this design. A refining of the design in the ground slot had been done to achieve better results. Finally, our antenna is able to achieve around 8.49 dB peak gain on 10.5 GHz which is a X-band Frequency also our antenna has a wide IBW range from 5.8 GHZ till 12 GHZ as the value of VSWR is less than 2 within this range so this antenna could be used effectively with the whole frequency band of the X-band, later on the current surface distribution of the antenna has been analyzed and found out the importance of the rectangular slots that had been done on the radiated patch and on the ground slot of the antenna.

After that a comparing of the results had been done to similar designed antennas that have been used for X-band frequencies. In a conclusion our antenna has a very good results in X-band frequency range and it could be used in many applications that operate at the band range, TV broadcasting is one of these applications and it could be used in radar applications and many more applications. The antenna design and analysis had been done using CST studio simulation software. For future work we recommend to use our designed antenna as a single element within an array antenna to give a higher gain and to be able to replace other antenna types that give a high gain but have a much bigger physical size compared to an array micro-strip antenna such as the reflector antenna.

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