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16 ELEMENT RECTANGULAR PATCH ANTENNA ARRAY

Dr.S.A Arunmozhi [1], Rahul R[2], Nigilesh D[3], Niruban J[4], Srinivasa Gupta[5]

Assosciate Professor - Department of Electronics and Communication Engineering, Saranathan college of Engineering, Trichy, TamilNadu[1]

UG - Department of Electronics and Communication Engineering, Saranathan college of Engineering, Trichy, TamilNadu[2,3,4,5]

Abstract: A microstrip patch antenna consists of radiating patch on one side of dielectric substrate and has the ground plane on other side. The study of microstrip patch antennas has made great progress in recent years. Compared with conventional antennas, microstrip patch antennas have more advantages and better prospects. They are lighter in weight, low volume, low cost, low profile, smaller in dimension and ease of fabrication and conformity. Moreover, the microstrip patch antennas can provide dual and circular polarizations, dual-frequency operation, frequency agility, broad band-width, feedline flexibility, beam scanning omnidirectional patterning. This work explores the performance enhancement of microstrip patch antenna. The antennas are analysed using the different antenna parameters like Radiation pattern, Gain, Return loss, Directivity and Radiation pattern. Mobile communication systems of today needs antennas with high gain, big bandwidth, and small size that can provide greater performance over a wide frequency spectrum. The design of a 16-element microstrip patch antenna array is proposed in this study, which employs the corporate series feed technique excited by one port via a T-Junction power divider. For maximal radiation, substrates with a low dielectric constant are desirable. The array's bandwidth ranges from 26.42 to 28.94GHz, with a gain of 17.1dB. CST Microwave Studio Suite is used in the simulations.

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Keywords: Microstrip patch antenna; Millimeter wave; Mobile wireless

I. INTRODUCTION

Microstrip patch antennas are very popular among Wireless Local Area Network (WLAN), Wide Area Network (WAN) technologies due to their advantages such as light weight, low volume, low cost, compatibility with integrated circuits and easy to install on rigid surface. In this project a millimeter wave microstrip patch antenna and its array for 5G applications is proposed. The spectrum available for the 5G, allocated by the Third Generation Partnership Project (3GPP), is separated into two different frequency ranges. Frequency Range 1 that includes frequency bands below 6GHz [1], Range 2 frequency bands above 24GHz and into the millimeter wave range (24GHz, 26GHz, 28GHz and 39GHz) [2]. The 5G Microstrip patch of 2×2 is designed on rogers RT Duroid 5880 substrate with standard thickness 0.786 mm having relative dielectric constant (r) = 2.2 and tan δ = 0.001.The antenna resonates at 26.5GHz with a return loss -27.5 dB and a bandwidth 4 GHz. An array of 4×2, 6×2, 8×2 elements of the proposed antenna is designed using CST software. Appreciable improvement in gain is observed with the array of antennas. The antenna and its array can be used for 5G mobile communication because of its compactness.

II. ARRAY ANTENNA DESIGN

Among the existing feeding systems, the simplest feeding method for linear antenna arrays is the series feed. Because the feeding design is compact, space utilization can be enhanced and the line losses related to this type of array will be reduced compared to a corporate-fed array. Since the antenna input power must come from an extremity of the array, the principal limit of series fed arrays is the significant variation of the input impedance and the main beam direction. In the parallel or corporate feed, the benefits in this method are simplicity of design, flexible choice of element spacing and wider bandwidth since the antenna elements are powered by a “1 to n” power divider with the same line lengths between the feed point and each element. However, a linear array fed by the corporate method will occupy a much larger area, which will prevent it from being stacked to form a two-dimensional array. To limit the variation of the main beam direction and obtain better efficiency, the combination of parallel and series feeding techniques is used in this work [8]. The Rogers RT5880 (Ɛr= 2.2, tan δ= 0.001) is used as substrate material with thickness h=0.786mm, which is efficient for high frequencies. In this work, the CST Microwave Studio software is used for simulations.

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The proposed antenna array is shown in Fig.1. It contains 16 elements, each of which 8 elements are fed in series. The 2 series are fed in parallel through the use of Y-junction power divider. The dimensions that were obtained have been optimized via the software and are shown in Table 1.
The initial values of the dimensions of patch antennas are obtained by using the following equations [9] [10]:

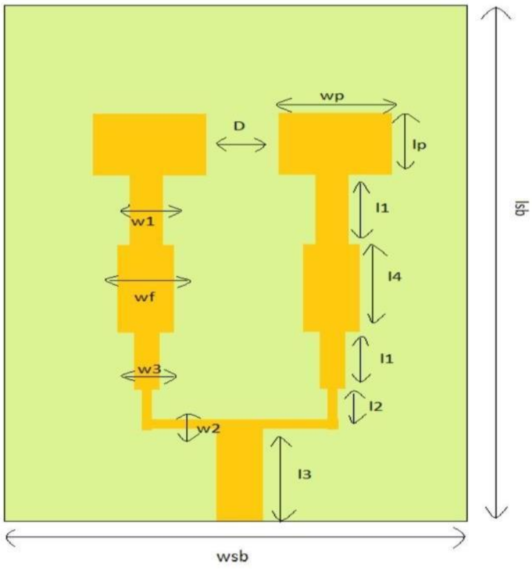

Figure 1: The proposed antenna array

Width of patch

$$W_p = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Effective Dielectric

$$\epsilon_{eff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_r-1}{2}$$

Effective length

$$\ell_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}}$$

Length Extension

$$\Delta L = (0.412)\, h \frac{(\varepsilon_{eff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{w}{h}+0.8)}$$

Length of patch

$$L = L_{eff} - 2\Delta L$$

Design of Quarter Wave transformer

$\ell_1 = \lambda/4$

$Z(\ell_1) = \sqrt{z(\ell_2)\, z(\ell_4)}$

$$w_3 = \frac{120\pi}{\sqrt{\epsilon eff}\left[\frac{w}{h}+1.393+0.667\ln\left(\frac{w}{h}+1.444\right)\right]}$$

$Z(w_2) = 100\ \Omega$

$$100 = \frac{60}{\sqrt{\epsilon eff}} \ln\left[\frac{8(0.786\times10-3)}{w} + \frac{w}{6\,(0.786\times10-3)}\right]$$

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- Wp and Lp: width and length of the patch antenna.
- c: speed of light.
- f: resonant frequency.
- h: thickness of the substrate.
- er: dielectric constant of the substrate.
- DL: length extension.
- εeff: effective dielectric constant of the substrate

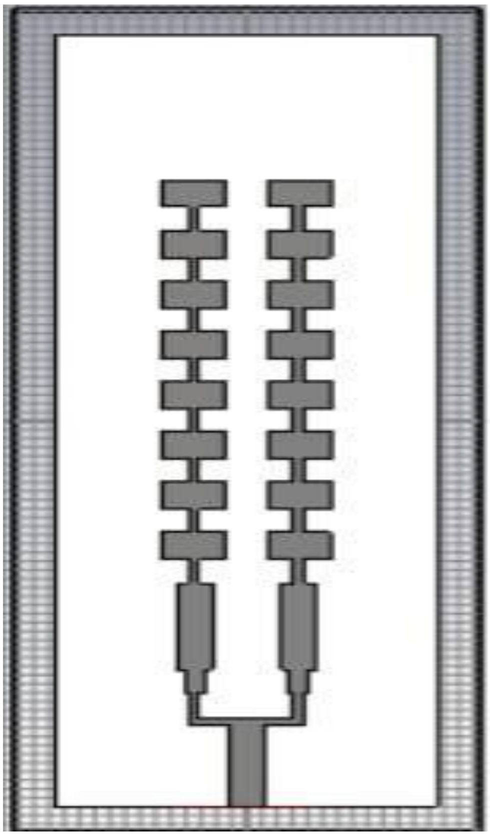

Fig.2 8 X 2 Array Prototype

Parameters	Description	Value(mm)
Lsb	Length of substrate	88
Wsb	Width of substrate	25
H	Height of substrate	0.786
Lp	Length of patch	3.05
Wp	Width of patch	4.25
T	thickness of patch	0.035
Lambda	Wavelength	10.70687
wf	Width of feed	2.37
l3	Length of feed	0.87*lambda
w2	Width of 100ohm line	0.643
l2	Length of 100ohm line	3
l1	Length of quarter wave transformer	Lambda/4
w3	Width of quarter wave transformer	1.394
w1	Width of 2nd quarter wave transformer	0.68
D	Distance between patches	Lambda/4

Fig. 3 Array Parameters

III. SIMULATION RESULTS

The proposed antenna array was simulated in the CST Microwave Studio software. The simulation has been validated by comparing the results obtained from CST software.

RETURN LOSS

The S parameter of the proposed antenna array. The return loss at the resonant frequency 26.25GHz is -22dB with a bandwidth of 4GHz taking as criteria S11 is -10dB to define bandwidth. As we can see, it has a good agreement between the two software

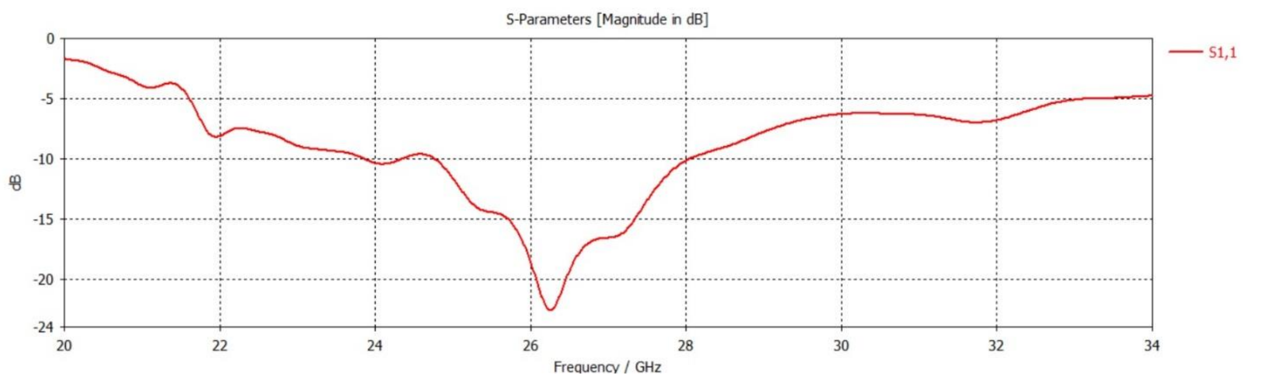

Fig. 4 Return Loss for 8×2 array

VSWR

The value of VSWR is 1.2 at the 26.5GHz resonant frequency and less than 2 for the rest of our bandwidth, this means that the antenna array presents an acceptable value of VSWR. The result is presented in fig. 5

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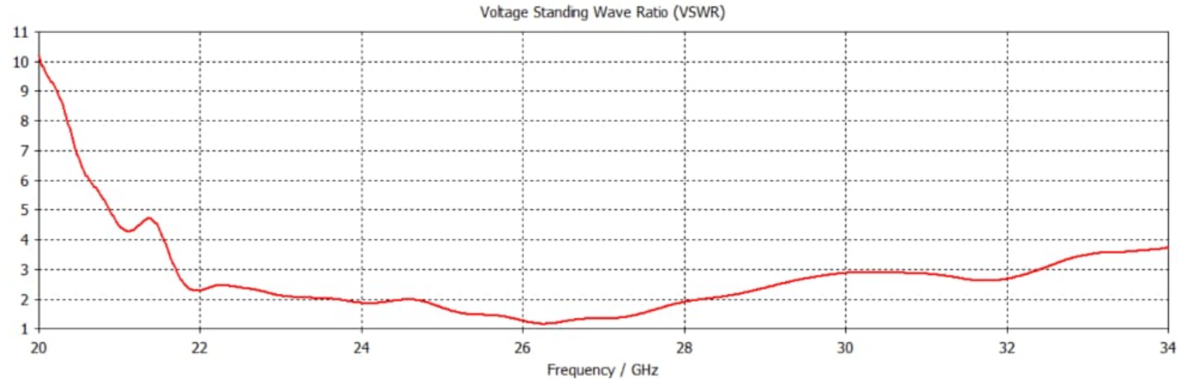

Fig. 5 VSWR for 8×2 array

GAIN AND RADIATION PATTERN

The 3D Radiation Pattern, shows the gain of 15.5dB for the resonant frequency with a radiation efficiency of 92%, Fig.6 present the variation of the gain on our bandwidth, the figure shows the maximum gain of 15.5dB for 26.25GHz.
This high gain value meets the requirement of an antenna for 5G applications since it will compensate for the significant free space path loss due to millimeter waves propagation.

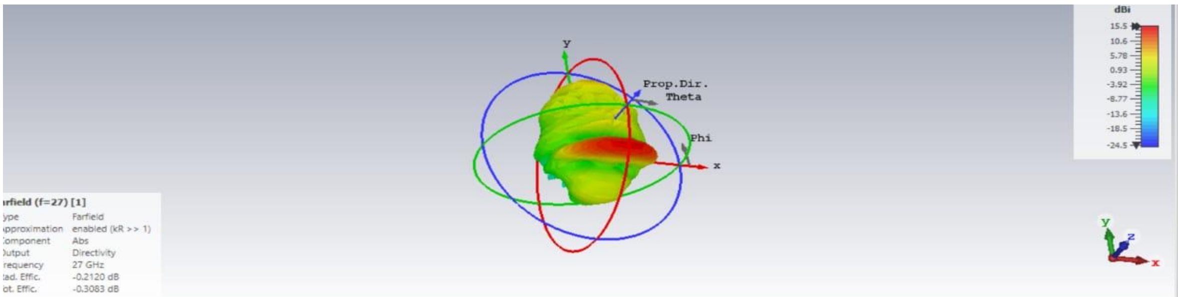

Fig 6 Radiation pattern for 8×2 array

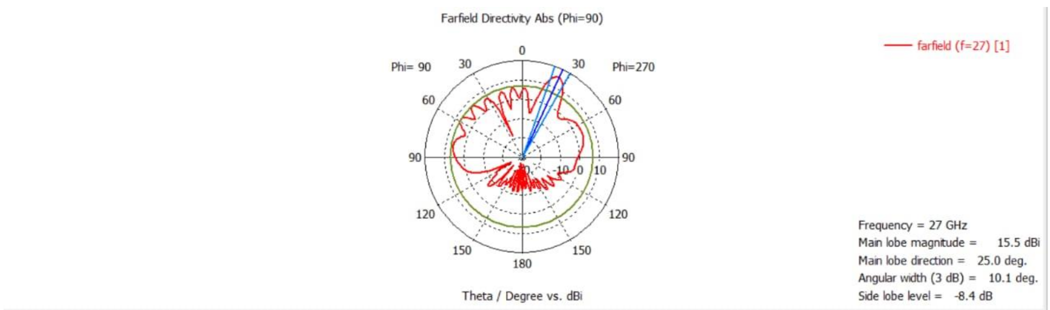

Fig 7 Far field directivity for 8×2 array

IV. CONCLUSION

A 16-elements, Corporate-series Feed Rectangular Patch Antenna Array operated at 28GHz, for 5G mobile wireless applications have been designed and simulated. Combination of corporate and series feeds, an antenna array operated at millimeter waves with a wide bandwidth of 4 GHz, high efficiency and maximum high gain of 15.5 dB is achieved. Our next step is to validate these results by making a prototype of the proposed antenna array and measure its characteristics.

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