DESIGN A SQUARE MICROSTRIP PATCH ANTENNA AT 2.4 GHZ, AND COMPARISON BETWEEN UNSLOTTED AND SLOTTED VERSION

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ABSTRACT

Low profile antennas support the operation of many modern communication systems. Microstrip patch antennas represent one family of compact antennas that offer a conformal nature and the capability of ready integration with communication system's printed circuitry. And it has many advantages over conventional antennas. In this paper a square Microstrip Patch Antenna has been designed at 2.4 GHz frequency. By using Microwave office 2006 software (AWR) for design simulation to get the best parametric design, and compared with a slotted version of the antenna having a slitting shape of letter (P). It included in the design the return loss, gain, radiation pattern, bandwidth, HPBW, co and cross polar isolation parameters. The square slotted antenna that designed has a result of a return loss is about (-42.41dB) and about 12.92% bandwidth.

Keywords: Return Loss, Coaxial Feed, Bandwidth, Antenna Radiation Pattern, Co-Polar Isolation, Cross-Polar Isolation.

1. INTRODUCTION

Microstrip antennas (MSAs) are used in a broad range of applications from communication systems to biomedical systems, primarily due to several attractive properties such as light weight, low profile, low production cost, conformability, reproducibility, reliability, and ease in fabrication and integration with solid state devices. In recent years the rapid decrease in size of personal communication devices has lead to the need for more compact antennas. As communication devices become smaller due to greater integration of electronics, the antenna becomes a significantly larger part of the overall package volume. Presently there are many other government and commercial applications, such as mobile radio and wireless communications that use microstrip antennas [1] [2]. Microstrip antennas however have limitations in terms of bandwidth and efficiency, all imposed by the very presence of the dielectric substrate. The following drawing shows a patch antenna and its basic form: a flat plate over a ground plane, the center conductor of a coax serves as the feed probe to couple electromagnetic energy in and/or out of the patch [3].

Figure 1: Shows The Form Of The Microstrip Patch Antenna

In its most basic form, a microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the
Feed lines are usually photo etched on the dielectric substrate [4].

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories—contacting and non-contacting [5]. 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, aperture coupling and proximity coupling [6].

In this paper, more details were mentioned such as the dielectric substrate dimensions, feeding contact point dimensions and also the slotted design in our letter (P), which depends on position & size of letter. And there is another thing also important the (positioning the feeding point), because when we want to get the best RL result, it must move the feeding point randomly until getting a best results, and this takes a lot of time to get it.

2. DESIGN CONSIDERATION

There are many things or parameters that should be put in consideration before starting the design of microstrip patch antenna, like the length (L), width (W) and the thickness (h) of the patch, and also Dielectric constant of the substrate (\(\varepsilon_r\)) and the Frequency of operation. And these parameters showed in figure 2.

To start there are two important values in the design must be found, the Width and Length of the patch [7].

Firstly the width can be found from the equation (1):

\[
W = \frac{C}{2f \sqrt{\varepsilon_r + \frac{1}{2}}}
\]  

And the operating frequency \(2.4\) GHz is given and also the dielectric constant \(4.7\) that it needs to calculate the width (w). It was founded the width equals approximation: \(W=37\) mm.

Then also must calculate the length, it can be found from the equation (2) [8]:

\[
L = \frac{C}{2f \sqrt{\varepsilon_r(\varepsilon_{\text{eff}})}} - 2\Delta L
\]  

As seen in the above equation it needs to find \(\Delta L\) and \(\varepsilon_{\text{eff}}\) (Effective dielectric constant), and they can be found from equations (3) and (4) [9].

\[
\Delta L = \frac{0.412h[\varepsilon_r(\varepsilon_{\text{eff}})+0.3](\frac{W}{h}+0.264)}{[\varepsilon_r(\varepsilon_{\text{eff}})-0.258](\frac{W}{h}+0.8)}
\]  

And

\[
\varepsilon_r(\varepsilon_{\text{eff}}) = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2\sqrt{(1 + \frac{10w}{h})}}
\]  

From equation (4) having \((\varepsilon_r)\), so easily \((\varepsilon_{\text{eff}})\) can be found, that equals 4.397, and then uses the last one in equation (3) to find \(\Delta L\) that equals 0.731. After that to calculate the length (L) and it will be 28.5 mm.

As seen from the results \(W=37\) mm, and \(L=28.5\) mm. This means the patch is not square, its rectangle. But it must be square. So it will take these measurements in form of (L x L). Means, on square patch it will neglect the value of the width (w).
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), and these dimensions have been chosen of the substrate to be 40mmX40mm, which is bigger than the patch, to be enough, it used co-axial as a feeding technique. And the dimensions of feed point is 0.5mmX0.5mm have been taken.

In the end after all these measurements, the un-slotted patch antenna designed and get the best value of return loss is about (-42.8dB), after moving it randomly and at last get this value, as shown in figure 3.

Now design the slotted version of the same patch above, to implement the letter (P). And here in design also must change the shape of the letter and change it's position of course randomly until we get the best result. The design becomes as shown in figure 4.

After the slotted patch designed, the return loss and bandwidth must be computed. All of these computations for unslotted and slotted will show in simulation results.

3. SIMULATION RESULTS

Firstly it will show the simulation results of the un-slotted version. And then it will show the simulation results of the slotted version and compare between them.

The return loss for un-slotted design in the figure below:

Figure 4: Slotted Patch Antenna With Shape Letter (P)
From figure 5 above the bandwidth can be calculated (BW) in -10dB RL in the lower & upper frequencies f1 and f2. Upper frequency was 2.556GHz while the lower frequency was 2.245GHz and operation frequency was 2.4GHz. Firstly subtract f1 from f2 and the result divide it by square root of multiplying f1 and f2. And this gives the BW = 12.98%. As shown in Eq. below

\[ BW = \frac{f_2 - f_1}{f} \]

Now from radiation pattern figure below, the other parameters can be calculated.

\[ \text{Gain} = 4.634 \text{ dB} \]

For calculating the HPBW (Half Power Beam Width) which is the maximum angle, and to compute HPBW it should be dropped from 4.634 dB to 3dB gain and measure the angle from the top to that position. Ones in the right side and then in the left side and add them. Founding HPBW has 66.86°, it gives 33.43° on each side, because the two sides are symmetrical.

And for the Co-Polar isolation is the same as the top value of what has E-Phi 90° value, which is 4.634 dB, while the Cross-polar isolation is calculated by subtracting the top value of E-Phi 90° from the top value of E-Phi 0° which will be:

\[ 4.634 \text{ dB} - (-12.9 \text{ dB}) = 17.534 \text{ dB} \]

Returning to slotted patch design, and compute the parameters as it had been done in un-slotted patch.

From figure (7) above the bandwidth can be calculated (BW) in -10dB RL in the lower & upper frequencies f1 and f2. Upper frequency was 2.551GHz while the lower frequency was 2.242GHz and operation frequency was 2.4GHz. Firstly subtract f1 from f2 and the result divide it by square root of multiplying f1 and f2. And this gives the BW = 12.92%. As shown in Eq. below

\[ BW = \frac{f_2 - f_1}{f} \]

Now from radiation pattern figure below, the other parameters can be calculated.
As obvious from figure above is approximately the same in slotted and un-slotted design. The Gain is 4.647 dB, the HPBW has 67.3°. And for the Co-Polar isolation is the same as the top value of what has E-Phi 90° value, which is 4.647 dB. Cross-polar isolation is calculated by subtracting the top value of E-Phi 90° from the top value of E-Phi 0° which will be:

$$4.647 - (-12.8 \text{ dB}) = 17.447 \text{ dB}$$

5. CONCLUSION

A square microstrip patch antenna was designed at frequency 2.4 GHz. As seen in this paper in the results an important parameters included like feed network and impedance matching in microstrip patch antenna design. And also the affect of changing the position of feed point on the performance of the antenna. And a comparison has made between the un-slotted design and slotted one. And the results discussed if the size and position of letter (P) changed.

REFERENCES: