Design of Rectangular Microstrip Patch Antenna Array for S, C and X- Band

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ABSTRACT
In this paper the rectangular microstrip patch antenna arrays has been designed for S, C and X-band application by using the IE3D simulator. Roger RT/duroid material with dielectric constant 2.2 and height 1.588 has been used as a substrate material. Microstrip inset line feed has been used for feeding the rectangular patch antenna. Here 1x2 and 1x4 patch antenna array has been designed using series feed network and performance parameters of patch antennas array such as return loss, gain, directivity and VSWR has been computed and compared.

Keywords
Microstrip antenna; inset line feed; antenna array; return loss.

1. INTRODUCTION
Antennas are one kind of transducer to convert generated electrical energy into radiating energy. Antennas are also used in receiver to collect radiation from free space and deliver the energy contained in the propagating to the feeder and receiver [1] .It has been observed in the recent year that development in communication system required a light weight, high gain, high directivity, and high efficiency antenna with minimum return losses and with minimum cost that should work at a number of frequencies. Microstrip patch antennas fulfill all these requirements where in construction such antenna has been consists of a conducting patch, a substrate material and a RF power feed [4]. According to the IEEE the different bands of frequencies has been defined with different ranges of frequencies such as L, S, C and X -bands and each frequency band has been used for different applications [5]. Microstrip antennas found useful in non-satellite based application such as remote sensing, medical hyperthermia and cancer detection application [2] [6]. From the past history of experiments it has been observed that at high frequency range such as X – band (8GHz-12GHz) the microstrip antenna are quite effective response as compare to other antenna. However, microstrip antenna has some drawbacks including narrow bandwidth, low power handling capability and low gain[6]. Here a rectangular microstrip patch antenna has been designed using the microstrip inset line feed and roger RT/ duroid material has been used which shows high value of gain than other substrate material such as Teflon and FR4 [10].

2. DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNA
The development of antenna for wireless communication requires an antenna with more than one operating frequency because there are various wireless communication systems and many telecommunication operators using various frequencies [3]. A number of shapes have been used for the designing of microstrip patch antennas but the rectangular and circular patches has been most common to use for the different application in different fields due to their effective radiation character shown by them when the RF power has been fed to the patch antenna [4][6].

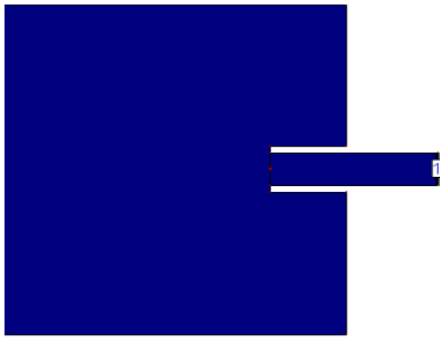

Fig 1: Rectangular patch antenna with inset feed

Here the dimension of rectangular patch has been computed by using [6] the equations, given below. Width is calculated by using equation (1)

$$W = \frac{1}{2 f_r \sqrt{\mu_o \varepsilon_o}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{v_o}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

And the effective dielectric constant is computed by using equation as

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

Due to fringing effect the increase in length is given by

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + o.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (3)$$

The actual length of patch is computed by using equation

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_{reff}} \sqrt{\mu_0 \varepsilon_o}} - 2\Delta L \quad (4)$$

After calculating the dimension of RMPA now the inset length of feed inside the patch has been [7] calculated by using the equation as

$$y_o = 10^{-4}\begin{bmatrix} 0.001699\ \varepsilon_r^7 + 0.13761\ \varepsilon_r^6 - 6.1783\ \varepsilon_r^5 + 93.187\ \varepsilon_r^4 \\ -682.69\ \varepsilon_r^3 + 2561.9\ \varepsilon_r^2 - 4043\ \varepsilon_r + 6697 \end{bmatrix}\frac{L}{2} \quad (5)$$

Impedance matching between two elements is the main factor affecting the performance of antenna. Here the width of microstrip inset line feed with characteristic impedance Zo has been given by using the below [4] equations.

$$\frac{W}{h}=\left\{\frac{8\exp(A)}{\exp(2A)-2}\right\} when\ Z_0\sqrt{\varepsilon_r}\geq 89.91 and\ A\geq 1.52 \quad (6)$$

$$\frac{W}{h}=\frac{2}{\pi}\left\{B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{2\varepsilon_r}\left[\ln(B-1)+0.39-\frac{0.61}{\varepsilon_r}\right]\right\} \quad (7)$$

$$when \quad Z_0\sqrt{\varepsilon_r}\leq 89.91 \quad and\ A\leq 1.52$$

Where the value of A and B has been [4] calculated using equation (8) and (9)

$$B=\frac{60}{Z_0\sqrt{\varepsilon_r}} \quad (8)$$

$$A=\frac{z_0}{60}\left\{\frac{\varepsilon_r+1}{2}\right\}^{1/2}+\frac{\varepsilon_r-1}{\varepsilon_r+1}\left\{0.23+\frac{.11}{\varepsilon_r}\right\} \quad (9)$$

And length of transmission feed line has been given by using equation (10)

$$\frac{\lambda}{4}=\frac{c}{f_r\sqrt{\varepsilon_{reff}}} \quad (10)$$

Dimension of the rectangular patch antenna has been given by using inset feed line has been given in table 1.

Table 1. Dimension of Single Multiband Rectangular Patch Antenna with Inset Feed

Length of Rectangular Patch (L)	40.48 mm
Width of Rectangular Patch (W)	48.40 mm
Inset Length of Feed (yo)	9.3167 mm
Width of Inset Feed for Patch (Wi)	4.93 mm
Length of Transmission Feed (λ/4)	20.63 mm
Dielectric Constant of Substrate (εr)	2.2
Effective Dielectric Constant of Substrate (εreff)	2.032
Gap width (Wo)	0.34 mm

3. RESULT AND DISCUSSIONS

The use of the array of antenna has increased much in the communications by transmit their signals over long distances without the need for relay stations [8]. Here Rectangular patch antenna arrays has been designed which resonates at C, S and X-band frequency so such antenna arrays has been used for the number of application such as wireless communication, radar system, Wi-Max and in biomedical field [6]. Rectangular patch antenna with inset feed has been shown in Figure 1 and dimension of patch antenna has been given in table 1 on IE3D simulator. In Figure 2 and Figure 3, 1x2 and 1x4 multiband RMPA array has been designed using inset feed line where these antenna elements has been combined with each other using the series feed network . Different performance parameters have been obtained using IE3D simulator such as return loss, gain , directivity and VSWR .

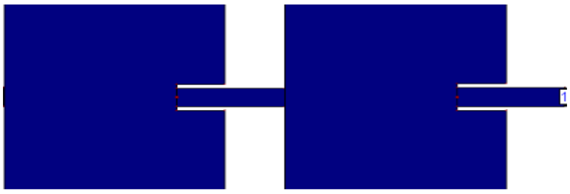

Fig 2: Rectangular 1x2 MPA Array

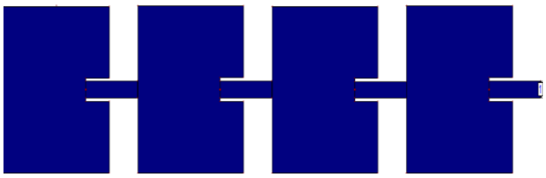

Fig 3: Rectangular 1x4 MPA Array

3.1 Results of 1X2 RMPA Array

Please Return loss Vs Frequency, Gain Vs Frequency, directivity Vs Frequency and VSWR Vs Frequency plots of 1x2 RMPA array are shown in Fig 4 to Fig 7**.**

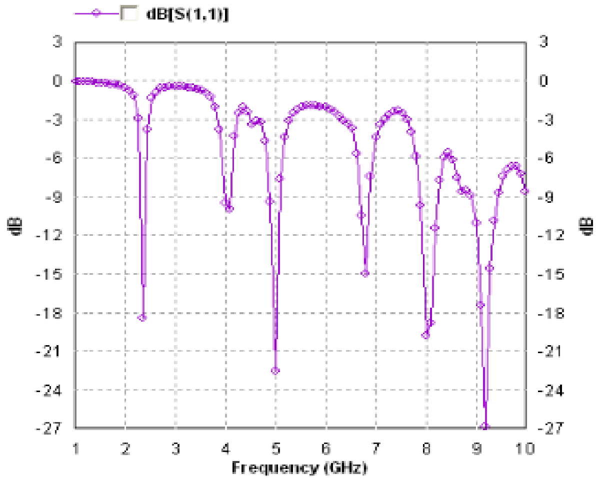

Fig 4: Return Loss versus Frequency plot

Table 2. Performance Parameters for Rectangular 1x2 Patch Antenna Array

Frequency (GHz)	Return loss (dBi)	VSWR	Gain (dBi)	Directivity (dBi)
2.35	-18.3	1.73	2.45	8.30
4.08	-10.01	1.93	3.54	7.58
5	-22.52	1.20	1.63	6.88
6.82	-14.54	1.63	7.01	11.68
8	-19.84	1.23	3.85	10.01
9.17	-27	1.11	9.24	13.78

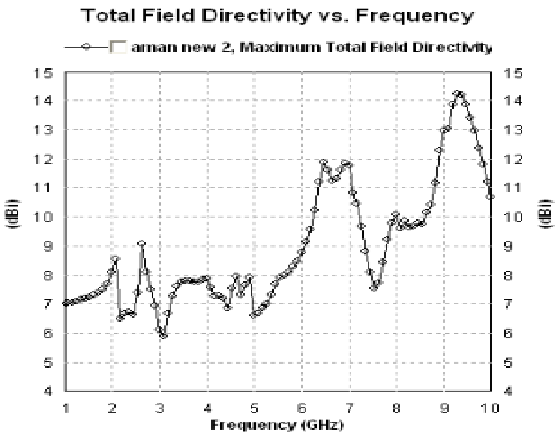

Fig 5: Directivity Vs Frequency

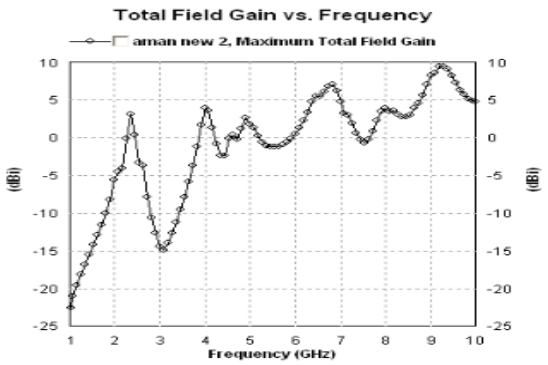

Fig 6: Gain Vs Frequency

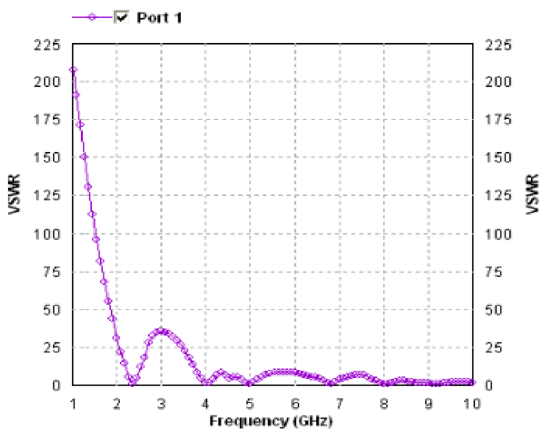

Fig 7: VSWR Vs Frequency

It is clear from Figure 4 that 1x2 RMPA array resonates on 2.35GHz, 4.08GHz, 5GHz, 6.82GHz, 8GHz and 9.17GHz and each frequency iteration has return losses less than -10dB which is necessary condition for the working of RMPA [4] [11]. The performance parameters (return loss, gain, directivity and VSWR) at each frequency are shown in Table 2. From Figure 5 and Figure 6 it has been observed that such multiband patch antenna array has maximum gain 9.24dB and directivity 13.46dB at 9.17GHz frequency.

3.2 Results of 1X4 RMPA Array

The four antenna elements has been connected in series feed network as shown in Figure 3 and when such antenna array has been simulated on the IE3d software then shows the following results. Return loss Vs Frequency, Gain Vs Frequency, directivity Vs Frequency and VSWR Vs Frequency plots of 1x2 RMPA array are shown in Fig 8 to Fig 11.

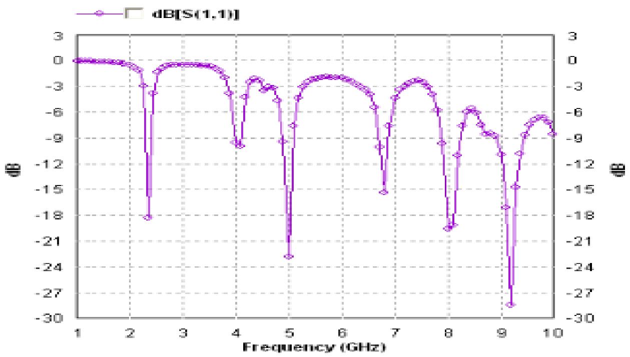

Fig 8: Return Loss Vs Frequency

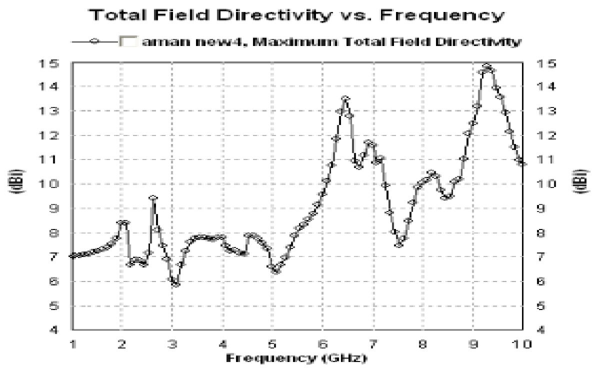

Fig 9: Directivity Vs Frequency

It is clear from Figure 8 that return losses of 1x4 RMPA array has less value than 1x2 RMPA array and shows minimum return loss at 9.17GHz frequency that is -28dB. From Figure 9 and Figure 10 it is clear that RMPA array has maximum gain 9.93dB and directivity and gain at 9.17GHz frequency. These values of gain and directivity are more than 1x2 RMPA array. It is clear from Figure 11 that each frequency band has VSWR [9] less than 2. The different performance parameters for 1x4 RMPA are shown in Table 3.

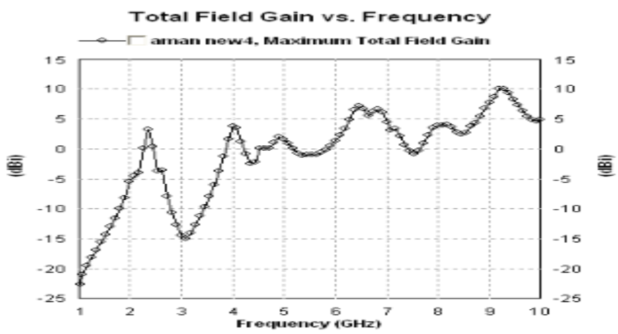

Fig 10: Gain Vs Frequency

4. CONCLUSION

The multiband rectangular microstrip patch antenna has been designed for S, C and X-band application by using the IE3D simulator. Roger RT/duroid material with dielectric constant 2.2 and height 1.588 has been used as a substrate material. Here 1x2 patch antenna array and 1x4 patch antenna arrays has been designed in series feed network and it has been concluded that such proposed antenna arrays works for s, c and x-band applications. When the number of elements has been increased in the series feed network then performance parameters also increased efficiently. Work can be extended by designing 1x8 and 1x16 antenna arrays for S, C and X band applications. Also antenna arrays with fractal antenna can also be designed for S,C and X band applications

Table 3. Performance Parameters for Rectangular 1x4 Patch Antenna Array

Frequency (GHz)	Return loss (dBi)	VSWR	Gain (dBi)	Directivity (dBi)
2.35	-18.32	1.74	2.63	6.84
4.08	-10.02	1.93	3.414	7.44
5	-22.84	1.20	1.53	6.56
6.82	-15	1.63	6.66	11.34
8	-19.61	1.23	3.93	10.06
9.17	-28	1.10	9.93	14.44

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