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# Comparison of Grid Array and Microstrip Patch Array Antennas at 28 GHz

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**Abstract**— A millimeter wave Grid Array Antenna for fifth generation (5G) communications is presented. The 20 cell, nearly-rhombic,  $40 \times 40$  mm<sup>2</sup> Grid Array Antenna structure is simulated and fabricated on a Rogers RT/Duroid 5880 substrate with thickness of 0.25 mm. The grid array has  $|S_{11}| < -10$  dB for two frequency ranges in the upper 26 GHz millimeter wave band and has a percentage bandwidth and gain of 5.41% and 16.5 dBi, respectively. The antenna is compared with a Microstrip Patch Array using same substrate and dimensions.

**Keywords**—5G; millimeter wave; grid array; microstrip array

## I. INTRODUCTION

With the expansion in wireless industry across the world, the demand for high data rates has risen exponentially to accommodate and enable people to access the internet. In order to cater the huge demands of data traffic, the millimeter wave (mm-waves) frequency region has drawn attention of the research community as potential solution to the bandwidth and capacity issues and it is being recognized as the primary technology in fifth generation communications (5G) [1].

The introduction of 5G in the mm-waves spectrum has attracted many researchers which has enabled them to think about the applications for 5G that were not efficiently possible to implement previously. These applications include industrial automation, health and fitness applications, virtual and augmented reality etc [2]. Several antennas have been proposed for 5G communications which include a  $4 \times 1$  and  $2 \times 2$  stacked patch array on LTCC and PCB substrates with peak gain of 13 dBi [3]. A review for several 5G antennas was presented in [4]. The Grid Array Antenna (GAA) was first introduced by J. D. Kraus in 1964 [5]. Nakano has contributed several papers in the research of GAA using Method of Moments (MoM) calculation techniques [6]. Nakano also proposed a centre-fed GAA with split beams for the first time [7]. Most recently, GAAs were used in antenna-in-package technology for mm-wave region as well [8].

In this article, a non-centre-fed square symmetric dual resonance Grid Array antenna, with different characteristic modes, is presented alongwith a comparison with a similar-sized microstrip patch array. The GAA operates in the upper 26 GHz mm-wave band [9] and has two resonances in close proximity.

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## II. GRID ARRAY ANTENNA GEOMETRY

The geometry of the proposed grid array antenna is shown in Figure 1. A flexible Rogers RT/Duroid 5880 substrate with loss tangent of 0.0009, thickness of 0.25 mm, relative permittivity of 2.2 and double-sided 0.017 mm copper cladding, is chosen to design this antenna. The substrate has dimensions of  $40 \times 40$  mm<sup>2</sup>. The grid array on the top of the substrate consists of 20 brick cells with the horizontal metal thickness of  $W_t$  and vertical metal thickness of  $L_t$  between each brick cell. The long side of each brick cell,  $W_b$ , acts as a transmission line and the short side,  $L_b$ , operates as radiating element as well as the transmission line. The lengths  $W_b$  and  $L_b$  are almost equal to  $\lambda_g$  and  $\lambda_g/2$ , respectively. Unlike the conventional GAA designs [5][7], this antenna is fed between the first and the second row from the top on the y-axis.

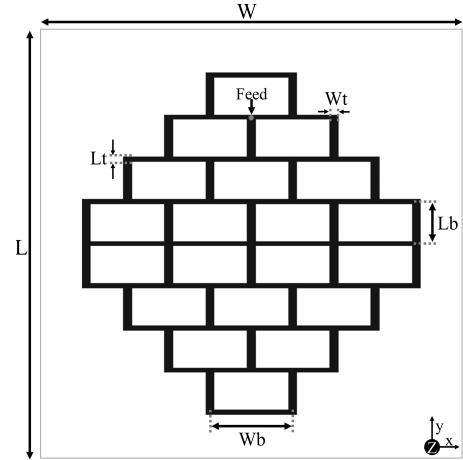


Fig. 1 The geometry of rear-fed Grid array

TABLE I. DESIGN PARAMETERS OF GRID ARRAY ANTENNA

Parameter	W	W <sub>b</sub>	W <sub>t</sub>	L	L <sub>b</sub>	L <sub>t</sub>
Dimension (mm)	40.0	7.83	0.8	40.0	3.93	0.42

## III. $4 \times 4$ MICROSTRIP PATCH ARRAY GEOMETRY

The geometry of the proposed microstrip patch array (MPA) is shown in Figure 2. This geometry is the extension of the work presented in [10] with  $4 \times 4$  array structure in order to compare with the grid array in terms of the covered area (1600 mm<sup>2</sup>). Similar to the earlier work, the microstrip array is designed on Rogers RT/Duroid 5880 substrate having thickness of 0.25 mm. The array consists of 16 radiating elements with  $0.75\lambda$  spacing between the patches in the same row. The patches are connected to 100  $\Omega$  lines and then to a

matching network using quarter-wave transformers. The  $90^\circ$  bends in the network are mitred. The rows of the array are connected through a  $100\ \Omega$  one wavelength network where each network consists of two quarter-wave transformers and two  $50\ \Omega$  lines. An additional  $50\ \Omega$  pad is placed between the top two rows to drill a 0.5 mm hole to excite the array.

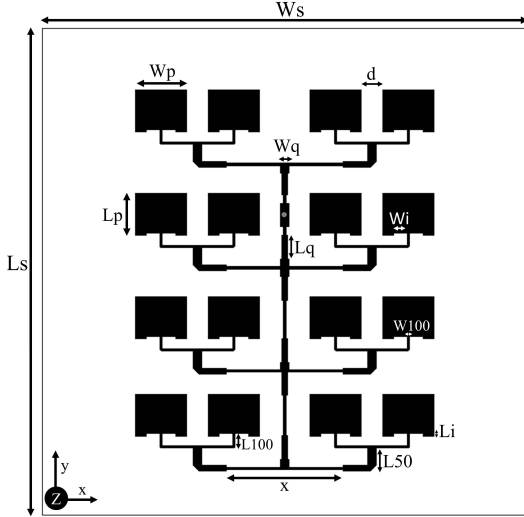


Fig. 2 The geometry of 4x4 rear-fed Microstrip Patch array

TABLE II. DESIGN PARAMETERS OF MICROSTRIP PATCH ARRAY

Parameter	Dimension (mm)	Parameter	Dimension (mm)
$W_s$	52.0	$L_s$	31.0
$W_p$	4.48	$L_p$	3.55
$W_i$	1.10	$L_i$	0.20
$W_q$	0.48	$L_q$	1.99
$W_f$	0.80	$L_f$	2.30
$W_{100}$	0.25	$L_{100}$	1.11
$d$	1.52	$x$	8.10

#### IV. RESULTS AND COMPARISON

Figure 3 shows the  $|S_{11}|$  of the GAA and the MPA. The grid array antenna is measured using Rohde and Schwarz Vector Network Analyzer (ZVA40). The simulated microstrip patch array has  $|S_{11}| < -10\text{dB}$  from 27.42 GHz to 28.08 GHz with 2.38% fractional bandwidth. The simulated grid array antenna has  $|S_{11}| < -10\text{dB}$  from 26.79 GHz to 27.10 GHz and 28.44 GHz to 29.23 GHz with a fractional bandwidth of 3.89%. However, the measured results of the grid array shows

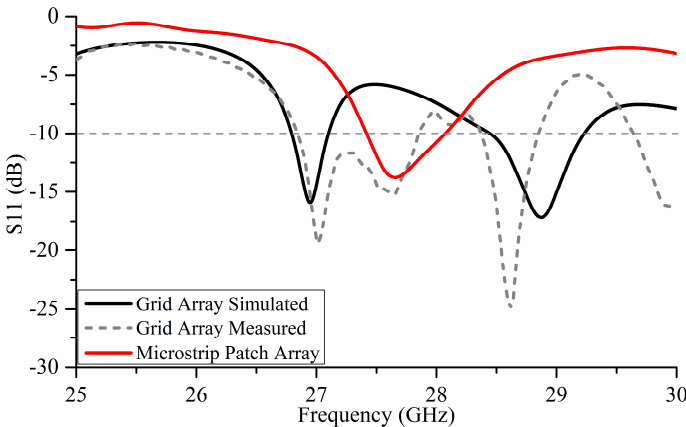


Fig. 3  $S_{11}$  of GAA and MPA

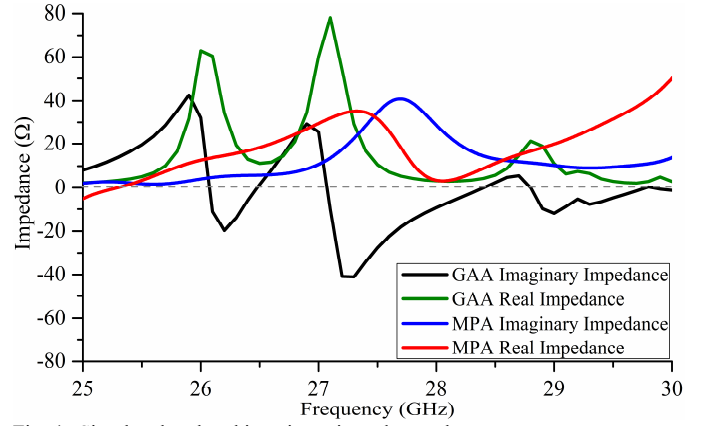


Fig. 4 Simulated real and imaginary impedance plots

the antenna operates from 26.84 GHz to 27.86 GHz and from 28.37 GHz to 28.85 GHz having a fractional bandwidth of 5.41%. The simulation of the grid array requires very fine meshing throughout the structure because of the slot based geometry which comprises of numerous bends and edges that affect the operation of the structure. A dense mesh size increases the simulation time and needs a lot of resources. The position of feed in GAA can also greatly affect the results. A displacement by 0.1 mm in the feed position, while manufacturing the design, can change the results altogether because of the sensitive optimization of the geometry.

Figure 4 shows the impedance characteristics of both grid array and microstrip patch array. The imaginary impedance of the microstrip patch validates it as a narrowband antenna whereas the grid array antenna shows broadband characteristics between 27.05 GHz and 28.3 GHz. The imaginary impedance plot of grid array in figure 4 further verifies the claim of two resonances in the upper 26.5 GHz region as the reactance becomes zero at 26.8 GHz and 28.4 GHz.

Figure 5 shows the radiation efficiency of both Microstrip and Grid Array antennas. The percentage power to the antenna to the power radiated from the antenna is around 90% for microstrip array which is around 7% more than the grid array.

The radiation characteristics of GAA and MPA are shown in Figure 6. Figure 6 (a) shows the 2-D yz-plane (E-plane) simulated plot of Microstrip Patch Array at 27.8 GHz and both

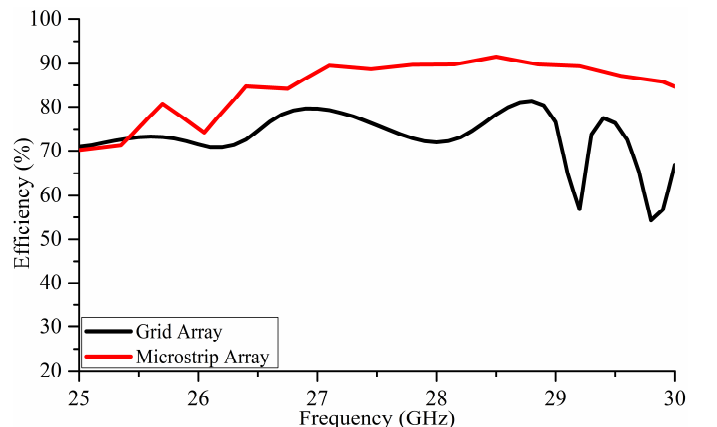


Fig. 5 Radiation efficiency of GAA and MPA

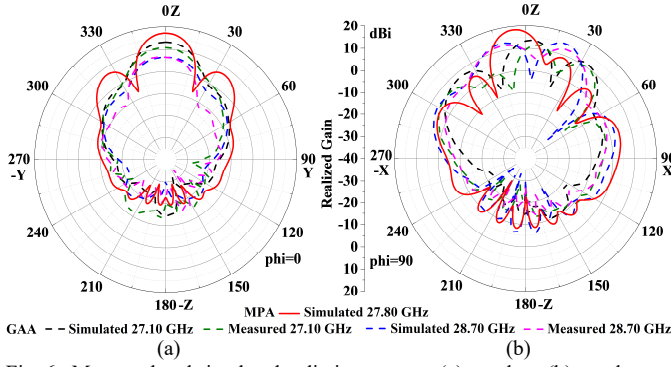


Fig. 6 Measured and simulated radiation patterns (a) yz-plane (b) xz-plane

simulated and measured plots of Grid Array Antenna on both resonant frequencies. The radiation patterns are tested in an anechoic chamber. Figure 6 (b) shows the xz-plane (H-plane) of the both GAA and MPA. The grid array has a directive pattern at the first resonance (27.10 GHz) similar to microstrip patch array only with lower gain but at the second resonance of the grid array the characteristic mode changes and the beam splits into two beams at 28.70 GHz in the xz-plane. The grid array has lower side lobe and back lobe level compared to the microstrip array in yz-plane and has wider half power beamwidth (HPBW) in both yz-plane and xz-plane.

Figure 7 presents the realized gain of grid array and microstrip array. The grid array has two peaks at the two resonances. For an antenna of same dimension, the microstrip array is better than the grid array in terms of the magnitude of gain which peaks around 18.41dBi at 27.80 GHz whereas the grid array has peak gain of 16.50dBi at 27.02 GHz.

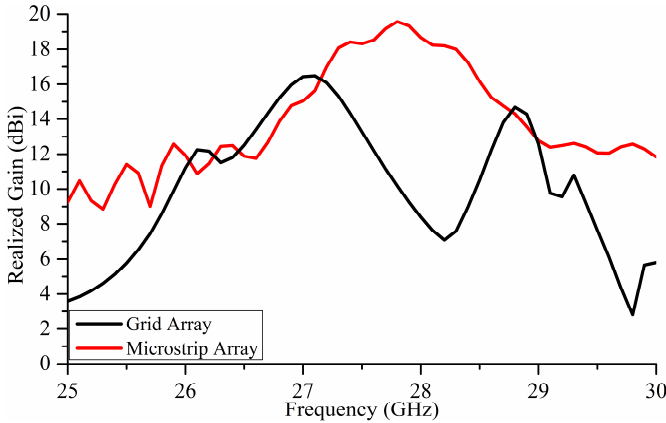


Fig. 7 Realized gain of GAA and MPA

Figure 8 shows the fabricated prototype of the grid array antenna and a performance comparison summary between GAA and MPA is presented in table III.

## V. CONCLUSION

A  $40 \times 40$  mm<sup>2</sup> grid array antenna, presented in this paper, is compared with a  $4 \times 4$  element microstrip array antenna of same dimension. The grid array has more than twice the bandwidth of microstrip array's 2.38%. Although both antennas have high gain, the grid array's obtained bandwidth is at the expense of lower gain (1.9dBi less than microstrip

patch antenna) and lower efficiency. The wider beamwidth of the grid array makes it suitable to be used for the applications in the upper 26.5 GHz 5G spectrum.

TABLE III. DESIGN PARAMETERS OF MICROSTRIP PATCH ARRAY

	Grid Array (Fig. 1)	Microstrip Patch Array (Fig. 2)
Dimensions (mm <sup>2</sup> )	40 × 40	40 × 40
Operating Frequency bands	26.84 GHz – 27.86 GHz and 28.37 GHz – 28.85 GHz	27.42 GHz – 28.08 GHz
Fractional Bandwidth	5.41%	2.38%
Peak Realized Gain (dBi)	16.5	18.41
HPBW (E-Plane / H-plane)	25° / 17.1° (27.10 GHz)	19.4° / 16.5° (27.80 GHz)
Peak Radiation Efficiency	83%	90%

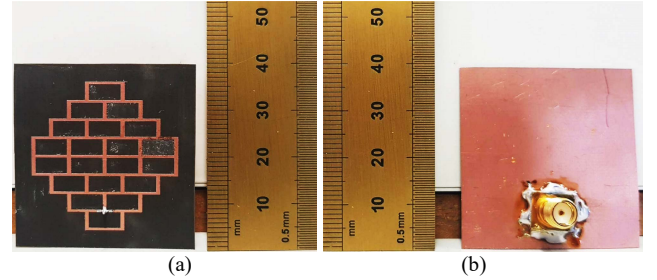


Fig. 8 Prototype of grid array antenna (a) front (b) back

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