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Research Article

Design and Analysis of 2x1 and 4x1 Rectangular Microstrip Patch Array Antenna for 5G C-Band Access Point Applications

Gurudev[1], Md Bakhar[2]

[1]Department of Electronics Communication Engineering, GNDEC Bidar and Sharnbasva University Kalaburagi, India.
[2]Department of Electronics Communication Engineering, GNDEC Bidar, Karnataka, India.

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Corresponding Author:
Gurudev, Department of Electronics Communication Engineering, GNDEC Bidar and Sharnbasva University Kalaburagi, India.
E-mail Id:
grzalki16@gmail.com

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ABSTRACT

The microstrip antennas are most preferred antennas for the present trend of applications in wireless communication. The characteristics like light weight, easy to fabricate, low profile, planar structures make them beneficial as compared to other type of antennas. The electromagnetic parameters such as gain, radiation pattern, impedance, polarization and cheaper in cost are main key features of microstrip antennas. This paper represents design and analysis of single element, 2x1 and 4x1 rectangular microstrip patch antenna array operating in 3.4 GHz to 3.6 GHz for 5G C-Band access point applications. The rectangular patch antenna array designed will be feed with microstrip feeding technique in the proposed deign. The proposed microstrip antenna array designed with low profile and simple structure is good candidate operating in 3.4 GHz to 3.6 GHz for 5G C-Band access point applications.

Keywords: Microstrip Antenna, Rectangular Microstrip Antenna Arrays, FR-4 Substrate, Microstrip Feed Technique

Introduction

The roles of microstrip antennas are especially important in the field of wireless communication applications. Each one of the antenna is best known for their own nature of characteristics, design implementations and applications. The existing days are cannot be imagined without technology and microstrip antennas are backbone and strength of various wireless communication applications. In the today's era of wireless communication equipment application world the microstrip patch antennas perform an especially important role.[1]

The rectangular microstrip patch antenna configurations are frequently used as compared to other types like circular, triangular, hexagon etc. For simple and the most challenging applications we prefer the microstrip patch antennas. Dual frequency operation, Dual characteristics, Frequency agility, circular polarizations, broad bandwidth, beam scanningand feed line flexibility can be achieved easily from these microstrip patch antennas. We use the FR4 (flame retardant)dielectric material where 4 indicates the type of glass epoxy with ε_r=4.4). FR4 is selected becausereasonably cheap in the market and it is easily available.

Microstrip Antenna Array

The preferred radiation patterns which are unable to achieve with the single element can be obtained with the microstrip antenna array configurations. Also, they used to improve the directivity, scan the radiation pattern of antenna system, and perform many other functions which are not easy to achieve with single element. The frequency of operation (f_r) is the important parameters for the design of a Microstrip patch antenna. The resonant frequency (f_r) of the antenna should be selected carefully. Till now the Fourth Generation (4G) mobile network had fulfilled the people's requirements. Now change is towards the Fifth Generation (5G) mobile network which is 100 times faster as compared to the Fourth Generation (4G) mobile network. The Fifth Generation (5G) mobile network is an emergingarea for wireless systems. The array uses the element of rectangular microstrip antenna with 2x1 and 4x1 design configurations for 3.4 GHz to 3.6 GHz 5G C-Band access point applications.[2]

In the proposed work, we use the FR4 (flame retardant) dielectric material where 4 indicates the type of glass epoxy with ε_r=4.4) and the substrate thickness (h) to be 1.6 mm. Then, we calculated the width and length of the Rectangular Patch using the formula.[3]

The width of patch is calculated as:

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

Where 'f_r' is the resonant frequency, c is the velocity of light in free space,e_r is the dielectric constant of substrate.

Efficient dielectric constant e_{reff} is given by:

$$\frac{W}{h}>1$$

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

The Normalized extension in the length L, is given by:

$$\frac{\Delta L}{h}=0.412\frac{(\varepsilon_{reff}+0.3)}{(\varepsilon_{reff}-0.258)}\frac{(\frac{W}{h}+0.264)}{(\frac{W}{h}+0.8)}$$

The relation of the effective length of patch and actual length of patch is given by:

L_{eff}= L+2ΔL

The effective length of patch is given by:

$$L_{eff}=\frac{\lambda g}{2}$$

Where λg is guided wavelength in dielectric medium and is given by:

$$\lambda g=\frac{\lambda}{\sqrt{\varepsilon_{reff}}}\text{and}\lambda_0=\frac{c}{f}$$

The characteristic impedance of a Microstrip line is given by:

$$\text{For}\frac{W}{h}\leq 1$$

$$Z_c=\frac{60}{\sqrt{\varepsilon_{reff}}}\left[\ln\left(\frac{8h}{w}+\frac{w}{4h}\right)\right]$$

$$\text{For}\frac{W}{h}\leq 1$$

$$Z_c=\frac{120\pi}{\sqrt{\varepsilon_{reff}\left[\frac{w}{h}+1.393+0.667\ln\left(\frac{w}{h}+1.444\right)\right]}}$$

We selected the inter-element spacing for the 2x1 and 4x1 antenna arrays to be 42.85 mm.[4]

Further, we also analyzed the Return loss, Impedance Bandwidth, Gain, VSWR, 3 dB Beamwidth for single microstrip patch antenna. Then we further extended the work to calculate the above-mentioned parameters to 2x1 and 4x1 array by using 3DEM of Mentorgraphics software.

Design of Rectangular Microstrip Patch Antenna Arrays

Design of Single Rectangular Patch Antenna

The single rectangular microstrip patch antenna of size 26.08mm Width and 19.98mm Length is designed for width of 100Ω feedline 0.7mm and length of feed 5mm.

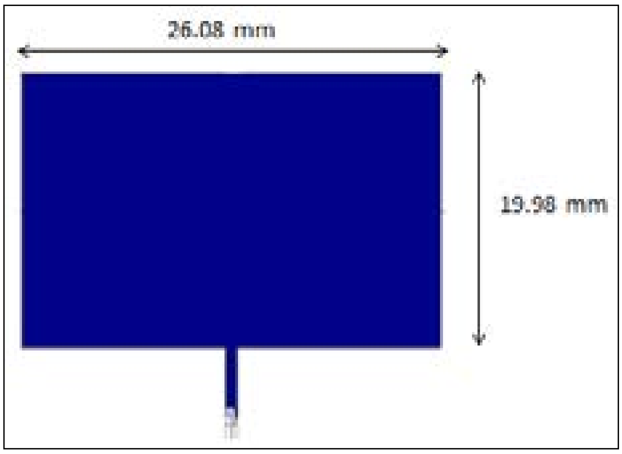


Figure 1.Design of Single Rectangular Patch Antenna

Design Analysis for 2x1 Antenna Array

The designed 2x1 patch antenna array uses the same value of dielectric substrate height (h) and dielectric material (FR4) at the required frequency.

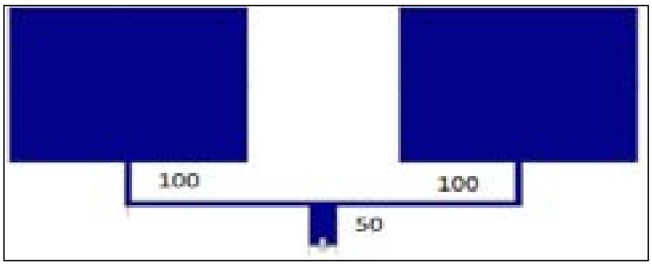


Figure 2.Design of 2X1 Patch Antenna Array

Table 1.Patch and Feedline Dimensions of 2X1 Array

Size of each patch	26.08 mm x 19.98 mm
Inter-element spacing	42.85 mm
Width of 100Ω feedline	0.7 mm
Width of 50Ω feedline	3 mm

Each of the patches is connected to 100Ω feedline. The equivalent at the junction of the two 100Ω lines is 50Ω. A 50Ω feedline is connected to microstrip feed. The calculated dimensions are given in Table 1.

Design Analysis for 4x1 Antenna Array[5]

The designed 4x1 patch antenna array uses the same value of dielectric substrate height (h) and dielectric material (FR4) at the required frequency.

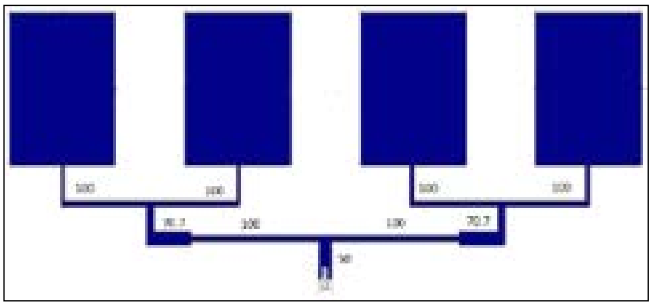


Figure 3.Design of 4X1 Patch Antenna Array

All the patches are connected to 100Ω lines each. The equivalent at the junctions of each pair is 50Ω. As shown in the above design a quarter wave transformer is placed between a 50Ω equivalent point and 100Ω line whose resultant impedance is calculated asZ=70.7Ω. Finally, two pairs of 100Ω lines from each side result in an equivalent of 50Ω where the microstrip feeding is considered. The calculated dimensions are tabulated in the Table 2.

Table 2.Patch and Feedline Dimensions of 4X1 Array

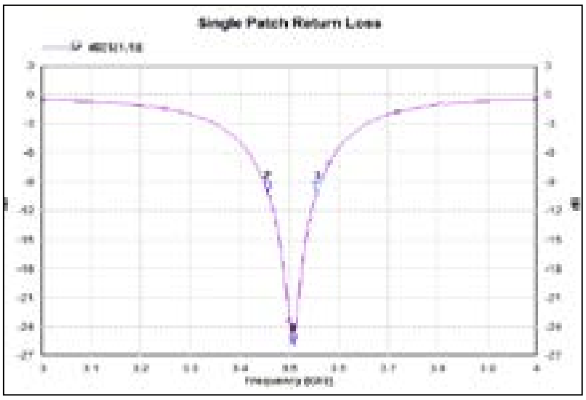
Size of each patch	26.08 mm x 19.98 mm
Inter-element spacing	42.85 mm
Width of 100Ω feedline	0.7 mm
Width of 70.7Ω feedline	1.6 mm
Width of 50Ω feedline	3 mm

Simulation Result of Rectangular Microstrip Patch Antenna Arrays

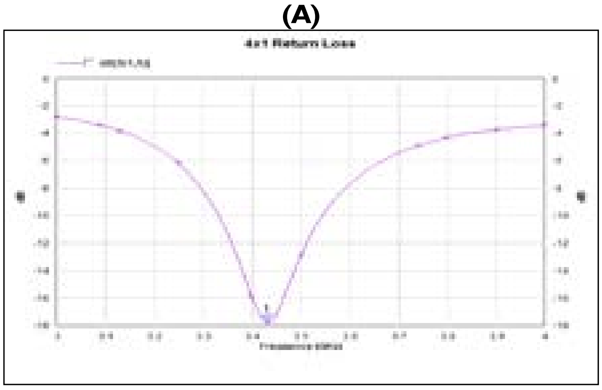
The proposed antenna is designed[6-10] and simulated in 3DEM of Mentorgraphics software. We calculated the Return loss, Impedance bandwidth, Radiation patterns, VSWR and Gain.

Simulation Results of Return Loss and Impedance Bandwidth

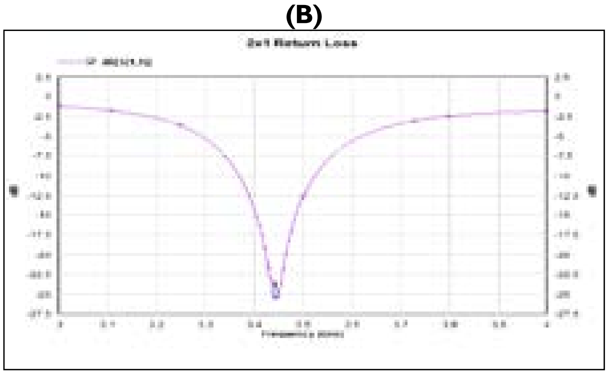
Below Figure 4 (a), (b) and (c) shows the Return Loss [S_{11}] of the proposed antenna in dB. S_{11} Gives the Return Loss at the feed position where the input to the Microstrip patch antenna was applied. It should be less than -10 dB for an acceptable operation. From the Figure 4, (a), (b) and (c), It is evident that the proposed Rectangular Single Patch Antenna, 2x1 Rectangular Patch Antenna array and 4x1 Rectangular Patch Antenna array are operated at a resonant frequency of 3.50965, 3.44402 and 3.4305 for 3.4 GHz to 3.6 GHz 5G C-Band access point applications. The Return Loss values were obtained for the Rectangular Single Patch Antenna, 2x1 Rectangular Patch Antenna array and 4x1 Rectangular Patch Antenna array are -25.9433 dB, -25.4597 dB and -17.807 dB respectively shown in Table 3. The simulated impedance bandwidth values are 100.27 MHz, 152.2 MHz and 211.8 MHz for Single Patch Antenna, 2x1 Antenna array and 4x1 Antenna array respectively that are tabulated in Table 3.



(A)



(B)

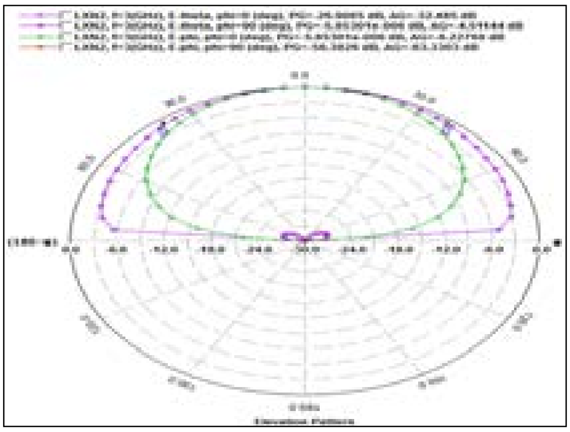


(C)

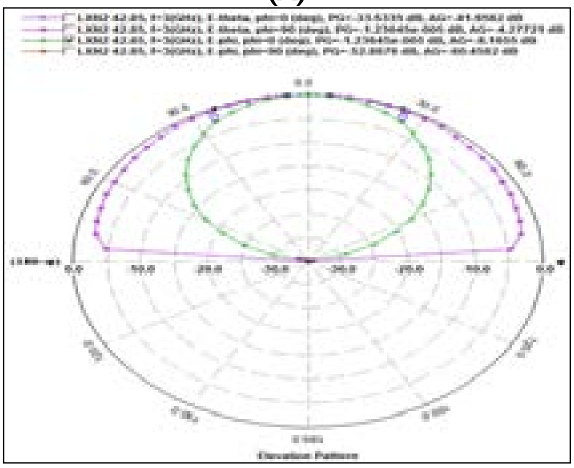
Figure 4. Return Loss S11 Obtained for the (A) Single Patch Antenna (B) 2X1 Patch Antenna Array (C) 4X1 Patch Antenna Array

Simulation Results of Radiation Pattern

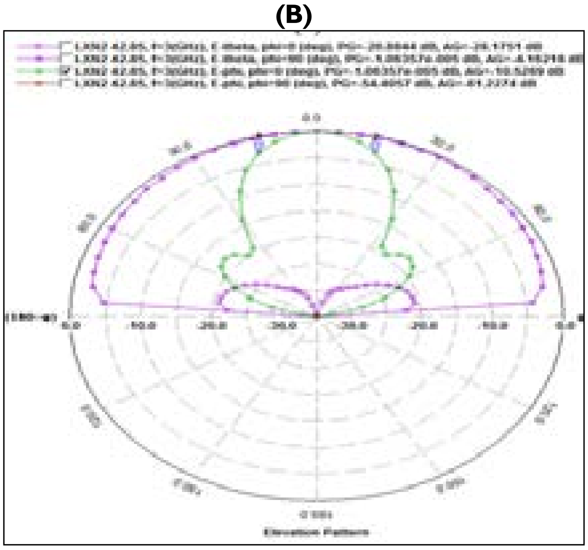
The radiation patterns of the single patch antenna, 2x1 patch antenna array and 4x1 patch antenna array in E-Plane and H-Plane at for 3.4 GHz to 3.6 GHz 5G C-Band access point applicationsare shown in Figure 5 (a), (b) and (c) respectively.



(A)



(B)

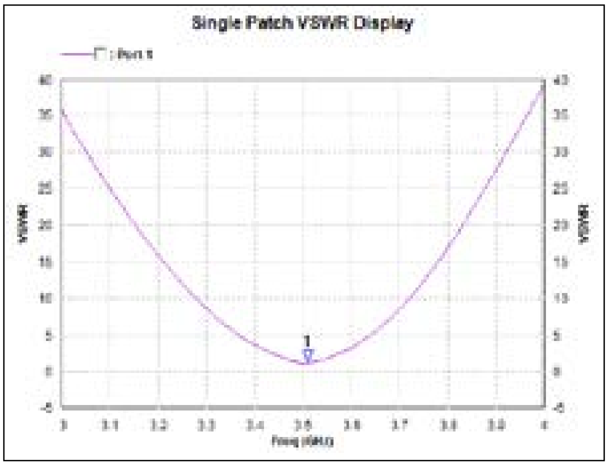


(C)

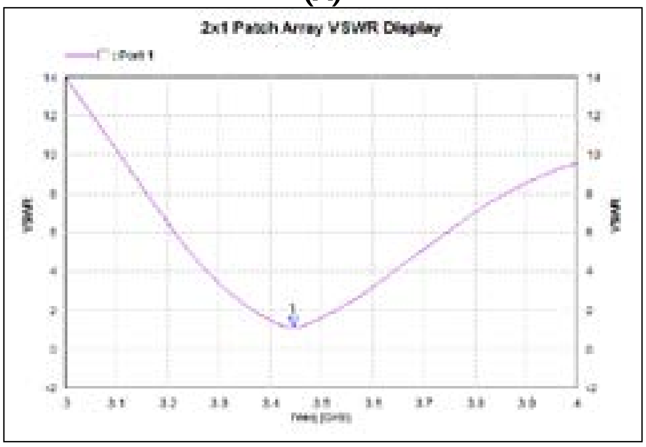
Figure 5.Radiation Pattern Obtained for the (A) Single Patch Antenna (B) 2X1 Patch Antenna Array (C) 4X1 Patch Antenna Array

Simulation Result of VSWR Plot

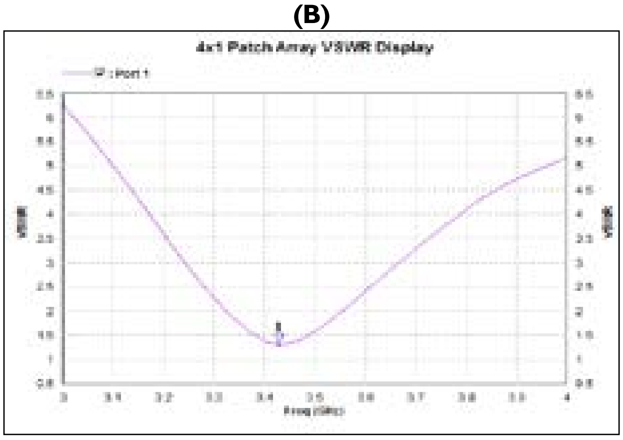
Figure 6 (a), (b) and (c) shows the VSWR (Voltage Standing Wave Ratio) plots for the three cases of Rectangular Single Patch Antenna, 2x1 Patch Antenna array and 4x1 Patch Antenna array respectively. Here the VSWR value for the proposed three cases of Rectangular Single Patch Antenna, 2x1 Rectangular Patch Antenna array and 4x1 Rectangular Patch Antenna array were obtained as 1.10553, 1.11268 and 1.29559 respectively at the resonating frequency for 3.4 GHz to 3.6 GHz 5G C-Band access point applications.



(A)



(B)

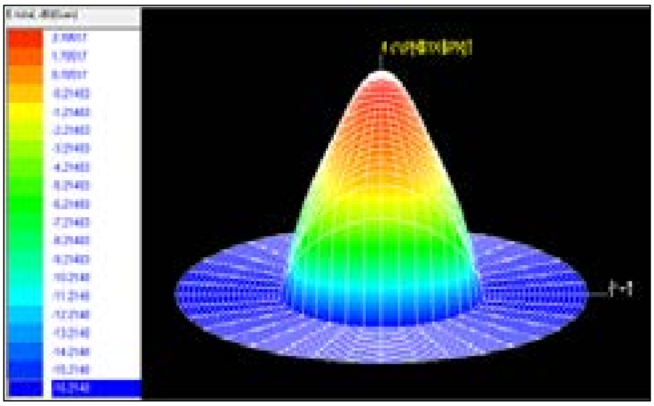


(C)

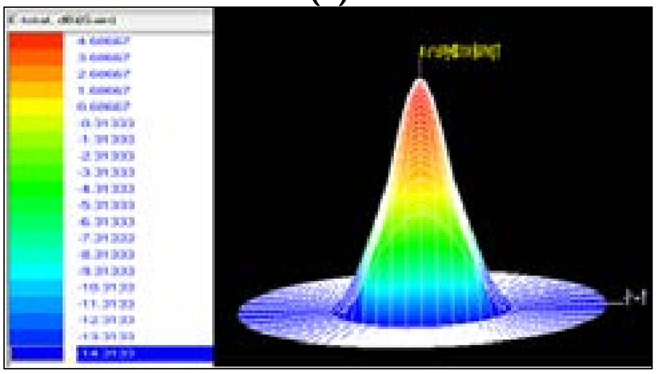
Figure 6.VSWR Obtained for the (A) Single Patch Antenna (B) 2X1 Patch Antenna Array (C) 4X1 Patch Antenna Array

Simulation Results of Gain and Radiation Patterns

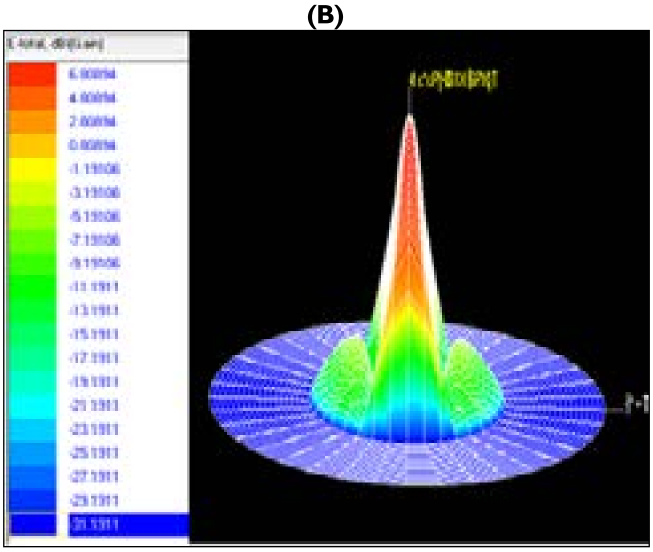
The peak gain values of the single patch antenna, 2x1 Patch Antenna array and 4x1 Patch Antenna array are 2.78517 dB, 4.68667 dB and 6.80894 dB respectively that are presented in Figure 7 (a), (b) and (c).



(A)



(B)



(C)

Figure 7.Gain and 3D Radiation Plot for the (a) Single Patch Antenna (b) 2x1 Patch Antenna Array (c) 4x1 Patch Antenna Array

The above simulated results for single patch antenna, 2x1 Patch Antenna array and 4x1 Patch Antenna array are tabulated as below:

Table 3.Consolidated Result Obtained for all Antennas

Array	Return loss (dB)	Impedance Bandwidth (MHz)	Gain (dB)	VS-WR	3dB beam width
Single Patch	-25.94 dB	100.27 MHz	2.78 dB	1.10	83.98^0
2x1	-25.45 dB	152.2 MHz	4.68 dB	1.11	51.85^0
4x1	-17.80 dB	211.8 MHz	6.80 dB	1.29	29.88^0

Conclusion

The rectangular shaped microstrip patch antenna arrays of radiating elements were successfully designed and executed using the FR4 (Flame Retardant) dielectric material. Through the analysis of results obtained in 3DEM of Mentorgraphics software, it was observed that the antenna resonated at 3.4 GHz to 3.6 GHz 5G C-Band access point applications. In the proposed work, microstrip feeding technique used for the simulation of single rectangular element, 2x1 patch antenna array and 4x1 patch antenna array. From the proposed design for single patch obtained gain is 2.78 dB, for 2x1 patch antenna array obtained gain is 4.68667 dB and for 4x1 patch antennaarray obtained gain is 6.80894 dB.

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