Linear Arrays of Rectangular Microstrip Patch Antennas: Analysis & Performance Assessment

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Abstract- This paper provides an insight into the design aspects of rectangular microstrip patch (RMP) antenna & its linear arrays and performance assessment is made in terms of bandwidth, directivity and gain by using different dielectric substrate materials. For enhancing the bandwidth, directivity and gain, 2x1 and 4x1 RMP antenna arrays are designed by placing same RMP antenna in linear configuration and utilizing power divider circuits. Performance assessment is made by comparing simulated results of RMP antenna and its linear array.

Keywords – Rectangular microstrip patch (RMP) antenna, RMP antenna array, CST & HFSS

I. INTRODUCTION

Antenna plays an important role in the field of communication. In wireless technology, there are many numbers of antennas but a microstrip antenna is the most popular antenna due to low profile, light weight, low cost, versatility, easy integration in MMIC's and other exceptional features. A Microstrip antenna array is very versatile antenna. It could be used to synthesize required radiation pattern and scanning the beam of the antenna array. The performance of a microstrip patch antenna and array antenna strongly depends on several factors such as type of substrate, feeding technique, the thickness of dielectric and dielectric constant of substrate respectively. But it has few drawbacks like narrow bandwidth, less gain and broad beam width. To increase the bandwidth, directivity and gain, the most common method is using multi-elements which are known as array. Selection of dielectric substrate materials and their thickness are the main parameters in terms of size and compactness a RMP antenna. Compactness comes with a trade-off in bandwidth, directivity and gain.

Objectives of this work are (i) Design and performance analysis of a rectangular microstrip patch antenna for different dielectric constants (ε_r)

ii. Design and performance analysis of a rectangular microstrip patch antenna and 2x1, 4x1 rectangular microstrip patch antenna array for WLAN.

II. DESIGN ANALYSIS & PERFORMANCE ASSESMENT OF A RMP ANTENNA (DIFFERENT DIELECTRIC MATERIALS)

The designed RMP antenna structure is shown in fig. 1. The calculated parameters are Dielectric constant ε_r = 4.4 (FR-4 epoxy), Resonant frequency = 2.4GHz, Substrate thickness, h = 1.58mm, Effective dielectric constant, = 3.91, Patch width = 38.01mm, Patch length = 28.77mm, Width of 50Ω transmission line = 5.93mm, Length of inset feed = 15.80mm, Inset depth = 9.23mm, Notch width g =1.51mm.

In a RMP antenna, when the dielectric materials of substrate varies then the physical dimensional parameters and other parameters are also changed as in table 1. The simulated results using HFSS (High Frequency Structural Simulator) are also given below in figs. 2-4.

Table 1: dimensional parameters of a RMP antenna

Parameters	ε_r =4.4 (FR4-epoxy)	ε_r =2.94(Rogers RT/duroid 6002)	ε_r =2.2(Rogers RT/duroid 5880)
Operating frequency (f_r)	2.4GHz	2.4GHz	2.4GHz
Dielectric constant ε_r	3.1mm	3.1mm	3.1mm
ε_{reff}	3.91	2.69	2.05
Patch width (W_p)	38.01mm	44.50mm	49.38mm
Patch length (L_p)	28.77mm	35.08mm	40.35mm
Feed width (W_f)	5.93mm	7.90mm	9.55mm
Feed length (L_f)	15.80mm	19.06mm	21.79mm
Inset feed length (y_0)	10.87mm	11.29mm	11.96mm

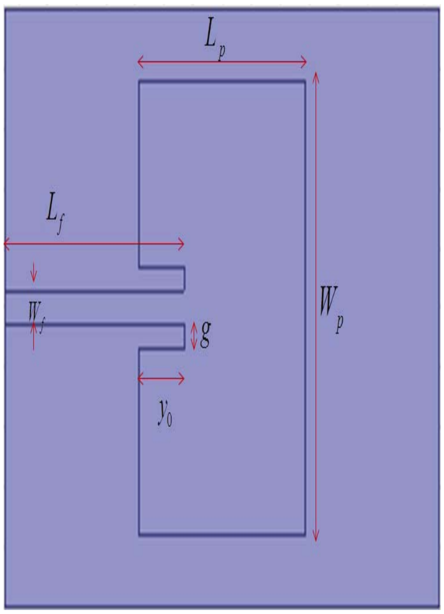


Figure 1. A RMP Antenna

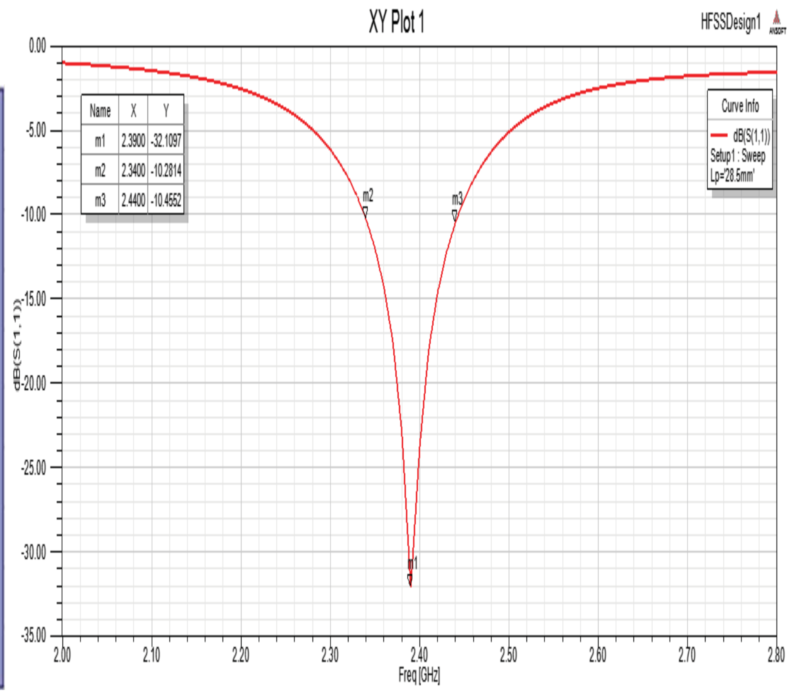


Figure 2. S_{11} Plot of RMP Antenna for ε_r =4.4

S_{11} Plot for a RMP antenna for different dielectric substrate with same thickness have different characteristics for different thickness. S-Parameter plot is given for microstrip patch antenna for dielectric constant=4.4 (FR4-epoxy). Here Return Loss is -32.11dB and BW is 3.75%. S-Parameter plot is given for microstrip patch antenna for dielectric constant=2.94(Rogers RT/duroid 6002). Here Return Loss is -26.40dB and BW is 2.33%. S-Parameter plot is given for RMP antenna for dielectric constant=2.2(Rogers RT/duroid 5880). Here Return Loss is -20.42dB and BW is 2.08%.

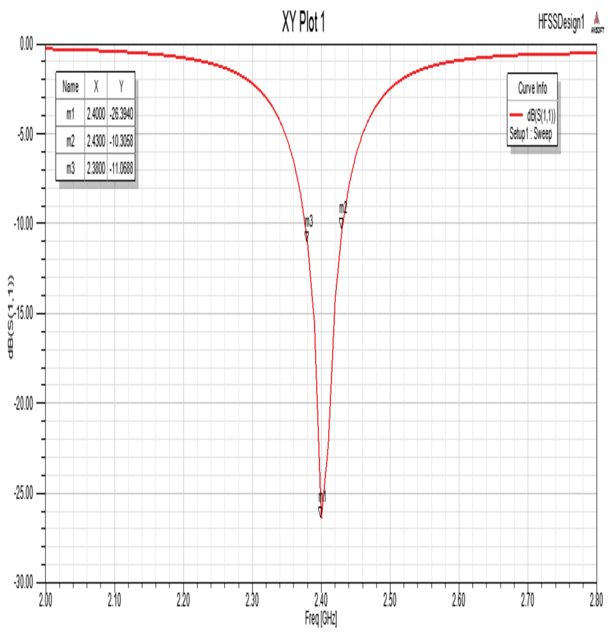


Figure 3. S_{11} Plot of RMP Antenna for ε_r =2.94

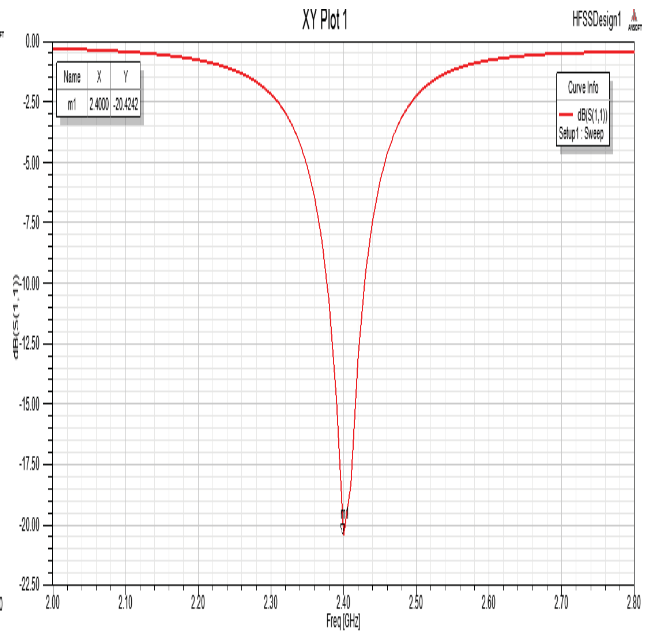


Figure 4. S_{11} Plot of RMP Antenna for ε_r =2.2

III. DESIGN ANALYSIS & PERFORMANCE ASSESMENT OF A 2×1 RMP ANTENNA ARRAY

The 2x1 rectangular microstrip patch antenna array is designed using HFSS by placing same microstrip antenna in linear configuration. The power divider technique for feeding is used in 2x1 antenna array. Using this technique the power goes to equal in every antenna element. The designed RMP antenna array structure is shown in fig. 5. Dimensional Parameters of designed Antenna Array is given in table 2.

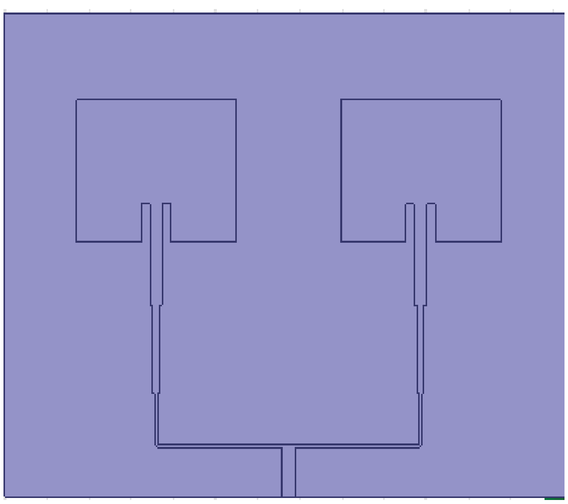


Figure 5. 2×1 Rectangular Microstrip Patch Antenna Array

Table 2 Dimensional Parameters of designed 2×1 RMP Antenna Array

Parameter	Value
Dielectric constant, ε_r	4.4
Resonant frequency, f_r	2.4GHz
Substrate thickness, h	1.58mm
Effective dielectric constant, ε_{reff}	3.91
Patch width, W_p	38.01mm
Patch length L_p	28.77mm
Width of 50 Ω transmission line W_f	5.93mm
Length of inset feed L_f	15.80mm
Inset depth y_0	9.23mm
Notch width g	1.51mm

A. Power divider for 2×1Rectangular Microstrip Patch Antenna Array –

The use of 3-port power divider is especially important for an antenna array system that utilizes a power-splitting network, such a parallel or corporate feed system. The corporate feed is simply a device that splits power between n outputs ports with a certain distribution while maintaining equal path lengths from input to output ports. Here we used the power divider circuit for 2x1 antenna array. Power divider makes using the microstrip lines of different resistances due to impedance matching. Since single microstrip patch antenna has 50ohm input impedance, 2x1 antenna arrays also should have 50ohm input impedance. We use maximum power theorem for impedance matching. The power divider of 2x1 antenna array is given below in figure 6. Dimensional Parameters of designed Power Divider is given in table 3.

Table 3 Dimensional Parameters of designed Power Divider

Parameters	Value
Length of 50Ω transmission line	5.93mm
Width of 50Ω transmission line	17.12mm
Length of 70Ω transmission line	3.21mm
Width of 70Ω transmission line	17.53mm
Length of 100Ω transmission line	1.37mm
Width of 100Ω transmission line	17.98mm

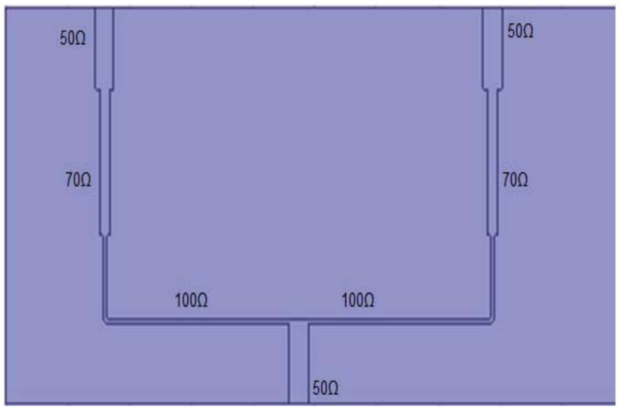


Figure 6. Power divider for 2×1 RMP Antenna Array

B. S Parameter for Power divider (2×1Rectangular Microstrip Patch Antenna Array) –

S Parameter of Power Divider for 2X1 antenna array shows the return loss on port 1. Return loss value is S_{11} = -23.07dB at 2.4GHz as shown in fig. 7.

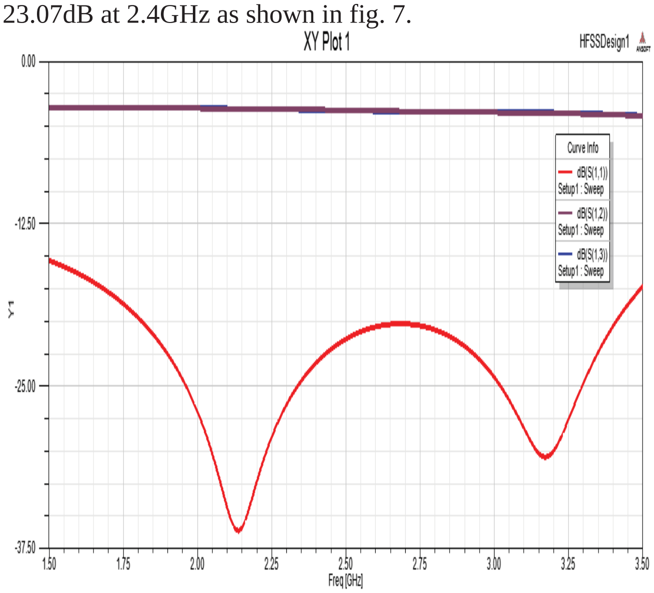


Figure 7. S Parameter for Power divider

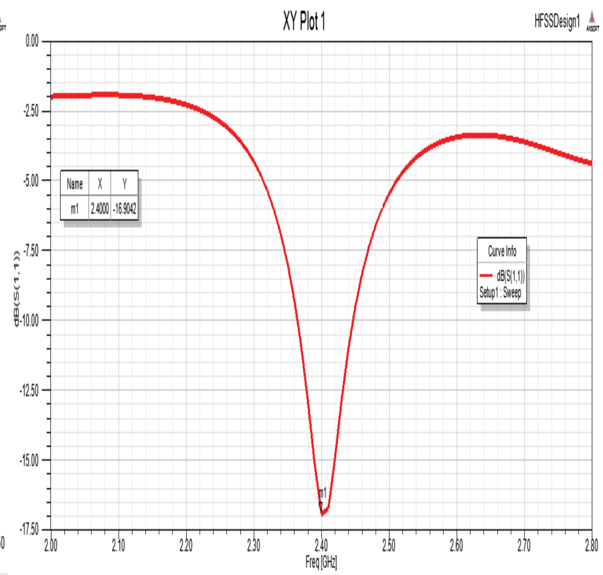


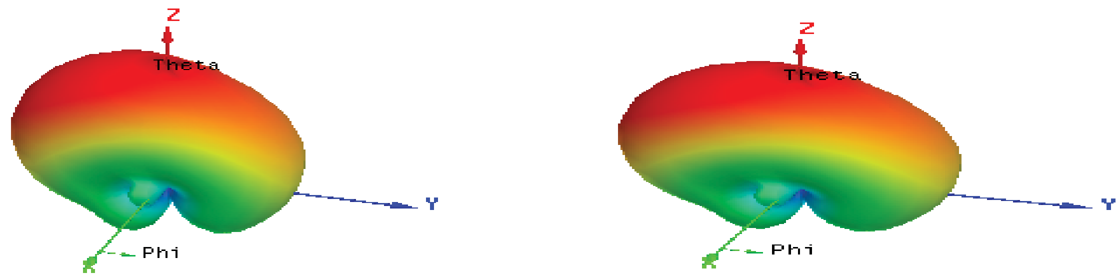
Figure 8. S Parameter for 2×1 RMP Antenna Array

C. S_{11} Plot for 2×1Rectangular Microstrip Patch Antenna Array –

The S_{11} plot of the designed 2x1 microstrip patch antenna array is shown in figure 8. The bandwidth of patch antenna is determined by the return loss graph. The bandwidth of patch antenna is the frequency range over which return loss or S_{11} = -10dB. The Return loss and Bandwidth of 2x1 antenna array is S_{11} = -16.91dB and BW=4.17%.

D. Gain and Directivity for 2×1Rectangular Microstrip Patch Antenna Array –

The designed antenna array radiates in broadside direction with gain of 6.50dB and the directivity of 8.68dBi. It has a broad beam width. Gain and Directivity 3D far field plots are given below in figure 9. Gain and Directivity polar plots are given below in figure 10.



(a) Gain 3D Far Field Plot (b) Directivity 3D Far Field Plot

Figure 9. Directivity and Gain 3D Far Field Plot of 2x1 RMP Antenna Array

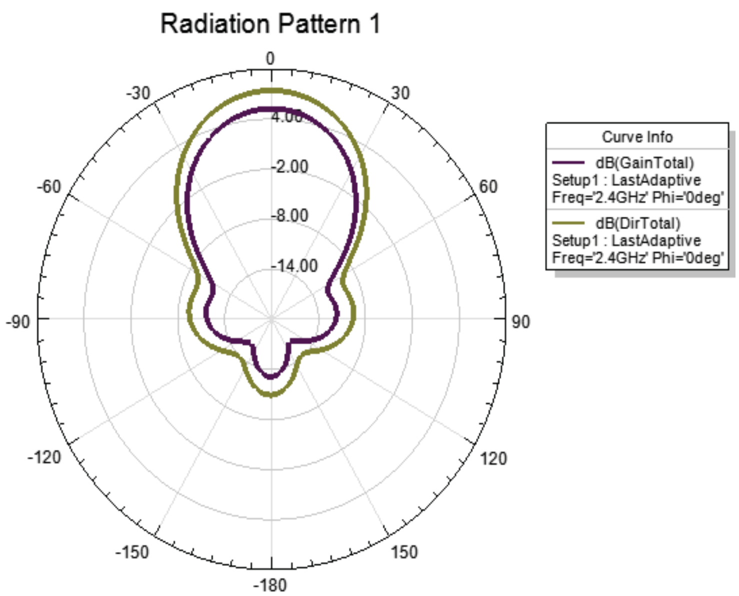


Figure 10. Directivity and Gain Polar Plot of 2x1 RMP Antenna Array

Table 4 Simulated Results of 2x1 RMP Antenna array

Parameter	Value
Return Loss S_{11} (dB)	-16.91
VSWR	1.33
Gain (dB)	6.50dB
Directivity (dBi)	8.68dBi
FBW(%)	4.17
Efficiency (%)	74.88

E. Simulated Results for 2×1Rectangular Microstrip Patch Antenna Array –

Table 4 shows all simulated results viz. Return loss, VSWR, Gain and Bandwidth of 2x1 antenna array using HFSS.

IV. Design analysis & performance assesment of a 4×1 RMP antenna array

The 4x1 rectangular microstrip patch antenna array is designed using HFSS by placing same microstrip antenna in linear configuration. The power divider technique for feeding is used in 4x1 antenna array. Using this technique the power goes to equal in every antenna element. The 4x1 microstrip patch antenna is designed using same dimensions which are given in table 2. The 4x1 antenna array is given below in figure 11.

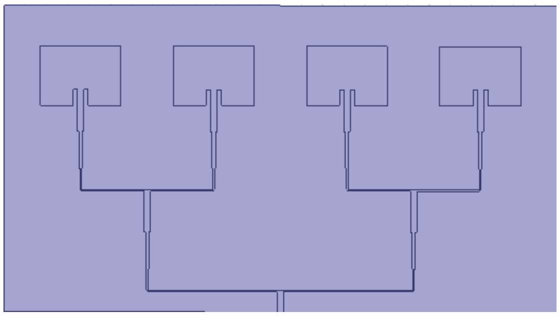


Figure 11. 4×1 RMP Antenna Array

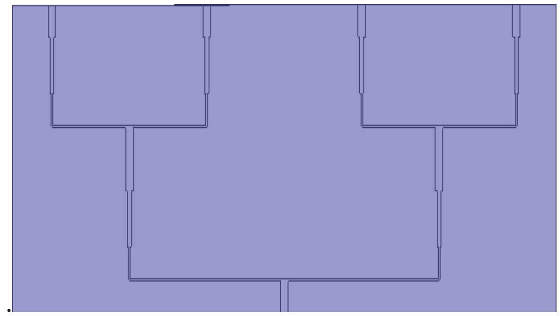


Figure 12. Power divider for 4×1 RMP Antenna Array

A Power divider for 4×1Rectangular Microstrip Patch Antenna Array –

The use of 5-port power divider is especially important for an antenna array system that utilizes a power-splitting network, such a parallel or corporate feed system. The 5-port power divider is combination of two 2-port power dividers. The corporate feed is simply a device that splits power between n outputs ports with a certain distribution while maintaining equal path lengths from input to output ports. The power divider of 4x1 microstrip patch antenna is designed as shown in fig. 12 using same dimensions which are given in table 3.

B S Parameter for Power divider (4×1Rectangular Microstrip Patch Antenna Array) –

S Parameter of Power Divider for 4X1 antenna array shows the return loss on port 1. Return loss value is S_{11} =-19.47dB at 2.4GHz as shown in fig. 13.

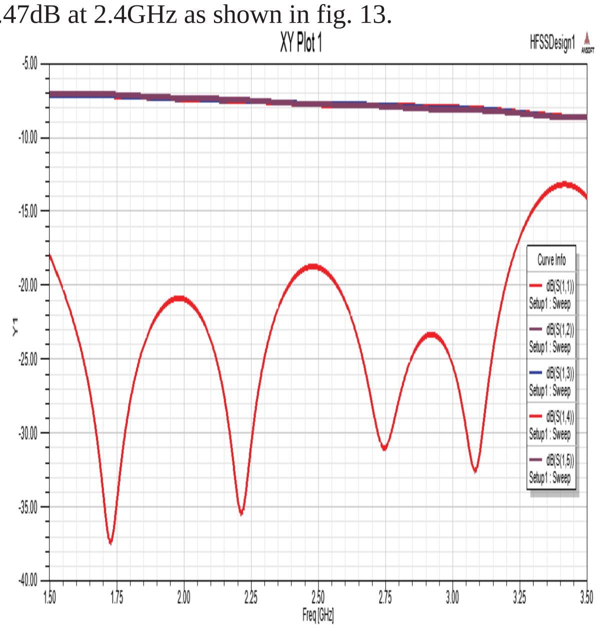


Figure 13. S Parameter for Power divider

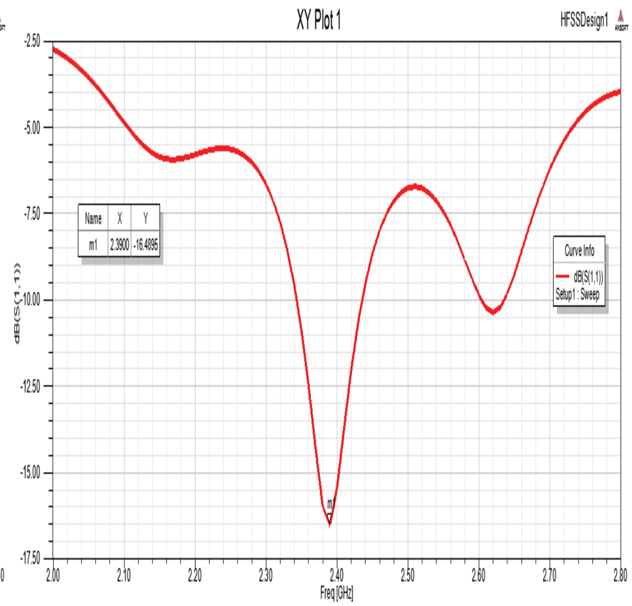


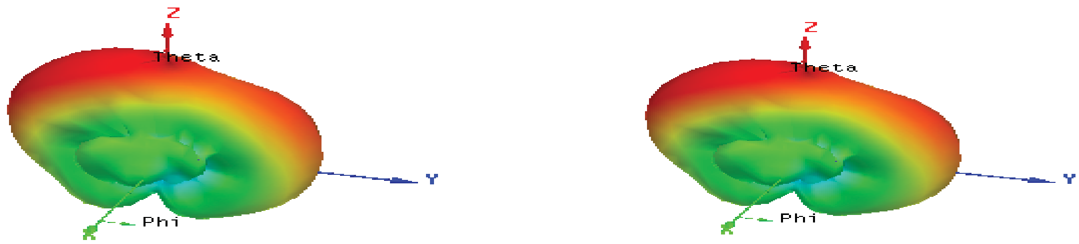
Figure 14. S Parameter for 4×1 RMP Antenna Array

C S_{11} Plot for 4×1Rectangular Microstrip Patch Antenna Array –

The S_{11} plot of the designed 4x1 microstrip patch antenna array is shown in figure 14. The bandwidth of patch antenna is determined by the return loss graph. The bandwidth of patch antenna is the frequency range over which return loss or S_{11} = -10dB. The Return loss and Bandwidth of 4x1 antenna array is S_{11} = -16.49dB and BW=4.61%.

D Gain and Directivity for 4×1Rectangular Microstrip Patch Antenna Array –

The designed antenna array radiates in broadside direction with gain of 7.23dB and the directivity of 9.78dBi. It has a broad beam width. Gain and Directivity 3D far field plots are given below in figure 15. Gain and Directivity polar plots are given below in figure 16.



(a) Gain 3D Far Field Plot (b)Directivity 3D Far Field Plot

Figure 15. Directivity and Gain 3D Far Field Plot of 4x1 RMP Antenna Array

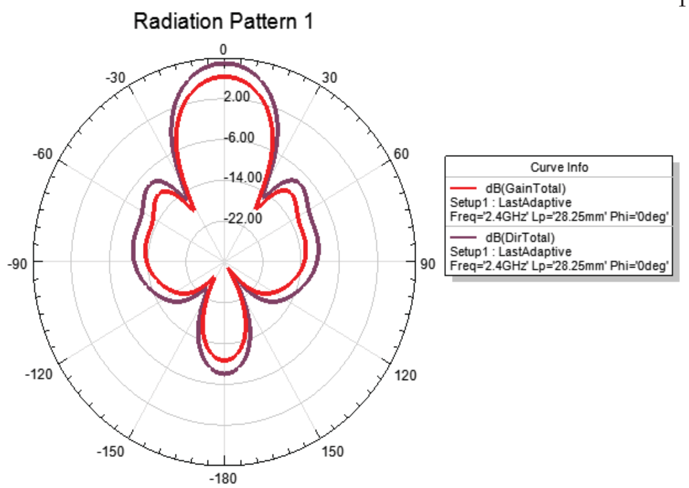


Figure 16. Directivity and Gain Polar Plot of 4x1 RMP Antenna Array

Table 5 Simulated Results of 4x1 RMP Antenna Array

Parameter	Value
Return Lo	-16.49
VSWR	1.35
Gain (dB)	7.23dB
Directivity (dBi)	9.78dBi
FBW(%)	4.61
Efficiency (%)	76.93

E Simulated Results for 4×1Rectangular Microstrip Patch Antenna Array –

Table 5 shows all simulated results viz. Return loss, VSWR, Gain and Bandwidth of 4x1 antenna array using HFSS.

V. RESULTS

A microstrip patch antenna has small bandwidth, gain and directivity. For increasing the bandwidth, gain and directivity, we use the array of microstrip patch antenna. For making of antenna array we use the same antenna by placing equal distances and linear configuration. When we use a 2x1 array, it has more return loss than single microstrip patch antenna. When we use a 4x1 antenna array, it has more return loss compare to single microstrip patch antenna and 2x1 antenna array. Comparison between S Parameter of RMP antenna and array is given in figure 17. Comparison between VSWR Parameter of RMP antenna and array is given in figure 18. Simulated results for RMP antenna and array are given in table 6.

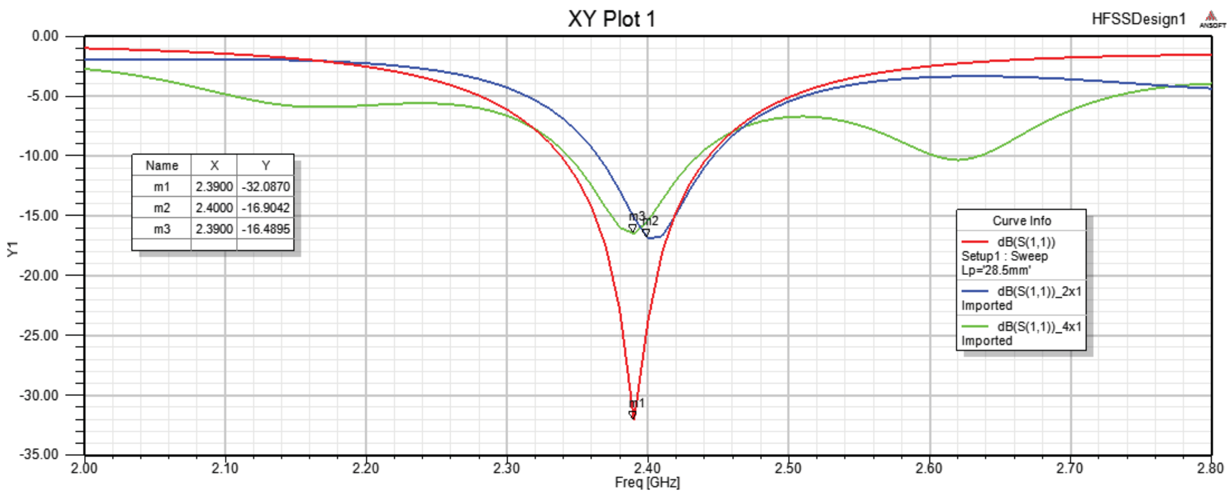


Figure 17 Comparison between S Parameter of RMP antenna and array

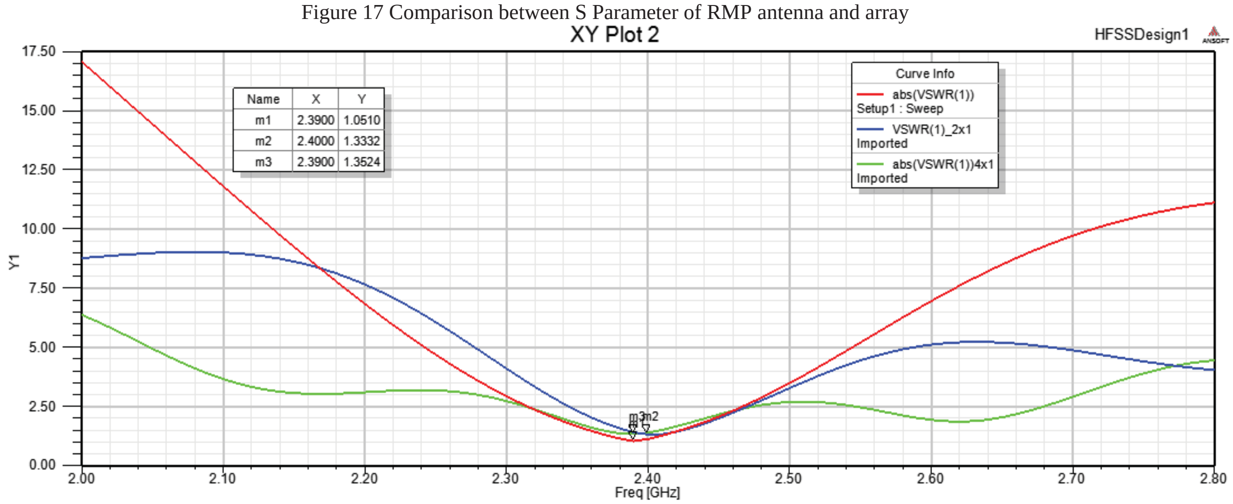


Figure 18 Comparison between VSWR of RMP antenna and array

Table 6 Simulated results of a microstrip patch antenna, 2x1 and 4x1 RMP antenna array

Parameters	Microstrip Patch Antenna	2x1 Antenna Array	4x1 Antenna Array
Return Loss S_{11} (dB)	-32.11	-16.91	-16.49
VSWR	1.051	1.333	1.352
Gain (dB)	4.023	6.503	8.776
Directivity (dBi)	5.989	8.683	11.407
FBW (%)	3.75	4.17	4.61
Efficiency (%)	67.17	74.88	76.93

VI. CONCLUSION & FUTURE SCOPE

The result obtained in simulation proved that the FBW(%), Gain and Directivity of single microstrip patch antenna is less than FBW(%), Gain and Directivity of 2x1 and 4x1 antenna array. Some optimization technique can be used for getting better results because in this work optimization has done manually.

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