Design, analysis and fabrication of 2X1 rectangular patch antenna for wireless applications

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***Abstract* — The prime focus of this paper is to design and fabricate a single rectangular patch and to analyze the performance by modifying it into 2X1 array antenna with a single feed at an operating frequency of 5.5 GHz on an FR4 substrate. The proposed antennas are designed with the help of HFSS software. The results of designed antennas were compared with the fabricated antenna in terms of antenna parameters such as gain, return Loss, VSWR, impedance matching, bandwidth, directivity and radiation pattern. The antenna was tested using vector network analyzer (VNA) and it was found that the simulated antenna achieved 337MHz of bandwidth with return loss of -28.0714dB and the experimental antenna yielded 719MHz of bandwidth with the tolerable return loss of -14.2344dB.**

***Index Terms*—Micro strip patch antenna, FR4, vector network analyzer**

I. INTRODUCTION

With the increase in data rates and a trend of miniature electronic circuits for wireless digital applications, the antennas required for these applications should be light weight, easily mountable and have a broad bandwidth. [1] These requirements can be met by using micro strip antennas and patch arrays. [2]

The patch is made up of conducting material such as copper or gold. [3] The radiating patch and the feed lines are usually photo etched on the dielectric substrate. These antennas radiate primarily because of the fringing fields between the patch edge and the ground plane the designed antennas are in the shape of rectangular patch since the rectangular patch antenna is approximately a one-half wavelength long section of rectangular micro strip transmission line. [4] In this paper the proposed antennas was designed to operate at 5.5 GHz using FR4 as the substrate of height 1.66mm

With these considerations the patch calculation, Ground plane calculation and the feed point calculation are briefly explained in section II. By analyzing all the necessary calculations the design of single patch is described in section II with the help of EM simulator ANSOFT HFSS 13 software. Section III describes the design of 2X1 array patch. The length and width of the patch and the substrate is calculated by having the single patch as a reference. Hence, to feed each individual element, micro strip line feeding network made of transmission line is used [5]. The section IV indicates the parameters of results such as the Gain, Return Loss, VSWR, Bandwidth, Radiation Pattern, and Impedance Matching which shows the characterization of the experimental micro strip patch antenna. The section V shows the comparison of the experimental and the simulated antenna followed by the conclusion in section VI.

II. DESIGN OF SINGLE RECTANGULAR PATCH ANTENNA

A. PATCH CALCULATION

The design calculation of patch consists of width, length, effective length and effective dielectric constant. [6]

1. The width of the patch was calculated from the following formula

$$w = \frac{c}{2f_c\sqrt{\frac{(\varepsilon_r+1)}{2}}} \qquad (1)$$

Where, c is the velocity of light, f_c is the operating frequency and ε_r is the dielectric constant of the substrate,
By substituting all the values in the equation (1) the width of the patch was found to be **16.597mm**.

2. The effective dielectric constant of the patch is calculated [7] by the following equation

$$\varepsilon_{reff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \qquad (2)$$

By substituting the values of "h" as **1.66mm** the effective dielectric constant is **3.846**.

3. The length extension of the patch is determined from the following equation [8]

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.813\right)} \qquad (3)$$

ΔL is the length due to the fringing effect. By substituting the required values of height, relative dielectric and the width of the patch in equation (3) ΔL was found to be **0.7510**.

ISSN: 2278 – 909X

4. The equation of effective Length of the patch [9]

$$L_{eff} = \frac{c}{2 f_c \sqrt{\varepsilon_{reff}}} \quad (4)$$

By substituting all the required values the effective length of the patch is **13.90666mm**.

5. The length of the patch [10] :

$$L = L_{eff} - 2\Delta L \quad (5)$$

By substituting the values in the above equation the length of the patch was found to be **12.43466mm**

B. GROUND PLANE CALCULATION

The length and width of the ground plane was calculated from the following formula [11]

$$Lg = 6h + L \quad (6)$$

$$Wg = 6h + W \quad (7)$$

Where,

L = Length of the patch
W = Width of the patch

By substituting the height =1.66mm, length=12.43466mm and width as 16.597mm the required length and width of the ground plane was found as **22.03779mm** and **26.197mm** respectively.

C. FEED CALCULATION

The length of the feed of **4.271mm** is calculated from the following equation [12]

$$Y_o = \{0.001699\epsilon^7 + 0.13761\epsilon^6 - 6.1783\epsilon^5 + 93.187\epsilon^4 - 682.69\epsilon^3 + 2561.9\epsilon^2 - 4043\epsilon + 6697\}L/2 \quad (8)$$

The design specifications of single patch are shown in table I.

Parameters	Theoretical Values	Practical design
Patch width	16.597 mm	16.597 mm
Patch length	12.43466 mm	12.13466 mm
Ground plane width	26.197 mm	32.197 mm
Ground plane length	22.03779 mm	32.03779 mm
Feed width	1 mm	1 mm
Feed length	4.271 mm	5.4 mm

Table I. Design specification of a single rectangular patch antenna

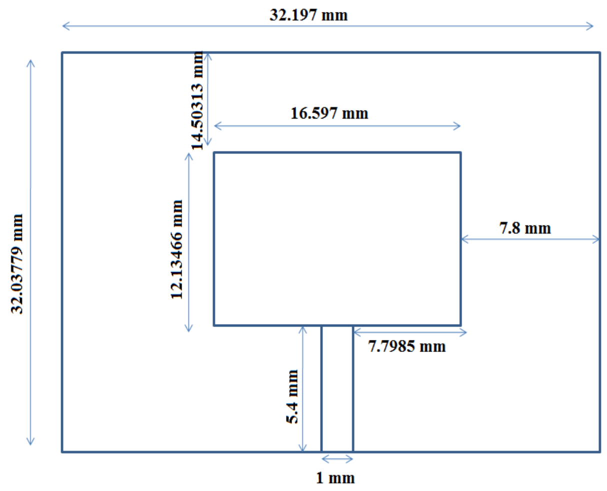

Fig: 1. Geometry of single rectangular micro strip patch antenna

III. DESIGN OF 2X1 RECTANGULAR ARRAY MICRO STRIP PATCH ANTENNA

The purpose of array patch is to get better radiation, gain and directivity. The distance between the two patches is $\lambda / 4$.

A. GROUND PLANE DIMENSION

Lg= (32.03779+5.4+0.1) mm =**37.53779mm** (9)
Wg= (7.8+16.597+13.64+16.597+7.8) mm=**62.434mm** (10)

B. STRIP LINE DIMENSIONS

WIDTH = (7.7985+6.06+7.7985+1+1) mm=**23.657mm**
LENGTH = **0.1mm**

A heuristic approach was made to find the strip line width. The design specifications of array patch are shown in table II.

Parameters	Theoretical Values	Practical design
Patch width	16.597 mm	16.597 mm
Patch length	12.43466 mm	12.13466 mm
Ground plane width	62.434 mm	32.197 mm
Ground plane length	37.53779 mm	32.03779 mm
Feed width	1 mm	1 mm
Feed length	4.271 mm	5.4 mm
Distance between patches (λ/4)	13.64 mm	6.06 mm
Strip line length	23.657 mm	23.657 mm
Strip line width	0.1 mm	0.1 mm

Table II. Design specification of an array patch antenna

ISSN: 2278 – 909X

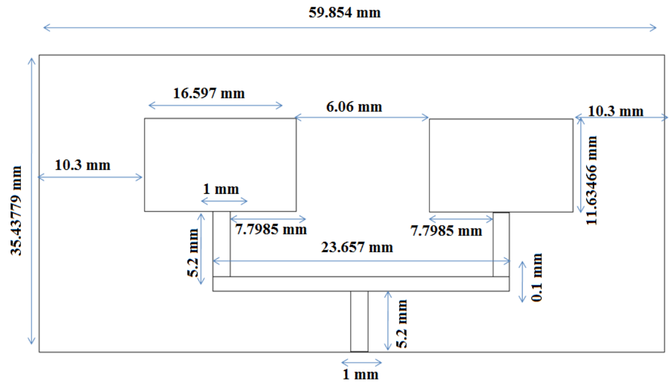

Fig 2. Geometry of Rectangular array micro strip patch antenna

IV. Results and Discussion

HFSS software was used to design the Single and array micro strip patch antennas. Further the optimum designed antenna was fabricated and the key parameters like Gain, Return Loss, Bandwidth, VSWR, Radiation Pattern, and Impedance Matching were analyzed. The simulated results were compared with the experimental antenna also.

A. Comparison of Single Patch and Array antenna

i. Model
ii. Gain
iii. Directivity
iv. Return Loss with bandwidth
v. VSWR
vi. Radiation Pattern
vii. Polarization
viii. Impedance Matching

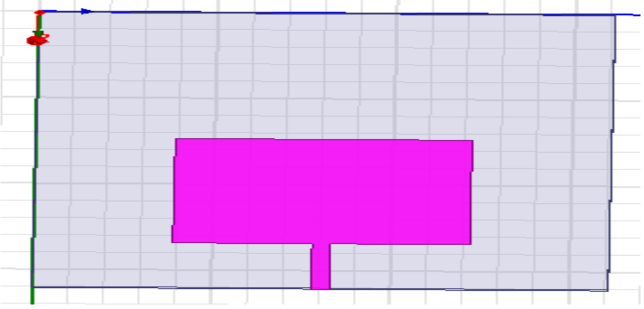

Fig 3. Simulated diagram of single Rectangular micro strip patch antenna

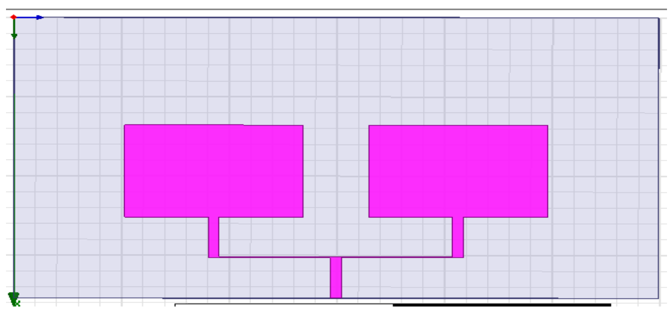

Fig 4. Simulated diagram of Rectangular array micro strip patch antenna

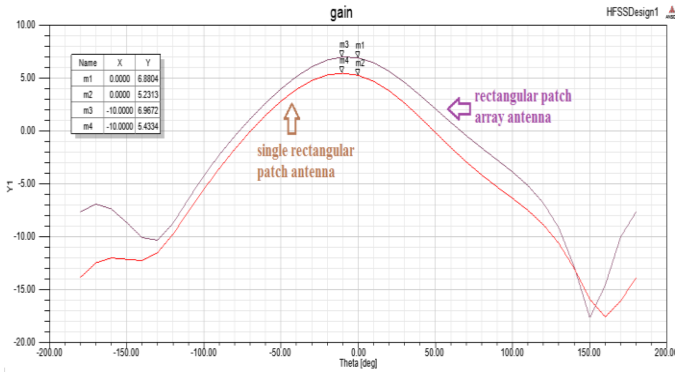

Fig 5. Simulated gain of single and rectangular array micro strip patch antenna

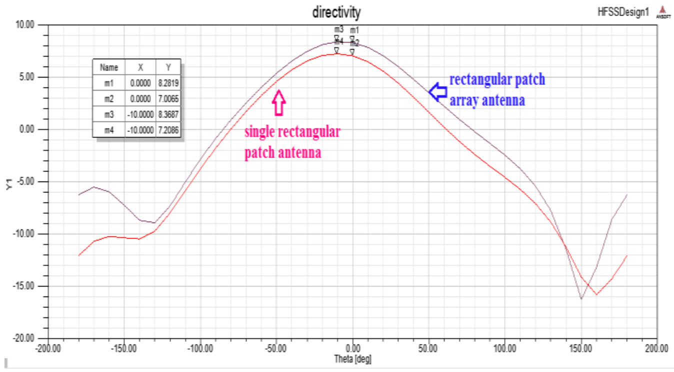

Fig 6. Simulated directivity of single and rectangular array micro strip patch antenna

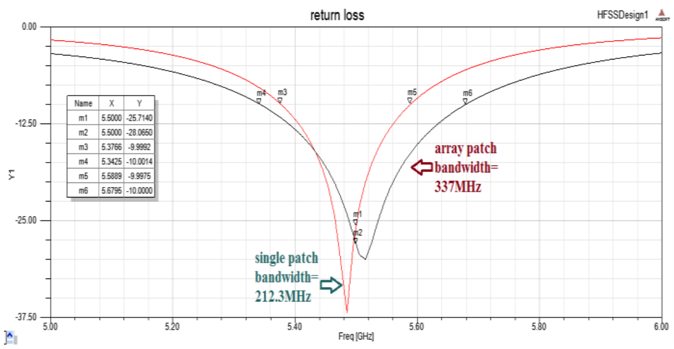

Fig 7. Simulated return loss of single and rectangular array micro strip patch antenna

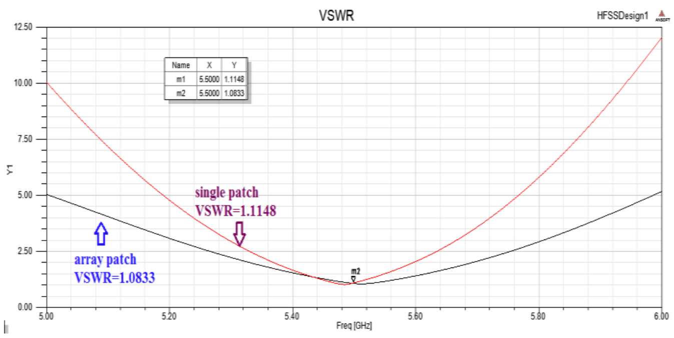

Fig 8. Simulated VSWR of single and rectangular array micro strip patch antenna

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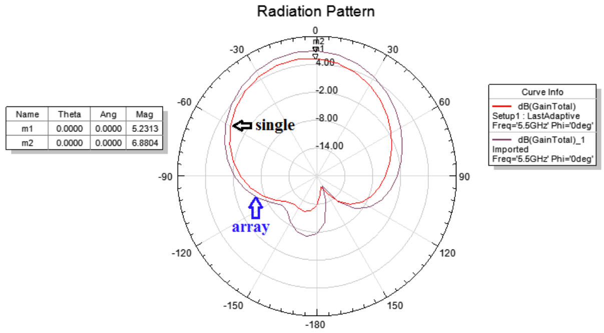

Fig 9. Simulated radiation pattern of single and rectangular micro strip patch array antenna

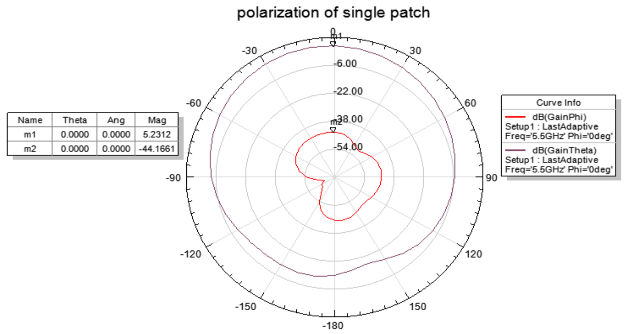

Fig 10. Simulated polarization of single rectangular micro strip patch antenna

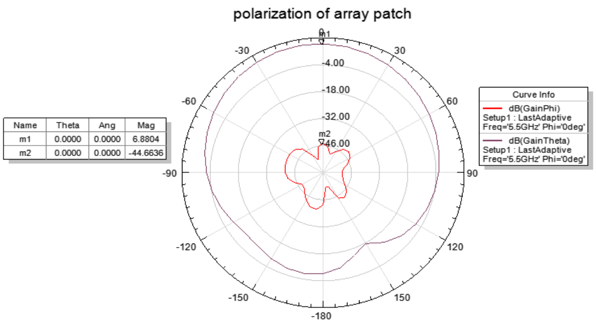

Fig 11. Simulated polarization of array micro strip patch antenna

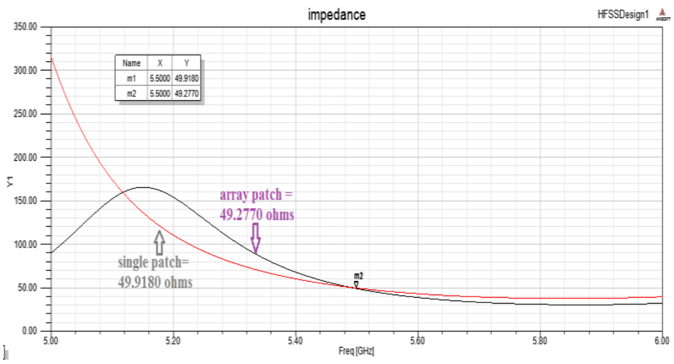

Fig 12. Simulated impedance matching of single and rectangular array micro strip patch antenna

Table III. Tabular column for comparison single patch and array antenna

Parameters	Single Patch	Array Antenna
Gain	5.4334dB	6.9672dB
Directivity	7.2086dB	8.3687dB
Return Loss	-25.7140dB	-28.0650dB
Bandwidth	212.3MHz	337MHz
VSWR	1.1148	1.0833
Impedance matching	49.9180 ohms	49.2770 ohms

B. Comparison of Array antenna and experimental antenna

i. Return Loss with bandwidth
ii. VSWR
iii. Fabricated model of Array Antenna

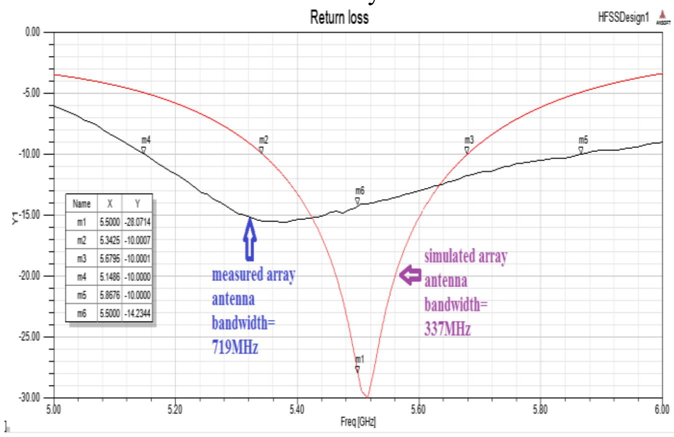

Fig 13. Return loss of measured and simulated rectangular array micro strip patch antenna

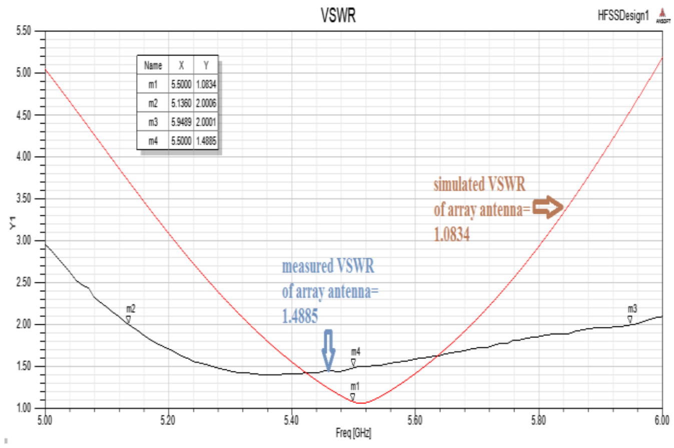

Fig 14. VSWR of measured and simulated rectangular array micro strip patch antenna

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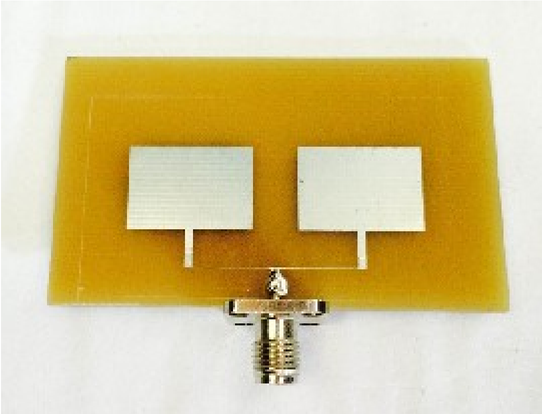

Fig 15. Fabricated Model of 2X1 Rectangular microstrip patch array antenna

Parameters	Array Antenna	Experimental Antenna
Return Loss	-28.0714dB	-14.2344dB
Bandwidth	337MHz	719MHz
VSWR	1.0834	1.4885

Table IV. Tabular column for comparison Array Antenna and Experimental Antenna

V. CONCLUSION

The proposed single and array patch shows the best results for the antenna parameters which were discussed above. The bandwidth percentage of the proposed simulated array antenna is 6.3% and the bandwidth percentage of the experimental antenna is 13.93%.The gain of the simulated antenna was found to be 6.9672dB.From the optimum results we conclude that the designed antennas are linearly polarized that are having the phase difference of about -38.9349dB for the single rectangular patch antenna and -37.7832dB for the rectangular patch array. Since the fabricated array antenna covers wide bandwidth it can be used for the application like WiMAX, WiFi and ISM (industrial, scientific and medical).

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ISSN: 2278 – 909X