IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⋇ Impact Factor 7.047 ⋇ Vol. 10, Issue 5, May 2022

DOI: 10.17148/IJIREEICE.2022.10549

Design and Simulation of a Multiband Millimetre Wave Microstrip Patch Antenna Array for Wireless Communication

Rajeswari S[1], Abishek M[2], Dineshram R[3], Jaibalaji C[4], Jayshrinivaas B[5]

Associate Professor, Electronics and Communication Engineering, Saranathan College of Engineering, Trichy[1]

Student, Electronics and Communication Engineering, Saranathan College of Engineering, Trichy[2,3,4,5]

Abstract: In this paper, a 2x4 multiband patch antenna array is presented and it is designed and simulated by using CST Microwave Studio for the bands 10GHz, 46GHz-50GHz, 52GHz-58GHz, 82GHz-86GHz. The design of patch antennas is very efficient and widely used in wireless communication due to their lower cost of fabrication, light weight and can operate a microwave frequency but it offers low efficiency, low gain etc. Future upcoming wireless communication is needed of high gain. Similarly, the multiband antennas are highly desired to use a single antenna instead of multiple antennas for different bands. The antenna provides maximum and minimum gains of 9.33dB and 8.63dB at operating frequency 49.5 GHz and 85.56GHz. The overall size of antenna is 59.62mm X 25.79mm X 0.197mm make it to work better by fulfilling the requirements for wireless communication.

Keywords: Multiband, Millimetre Wave, Wireless Communication, Antenna Array.

I. INTRODUCTION

The new digital era demanded 5G wireless technology for its new exceptional features such as device to device communication (D2D), Internet of Things (IOT) and other new digital characteristics. The upcoming wireless technology promises to provide various features such as high data rate, handling traffic intensity and retaining lack of bandwidth etc. Wireless technology normed with IPOT, MIMO, multiband antennas and others various devices. For wireless application with greater frequency(millimetre wave) microstrip patch antenna is highly recommended. Among them array antennas are needed for higher gain and multiband. To achieve high data rate and mm wave high resolution band, mm wave antenna array used are generally consisting of limitations such as high production cost and complex etc. Up till now, no specific frequency is selected for 5G wireless communication, however some strong candidate frequencies are proposed which are 28 GHz, 38 GHz, 60 GHz, E-band (81-86 GHz). The proposed work provides a simple millimetre wave microstrip patch antenna array for wireless application.

In paper [2] a 1x6 array antenna proposed where operating frequency range is 58-77.3 GHz with the total bandwidth 5.35 GHz but peak gain is only 9 dB. In paper [6] a 2-D array antenna has been designed where operating frequency is 28- 39 GHz and 3 GHz narrow bandwidth achieved. In paper [10] a 1x4 MIMO antenna proposed where operating frequency is 5.1-80 GHz with a total bandwidth of 7.8 GHz but gin is extremely poor pick gain achieved -10 dB at 41 GHz resonant frequency.

By analysing all above works and challenges, the proposed work provides a simple millimetre wave micro strip patch antenna array, the designed and simulated antenna results provide high gain, multiband very low return loss and large bandwidth where the array antenna to provide efficient wireless communication.

II. ANTENNA DESIGN

A microstrip patch antenna is designed for lower frequency region. To calculate the antenna parameters equations have been used.

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⋇ Impact Factor 7.047 ⋇ Vol. 10, Issue 5, May 2022

DOI: 10.17148/IJIREEICE.2022.10549

Patch width is calculated using F_r equation given below,

$$W_p = \frac{c}{f}\sqrt{\left(\frac{2}{(\varepsilon r+1)}\right)}$$

Here, f_r = Resonant Frequency

ϵ_r = Substrate Dielectric Constant

C = Velocity of light.

Length of the patch is given by,

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

Effective length of the patch is given by,

$$L_{eff} = \left(\frac{c}{2f\sqrt{(\varepsilon eff)}}\right)$$

Effective Dielectric constant is given by,

$$\epsilon \mathrm{eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left(1+\frac{10h}{w}\right)$$

Now extension length ΔL as follows,

$$\Delta L = 0.412h\left(\frac{(\varepsilon r+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon r-0.258)\left(\frac{w}{h}+0.8\right)}\right)$$

Substrate length and width of single antenna is given by,

$$L_g = L_p + 6h$$

$$W_g = W_g + 6h$$

Substrate height is given by,

$$H = \frac{0.0606\lambda}{\sqrt{\varepsilon r}}$$

The above equation sets have been used to design a single element antenna and simulated by CST Microwave Studio. Fig. 1, shows the single element antenna (geometric view). Rogers 5880(lossy) substrate has been used as substrate material whose dielectric constant 2.2 and substrate height 0.127mm. The parameters used for simulation is described in TABLE I.

Parameter Symbols	**Parameter Description**	**Values (in mm)**
W_p	Patch width	11.858
L_p	Patch Length	9.847
W_f	Feedline Width	0.119
F_i	Insertion Feed	2.368
Gap	Gap	0.12

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⁜ Impact Factor 7.047 ⁜ Vol. 10, Issue 5, May 2022

DOI: 10.17148/IJIREEICE.2022.10549

H_s	Height of Substrate	0.127
H_t	Height of Patch	0.035
E_r	Relative permittivity	2.2

TABLE I

By using parameter of TABLE II, the proposed 2x2 array antenna designed the space between patch to patch is calculated by wavelength times divided by 4.
PAP

Parameter Symbols	**Parameter Description**	**Values (in mm)**
L_s	Array Substrate Length	59.62
W_s	Array Substrate Width	25.79
X	Space Between Patch	3.108

TABLE II

Below figures FIG 1 & FIG 2 shows, the model of single element and proposed element antenna respectively.

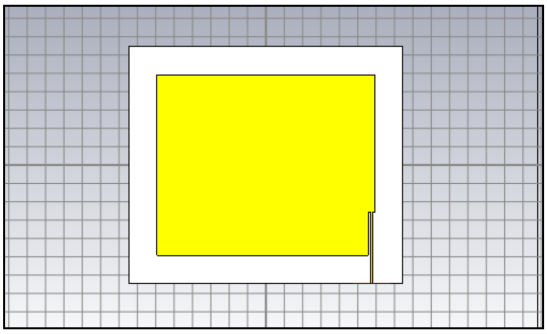


FIG 1

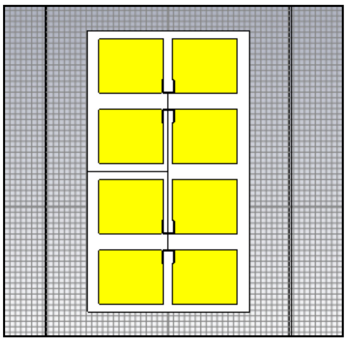


FIG 2

III.RESULTS AND DISCUSSION

A. RETURN LOSS (RL)

The S11 parameter defines how much power does antenna radiates, to radiate antenna efficiently S11 parameter need to be less than -10 dB. A microstrip patch antenna designed for lower frequency where only one -10 dB frequency band achieved it resonate at 10.112 GHz with return loss of -12.415 dB with only 0.07 GHz. As revealed in Fig. 3, and TABLE III, the projected multiband antenna has all return loss less than - 10 dB for all resonant frequencies.

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⁒ Impact Factor 7.047 ⁒ Vol. 10, Issue 5, May 2022

DOI: 10.17148/IJIREEICE.2022.10549

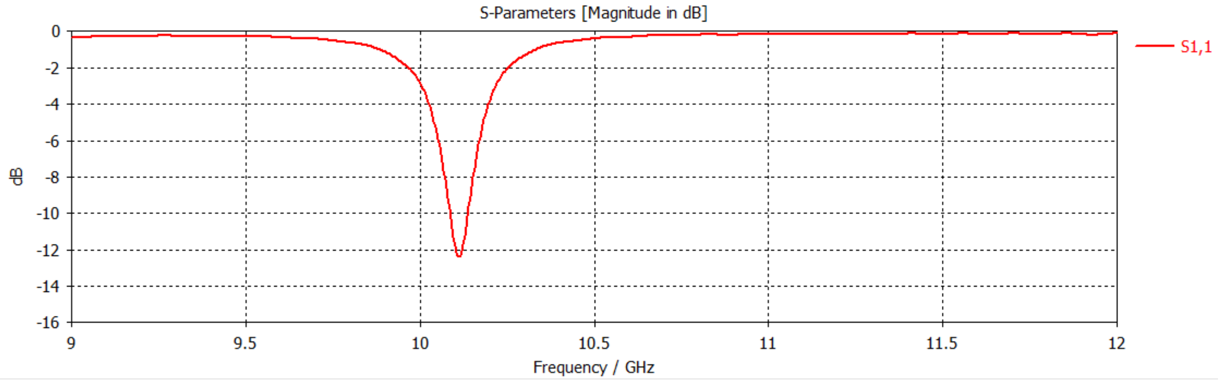


Fig.3

B. Gain

An antenna's power gain or simply gain is a key performance number which combines the antenna's directivity and electrical efficiency. The standard value of gain for 5G(wireless) application is 6-9dB. The proposed antenna has gain at 6-10 dB and meet its standard value in every resonant frequency shown in Fig. 4.

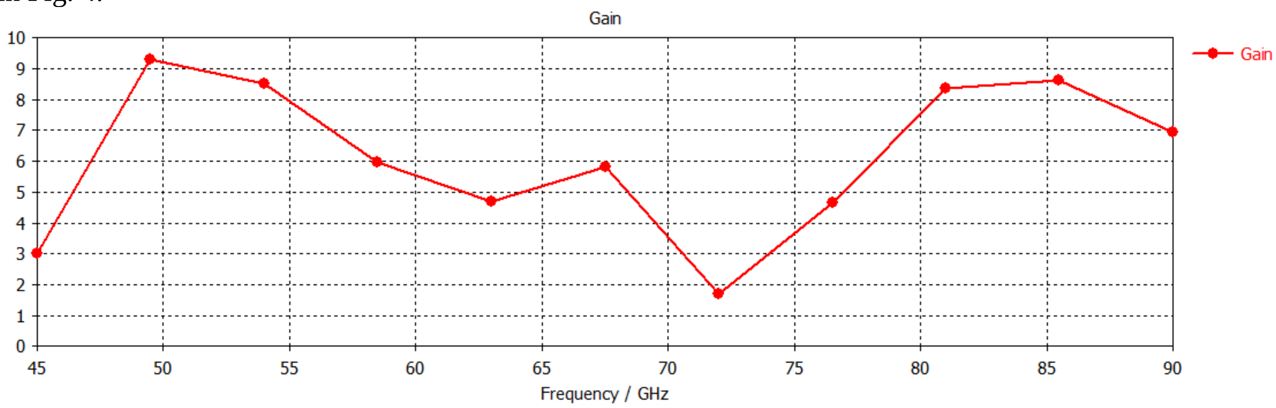


FIG 4

C. DIRECTIVITY

It is a measure of how 'directional' an antenna's radiation pattern is. The standard value of directivity for wireless antenna is 4-8 dBi. The single antenna has directivity 9.77 dBi where proposed antenna array has directivity at 4-14 dBi in every resonant frequency shown in Fig. 5.

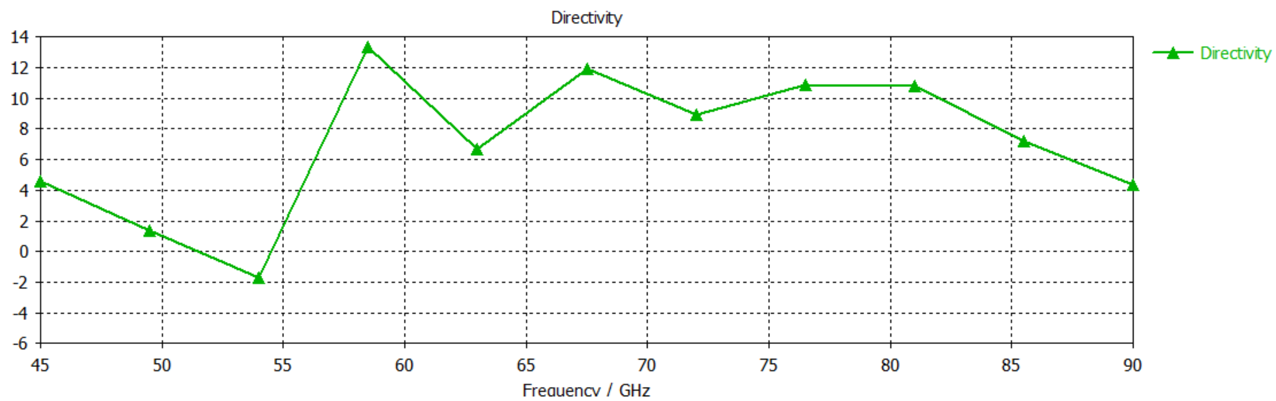


FIG 5

ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 7.047 ⁜ Vol. 10, Issue 5, May 2022
DOI: 10.17148/IJIREEICE.2022.10549

TABLE III shows the S11 parameters for the respective resonant frequency and also bandwidth is provided and FIG 6 shows the return loss graph.

Resonant Frequency	**Bandwidth (in GHz)**	**S11 parameters (in dB)**	**Bands (GHz)**
13.25	0.67	-27.65	13.10-14.13
49.65	1.27	-23.25	49.03-50.90
53.37	0.80	-13.29	52.50-55.50
57.69	0.97	-40.64	56.23-58.20
83.25	2.81	-24.84	82.10-85.78

TABLE III

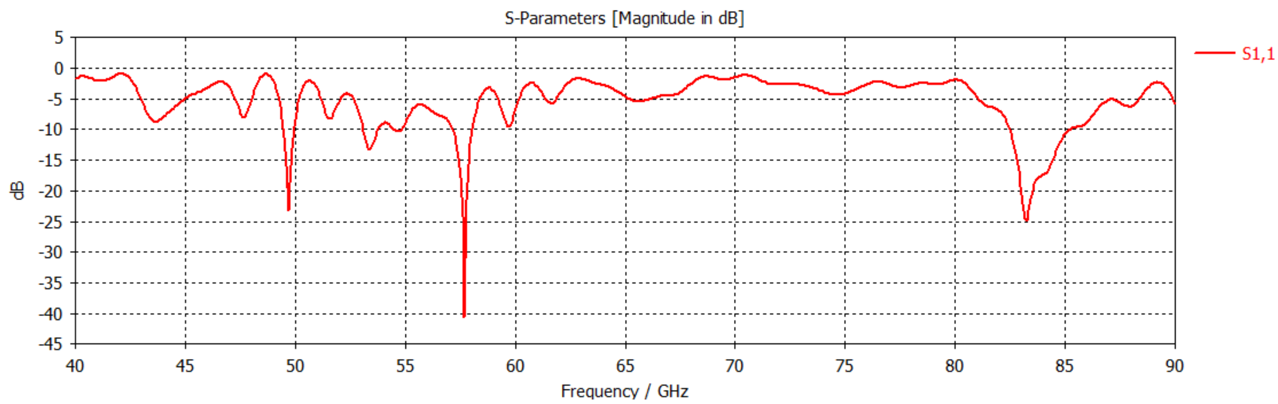
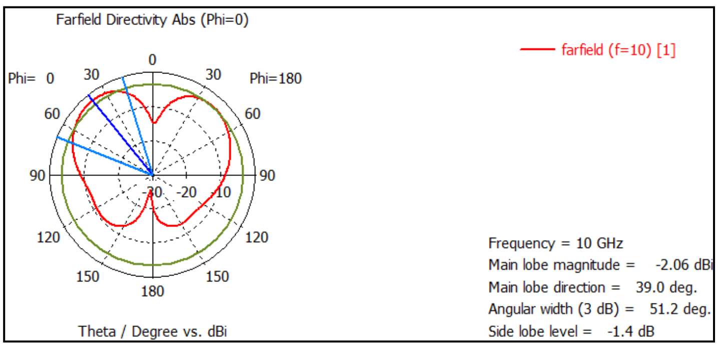


FIG 6

D. RADIATION PATTERN

The 2-dimension (2D) Polar radiation plot of the proposed antenna array for Elevation/Degree vs dBi shown below Fig 7(a – j). In Fig 7(a - j) at mentioned resonant frequency main lob magnitude is -2.06, 6.43, 6.64, 4.61, 1.63, 5.88, 12.4, 8.22, 5.28 and 4.64 dBi respectively. The angular width (3 dB) is 51.2, 14.0, 14.2, 14.4, 14.5, 14.5, 14.4, 8.5, 8.4, 10.3 and 18.9 degree respectively.



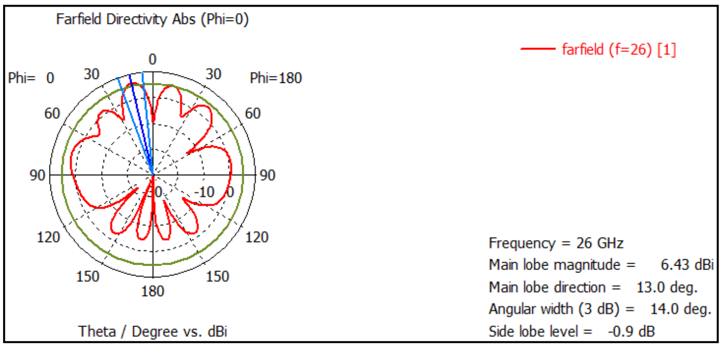
(a)

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

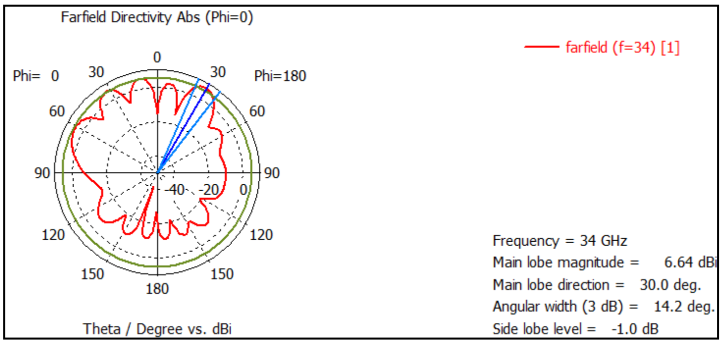
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⁑ Impact Factor 7.047 ⁑ Vol. 10, Issue 5, May 2022

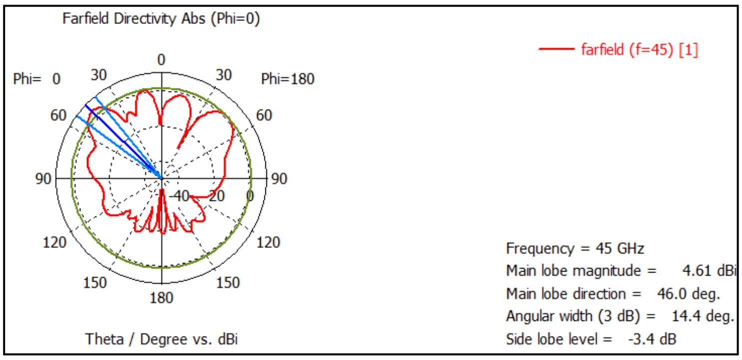
DOI: 10.17148/IJIREEICE.2022.10549



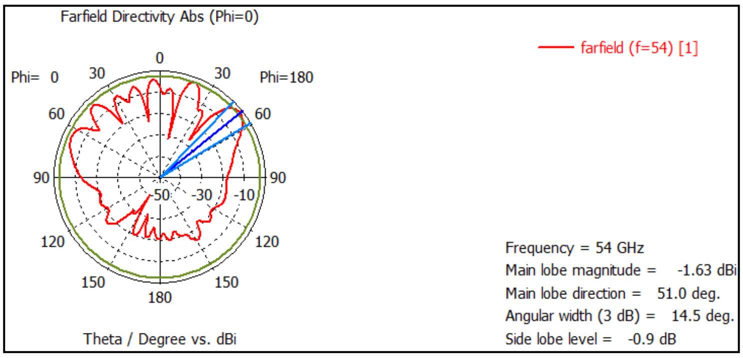
(b)



(c)



(d)



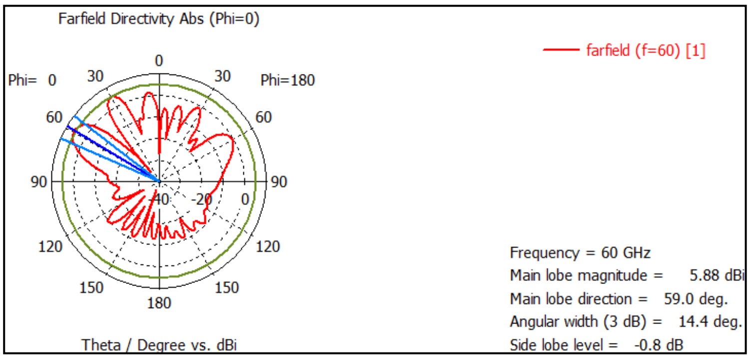
(e)

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

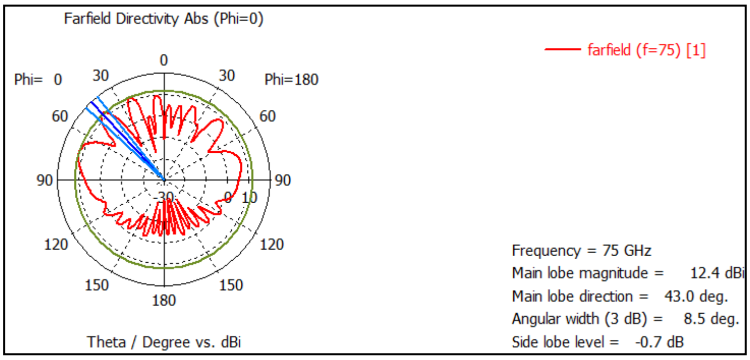
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⁜ Impact Factor 7.047 ⁜ Vol. 10, Issue 5, May 2022

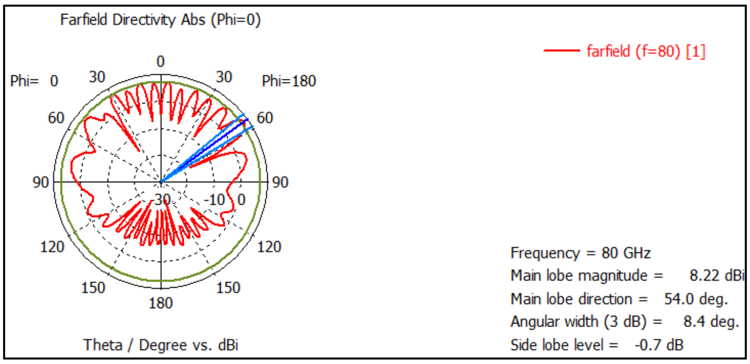
DOI: 10.17148/IJIREEICE.2022.10549



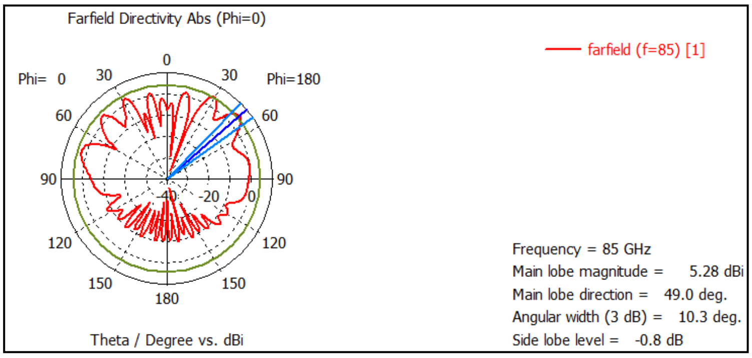
(f)



(g)

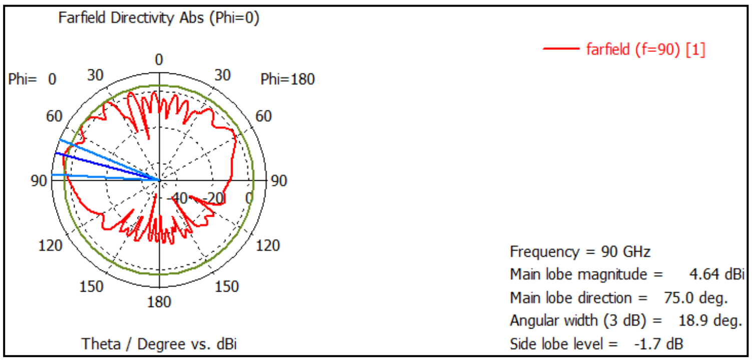


(h)



(i)

DOI: 10.17148/IJIREEICE.2022.10549



(j)

FIG 8 : 2D radiation pattern for
(a) 10 GHz (b) 26 GHz (c) 34 GHz (d) 45 GHz
(e) 54 GHz (f) 60 GHz (g) 75 GHz (h) 80 GHz
(i) 85 GHz (j) 90 GHz.

Comparison between single element antenna and array antenna has been shown in TABLE IV.

Antenna	**Frequency Range**	**Bandwidth**	**RL/dB (peak) at RF(GHz)**	**Gain (dB) Peak/ RF(GHz)**
Single Element	10.135 – 10.081 GHz	0.054	-12. 415 / 10.11	3.5 / 10
4 x 2 Element	45 – 90 GHz	0.97	-40.64 / 57.69	9.3 / 49.5

Comparison of the proposed array antenna with the different antennas has been given on the TABLE V.

Reference	**Array Type**	**Frequency Range (GHz)**	**RL/(dB) peak At/ RF(GHz)**	**Gain (dB) Peak/ RF**
[3]	1 x 4	28 - 67.8	-27 / 44.8	14.22 / 44.8
	2 x 2	25.4 - 69	-31.3 / 69	12.3 / 29
[2]	1 x 6	58 - 77.3	-34 / 59.6	9 / 62.1
[10]	1 x 4	5.1 - 80	-23 / 6.2	-10 / 41
Proposed	4 x 2	45 - 90	-40.64 / 57.69	9.3 / 49.5

IV. CONCLUSION

The multiband antennas are highly desired to use a single antenna instead of multiple antennas for different bands. The proposed multiband antenna achieved good performance parameter. All the bands of proposed multiband antenna satisfied the standard value for Return Loss less, Gain, Directivity, Radiation pattern, All the frequency bands of designed antenna have in the range of 45-90GHz which is in the range of wireless communication system. The Proposed system focuses on the application that are to be used or the antenna to be utilized for E-Band. The Directivity of the proposed model at its peak is 13.36 dBi at 58.5GHz resonant frequency also gain achieved at this point is 6.48 dB, where it comes under the standard conditions. The Peak gain achieved at resonant frequency 49.5GHz where the value is 9.3 dB.

DOI: 10.17148/IJIREEICE.2022.10549

REFERENCES

[1] I. Gharbi, R. Barrak, M. Menif and H. Ragad, "Design of patch array antennas for future 5G applications," 2017 18th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Monastir, 2017, pp. 674-678.

[2] P. Roy, R. K. Vishwakarma, A. Jain and R. Singh, "Multiband millimeter wave antenna array for 5G communication," 2016 International Conference on Emerging Trends in Electrical Electronics & Sustainable Energy Systems (ICETEESES), Sultanpur, 2016, pp. 102-105.

[3] A. Sohail, H. Khan, U. Khan, M. I. Khattak, N. Saleem and J. A. Nasir, "Design and Analysis of a Novel Patch Antenna Array for 5G and Millimeter Wave Applications," 2019 2nd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET), Sukkur, Pakistan, 2019, pp. 1-6.

[4] Fitri and T. A. A. Akbar, "A new gridded parasitic patch stacked microstrip antenna for enhanced wide bandwidth in 60 GHz Band," 2017 International Conference on Broadband Communication, Wireless Sensors and Powering (BCWSP), Jakarta, 2017, pp. 1-4.

[5] Mudit Gupta, Pramod Kumar Morya and Satyajit Das, “Design & Fabrication of Rectangular Microstrip Patch Antenna for WLAN using Symmetrical slots,” International Journal on Emerging Technologies (Special Issue NCETST-2017) 8(1): 11-15(2017).

[6] Omar Darboe , Dominic Bernard Onyango Konditi and Franklin Manene, “A 28 GHz Rectangular Microstrip Patch Antenna for 5G Applications,” International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 6 (2019), pp. 854-857.

[7] Madhavi Devabhaktuni and Sudhakar Alapati, “Design of Microstrip Patch Antenna for MIMO Applications,” 2019 PhotonIcs & Electromagnetics Research Symposium — Fall (PIERS — FALL), Xiamen, China, 17–20 December.

[8] Fardeen Mahbub, Shouherdho Banerjee Akash, Sayed Abdul Kadir Al-Nahiun , Rashedul Islam, Raja Rashidul Hasan, Md. Abdur Rahman, “Microstrip Patch Antenna for the Applications of WLAN Systems using S-Band,” 2021 IEEE 11th Annual Computing and Communication Workshop and Conference (CCWC)

[9] Houda Werfelli, Khaoula Tayari, Mondher Chaoui, Mongi Lahiani, Hamadi Ghariani,” Design of Rectangular Microstrip Patch Antenna,” 2nd International Conference on Advanced Technologies for Signal and Image Processing - ATSIP'2016 March 21-24, 2016, Monastir, Tunisia.

[10] P. M. Sunthari and R. Veeramani, "Multiband microstrip patch antenna for 5G wireless applications using MIMO techniques," 2017 First International Conference on Recent Advances in Aerospace Engineering (ICRAAE), Coimbatore, 2017, pp. 1-5.

[11] Taimur Ahmed Khan, Muhammad Irfan Khattak, Abdul Baseer Qazi, Nasir Saleem,” Stacked Microstrip Array Antenna with Fractal Patches for Satellite Applications,” 978-1-5386-5892-5/18/$31.00 ©2018 IEEE ICIS 2018, June 6-8, 2018, Singapore.

[12] C. A. Balanis, “Antenna theory: A review.” Proceedings of the IEEE 80.1, 1992: 7-23.

[13] R. W. Dearnley and A. R. F. Barel, “A comparison of models to determine the resonant frequencies of a rectangular microstrip antenna”, IEEE Trans. Antennas Proprag., Vol.37, No.1, pp.114-118, Jan 1989.

[14] S. F. Jilani and A. Alomainy, "A Multiband Millimeter-Wave 2-D Array Based on Enhanced Franklin Antenna for 5G Wireless Systems," in IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 2983- 2986, 2017.

[15] M. Kamran Shereen, M. I. Khattak, M. Shafi, N. Saleem, “Slotted Y-Shaped Millimeter Wave Reconfigurable Antenna for 5G Applications,” 2018 International Conference on Computing, Mathematics and Engineering Technologies – iCoMET 2018, 978-1-5386-1370-2/18/$31.00 ©2018 IEEE.