Design and Implementation of a Quad Element Patch Antenna at 5.8 GHz

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Abstract **─** This paper presents simulation and experimental verification of a quad microstrip patch antenna that operates at 5.8 GHz. Sonnet antenna design software was used to simulate the performance of the antenna. To reduce the design's complexity and the computational load, the antenna and the feeding lines were simulated separately. An optimization was done for each subpart to get the optimum desired results. Finally, all the subparts were merged and the final structure was simulated to check the performance. A prototype of the antenna was fabricated on a double-sided PCB substrate (relative permittivity=10.2, thickness=1.28 mm) using a PCB milling machine. The S11 of -14 dB and -18.8 dB and maximum gain of 6.2 dB and 4.2 dB were obtained, from the simulation and experimental measurements, respectively.

Index Terms **─** 2x2 Microstrip Patch Antenna, 5.8 GHz Antenna, Quad Microstrip Patch Antenna.

I. INTRODUCTION

An antenna is a transducer that converts voltage and current on a transmission line into an electromagnetic wave and to transmit and receive data wirelessly. Antennas are a crucial component of all types of wireless devices and technologies that we use everyday and almost everywhere.

Nowadays, microstrip patch antennas are frequently used in telecommunication products like Wireless Local Area Networks (WLAN), cellphones, Global Positioning Systems (GPS), and in many other technologies due to their low cost, low profile, light weight, and easiness of fabrication and integration [1-3]. Because the size of the microstrip antennas are directly related to wavelength of resonance frequencies they are typically used at microwave band frequencies. The small features of these devices and feasibility of fabrication on the same electrical board, increases the demand of patch antennas for of grid sensor and energy harvesting applications too, as providing the energy to a sensor operating in harsh environment is important [4-7].

Literately, when the microstrip patch antenna is excited, the electrical charges are accumulated at the edges of the patches. These electrical charges make curved fringing fields and therefore these fields at the edges of the microstrip antenna generate electromagnetic radiation [8, 9]. Therefore, the parameters such as frequency, input impedance and gain of the antenna depend on the geometrical shape and the feeding type as well as the physical properties of the substrate [10].

The frequency band of 5.8 GHz is especially important for high speed Wi-Fi routers, FPV (First Person View) applications like remote controlling and online streaming where the transmitter could be placed in a remotely controlled device where antennas with smaller dimensions and profile are desirable.

This paper represents a designed and fabricated antenna to operate at 5.8 GHz, optimizing all the geometrical shape and feeding lines of a 2x2 array. For the antenna, the architecture presented in [11, 12] was used where a 2x2 array of microstrip patch antennas were simulated. The shape and feeding lines were changed and redesigned to operate the antenna at 5.8 GHz. An inset-fed feeding method was chosen which provides an effortless way of impedance control [13-15].

II. DESIGN CONSEDIRATION

The design of the antenna array was started by choosing the suitable patch shape of the antenna. The rectangular patch shape antenna was chosen because it

Submitted On: September 29, 2018
Accepted On: October 12, 2018

simplifies the analysis and numerical calculations. The single path antenna was designed with input impedance of 100 Ohm on a substrate with high ε_r of 10.2 and thickness of 1.28 mm (ROGERS, RO3010) to operate at 5.8 GHz. The single patch antenna was simulated in SONNET and the inset feed's parameters were adjusted to obtain lowest input reflection coefficient as much as possible.

As a start point, the patches were simulated with inset feeds. The simulations were started with known theoretical equations for the rectangular single patch antenna. The dimensions and the feed lines were optimized using Sonnet Suite. Then 4 of these single patch antennas were combined through feed lines and the central input via. A 100 mm thick of air layer was added during the Sonnet simulations such that the whole antenna was placed in a 100 x 400 x 300 mm insulation box.

Separately, the feed line for an array of 2 by 2 antennas was simulated where 100 Ohm resistors were connected to end of the lines. Finally, all the components were merged and connected to each other and the parameters were swept to get the lowest S11. Figure 1 shows the geometry of the 2x2 microstrip patch antenna that was designed in this paper.

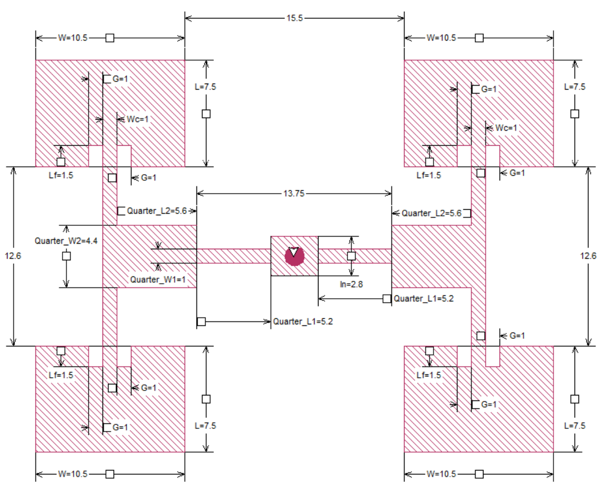
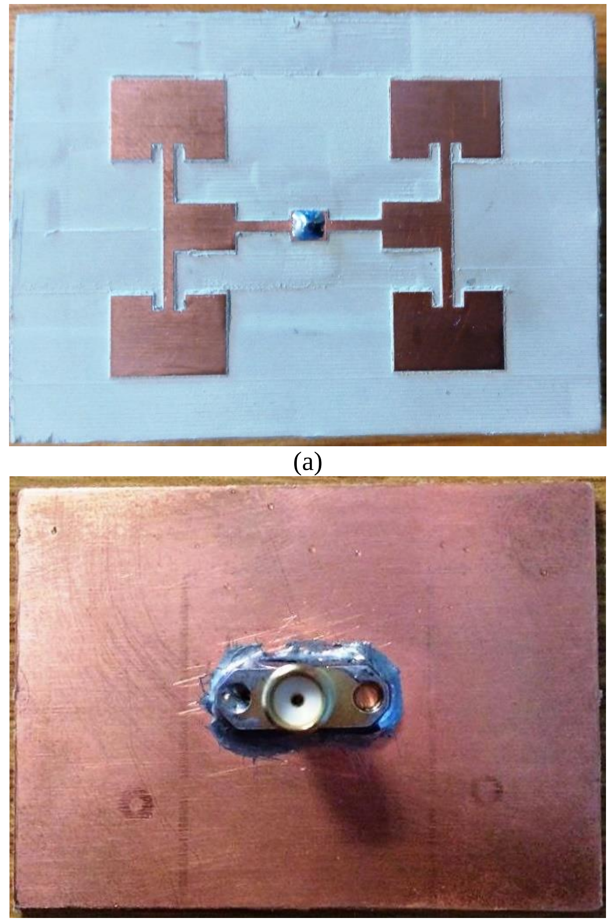


Fig. 1. Proposed 2x2 microstrip patch antenna with via feeding. The antenna was put inside a box with multiple times of the antenna's exact size (box size of 400 x 300 mm and air height of 100 mm on top of it).

The input port of the antenna was a via placed at the center as shown in the Fig. 1. The input was coupled to the antenna patches through a 2 stage Binomial feeding line to achieve good impedance matching. Dimensions of the patch antennas were calculated using analytical equations and then few optimizations were done to get the optimum dimensions. In order to reduce the proposed antenna size, a substrate with high ε_r of 10.2 with thickness of 1.28 (ROGERS, RO3010) was used for the simulations and the prototype.

The last optimization was done to adjust the dimensions of the whole antenna to reach the lowest reflection coefficient as much as possible. The final dimensions of the antenna are shown in Table 1. Figure 2 shows the fabricated antenna using drilling machine.



(a)

(b)

Fig. 2. Prototype of the designed antenna on the RO3010 substrate using drilling machine: (a) front view and (b) back view.

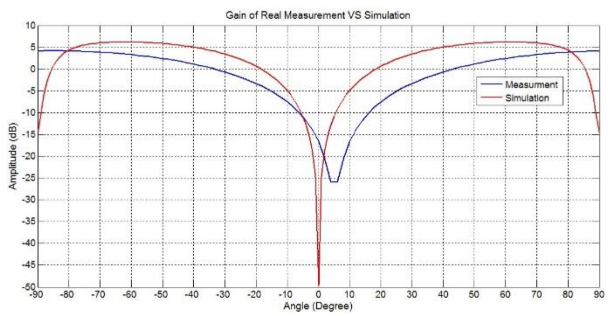
Table 1: Dimensions of the proposed antenna

Uppercase	**Dimensions (mm)**
Rectangular patch	W = 10.5 L = 7.5
Inset feed	G = 1 Lf = 1.5 Wc = 1
Microstrip feed line	Quarter_L1 = 5.2 Quarter_W1 = 1 Quarter_L2 = 5.6 Quarter_W2 = 4.4 In = 2.8
Other parameters	Vertic. gap = 12.6 Horiz. gap = 15.5

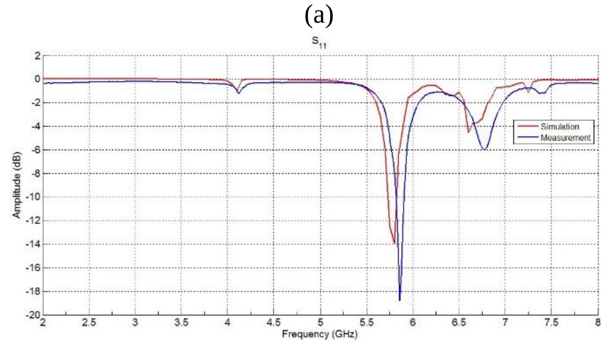
III. RESULTS

Based on the results obtained from simulations by SONNET, the maximum gain of 6.2 dB on the side lobes, and the input reflection coefficient of -14 dB were achieved at the operation frequency of 5.8 GHz. Obtaining these satisfying results from the simulations made the fabrication to start for prototype antenna.

The antenna was fabricated on the specified substrate (ROGERS, RO3010) as shown in Fig. 2. A 50 Ohm female socket was soldered from back side of the antenna. The antenna was sent to another facility to perform the practical measurements by an expert. The measurements for the prototype antenna and the simulation results are shown in Fig. 3. There is a good agreement between the measurements and the simulations. However, the slightly differences can be attributed to the inaccuracies during the fabrication and measurement process. The used substrate has a soft dielectric layer and it is not good to be fabricated by drilling machine.



(a)



(b)

Fig. 3. Comparison of measurement and simulation results: (a) directivity gain of the antenna and (b) input reflection coefficients.

A simulation for the current density over the antenna patches also was done as illustrated in Fig. 4. The microstrip patch antennas emit electromagnetic waves at the outer edges of the antennas; therefore, the current density along the perimeter of the patch antenna should be higher compared to the other parts at resonance frequencies. Figure 4 illustrates the JXY Magnitude for the current density in Amps/Meter unit.

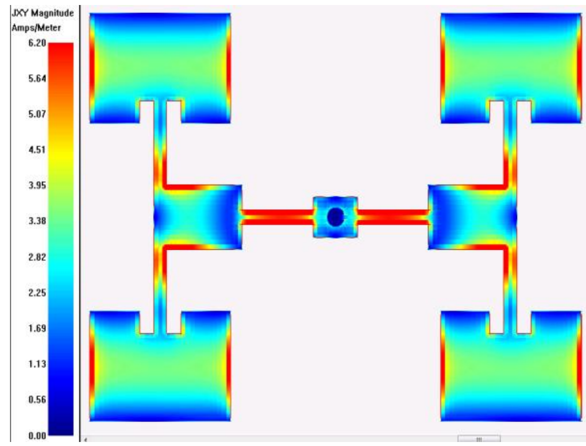


Fig. 4. Current density of the antenna operating at 5.8 GHz in JXY Magnitude (Amps/Meter).

IV. CONCLUSION

In this work, a 2x2 microstrip patch antenna was designed and fabricated at 5.8 GHz that only occupies 2.7 cm by 3.6 cm. The design was done somehow to obtain the low S11 as much as possible. The measured gain of 4.2 dB and S11 of -18.8 dB were obtained for the antenna. There is a good agreement between results obtained by measurements and simulations. However, the slight differences between the simulation and measurements are due to the inaccuracy of the drilling machine that was used to build the antenna. Inaccuracy in the directivity gain may come from slightly shifted mounting of the antenna on the chunk. Also, from fabricated errors which introduces nonsymmetric shapes to the array.

To keep the computational load as low as possible, only a few parameters were contributed in the parameters sweep. However, the results can be further optimized by using high performance workstations to execute the sequential optimization algorithms and manipulation of all possible parameters to obtain the optimum dimensions.

Also, a precise antenna can be fabricated using laser-based fabrication methods. This will further reduce the error of fabrication and prevent of dielectric layers peeling off.

ACKNOWLEDGMENT

The authors would like to thank Mert Karaca from Ozyegin University who has assisted us during the antenna fabrication, and Omer Yilmaz and Fatma Zengin from TUBITAK for performing the practical measurements.

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