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### Research Article

## Design and Implementation of a Microstrip Patch Antenna for WLAN 802.11b Communication Standard

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#### Abstract

Microstrip patch antennas have been studied extensively over the past two decades because of its low profile structure, light weight and low cost. They have many advantages over conventional antennas, which make them suitable for a wide variety of applications. However, bandwidth has been a major drawback for this type of antennas. This paper presents the guidelines for constructing a square patch antenna in 2.4GHz frequency for WLAN 802.11b application with design equations and Microwave office 2006 software (AWR) for design simulation to get the best parametric design, then comparing with a slotted version of the corresponding antenna having a slotting shape of the letter (k) in the English alphabet has been put it in different places for best result. The design analyses will include the return loss, bandwidth, radiation pattern, HPBW, gain, co and cross polar isolation parameters. The square non-slotted antenna was well made following the exact design equation results that lead the antenna to have a return loss of about -47dB and about 6.8% bandwidth, 760 Half Power Beam Width in the desired operating frequency.

**Keywords:**Microstrip patch antennas, Coaxial Feed, Return Loss, Bandwidth, Antenna Radiation pattern, HPBW, Gain, Co-polar isolation, Cross-polar isolation.

#### 1. Introduction

A microstrip or patch antenna is a low profile antenna that has a number of advantages over other antennas it is lightweight, inexpensive, and easy to integrate with accompanying electronics But the drawback of mocrostrip antenna designs is its narrow impedance bandwidth. While the antenna can be 3D in structure (wrapped around an object, for example), the elements are usually flat; Hence their other name, planar antennas. Note that a planar antenna is not always a patch antenna. However the problem of narrow bandwidth still limits its widespread usage. Presently there are many other government and commercial applications, such as mobile radio and wireless communications that use microstrip antennas. However microstrip antennas have limitations in terms of bandwidth and efficiency, all imposed by the very presence of the dielectric substrate [1] [10].

The following drawing shows a patch antenna in its basic form: a flat plate over a ground plane (usually a PC board). The center conductor of a coax serves as the feed probe to couple electromagnetic energy in and/or out of the patch. The electric field distribution of a square patch excited in its Fundamental mode is also indicated [7].



# Fig.1 Shows the basic form of the microstrip patch Antenna [7]

The electric field is zero at the center of the patch, maximum (positive) at one side, and minimum (negative) on the opposite side. It should be mentioned that the minimum and maximum continuously changes side, according to the instantaneous phase of the applied signal. The electric field does not stop abruptly at the patch's periphery as in a cavity; Rather, the fields extend the outer periphery to some degree. These field extensions are known as fringing fields and cause the patch to radiate. Some popular analytic modeling techniques for patch antennas are based on this leaky cavity concept. Therefore, the fundamental mode of a square patch is Often denoted using cavity theory as the

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TM10 mode(TM stands for transversal magnetic field distribution) [4].

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories-contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both noncontacting schemes) [5].

More details are mentioned in this paper about regarding the dielectric substrate dimensions, feeding contact point dimensions, and comments on (position & size of letter (k) slotted shape) are also made. Then the desired parameters are all shown depending on the simulated graphs resulted from using Microwave studio 2006. It should be stated that decreasing the grid steps will drive the simulation to be slow meanwhile the results are much accurately calculated. Also important to be mentioned that positioning the feeding point to get the best RL must be chosen randomly until getting a good result. Two major shaping operations will be applied. Two for different size of letter (k) and for each size, there are two different positions. 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 resimulated again. Tables will be implemented having each of the values simulated to facilitate presenting the results.

#### 2. Design Consideration

To implement a simpler design of microstrip patch antenna we should put in our consideration the parameters, which are the length (L), width (W) and the thickness (h) of the patch as well as the parameters of the Frequency of operation (f0) and Dielectric constant of the substrate ( $\epsilon$ r).



Fig.2 The parameters of the Microstrip patch antenna [3]

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 from the equation (1):

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

Operating frequency is given besides the dielectric constant and substrate thickness, which are **2.4GHz** and **4.7** and **1.6mm** respectively. The width was found to be W=**37mm.**Then the length should also be calculated from equation (2) as shown: [9]

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

As obvious from the equation (2) we must find  $\Delta L$  from equation(3) and  $\varepsilon reff$  (Effective dielectric constant) from the equation(4), as shown:

$$\Delta L = \frac{0.412h[\epsilon r(eff) + 0.3](\frac{W}{h} + 0.264)}{[\epsilon r(eff) - 0.258](\frac{W}{h} + 0.8)}$$
(3)

$$\varepsilon r(eff) = \frac{(\varepsilon r+1)}{2} + \frac{(\varepsilon r-1)}{2\sqrt{(1+\frac{10w}{h})}}$$
(4)

After making the all calculation,  $\Delta L$  was found to be **0.7313** and sreff equals **4.395**, L afterwords was found to be **28.3mm**.

It should be noted that the square patch design dimensions will both have the value of L (means, on square patch we will neglect the value of the width (w) and the dimension of the patch will be (L x L) to make it square), which is 28.3mm, also the (resonant frequency is a function of wavelength especially of the dominant  $TM_{010}$  mode..) [2] [6].

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 16mm 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 40mmX40mm, which is slightly bigger in area than the patch itself. 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. 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. It's important to mention that all of the coming simulation will have a Via port (coaxial) 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 of unslotted patch antenna which got the best return loss of about (-42.84dB), as shown in the following figure:



Fig.3 Un-slotted patch antenna

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 shape) in Microwave Studio software(AWR) to apply some slots inside the patch designed in the shape of the letter (k) in two sizes and different places. And as shown below:



Fig.4 Slotted patch antenna with shape latter (k)



Fig.5 Slotted patch antenna with different shape (k) size and place

The two figures (figure.4 & figure.5), 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. (All the results have been discussed in simulation results section).

#### 3. Simulation Results

The software used to model and simulate the microstrip patch antenna is AWR software. AWR is a full-wave electromagnetic simulator based on the method of moments (discrete events). It analyzes multilayer structures of general shapes. It has been widely used in the design of MICs, RFICs, patch antennas, wire antennas, and other RF/wireless antennas. It can be used to calculate and plot the S11 parameters, VSWR, current distributions as well as the radiation patterns [8] [9]. A version 7.03, 2006 of the software was used to obtain the results of this paper. In this section, the simulation results of the un-slotted version will be presented first. 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 unslotted design resulted in the following return loss:



Fig.6 Un-slotted patch Return Loss

From figure (6), The Bandwidth (BW) can be measured in the **-10dB** RL, which resulted in **(6.67%)** according to the following equation (5):

$$BW = \frac{f1 + f2}{f} * 100\%$$
(5)

From equation (5), f1 and f2 are the lower & upper frequencies along (-10dB) Return Loss, while (f) alone is the operating frequency. Upper frequency was **2.48GHz** while the lower one was **2.32GHz** and operation frequency was **2.4GHz**. The others parameter to find is

from the radiation pattern figure which is shown in figure 7 as, shown:



Fig.7 Un- slotted patch radiation pattern in the planes of I=0 and I=90 degrees

The radiation pattern was taken in terms of  $\phi$  (Phi) which is the significant angle rather than referring to  $\theta$  (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  $\varphi$ =90<sup>o</sup> was taken into account in calculating the forthcoming parameters because it gave a Gain of **5.451dB**, so for calculating the HPBW, one should drop from 5.451dB till 3dB gain and measure the angle from the top of that position. In this patch, the HPBW has given **76.84**<sup>o</sup> by giving **38.42**<sup>o</sup> 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 90<sup>o</sup> gave, which is 5.451dB, while the Cross-polar isolation is calculated by subtracting the top value of E-Phi 90<sup>o</sup> from the top value of E-Phi 0<sup>o</sup> which will be:

#### 5.451dB - (-12.9dB) = 18.45dB

Now for the slotted patch, a table will be designed tabulating the parameters' results mentioning each case. It should also be mentioned that the Via-Point (Feeding Port) is remaining still in its position while all of the possibilities of slots are taken. As mentioned before, there are two slotted designs (figure 4&figure 5)and these just to explain how is the slotted shape and place giving different results especially in RL & BW and as shown :



Fig.8 Represents the RL for the design in figure (4).

From figure (8), the RL will be about **-46.78**, and the BW at -10 dB it's about **6.8%**.



Fig.9 Represents the RL for the design in figure (5).

From figure (9), the RL will be about **-28.18** ,and the BW at -10 dB it's about **6.6%**.and as, its clearly from the figure above can see that the antenna working in another mode (mean at frequency 4.7).Table (1), illustrates how is the different places for these two un slotted design will give different values of RL while changing the position through the patch:

Table 1 Slotted patch version RL possibilities

Position	Figure (4)	Figure (5)
1	-6 dB	-13.8 dB
2	-5.2 dB	-5.2 dB
3	-13.6 dB	-10.7 dB
4	-12.4 dB	-11.2 dB
5	-17.8 dB	-13.8 dB
6	-29.1 dB	-17.7 dB
7	-38.9 dB	-22.3 dB
8	-46.78 dB	-28.18 dB

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 above table that at position 8 have given the best Return Loss, even higher than that of the un-slotted version, so it's worthy to go further into other parameter calculations for this case.

The Bandwidth given in this case is a little better than in the un-slotted case which is **6.8%**, **according** to the same way of getting it, while the radiation pattern from which the bandwidth have been taken is shown below:



Fig.10 Best slotted version case radiation pattern

From the figure (10), the radiation pattern is not changed for the slotted &unslotted design; also the HPBW is exactly the same as before, which is **76.84**<sup>o</sup>, Gain of **5.4dB**, Co-polar isolation of **5.4dB**, but some change happen in Cross-polar isolation of **5.4** - (-10) = **15.4dB**.

#### 4. Analysis and Discussion

Firstly, from all the results that have been got it from the slotted and the un slotted design ,its represent that by making slot on the patch that will be increase the performance of the antenna but that will be depend on the position and size of the slot(latter k), the slot is a kind of interruption to all of the calculations made for the unslotted version of the patch, also it seemed to be arbitrary and no specific relation can be concluded For positions and size, means the choice of the slot position and size its randomly no mathematical calculation just seemed like trial and error until get the best results, also the results depend on how the simulation work like In both unslotted 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 better the performance acquired. But impractical to apply dimensions less than 0.5mm. The performance will degrade if the dimensions are increased.

Back to the Radiation Pattern, it seemed that there is no change or wasn't affected significantly by making the slot, when RL negativity increases as long as we are depending on the biggest main lobe in the calculation. The back lobe can be seen changed which pushed down the Cross-polar isolation value from -18.45dB to -15.4dB. 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 unslotted and the best case slotted version is about 47-43  $\approx$  4dB even the difference is not big but that made BW better than before.

#### Conclusion

Two microstrip patch antennas are proposed for WLAN 802.11b communication standard at 2.4 GHz band slotted and un-slotted. It can be concluded from the above results that, designing a proper feed network and impedance matching are very important parameters in Microstrip Patch antenna design. Also, choosing a proper position for terminating the feed line affects the overall performance of the antenna. Different types of feed methods affect the performance of an antenna. In this design, the coaxial feed method is chosen. The slotted version of the patch has outperformed the un-slotted one in some parameters in certain cases of positioning letter slots, also in the slotted design has different parameter values and that's depend on the size and the position of the slot (letter K) on the patch.

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