



# DESIGN AND ANALYSIS OF 2.4GHZ RECTANGULAR MICROSTRIP PATCH ANTENNA ARRAY FOR ISM APPLICATIONS

<sup>1</sup>Mrunal A Marihal, <sup>2</sup>Debasish Dash

<sup>1</sup>Junior Research Fellow, <sup>2</sup>Engineering Consultant

<sup>1</sup>Microwave Tube Research and Development Center, Bangalore, India

<sup>2</sup>Sela Cloud, Bangalore, India

**Abstract :** Microstrip antenna arrays are widely used for Industrial, Scientific and Medical (ISM) application. The aim of the proposed work is to design a single element rectangular microstrip patch antenna (RMPA), double element (2X1) RMPA array to study the antenna performance parameters such as gain, return loss, directivity, VSWR and radiation pattern at 2.4GHz. Antennas are designed over RT/Duroid 5880 substrate with 2.2 dielectric constant, thickness of 1.575mm and loss tangent of 0.0009. For feeding microstrip edge inset line feeding technique was used. The simulation was performed using an electromagnetic solver software tool namely Computer Simulation Technology (CST) Microwave Studio. Based on the analysis it was found that as the number of patch element increases in a microstrip antenna, the efficiency, gain and directivity of the antenna increases. The simulated results for double elements (2X1) RMPA array shows return loss of -51.95dB, gain of 10.4dB, directivity of 10.99dB, VSWR of 1.005 and 87.73% of efficiency at operating frequency.

**Keywords:** 2.4GHz, CST Microwave Studio, ISM, Microstrip Patch Antenna Array, RT/Duroid 5880

## I. INTRODUCTION

In today's world microstrip antennas are in the demand. These antennas prehend everyone's attention because of its tremendous applications in all areas. Microstrip antennas are compact, low cost, easy to fabricate, light weight, flexible with frequencies and shapes and simple to match with 50Ω line impedance. Microstrip antennas can be used in defence applications such as high-performance satellite, spacecraft, missile and aircraft. It can be also used for commercial applications like radio, mobile and other wireless communications [1]. Microstrip antenna consists of a substrate with a ground plate on one side and conducting patch placed on another side. Through the gap between ground plane and patch periphery, the signal try's to radiates outwards [2].

In microwave planar circuit technology, microstrip line has gained extensive usage, importance and popularity among all planar transmission lines. The substrates are used in the manufacture of the microstrip lines. The most famous dielectrics are RT/Duroid, FR4, alumina, silicon, quartz and epsilam [3]. The substrate of microstrip antenna with low dielectric constant provides higher efficiency, gain and directivity. RT/Duroid 5880 shows better performance as compared to FR4 substrate [4]. The gain can also be increased by increasing the number of patches in a microstrip antenna. In simple words an array antenna produces better performance results as compared to signal element microstrip patch antenna. Voltage Standing Wave Ratio (VSWR) value lies between 1 and 2. With the smaller VSWR value more power can be delivered to the antenna. Even with the smaller VSWR better impedance matching can be achieved [5-7].

One more important parameter of an antenna is height or thickness of the substrate which directly affect the fringing field of the patch. Therefore, smaller thickness substrate is preparable. Even the communication devices like mobile, walkie-talkie, radio requires smaller height antennas [8].

In [9], a single-element RMPA is designed and fabricated for ISM applications say, RT/Duroid or Roger series achieves the higher gain, directivity and maximum efficiency compared to FR4, due to which the cost of the material is more. Lower the dielectric constant value higher the antenna size. Therefore, the antenna with substrate FR4 has the smaller size than the Roger series antenna.

The proposed microstrip antenna is designed using CST Microwave Studio. The motivation behind this process is to achieve higher gain with MPA for ISM applications (at 2.4GHz). The remaining structure of the paper is as follows. Section-II explains the design of single element MPA. The design of the MPA array is explained in section-III. In Section-IV the simulation result of the antennas is discussed. Section-V address the conclusion of the proposed work.

## II. DESIGN OF MICROSTRIP PATCH ANTENNA

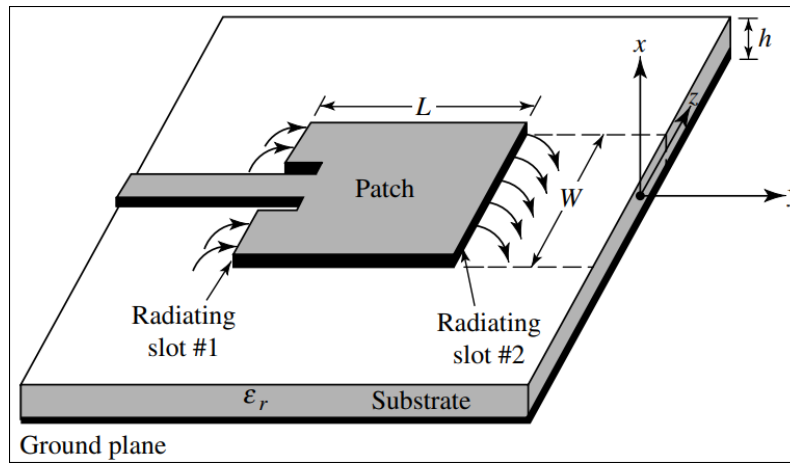


Figure 1: Structure of Microstrip Patch Antenna [1]

The figure 1 shows the basic structure of the RMPA. This antenna mainly consists of a radiating patch, dielectric substrate, microstrip feedline and ground plane.

The proposed microstrip antenna is designed to operate at 2.4GHz. To achieve maximum electromagnetic radiation in the desired direction, one has to choose a substrate which is having low dielectric permittivity. Therefore RT/Duroid 5880 has been selected as a substrate whose dielectric constant is 2.2. The thickness of the substrate is taken as 1.575mm and loss of tangent as 0.0009. Here radiating patch is situated on the top of the substrate and ground plate at the bottom of the substrate. The 'Microstrip Edge Inset Line Feeding' technique is chosen among the all types of feeding techniques, as it is easy to fabricate, simple in modelling and provide good impedance matching.

The design equations for the RMPA are as follows [1, 3]:

1. Resonant Frequency of the rectangular microstrip patch antenna

$$f_r = \frac{c}{2 * (L + 2\Delta L) * \sqrt{\epsilon_{reff}}}$$

2. Width of the Patch

$$W = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}}$$

3. The effective dielectric constant

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[ 1 + 12 \frac{h}{W} \right]^{-1/2}$$

4. Effective length

$$L = \frac{C}{2f_r \sqrt{\epsilon_{reff}}}$$

5. Extension in Patch length

$$\frac{\Delta l}{h} = 0.412 \frac{(\epsilon_{reff} + 0.3) \left( \frac{W}{h} + 0.264 \right)}{(\epsilon_{reff} - 0.258) \left( \frac{W}{h} + 0.8 \right)}$$

6. Length of the Patch

$$L = L_{eff} - 2\Delta L$$

Where,  $c$  is the speed of the light,  $\epsilon_r$  is the dielectical constant and  $h$  is the height of the substrate. The figure 2 shows the proposed single element MPA.

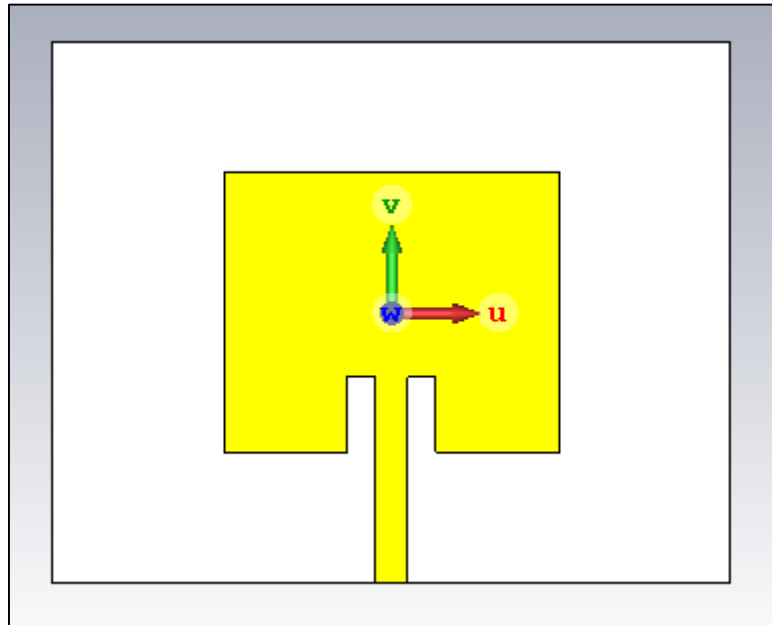


Figure 2: Front View of Proposed Single Element Microstrip Patch Antenna

The antenna is designed using CST Microwave Studio. The table-1 shows the dimension of single element MPA.

Table 1. Dimension of Single Element Microstrip Patch Antenna

Parameters	Values
Operating Frequency	2.4GHz
Dielectric Constant	2.2
Width of the patch	49.41mm
Length of the patch	41.37mm
Width of the substrate	100mm
Length of the substrate	80mm
Thickness/height of the substrate	1.575mm
Width of the ground	100mm
Length width of the ground	80mm
Width of the feed line	4.851mm
Length of the feed line	30.415mm
Gap	4.175mm

### III. DESIGN OF MICROSTRIP PATCH ANTENNA ARRAY

The Proposed double element (2X1) MPA array is as shown in Fig. 3. This antenna array is also designed to operate at 2.4GHz with same dielectric substrate. The length and width value of both the patch is same as single element microstrip patch antenna. Both the patches have to be connected to one microstrip feeding line. The design equations for width of the microstrip line is given by [3,10]:

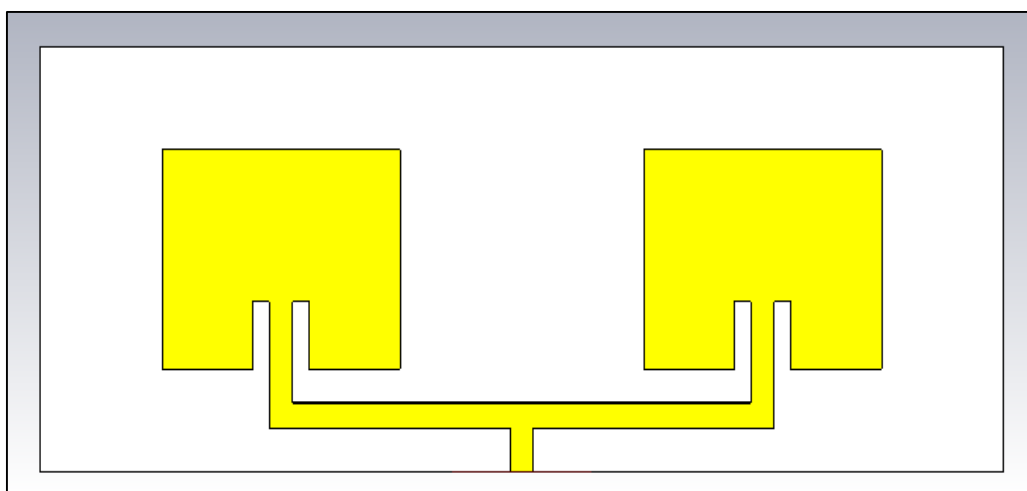


Figure 3: Proposed double element (2X1) Microstrip Patch Antenna Array

For  $W/h \leq 2$ :

$$\frac{W}{h} = \frac{8e^A}{e^{2A} - 2}$$

For  $W/h \geq 2$ :

$$\frac{W}{h} = \frac{2}{\pi} \left[ B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left\{ \ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right\} \right]$$

Where,

$$A = \frac{Z_o}{60} \sqrt{\frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{\epsilon_r + 1} \left( 0.23 + \frac{0.11}{\epsilon_r} \right)}$$

$$B = \frac{377\pi}{2Z_o\sqrt{\epsilon_r}}$$

For both microstrip patch antenna width of the microstrip line is calculated by assuming characteristic impedance  $Z_o$  as  $50\Omega$  [10]. The dimension of MPA array is shown in table-2.

Table 2. Dimension of Microstrip Patch Antenna Array

Parameters	Values
Operating Frequency	2.4GHz
Dielectric Constant	2.2
Width of the patch	49.41mm
Length of the patch	41.37mm
Width of the substrate	200mm
Length of the substrate	80mm
Thickness/height of the substrate	1.575mm
Width of the ground	200mm
Length width of the ground	80mm
Width of the feed line 1 and 2	4.851mm
Length of the feed line 1	23.92mm
Length of the feed line 2	8.15mm
Gap	3.5mm

#### IV. RESULTS AND DISCUSSION

The simulation results of single and double element RMPA for the selected frequency (2.4GHz) are provided in this section. CST Microwave Studio software is used for simulation. Fig. 4 shows the Return Loss (S11) of single element MPA. It can be observed that S11 value is -46.167dB at 2.4GHz and below -10dB as per the initial conditions.

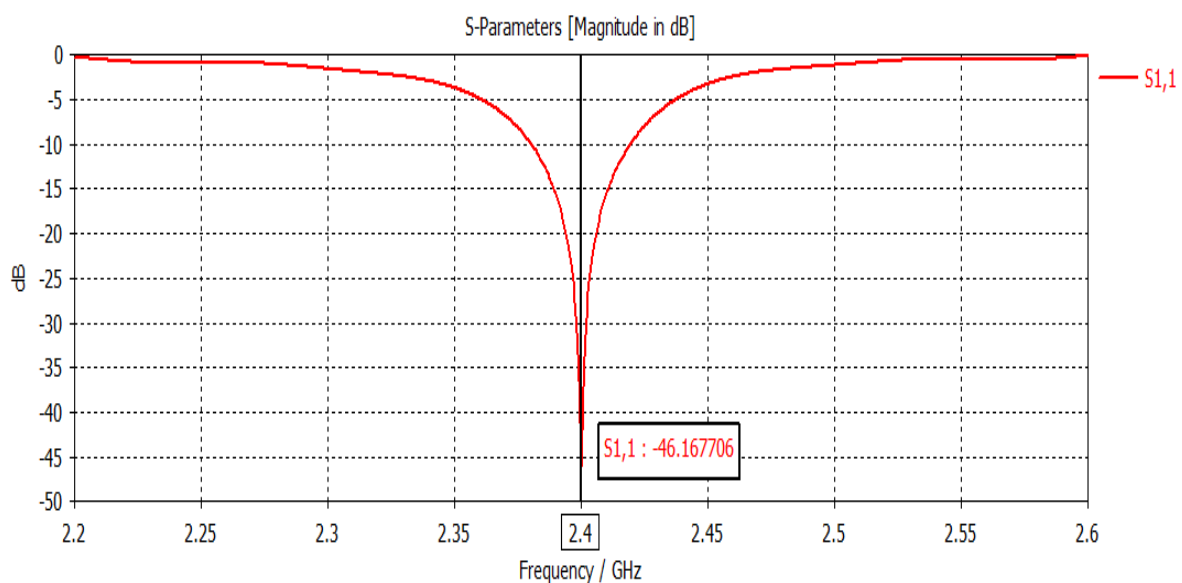


Figure 4: Return Loss of single element microstrip patch antenna

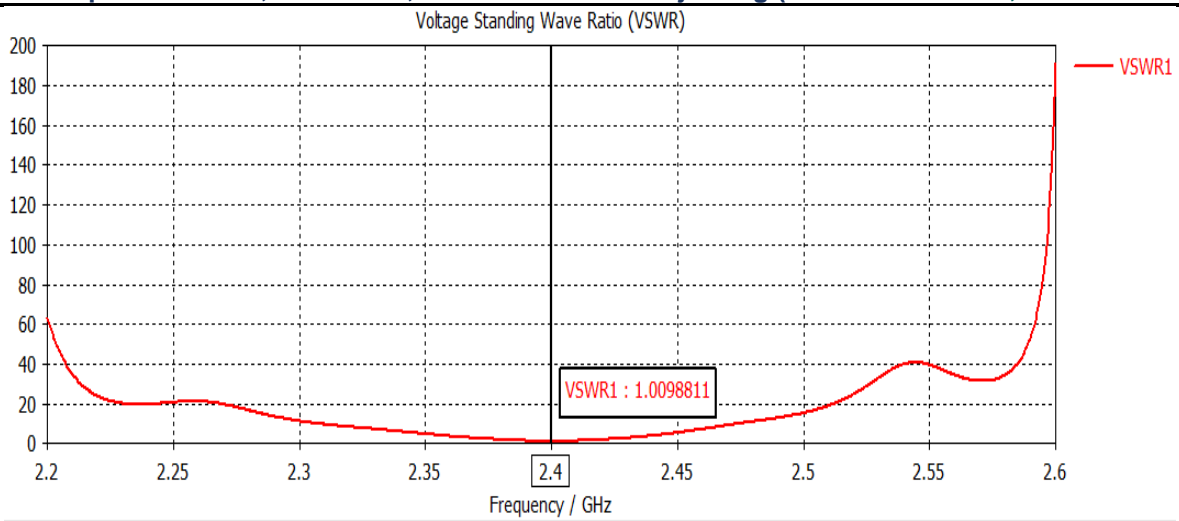


Figure 5: VSWR of single element microstrip patch antenna

VSWR value is preferable if it is between 1 and 2. Fig. 5 shows the VSWR graph for single element MPA. 1.009 of VSWR value is achieved at operating frequency.

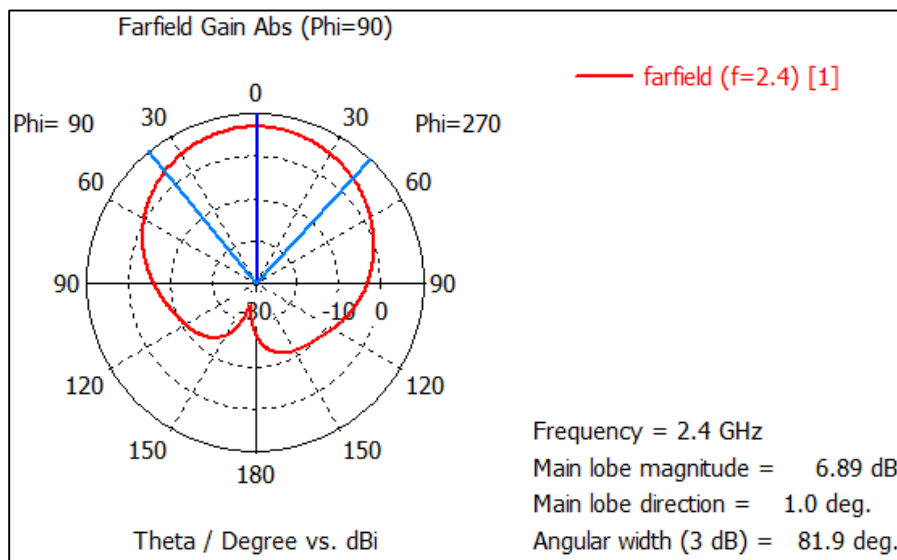


Figure 6: Gain of single element microstrip patch antenna

Fig. 6 shows the gain graph for single element MPA. 6.89dB gain is achieved at 2.4GHz. Fig. 7 shows the directivity graph for single element MPA where, 7.494dB of directivity is achieved.

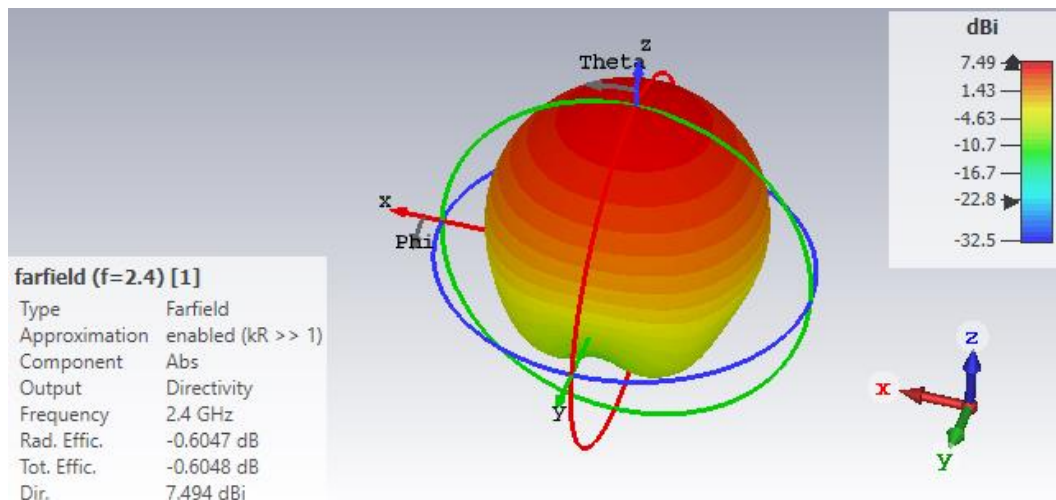


Figure 7: Single element microstrip patch antenna directivity

From efficiency graph we can observe that the total efficiency of the antenna is 87% as shown in fig. 8.

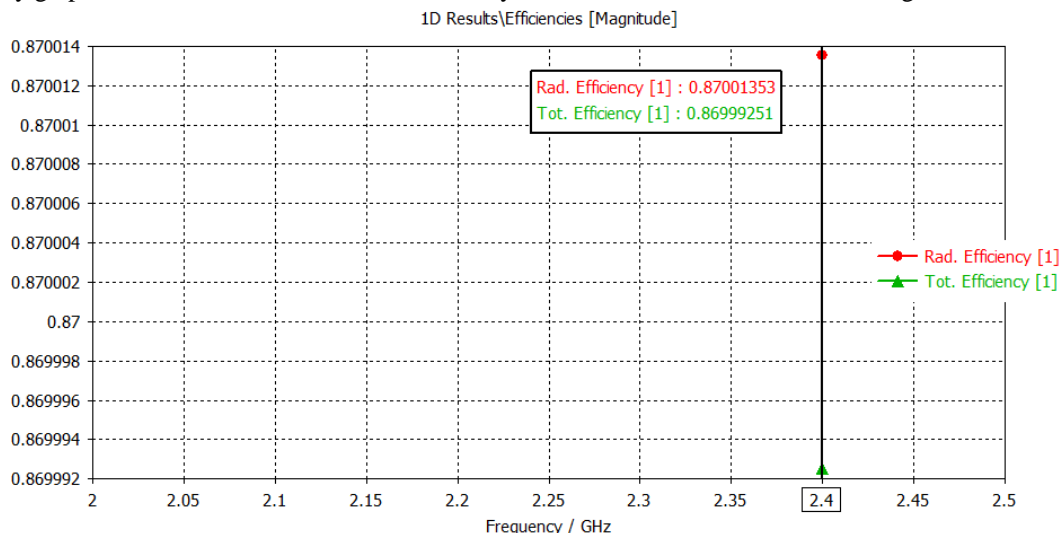


Figure 8: Total Efficiency of single element microstrip patch antenna

Fig. 9 shows the Return loss of double element (2X1) MPA array. At operating frequency S11 is -51.95dB. It can be observed that S11 value of 2 X 1 MPA array is less than single element MPA.

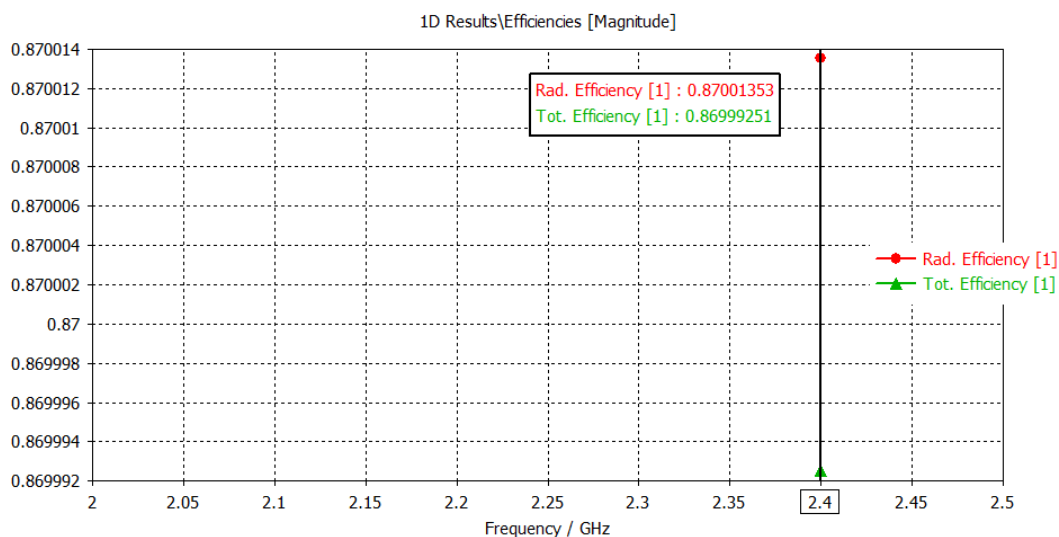


Figure 9: Return Loss of double element (2X1) microstrip patch antenna array

Fig. 10 shows the VSWR graph for double element MPA array. 1.005 of VSWR value is achieved at operating frequency 2.4GHz. Fig. 11 shows the gain graph for double element MPA array. 10.4dB gain is achieved at 2.4GHz. there is an increase of 3.51dB in gain because of the presence of two patches.

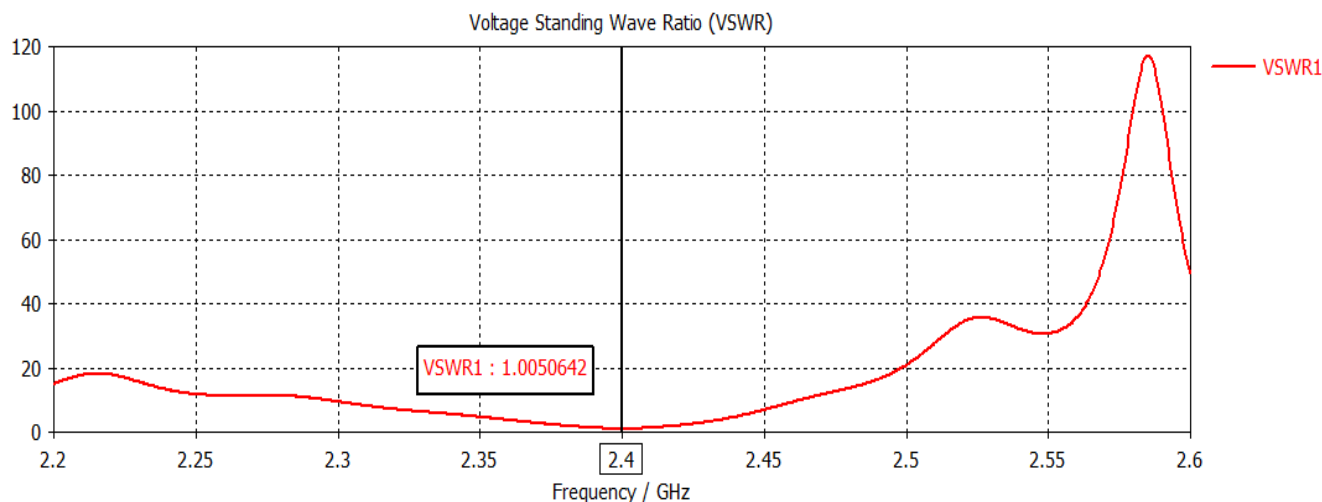


Figure 10: VSWR of double element microstrip patch antenna array

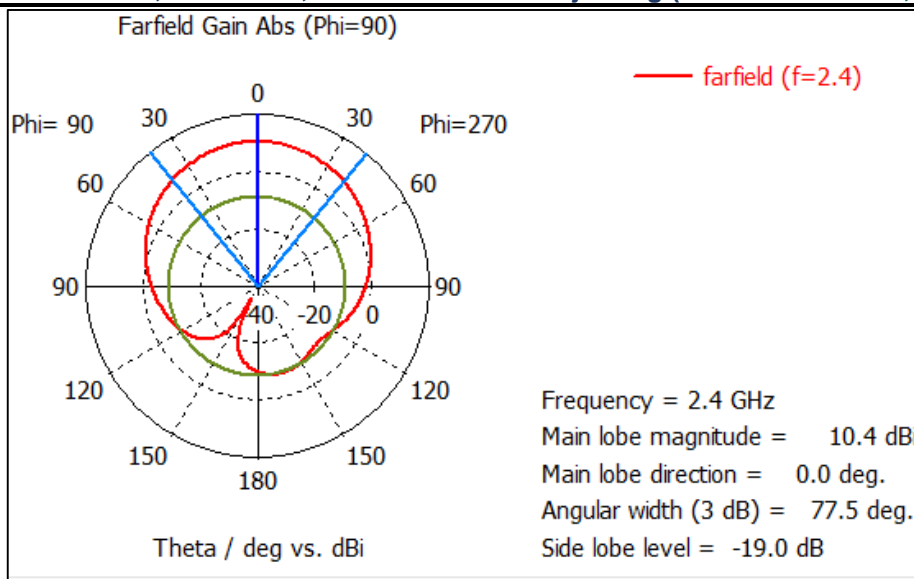


Figure 11: Gain of double element microstrip patch antenna array

Fig. 12 shows the directivity graph for double element MPA array where, 10.99dB of directivity is achieved. Both directivity and gain of antenna array are better than single element MPA.

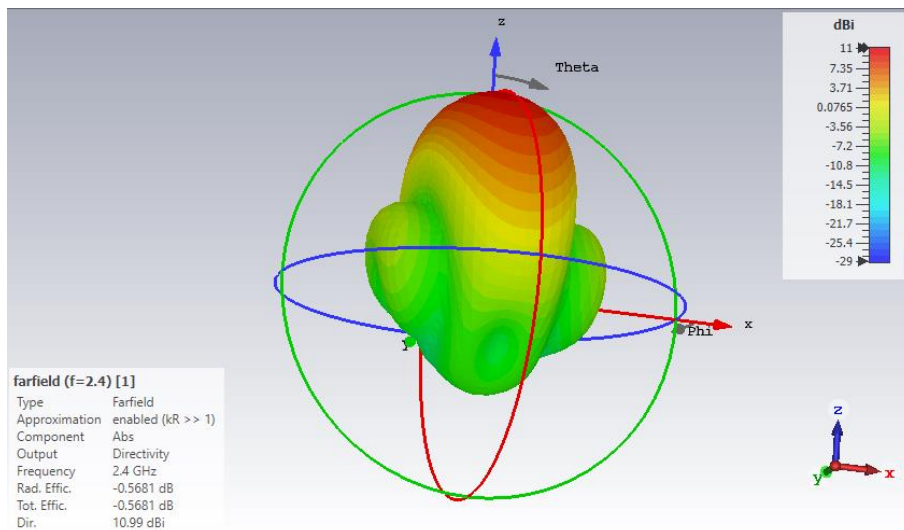


Figure 12: double element microstrip patch antenna array directivity

The efficiency of double element MPA is 87.73%. As we can observe that double element has 0.73% more efficiency than single element MPA. The fig. 13 shows the efficiency of double element MPA array. The comparison of the results between single and double element microstrip antenna is shown in Table-3.

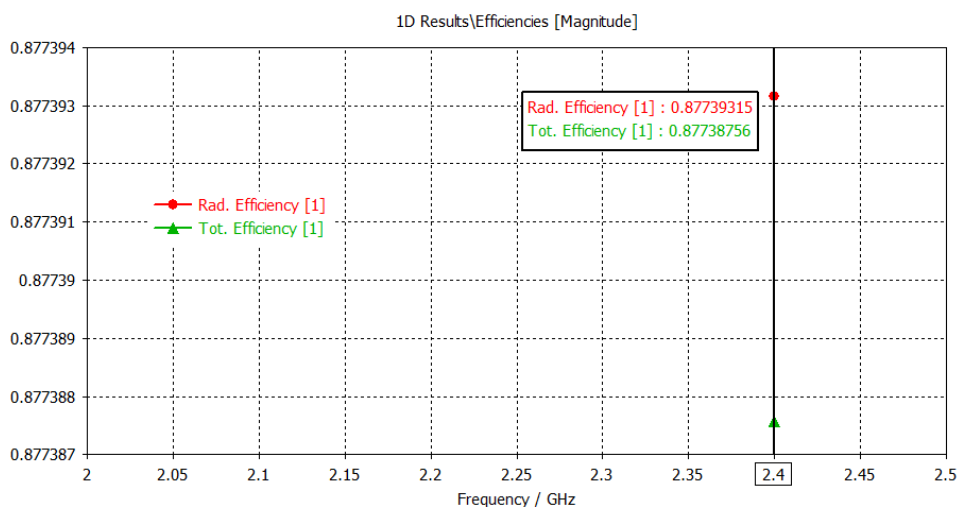


Figure 13: Total Efficiency of double element microstrip patch antenna array

Table 3. Comparison of proposed single and double element microstrip antenna

Parameters	Proposed single element microstrip patch antenna	Proposed double element microstrip patch antenna array
Operating Frequency	2.4GHz	2.4GHz
Substrate	RT/Duroid 5880	RT/Duroid 5880
Dielectric Constant	2.2	2.2
Return Loss	-46.167dB	-51.95dB
VSWR	1.009	1.005
Gain	6.89dB	10.4dB
Directivity	7.494dB	10.99dB
Total Efficiency	87%	87.73%
Bandwidth	38.8MHz	34.4MHz

The bandwidth covered by single element microstrip antenna is 38.8MHz and 34.4MHz by antenna array. Single element antenna covered more frequency range. It can be observed that the beamwidth of double element MPA array narrower than the single element MPA.

#### IV. CONCLUSION

In this project two rectangular microstrip patch antennas are designed to study the antenna performance parameters. One is single element RMPA and another one is double element (2X1) RMPA array. Both the patch antennas operate at 2.4GHz and are suitable for ISM applications. Antennas are designed over RT/Duroid 5880 substrate with 2.2 dielectric constant and thickness of 1.575mm. For feeding microstrip edge inset line feeding technique was used. These antennas are simulated using CST Microwave Studio software. From this study it can be observed clearly that the performance parameters like gain and directivity of 2X1 RMPA array produces better results. But as the number of patch element increases in an antenna beamwidth and bandwidth decreases and return loss and VSWR increases. The simulated results for single element RMPA show return loss of -46.167dB, gain of 6.89dB, directivity of 7.494dB and VSWR of 1.009 at 2.4GHz. And the simulated results for double element (2X1) RMPA array shows return loss of -51.95dB, gain of 10.4dB, directivity of 10.99dB and VSWR of 1.005 at operating frequency. For future work design and analysis of four elements (2X2) RMPA array is recommended to improve the gain further.

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