International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 4 Issue 2, Feb-2015, pp: (139-145), Impact Factor: 1.252, Available online at: www.erpublications.com

Rectangular Microstrip 5.8GHz Antenna Vs Slotted version design and performance

Zaid A. Hamid
Computer Science Department, College of Science and Technology, University of Human Development,
As Sulaymaniyah, Iraq

Abstract: This paper presents the guidelines for constructing a Rectangular patch antenna in 5.8GHz frequency with design equations and Microwave office 2006 software for design simulation to get the best theoretical performance, then comparing with a slotted version of the corresponding antenna having a slotting shape of letter (C) in the English alphabet. The design analyses will include the return loss, bandwidth, radiation pattern, HPBW, gain, co and cross polar isolation parameters. The rectangular non-slotted antenna was well made following the exact design equation results that lead the antenna to have a return loss of about -25.4dB and about 2.4% bandwidth, 78o half power beam width in the desired operating frequency.

Index Terms: Patch antenna, Return Loss, Bandwidth, Antenna Radiation pattern, HPBW, Gain, Co-polar isolation, Cross polar isolation.

I. INTRODUCTION

Patch antennas or even called (Microstrip antennas), due to their unique and attractive properties like light weight, low profile, conformal nature and low production cost are fast replacing conventional antennas. However the problem of narrow bandwidth still limits its wide spread usage. More details are mentioned regarding the dielectric substrate dimensions, feeding contact point dimensions, and comments on (positioning letter (C) slotted shape, orienting the letter, resizing it) are also made. Then the desired parameters are all shown depending on the simulated graphs resulted from using Microwave studio 2006 [8]. It should be stated that decreasing the grid steps will drive the simulation to be slow mean while the results are much accurately calculated. Also important to be mentioned that positioning the feeding point to get the best RL is arbitrarily known. The simulation is made from 4 to 8GHz range. Four major shaping operations will be applied. Two for each size of letter (C), and for each size there are two different orientations. The best one is chosen among each of the operations then the best result among these versions is taken into account at last in a special sense that radiation pattern and all of the other details are re-simulated again. Tables will be implemented having each of the values simulated to facilitate presenting the results.

II. DESIGN CONSIDERATION

Two important values are considered the main design essentials are to be found, the Width and Length of the patch.
Design is started with finding the width [4]:-

$$W = \frac{C}{2f\sqrt{\frac{\varepsilon r + 1}{2}}}$$

Operating frequency is given besides the dielectric constant and substrate thickness which are 5.8GHz and 4.7 and 1.6mm respectively. The width was found to be W=15.32mm from the above equation. Then the length should also be calculated [4]:-

$$L = \frac{C}{2f\sqrt{\varepsilon r(eff)}} - 2\Delta L$$

If one observes the equation above, we'll be in need to find ΔL and εreff (Effective dielectric constant) [4]:-

$$\Delta L = \frac{0.412h[\varepsilon r(eff)+0.3](\frac{W}{h}+0.264)}{[\varepsilon r(eff)-0.258](\frac{W}{h}+0.8)}$$

$$\varepsilon r(eff) = \frac{(\varepsilon r + 1)}{2} + \frac{(\varepsilon r - 1)}{2\sqrt{(1 + \frac{10w}{h})}}$$

After doing the calculations, ΔL was found to be 0.715mm and εreff equals 4.143, L afterword was found to be 11.27mm≈11.3mm.

It should be noted that the square patch design dimensions will both have the value of L, which is 11.3mm since it's a square patch as desired, also the (resonant frequency is a function of wavelength especially for the dominant TM010 mode.. C. A. Balanis). So we are mostly concerned with the Length than being concerned in Width. It should also be mentioned that the thickness of the air gap above the substrate is taken as 16 which is well known as a practical value (10 times the thickness of the dielectric), meanwhile the dimensions of the substrate were carefully chosen to be 18mmX18mm, which is slightly bigger in area than the patch itself [1].

On the other hand, the feeding technique was chosen to be a co-axial one, which is termed the (Via point) in Microwave Office 2006 [8]. While the Via-point position was chosen randomly by moving the co-axial point arbitrarily on the patch till the best return loss was found. The patch was centered on the dielectric constant such that both vertical and horizontal spaces (starting from the patch edge till dielectric edge) are symmetrical on both sides. It's important to mention that all of the coming simulation will have a Via Point (Co-axial) feed point of dimensions 0.5mmX0.5mm. Some other design considerations should also be mentioned like having two layers in the design. The upper one is the Air which has a 0 tangent loss, and lower conductor patch layer having a tangent loss of 0.019 as given. The final design which got the best return loss of about (-25.4dB) is shown in the following figure:-

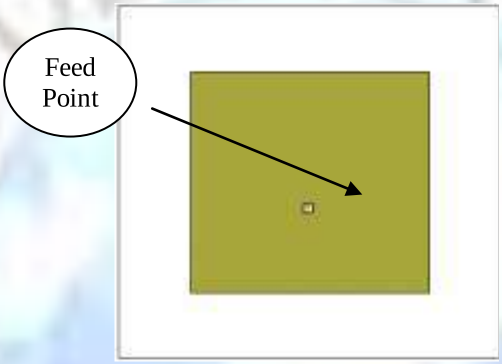

Figure (1), un-slotted patch

All of the simulation details will be shown in the (Simulation Result) section.

Now the design of the slotted version of the same patch above will be implemented with a special tool termed (Notch Conductor) in Microwave Studio software to apply some slots inside the patch designed in the shape of letter (C) in two sizes and two orientations which will look like the following:-

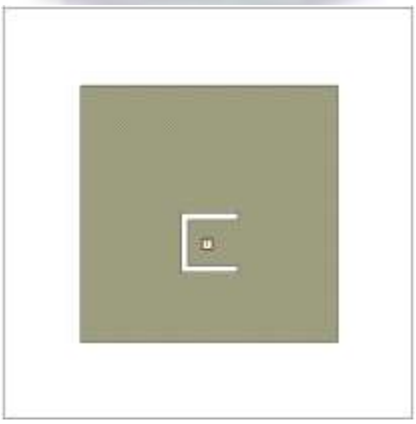

Figure (2), big letter size, first Orientation

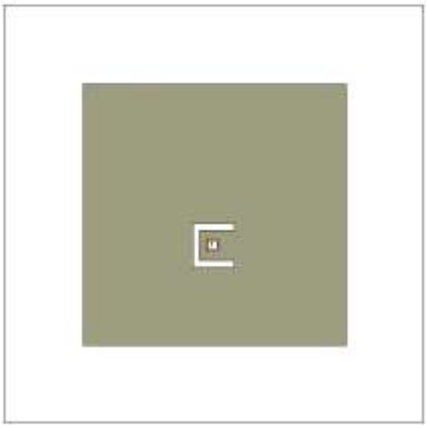

Figure (3), small letter size, first orientation

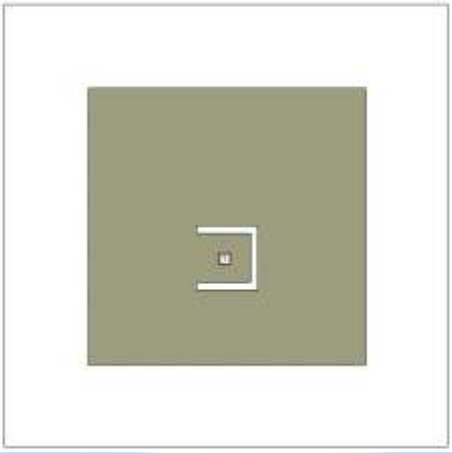

Figure (4), big letter size, second orientation

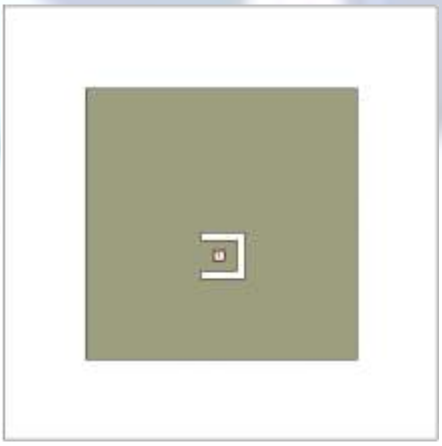

Figure (5), small letter size, second orientation

The above sizes and orientations where differently moved or situated on the patch as will be seen in the (Simulation Result) section, each having certain different parameters resulted in simulation. The best one having the best Return Loss and Bandwidth will be identified as long as the RL is highly related to BW, meaning as less as RL we get as much as BW resulted. The possibilities of moving the slotted letter (regardless of orientation or size) on the patch are numbered just for reference and shown below:-

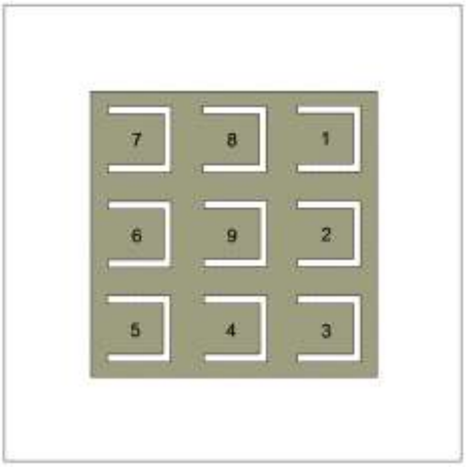

Figure (6), letter shape positions possibilities regardless of size and orientation (only positions)

It's important to know that the position seen in the figures before the one above is considered as position number 10 (the letter shape bounds the feeding point).

III. SIMULATION RESULTS

A- In this section, simulation results of the un-slotted version will first be presented. The same simulation results for the best one among the slotted versions will then be compared to the un-slotted in terms of all of the parameters given, even in graphs. The un-slotted design resulted in the following return loss:-

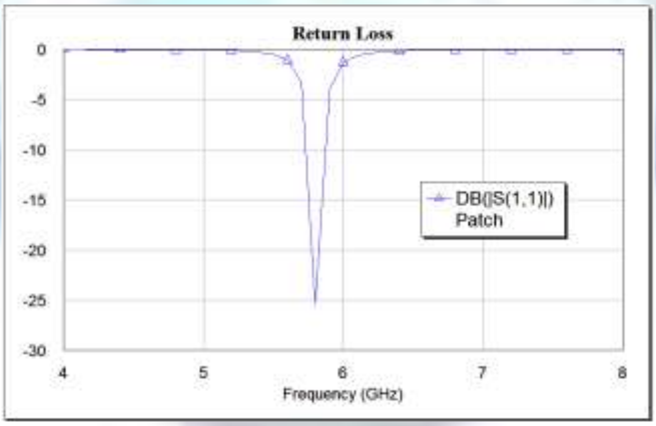

Figure (7), un-slotted patch return loss

It should be noted that the simulation was made in stepping of 0.1GHz (each 100MHz) to get an accurate result. Also the grid spacing of the whole design was taken **0.1mm**, which will slow down the simulation operation but will ensure giving an exact return loss and exact results in general.

The Bandwidth can be measured in the **-10dB** RL, which resulted in **(2.4%)** according to the following equation [3][5]:-

$$BW = \frac{f1 + f2}{f} * 100\%$$

Where f1 and f2 are the upper & lower frequencies along (-10dB) Return Loss, while (f) alone is the operation frequency. Upper frequency was **5.87GHz** while the lower one was **5.73GHz**.

The next parameter to find is the radiation pattern formed in 5.8GHz frequency which is shown in the following figure:-

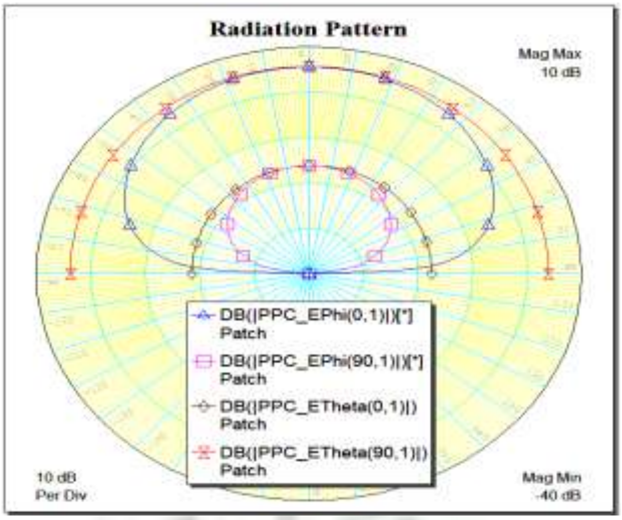

Figure (8), un-slotted patch radiation pattern

The radiation pattern was taken in terms of ϕ (Phi) which is the significant angle rather than referring to the θ (Theta) because the radiation pattern is already perpendicular to the patch itself. HPBW (Half Power Beam Width) which is the maximum angle at which the power radiated is not less than 3dB. The Electric field plotted with respect to ϕ=0º was taken into account in calculating the forthcoming parameters because it gave a Gain of **5.6dB**, so for calculating the HPBW, one should drop from 5.6dB till 3dB gain and measure the angle from the top to that position. In this patch, the HPBW has given **78º** by giving 39º on each side, so the two sides are symmetrical that lead to this result. Now for the Co-Polar isolation is the same as the top value of what has E-Phi 0º gave, which is **5.6dB**, while the Cross-polar isolation is calculated by subtracting the top value of E-Phi 90º from the top value of E-Phi 0º which will be:-

$$5.6 - (-16.2) = \mathbf{21.8dB}$$

B-The turn of evaluating the slotted versions parameters have come. For the ease and facilitative management of the results besides their multitude, a table will be designed tabulating the parameters' results mentioning each case. It should also be mentioned that the Via-Point (Feeding Point) is remaining still in its position while all of the possibilities of slots are taken. The table will contain parameters for each size of letter taken while mentioning all the orientation possibilities. It will only contain the values of Return Losses of each case, will not include any other parameter unless the best one among them is chosen, then the rest of the parameters are calculated and depicted and finally compared with the parameters of the un-slotted patch version[2][6].

The letter size possibilities are only two, **(1) large**, **(2) small**. The orientation possibilities are also two. One is **(1) normal (C) letter shape** while the other is **(2) rotated letter** (around the y-axis). Positioning possibilities are 10, and are depicted in Figure(6) except the tenth one which is the possibility of positioning the letter to be bounding the feed point which will make it lie in the center of the letter whatever its orientation and size was. Now the results can be seen in the following table:-

Position	Size 1, Orientation 1	Size 1, Orientation 2	Size 2, Orientation 1	Size 2, Orientation 2
1	-6 dB	-13.8 dB	-14.5 dB	-29.0 dB
2	-5.2 dB	-5.2 dB	-9.8 dB	-12.0 dB
3	-13.6 dB	-10.7 dB	-30.0 dB	-24.4 dB
4	-11.8 dB	-10.8 dB	-25.8 dB	-23.5 dB
5	-12.4 dB	-11.2 dB	-27.5 dB	-25.9 dB
6	-5.2 dB	-5.4 dB	-10.8 dB	-12.6 dB
7	-11.8 dB	-14.8 dB	-28.3 dB	-32.2 dB
8	-15.1 dB	-16.7 dB	-31.3 dB	-34.2 dB
9	-11.4 dB	-10.3 dB	-16.7 dB	-16.2 dB
10	-7.7 dB	-8.3 dB	-15 dB	-16.7 dB

Figure (9), slotted patch version RL possibilities

It's very easy now to compare the cases to the un-slotted version of the patch in terms of return loss, and it can also be seen from the table of Figure (9) that Size 2 (small) with Orientation 2 (rotated letter) in position 8 have given the best Return Loss, even higher than that of the un-slotted version, so it's worthy to go further in other parameters calculations for this case.

The Bandwidth given in this case is a little better than in the un-slotted case which is **2.75%** according to the same way of getting it, while the radiation pattern from which the bandwidth have been taken is shown below:-

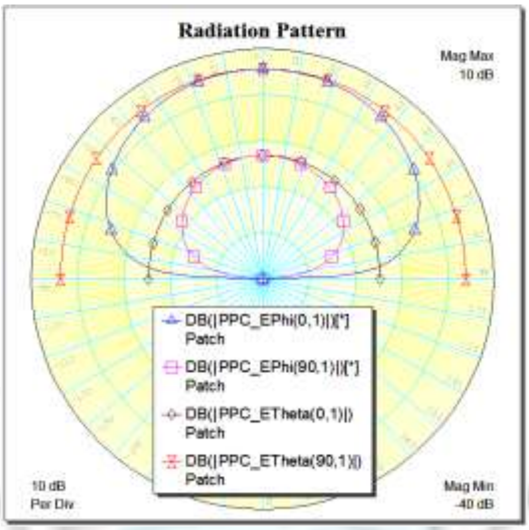

Figure (10), best slotted version case radiation pattern

HPBW is exactly the same as before, which is **78º**, Gain of **5.6dB**, Co-polar isolation of **5.6dB**, and Cross-polar isolation of 5.6 - (-13.2) = **18.8dB**.

It's also worthy to state the effect of the slot width on the performance of the patch. The current slot width used for all of the simulations is **0.3mm**. If the best case of the slotted version previously presented will be considered having a slot width of **0.5mm** rather than **0.3mm**, keeping the outer perimeter the same, RL has degraded to **-29dB**, the bandwidth will exactly be the same **2.75%** because it was insignificantly affected, HPBW will be exactly the same **78º**, Gain will be **5.6dB**, Co-polar isolation will be **5.6dB**, and Cross-polar isolation will be **20.3dB**. So, obviously the wider slot used the worst the result seen in simulation. No need to plot all of the results as long as the results are numerated and so close to each other for the sake of shortness.

IV. ANALYSIS AND DISCUSSION

It seemed that the concept of slotting the patch shouldn't always degrade the performance as always expected as long as the (Feeding Point) remains in the same position and the slot is a kind of interruption to all of the calculations made for the un-slotted version of the patch. Certain positions were suited for the slotted letter. Regarding size, the best results were given by the small (C) letter. Regarding orientation, it seemed to be arbitrary and no specific relation can be concluded. For positions, no rough idea can be reckoned either which makes the orientation effect dependant on position to a great extent.

In both un-slotted and slotted cases, the dimensions of the dielectric substrate were carefully chosen to achieve the best performance. In this case, once the dimensions are increased or decreased the performance will suffer from degradation. The dimensions of the feeding point were also kept constant during all simulation possibilities. The least the feeding point dimensions are set, the best the performance acquired. But impractical to apply dimensions less than 0.5mm. The performance will degrade if the dimensions are increased.

In general and for most cases of size and orientation, the small size oriented letter shape has achieved considerably higher Return Losses for almost all positions than all of the other corresponding cases. This can be seen in the last table column. Turning the focus to Radiation Pattern details, the gain value wasn't affected significantly due to the slot introduction even when RL negativity increases as long as we are depending on the biggest main lobe in calculation. The back lobe can be seen changed which pushed down the Cross-polar isolation value from 21.8dB to 18.8dB[7].

The other slightly affected value among the slotted and un-slotted patches is Bandwidth. Generally speaking, increasing RLs negativity will lead to a slight increase in Bandwidth, because the difference in RL between the un-slotted and the best case slotted version is about 34-25 ≈ 9dB that boosted BW to 2.75% from 2.4% which can be considered as 15% BW enhancement[5].

V. CONCLUSION

The slotted version of patch has outperformed the un-slotted one in some parameters in certain cases of positioning letter slots, certain size and orientation, which are small (C), 180º oriented around y-axis, position no. 8. While in most of other cases, the performance suffered from weakness in RL below the accepted threshold. So smaller size slots are better. Regarding the slots widths, also the lesser the better. The radiation pattern is better in Cross-polar isolation. BW is 15% more as seen, preserving the HPBW and Gain the same. As much as the grid spacing selected, as fast as the simulation becomes but the high precision of simulation is un-kept leading to a drastic difference in BW calculation which will lead it to be much more than using a smaller grid spacing. In this simulation case 0.1mm was used rather than higher values to prevent inaccurate simulation results. The feeding point size is also an important part in enhancing or degrading the performance. When decreased, the performance will increase so it's inversely proportional with its size.

VI. REFERENCES

[1]. Hongming An, Bart K. J. C. Nauwelaers, and Antoine R. Van de Capelle "Broadband Active Microstrip Antenna Design with the Simplified Real Frequency Technique", IEEE Transactions On Antennas And Propagation, Vol. 42, NO. 12, December 1994.
[2]. James R. James, Peter S. Hall, Colin Wood, And Ann Henderson "Some Recent Developments in Microstrip Antenna Design", IEEE Transactions on Antennas And Propagation; VOL. AP-29, NO. 1, January 1981.
[3]. Ching-Hong K. Chin, Quan Xue, and Chi Hou Chan, "Design of a 5.8-GHz Rectenna Incorporating a New Patch Antenna", IEEE Antennas And Wireless Propagation Letters, Vol. 4, 2005.
[4]. S. Lebbar, Z. Guennoun, M. Drissi, and F. Riouch "A Compact And Broadband Microstrip Antenna Design Using A Geometrical-Methodology-Based Artificial Neural Network", IEEE Antennas And Wireless Propagation Magazine, Vol. 48, NO. 2, April 2006.
[5]. Y.-H. Suh and K. Chang, "A high-efficiency dual-frequency rectenna for 2.45- and 5.8-GHz wireless power transmission," IEEE Trans. Microw. Theory Tech., vol. 50, no. 7, pp. 1784–1789, Jul. 2002.
[6]. K. Li, C. H. Cheng, T. Matsui, and M. Izutsu, "Simulation and experimental study on coplanar patch and array," in Microwave Conf., Asia-Pacific, Dec. 2000, pp. 3–6.
[7]. J. O. McSpadden, L. Fan, and K. Chang, "Design and experiments of a high-conversion-efficiency 5.8-GHz rectenna," IEEE Trans. Microw. Theory Tech., vol. 46, no. 12, pp. 2053–2060, Dec. 1998.
[8]. AWR Design Environment 2006 v7.03.