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Design and Development of Miniaturized Planar Array Antenna for Multi Functional Radar

P. Sai Vinay Kumar, M. N. Giri Prasad

Abstract: - Miniaturized multi functional planner array antennas are presented for both L and S bands in this paper. A 3x8 array is proposed and the distance between antenna elements is only λ/2 so that size reduced significantly. The two dielectric substrates FR4 and RT duriod 6010 are used for different antennas. The antenna with FR4 substrate is fabricated and compared the results with simulated values. Coaxial feeding technique is adopted. Dual frequency multi functional array is simulated .Better gains, return losses and radiation patterns are obtained .The circular polarization is obtained by truncating the elements and it is useful for navigation. The results are compared with existing multi object tracking radar (MOTR).

Keywords: Multi Frequency, Array, coaxial feed ,MOTR, circular polarization.

I. INTRODUCTION

In recent times, L-Band is frequently used in radar tracking terrestrial and cellular tracking for navigation and other purpose there has [1-2].With this advent of wireless technology and ever growing demand for elevated data rate mobile communications. Array antennas have been widely used in point-to-point, and radar communication systems. To outwit the aforesaid difficulties to some extent, antenna miniaturization and compact multifunctional antennas must be considered. However, this type of array antenna reqiures complex feed techniques with more number of the elements[3]. Couping between the elements degrade the performance of array like gain and axial ratio etc., [4-5]. To dimnish this inconvenience the spacing inbetween each antenna element is increased which leads to significant increase in antenna array size [6-9]. The circularly polarized antennas are predominant in view of the fact that acceptability is better than linear polarization. The present paper represents a 3×8 patch antenna array (tile) with independent feeding ports .

II. ANTENNA DESIGN

The design is carried out with two different substrates and the performance is analysed for both the antennas**.** Fig. 1 and Fig. 2 depict the schematic structure of the basic antenna element and Antenna array for two substrates.

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Stacking technique is implemented in the patch antenna. The antenna resonates at both L and S bands. The proposed antenna consists of two substrates and two patches which are stacked upon one another. The lower patch resonates at 1.60GHz and the elevated patch resonates at 2.492 GHz. The 3×8 antenna array (tile) for different substrates FR4 and Rogers RT Duroid 6010 for dual frequencies are designed. The dimensions of the patch are 80mm. The dielectric thickness is 4mm for specific layer with relative dielectric constant value 4.4. The dimensions of the lower patch are 39.4mm × 40mm and the dimensions of the upper patch are 27mm × 29.1mm.

For the antenna with substrate Rogers RT Duroid 6010, Length of the substrate is 80mm and width is also 80mm. Each layer thickness is 3.81mm with relative dielectric constant value of 10.2. The dimensions of the lower patch are 36mm × 36mm and the dimensions of the upper patch are 22.5mm × 22.5mm.

By truncating the corners the circular polarization is obtained. The lower and the upper patches are truncated by 6mm and 6.5mm respectively for antenna with FR4 substrate. The truncations of lower and upper patches by 5mm and 6mm respectively for antenna with RT duroid substrate. In both the cases coaxial feeding techniques is implemented for all the element of the array antenna. The coaxial feed is enforced to the upper and the lower patch and the antenna is excited due to the merging of the upper patch and lower patch for both cases. The patch width is calculated by using the equation 1

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1)$$

Using the equations 2,3 and 4 length can be calculated.

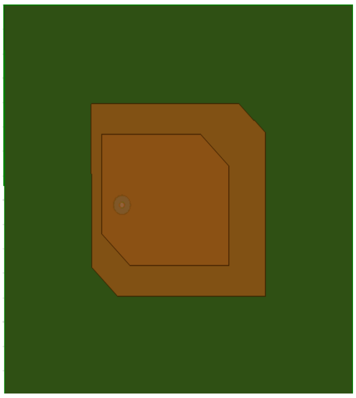
$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (2)$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \quad (3)$$

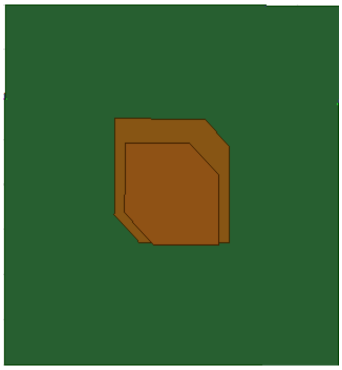
$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

The length (L) of the patch is computed using the equation 5

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



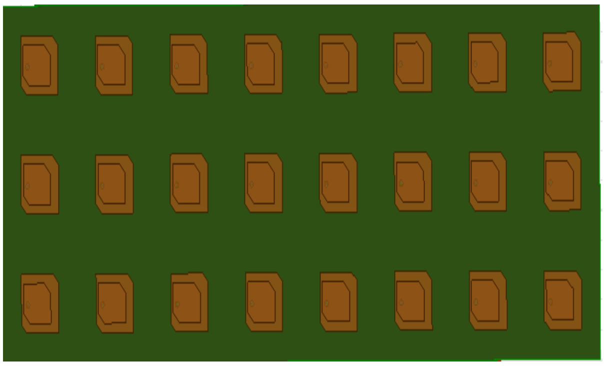
(a)



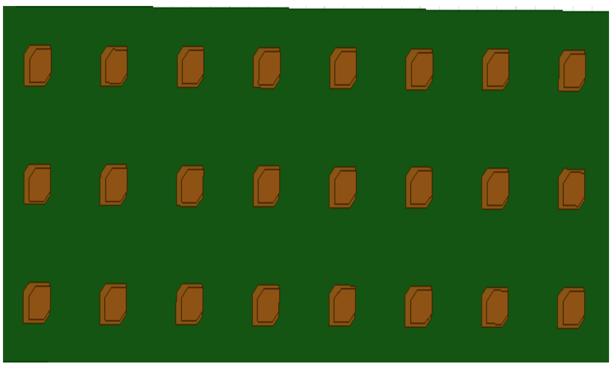
(b)

Fig. 1. Structure of the Antenna with different dielectric constants (a) FR4. (b) Rogers RT Duroid 6010

Fig. 2 represents the layout of 3x8 array antenna with a coaxial feed to the individual patch of an array.



(a)

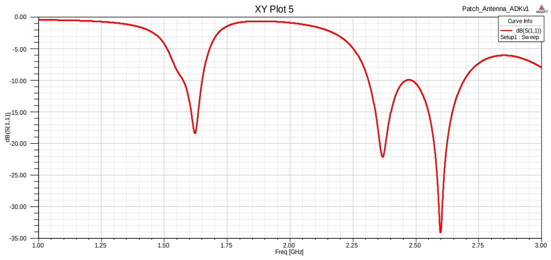


(b)

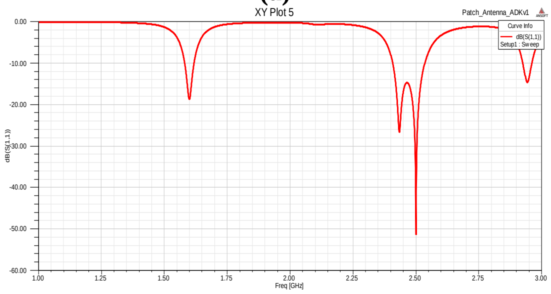
Fig. 2. 3×8 Antenna Array with different dielectric constants (a) FR4. (b) Rogers RT Duroid 6010

III. SIMULATION AND MEASUREMENT

The return loss of the antennas at the operating frequencies of 1.60 GHz, and 2.492 GHz.



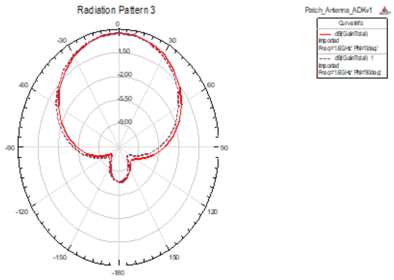
(a)



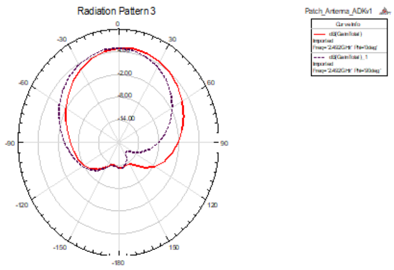
(b)

Fig. 3. Return loss of Single Element (a) FR4. (b) Rogers RT Duroid 6010

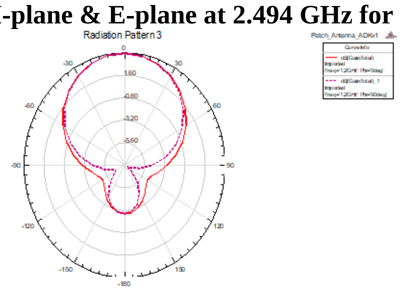
In Fig. 4, radiation pattern of stacked patch antenna in 2D is shown.



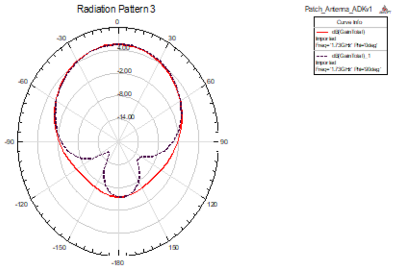
The patterns of H-plane & E-plane at 1.60 GHz for FR4



The patterns of H-plane & E-plane at 2.494 GHz for FR4



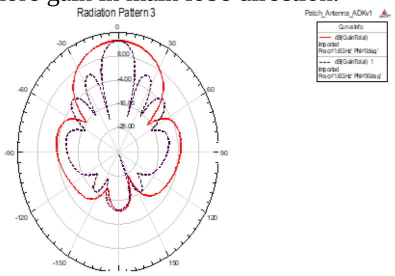
The patterns of H-plane & E-plane at 1.60 GHz for Rogers 6010



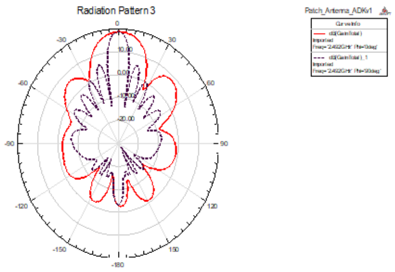
The patterns of H-plane & E-plane patterns at 2.494 GHz for Rogers 6010

Fig. 4. The Radiation patterns of Single Antenna Element at respective frequencies

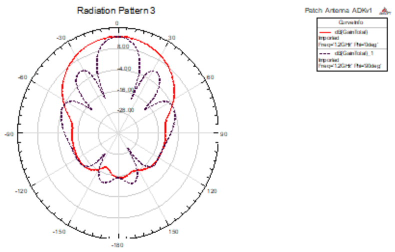
In Fig. 5, the 2D radiation plot of 3x8 array is shown. The array antenna has more gain in main lobe direction.



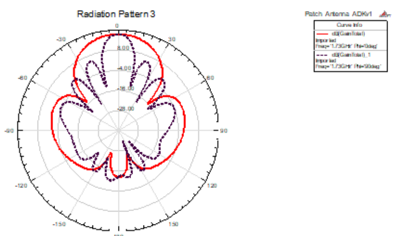
The H-plane & E-plane patterns at 1.60 GHz for FR4



The patterns of H-plane & E-plane at 2.494 GHz for FR4



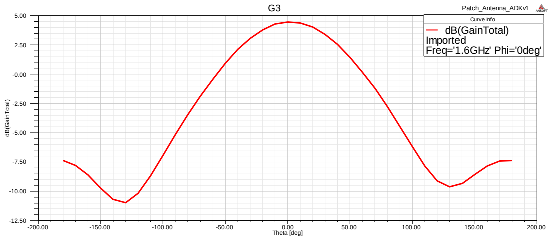
The patterns of H-plane & E-plane at 1.60 GHz for Rogers 6010



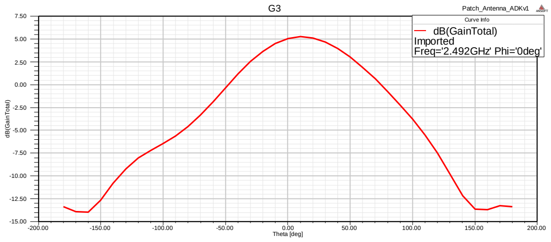
The patterns of H-plane & E-plane at 2.494 GHz for Rogers 6010

Fig. 5. The 3×8 Antenna Array Radiation patterns in 2D

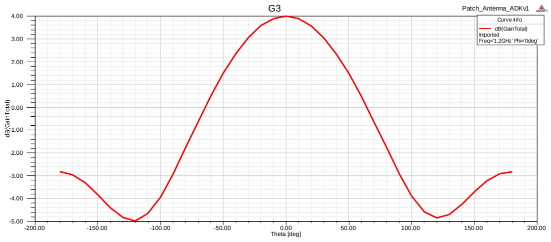
The gain of only element and 3×8 array are simulated in Fig. 6 and Fig.7. The gain of 4.45dB and 5.16dB is acquired for antenna element at frequency of 1.6GHz, and 2.492GHz respectively and a gain of 16.02dB, and 18.93dB is acquired for 3×8 Antenna Array at 1.6GHz and 2.492GHz respectively for the FR4 substrate Antenna. A gain of 4dB and 5.62dB is achieved for single antenna element at 1.6GHz, and 2.492GHz respectively and a gain of 15 dB, and 18.06dB is achieved for 3×8 Antenna Array at 1.6GHz and 2.492GHz respectively for the antenna with Rogers 6010 substrate



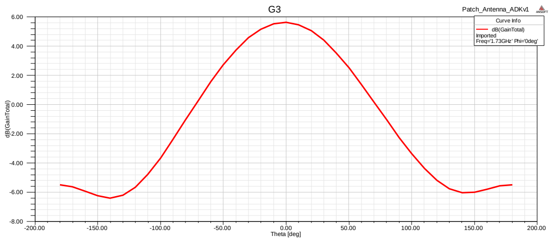
4dB Gain at 1.60 GHz for FR4



5.62dB Gain at 2.492 GHz for FR4

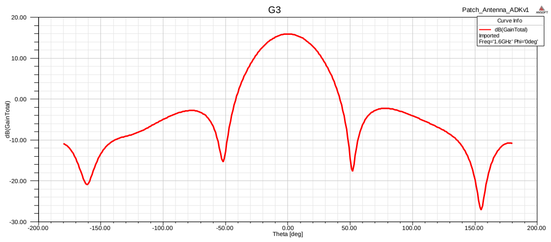


4 dB Gain at 1.2 GHz for Rogers 6010

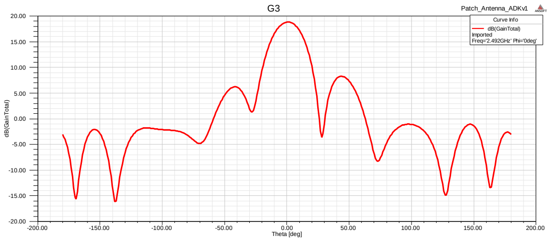


5.62dB Gain at 1.73 GHz for Rogers 6010

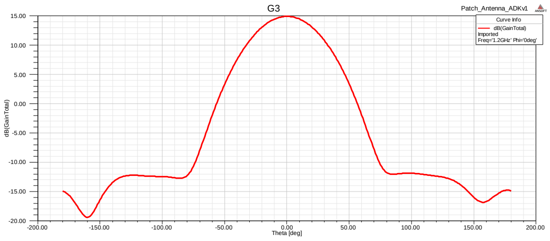
Fig. 6. Gain of Antenna Element at respective frequencies



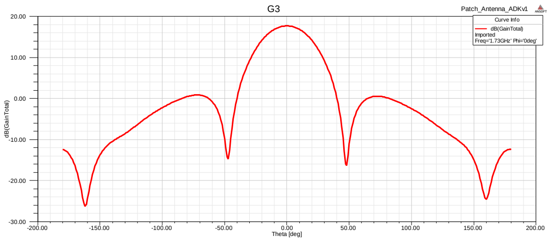
15dB Gain at 1.60 GHz for FR4



18.06 dB Gain at 2.492 GHz for FR4



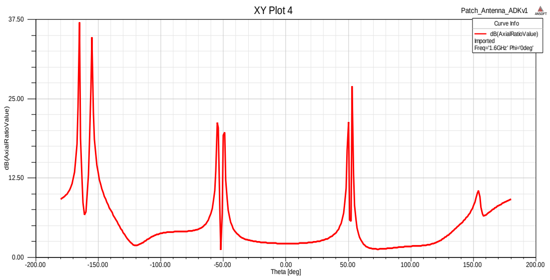
15dB Gain at 1.20 GHz for Rogers 6010



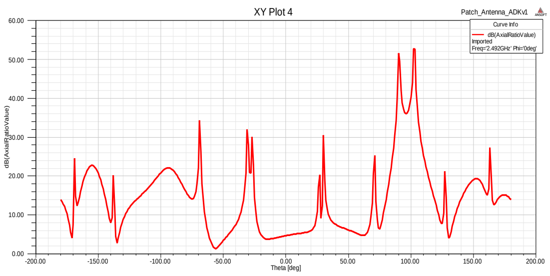
18.06dB Gain at 1.73 GHz for Rogers 6010

Fig. 7. Gain of 3×8 Antenna Array

Axial Ratio Plots of the both the proposed antennas are as shown below in figure 8. axial ratio values of 2.23dB and 4.2dB were observed for antenna with FR4 substrate and axial ratio values of 4.97dB and 3.92dB were observed for antenna with Rogers RT duroid 6010 substrate.

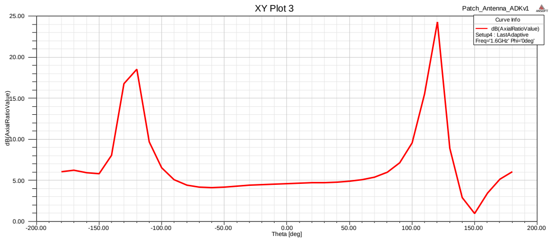


Axial **ratio at 1.60 GHz for FR4**

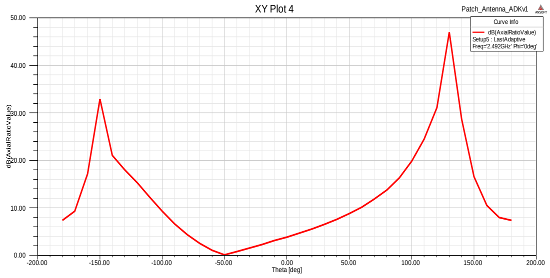


Axial ratio at 2.495 GHz for FR4

(a)



Axial ratio at 1.60 GHz for Rogers 6010



Axial ratio at 2.492 GHz for Rogers 6010

(b)

Fig. 8. The Axial ratio (a) FR4. (b) Rogers RT Duroid 6010

The fabricated antenna with FR4 substrate is compared with simulation results and found intact as shown below in Fig 9.

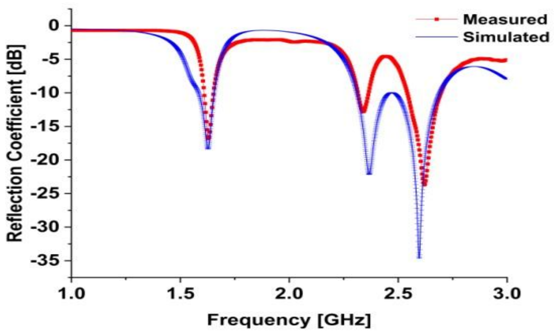


Fig. 9. Comparison of the Measured and Simulated results

Figure 10 below shows the measurement setup of the antenna with FR4 substrate.

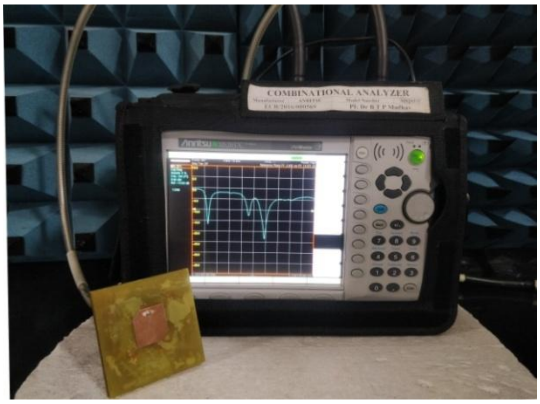


Fig. 10. The Measurement setup

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Table 1 explains the comparison of the proposed antenna with relevant tasks and proposed antenna obtained better results in terms of gain and impedance matching.

Table 1: Comparison of the Work proposed with the existing ones

Antenna	Size of the Antenna	Frequency of Operation	Gain (dB)
1	120mmx120mm	1.268GHz 1.615GHz	2.3 3.1
2	125mmX125mm	1.575	4.9
3	230mmx230mm	1.7GHz 2.3GHz	6 5.4
Proposed	80mmx80mm	1.60GHz 2.492GHz	4.45 5.16

The existing MOTR system is having a stacked patch antenna element with a gain of 4.5dB operating at the frequency of 1.35GHz. The existing system has a 3×8 antenna array (tile) and is having a gain of 17.5dB. Proposed antenna is a dual frequency array antenna operating at the frequencies of 1.6GHz and 2.492GHz with gains of 4.45 dB and 5.16 dB respectively. Proposed antenna is a dual frequency antenna with circular polarization which is useful to upgrade the existing system for Multifunctional applications so that the same system can be used for different applications. The circular polarization will be useful to overcome the data loss in long range RADAR applications. Table 2 below shows a Comparison of existing MOTR system with proposed antenna and it is also observed the dimensions of the proposed array (tile) is small compared with the existing array and miniaturization is obtained.

Table 2: Comparison of the proposed Antenna design tile with existing MOTR

S. no	Antenna Parameter	Existing MOTR	Proposed Design
1	Operating Frequency	1.35 GHz	1.60 GHz 2.492GHz
2	Array Configuration	3*8	3*8
3	Tile Gain	17.5 dB	16.02 dB 18.93 dB
4	Return Loss	-14dB	-16.52 dB
5	Tile Size	(93*35*4) cm	(64*24*0.8) cm
6	Polarisation	Linear	Circular

IV. CONCLUSION

Dual frequency circularly polarised array antennas are obtained using different substrates. Two 3X8 arrays produced reasonable gains, s_{11} and radiation patterns. Comparison of the results of the array with the existing tile in MOTR is made. The proposed tile has miniaturisation and multi functional properties.

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