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Circularly Polarized Patch Antenna Design For C – Band Applications

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Abstract – This work presents a novel design of a compact ultra-wideband (UWB) coplanar waveguide (CPW)-fed patch antenna that could that cover C-band frequency band. The antenna has a close-packed size of 50 x 50 x 0.8 mm and gives an appropriate impedance bandwidth all over the frequency range of 1.6GHz to 7GHz.The antenna gain has been reached to 5dB. The steps taken in order to achieve the proposed antenna will be discussed in this paper.

Keywords: Patch antenna, CPW, C - band, UWB

1. INTRODUCTION

In a wireless communication system, the increment of the gain of antennas used for communication yields in the increment of the wireless coverage range, minimizes the fallacies, rises possible bit rates and reduces the battery utilization of wireless transmission devices. Matching the polarization between the emitter and the receiver antenna is one of the main items in increasing this gain [1-5]. There are some characteristics that should be the same in both transmitter and receiver antennas to reach this polarization matching such as; spatial orientation, axial ratio (AR), and the same perception of polarization [3-5]. It is almost impractical to continuously match the dimensional orientation of the gadget in transportable wireless application where wireless gadget constantly changes their position and direction. Since the radiated waves keep on oscillating in a ring that is up-right to the direction of generated waves, circular polarization (CP) antennas can be easily matched in a broad scope of orientations [1-6].

Comparing to other kinds of antennas, micro-strip antennas are most repeatedly utilized in applications that require different kinds of polarization. Generally, micro-strip antennas are

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advantageous because they can operate in at microwave frequencies where other antennas cannot, they are cheap, light and easy to analysis [1][4][5].

A micro-strip patch antenna with the frequency range of 1.6GHz to 7GHz will be discussed in this paper. This frequency range covers the C-band range which is from 4GHz to 8GHz and also covers the UWB frequency range which is from 3.1GHz to 10.6 GHz. However, the main goal of this paper is to present a novel design of CP patch antenna for C-band(4-8GHz) applications [1-6].

In order to reach this novel antenna design, a survey has taken place comparing the effect of different patch, ground plane and substrate designs on the radiation features of circularly polarized micro-strip antenna. The analyzation of the characteristics parameters such as, VSWR, radiation pattern and return loss are done by HFSS 15.0 software.

2. ANTENNA DESIGN

In this part, the geometrical design of the proposed antenna will be discussed in detail with all the changes and improvements made in order to achieve the proposed antenna. The proposed antenna consists of radiating patch, ground plane, micro-strip feeding line, and a rectangular slot.

Figure1, is an illustration of the proposed antenna, the substrate of this antenna is square-shaped and is made of FR4 material. The square shaped substrate has the length of 50 mm and it's thickness is equal to 0.8mm. The dielectric constant of the substrate is equal to $\varepsilon r=4.4$. The feeding technique that is utilized in this antenna is 50Ω CPW feeding line. The signal strip-line has the width of 3.7mm and also the width of the gaps that are located between the signal strip and the ground plane have the width of 0.55 mm. In order to achieve a wider bandwidth and better axial ratio, an asymmetrical ground plane is designed for this antenna.

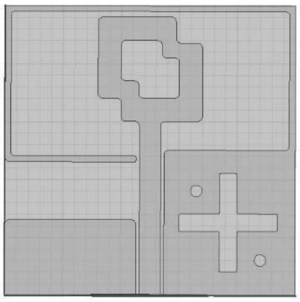


Figure1: The proposed antenna

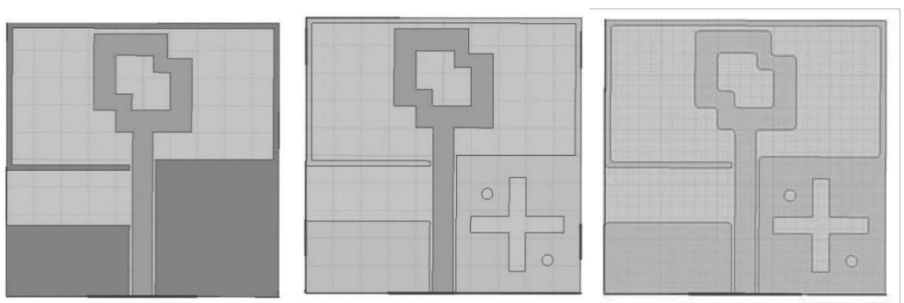
3. SIMULATION AND RESULTS

Figure 2(a) shows the uncomplicated and simple design of micro-strip antenna which's frequency band is from 1.698 GHz to 4.199GHz and from 4.98GHz to 6.80GHz.

In this part since geometrical configuration of the antenna are calculated. Some of the important characteristic of the antenna such as Return loss (S11), VSWR, Gain, Radiation pattern and Axial ratio (AR) will be discussed.

In order to achieve the final design, three steps have been taken. The first design is shown in Figure 2(a), In the second step as it is shown in Figure 2(b), to achieve better results than the initial design, defected ground structure (DGS) methods have been used by adding a plus shaped and two circular shaped cuts in the ground plane of the micro-strip antenna. These cuts in the ground plane improve the circular polarization (CP) and also minimizes the inductive characteristics of the patch by producing capacitive loads, also produces resistive input impedance which makes the bandwidth range increase.

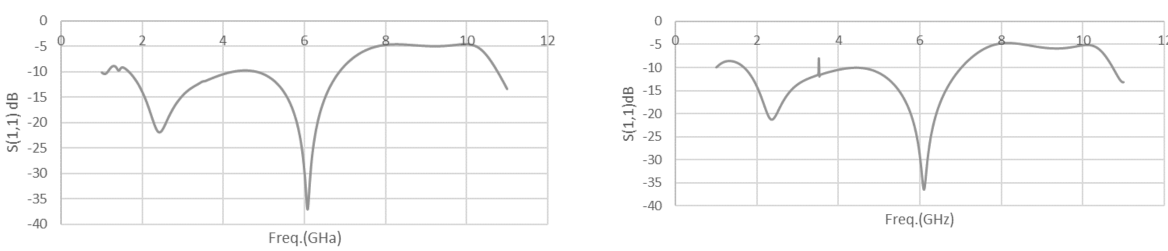
In the third step all the corners and edges of the antenna including patch and the ground plane, were rounded. Rounded corners in micro-strip patch antennas yields in a better return loss, flatter input impedance, more stable radiation pattern and uniform distribution of the surface wave at the same time. Figure 2(c) shows the third step of our proposed micro-strip antenna's design.



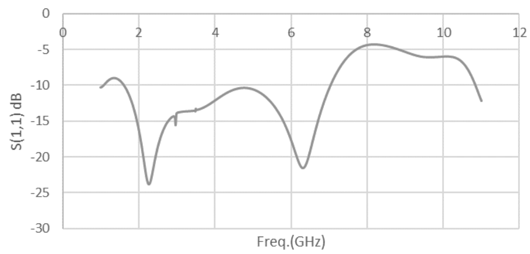
(a) (b) (c)

Figure 2: a) The initial design of the proposed antenna b) Micro-strip antenna with plus and circular shaped cuts c)The proposed antenna

This section is comparing some of the general results of all three steps that have been taken to achieve the final design.
The Return Loss (S11) of the three designs has been shown in figure 3. This figure 3(c) indicates that the proposed antenna is operating in 1.612 GHz to 7.173GHz.



(a) (b)



(c)

Figure 3: The Return Loss of the a) uncomplicated initial design, b) second design with slots in ground plane and c) proposed antenna with rounded edges

Figure 4 is a comparison between VSWRs of all three antennas that have been designed to achieve the final antenna. As the figure shows, the VSWR bandwidths of these three steps are 5.1GHz, 5.4GHz and 5.6GHz respectively. And the VSWR of the proposed antenna is smaller than 2 (VSWR< 2) at the frequency range of 1.55 GHz to 7GHz.

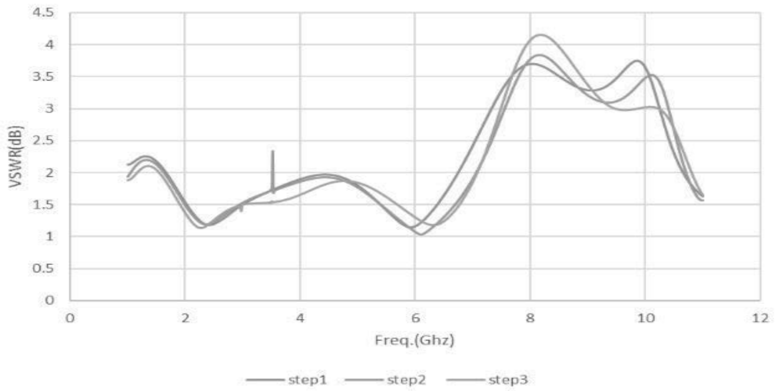
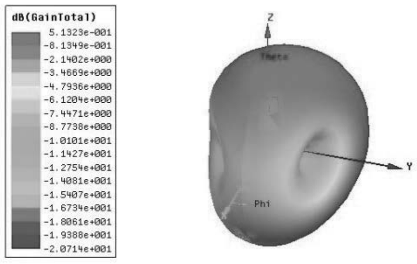


Figure 4: The comparison between VSWRs of all three antennas

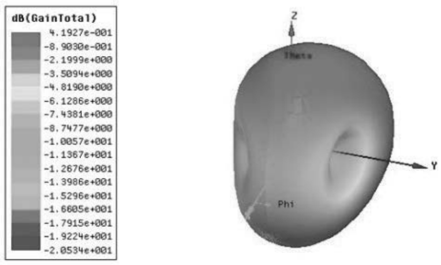
Step1: Basic antenna design, Step2: Second design with cuts in the ground plane, Step3: Proposed antenna

For the to Radiation pattern of the proposed antenna, the related measurements have been done at the frequency of 4GHz, also phi is equal to 0 degree and theta is 90 degrees.

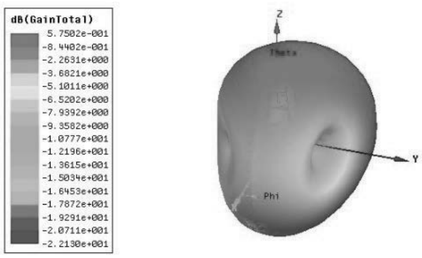
As it is shown in figure 5, the last design has the best radiation results comparing to earlier designs. Although their radiation pattern shapes may look like each other, the maximum power radiated by the proposed antenna is higher than the others.



(a)



(b)



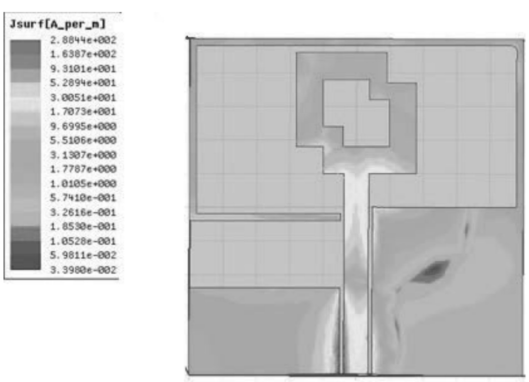
(c)

Figure 5: The 3D polar gain plot of the a) initial design b) second design c) final design

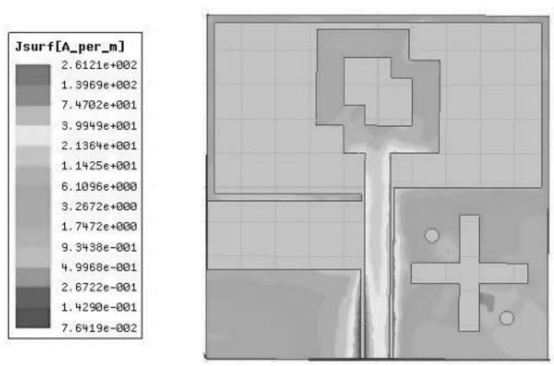
As it is mentioned before and shown in figure 6(a), by comparing the results of the three steps, in the first design (uncomplicated one) most of current is concentrated throughout the signal strip due the creation of capacitive load at a point and other parts of the antenna share a small portion of it.

At the second step by adding the plus-shape and the circle cuts to the ground plane, the surface wave distribution becomes more homogeneous on that area, figure 6(b).

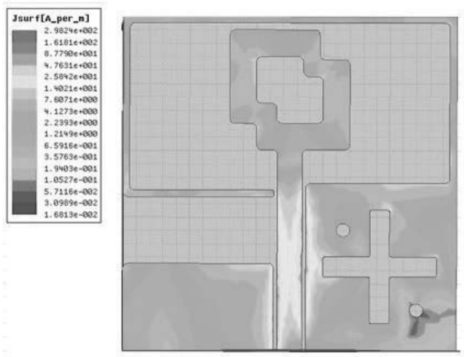
As it is shown in the figure 6(c), in the last step, by rounding all the edges of the antenna a much better surface current distribution comparing to the first design is achieved.



(a)



(b)



(c)

Figure 6: Surface current distribution of the a) initial design b) second design c) proposed antenna

Figure 7 Compares the Axial Ratios of all three antennas designs. As the figure indicates, Circular polarization frequency range of the first antenna is very small, for the second antenna with plus-shaped and circular slots in the ground plane it is from 3.08GHz to 3.90GHz. While Circular polarization frequency range of the final antenna is from 3.10GHz to 4.9GHz.

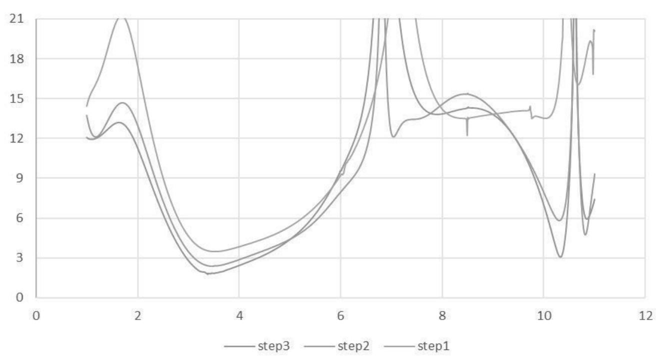


Figure 7: The comparison between Axial Ratios of the three antenna designs

Finally, A comparison has been made between the proposed antenna and some other antenna designs from the reference part in terms of dimensions, gain and operation frequency band. The related results are shown in table 1. As it is obvious from the table, the proposed antenna has a way better characteristics than most of them.

Table 1**:** Comparison of some References designs with proposed antenna in term of dimensions, gain and operation frequency band

Reference	Dimension	Operating Frequency	Gain
[8]	30x30x1.6	2.69-2.71GHz	3dB
[9]	70x70x1.6	1.84-2.08GHz	3.5 dB
[10]	100x100x1.6	3-4.5GHz	3.5dB
[11]	60x60x0.74	2-3GHz	3-4dB
Proposed Antenna	50x50x0.8	1.5-7GHz	5dB

4. CONCLUSION

In this work, CPW micro-strip line feed C-band antenna is designed. The simulation and design of this antenna was done in the High Frequency Structural Simulator (HFSS) software. This antenna is very small with the overall size of 50×50 mm. This antenna is designed on FR4 substrate with the thickness of 0.8mm. The operation frequency range is from 1.6GHz to 7GHz which could cover the C-band frequency range. In conclusion this survey was initially started with an uncomplicated design of micro-strip patch antenna. Later, some other changes in the initial design have been made in order to minimize the effects of unwanted frequency bands and improve the general performance of the antenna. And at the final stage, an optimized design of CP micro-strip patch antenna was achieved which is suitable for C-band (4GHz-8GHz) applications such as satellite communications, some Wi-Fi devices, wireless telephones, surveillance and weather radar systems.

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