Microstrip Planar Array Antenna for 5G base band Communications

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Abstract : The novel low cost high gain millimetre-wave (mmWave) 5th Generation (5G) antenna for mobile communication at base-station (BS) has been presented. The microstrip patch antenna planar arrays with rectangular, circular and hexagonal shapes are designed and results are compared using High Frequency Structure Simulator (HFSS) software. The proposed planar antenna array systems have gain over 23dB, return loss less than -10dB and high impedance bandwidths over the frequency range 23GHz to 30GHz and are capable of meeting tentative 5G base-station (BS) specifications.

Keywords - Base station, gain, impedance bandwidth, microstrip patch antenna, return loss.

I. INTRODUCTION

The wireless communication has been significantly improving in recent times with the advancement of Internet of Things (IoT), Intelligent Transportation Systems(ITS) which required very high data rates in orders of gigabits per second which cannot be provided by current fourth-generation(4G) communication systems because they have limited bandwidths[1]. When compared to 4G networks, 5G networks has advantages like high data rates, less power consumption, better connectivity and improved coverage. When 5G technology is used, there are issues like high path loss due to high frequencies. In order to overcome losses occurring due to these high frequencies, new technologies are required to design antennas for mobile station (MS) and base station (MS).

For mmWave applications, microstrip patch array antennas with linear and phased arrays are widely considered due to its properties like high gain and low profiles and radiation patterns which are beam steerable. Also the advantages like low manufacturing cost, simplicity in structure and achieved using microstrip patch antennas [2]. If the gain is to be increased, then number of elements has to be increased which in turn increases path loss. When microstrip patch antenna arrays are used, the patch elements are to be fed using different feeding techniques like direct feeding and coupled feeding. When direct feeding method is used, it can achieve only narrow bandwidths (1-5%) [3-4]. Coupled feeding techniques can increase the bandwidths but they are big in size due to power dividers and are complex to design [6-8]. When series and corporate feeding technique [9] is used more gain (20-25)dB can be achieved, but tend to possess narrow bandwidths. Also the antenna arrays of 2n (even) × 2n-1 (odd) elements are simple and more reliable in terms of corporate feeding design when compared to 2n (even) × 2n-1(odd). Also the various feeding techniques can be used to attain required antenna parameters. The required impedence bandwidth can be achieved by covering the entire frequency range of 5G by using corporate feed technique. The low cost novel cost tightly coupled planar array with series and corporate feed on the other hand will have many advantages when compared to proximity coupled feeding technique. In this paper, antenna array structures with high gain and low return loss are presented without compromise in bandwidth. The designed antenna meets the requirements for 5G base station (BS).

II. MICROSTRIP PATCH ANTENNNA ARRAY CONFIGURATION

The microstrip patch antenna with FR4 epoxy substrate with dielectric constant (ε_r=4.4) having thickness of 1.6mm and series-corporate feed network is designed to operate at frequency from 23GHz to 30GHz resonating at 28GHz. The 50Ω feed line is attached to the patch to input the signal from source. The power is parallely input to the attached patches first and remaining power to the next patch elements of microstrip patch antenna.The length L of the patch should be $0.3333 \leq L \leq \lambda_o$. Here λ_o is wavelength in free space. The relative permittivity of the substrate should lie between 2.2 to 12. Thickness (h) of the substrate should be $0.0003\lambda_o \leq h \leq 0.05\lambda_o$. Width (w) of the patch is given by

$$w = \frac{c}{2fr\sqrt{\frac{2}{\varepsilon r+1}}} \qquad (1)$$

Where f_r is the resonant frequency, c is the velocity of light in free space and ε_r is the relative permittivity.

The power dividers used will provide for equal power distribution which will provide equal amount of power for all the patch elements. The patch sizes taken are of equal sizes which in turn provides same amount of current to each patch. But, the drawback with this method is that more power is radiated to the surroundings. This can be overcome by using unequal patch elements of the designed antenna. This in turn increases the design complexity. Hence a compromise between antenna patch elements and parametric requirements is attained by using equal patch elements and by further varying the patch shapes and sizes. Better impedance matching is attained using equal patch elements. Also the compromise between number of patch elements and gain should also be attained.

III. ANTENNA DESIGN

A. Microstrip 5×4 planar array antenna

The 5×4 microstrip patch antenna array with corporate feed network and rectangular patch shape is constructed on a 25mm.× 21mm.× 1.6mm. Length of each patch is taken as 2mm. The patches are separated by a quarter wavelength line with a distance between patches of 3.6mm. The power distribution is symmetric since we use T-junction power divider.

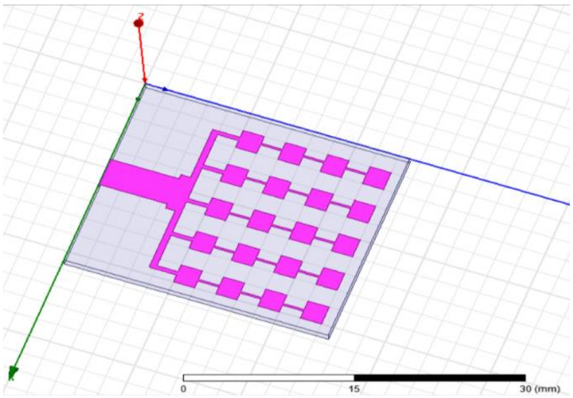
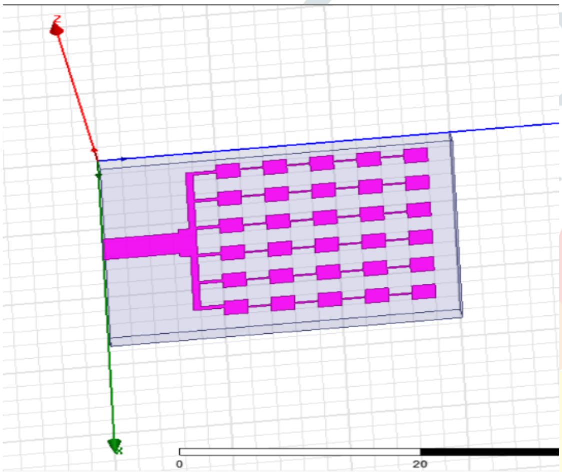


Fig.1 Microstrip 5×4 antenna array with rectangular patch shape

B. Microstrip 6.× 5 planar array antenna

The 6 × 5 microstrip patch array antenna is taken on substrate having dimensions 25mm × 25mm ×1.6mm. The rectangular and hexagonal patch shapes are considered. The patches are connected using quarter wavelength line. The T-junction power divider is incorporated to provide for symmetrical power distribution



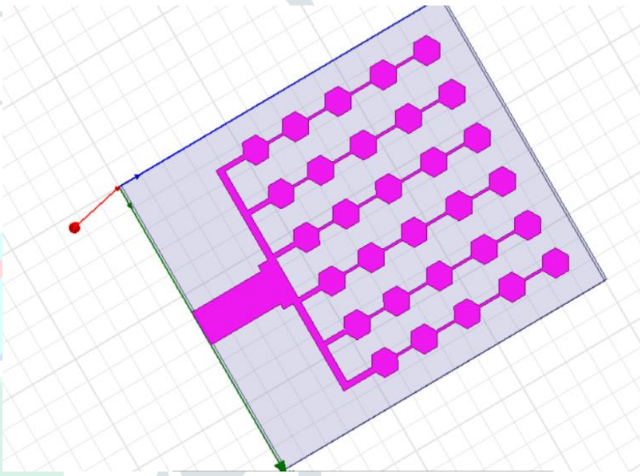


Fig.2 (a) Microstrip 6x5 antenna array with rectangle shape **Fig.2 (b)** Microstrip 6x5 antenna array with hexagonal shape

IV. SIMULATION RESULTS AND DISCUSION

A. 5 x 4 Microstrip antenna array with rectangular patch shape

1. Return loss:

The 5× 4 microstrip array antenna with rectangular patch resonates at 28GHz. It has return loss of -24.9 dB impedance bandwidth 15.23%.

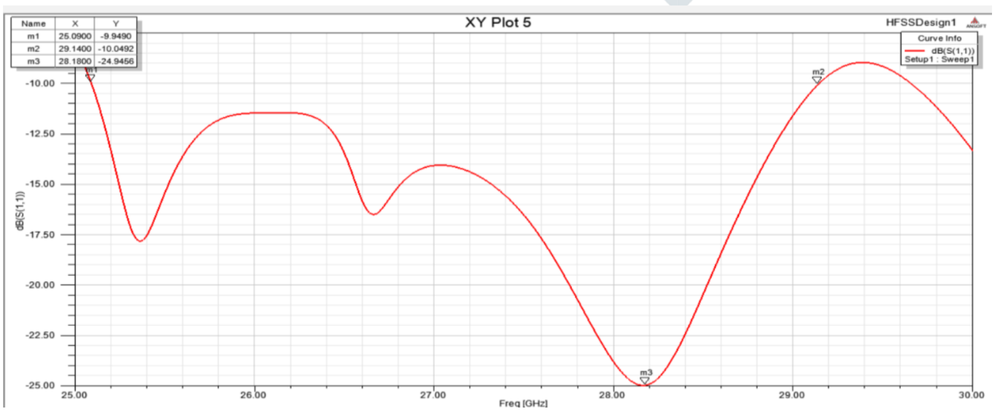
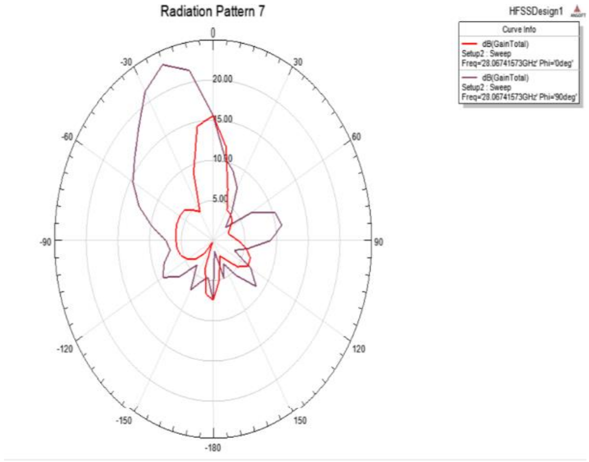


Fig.3 Return loss of 5 ×4 microstrip rectangular patch array antenna

2. Radiation pattern and gain:

The fig 4(a) shows radiation pattern and fig 4(b) shows gain in 3D of 5 ×4 microstrip array antenna with rectangular patch shape The gain is shown from the figures as 23.84 dB for Ø=0^0 and Ø=90^0



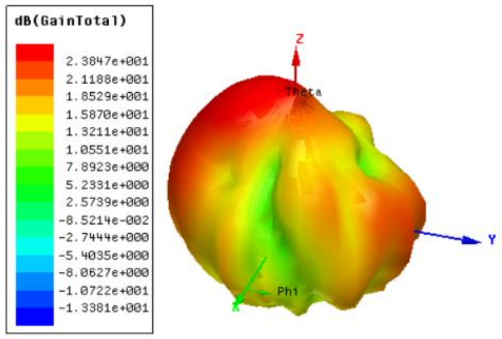


Fig. 4 (a) Radiation Pattern **Fig. 4 (b)** 3D Gain

B. 6 x 5 Microstrip antenna array with rectangular patch shape

1. Return loss

The 6 ×5 microstrip array antenna with rectangular patch resonates at 28GHz. It has return loss of -37 dB impedance bandwidth 30.49%.

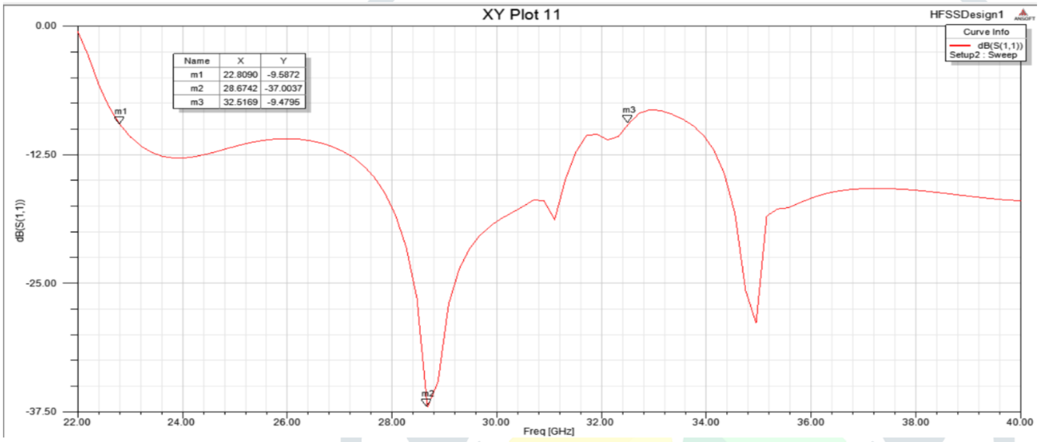
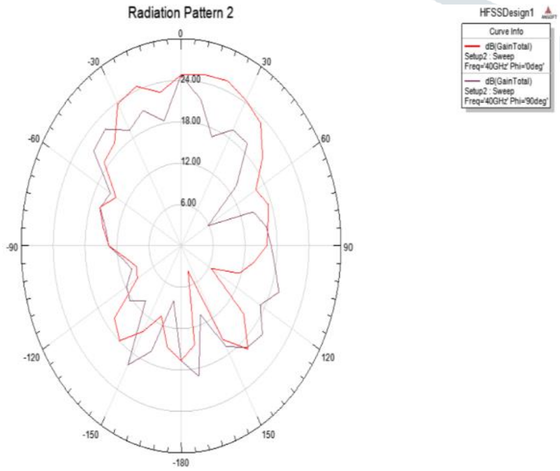


Fig. 5 Return loss of 6× 5 microstrip rectangular patch array antenna

2. Radiation pattern and gain:

The fig 6(a) shows radiation pattern and fig 6(b) shows gain in 3D of 6× 5 microstrip array antenna with rectangular patch shape the gain is shown from the figures as 25.45 dB for $Ø=0^0$ and $Ø=90^0$



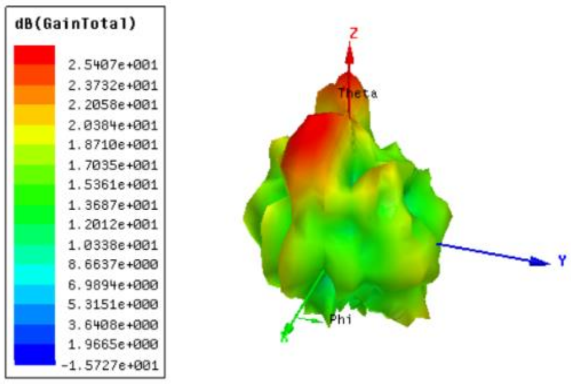


Fig. 6 (a) Radiation pattern **Fig. 6 (b)** 3D Gain

C. 6 x 5 Microstrip array antenna witch hexagonal shape patch

1. Return loss

The 6 ×5 microstrip array antenna with hexagonal patch resonates at 28GHz. It has impedance bandwidth 8.128% and return loss of -17.41 dB

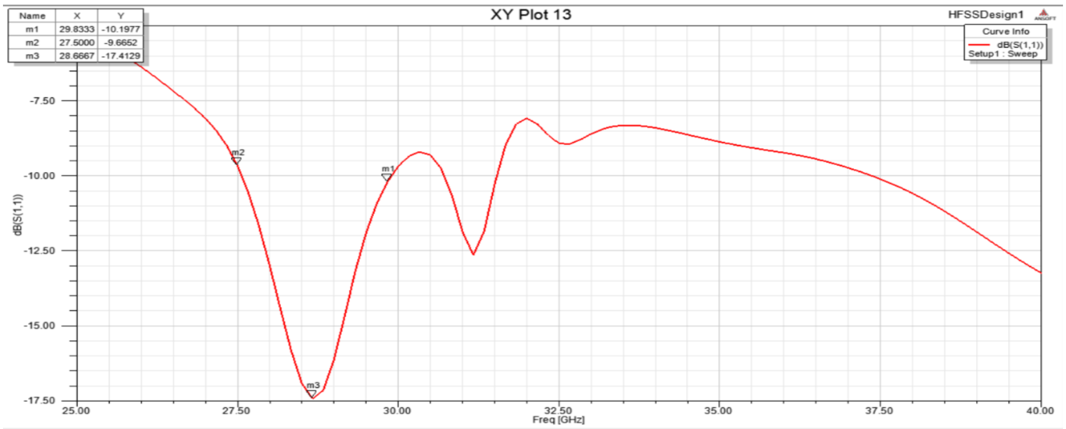


Fig. 7 Return loss of 6 ×5 microstrip hexagonal patch array antenna

2. Radiation pattern and gain

The fig 8(a) shows radiation pattern and fig 8(b) shows gain in 3D of 6× 5 microstrip array antenna with hexagonal patch shape. the gain is shown from the figures as 25.3 dB for $Ø=0^0$ and $Ø=90^0$

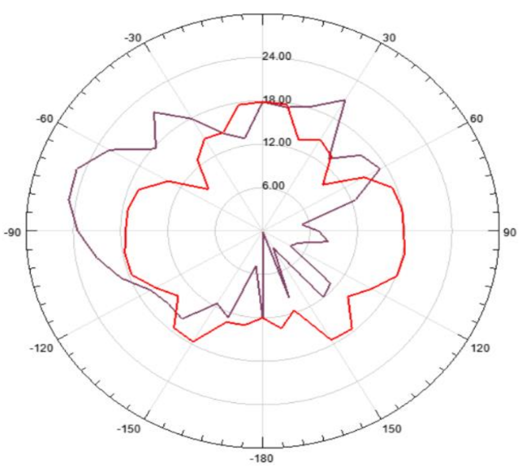


Fig. 8 (a) Radiation pattern

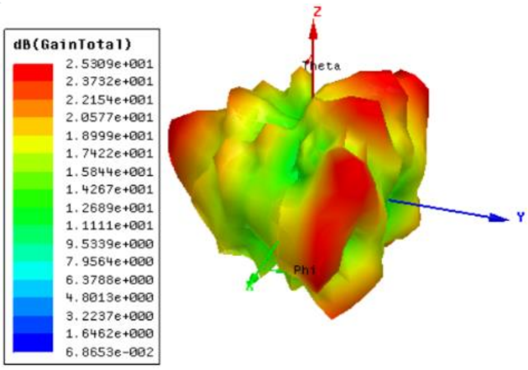
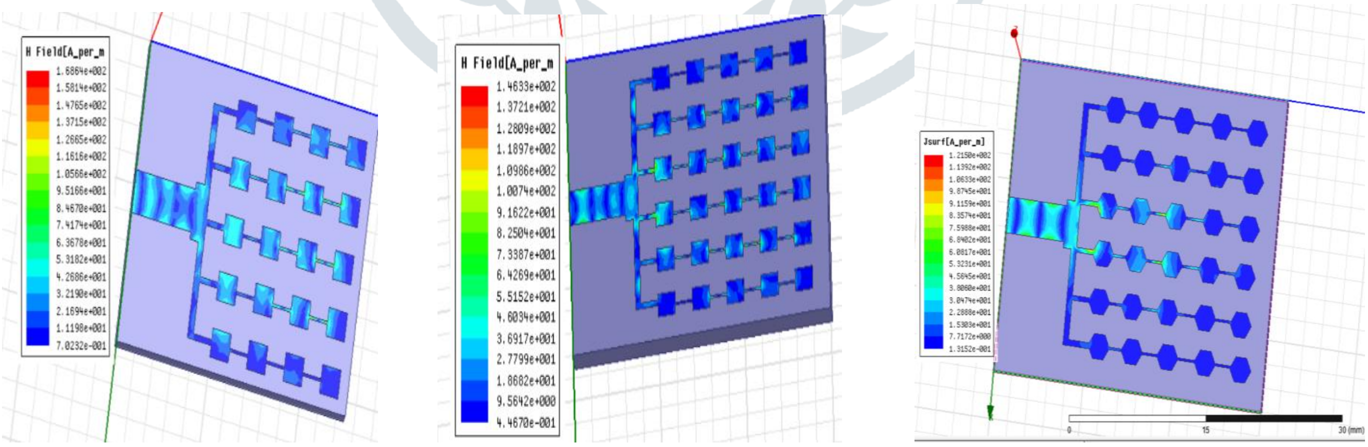


Fig. 8 (b) 3D Gain



(a) (b) (c)

Fig. 9 Current distributions of (a) 5x4 microstrip patch antenna with rectangular patch shape (b) 6x5 microstrip patch antenna with rectangular patch shape (c) 6x5 microstrip patch antenna with hexagonal patch shape

The microstrip patch antenna with different patch shapes and array sites are compared in table-1. The comparison shows that 6x5 microstrip patch antenna with rectangular shape has good bandwidth, high gain and improved return loss.

Table -1 : Performance analysis of microstrip patch antenna

Parameters	5x4 microstrip antenna with rectangular patch	6x5 microstrip antenna with rectangular patch	6x5 microstrip antenna with hexagonal patch
Gain (dB)	23.84	25.45	25.3
Return loss (dB)	-24.9	-37.0	-17.41
Bandwidth (%)	15.23	30.49	8.128
Size (mm)	25 x 21 x 1.6	25x25x1.6	25 x 25 x 1.6

The existing system [ ] is designed using proximity coupling and desired parameters are achieved. The proposed antenna system has improved the parameters like gain, return loss and band width when compared to existing system.

Table – 2 : Performance analysis of proximity feed with corporate feed networks

Parameters		Gain (dB)	Bandwidth (%)	Return loss (dB)
Existing system	6x5 antenna array irregular patches	21.5	8.12	-26
Proposed system	5x4 antenna array rectangular patches	23.84	15.23	-24.9
	6x5 antenna array rectangular patches	25.45	30.49	-37.0
	6x5 antenna array hexagonal patches	25.3	8.128	-17.41

V. CONCLUSION:

The microstrip patch antenna array with series and corporate feed techniques is designed and simulated. The feeding technique is easy to design and allows planar array configuration. The proposed and designed antenna array system covers the entire bandwidth of 23 GHZ to 30 GHZ. The antenna has required gain, impedence bandwidth and improved return loss and can be used at 5G base band station. The gain and impedence bandwidth of the antenna system can further be improved by using different patch shapes and feeding techniques.

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