

## Design of microstrip patch antenna to deploy unmanned aerial vehicle as UE in 5G wireless network

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### ABSTRACT

The use of unmanned aerial vehicle (UAV) has been increasing rapidly in the civilian and military applications, because of UAV's high-performance communication with ground clients, especially for its intrinsic properties such as adaptive altitude, mobility, and flexibility. UAV deployment can be monitored and controlled through 5G wireless network as user equipment (UE) along with other devices. A highly directive microstrip patch antenna (MPA) could establish long-distance communication by overcoming air attenuation and reduce co-channel interference in the limited region if UAV uses a specifically dedicated band, which might enhance spatially reuse of the spectrum. Also, MPA is highly recommended for UAV because of its low weight, low cost, compact size, and flat shape. In this paper, we have designed a highly directive single-band 2×2 and 4×4 antenna array for 5.8 GHz and 28 GHz frequency respectively for UAV application in a focus to deploy UAV through 5G wireless network. Here, The Roger RT5880 (lossy) material utilize as a substrate due to its lower dielectric constant which achieves higher directivity and good mechanical stability. Inset feed technique used to feed antenna for lowering input impedance which provides higher antenna efficiency. The results show a wider bandwidth of 702 MHz and 1.596 GHz for 5.8 GHz and 28 GHz antenna array correspondingly with a compact size.

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## 1. INTRODUCTION

The unmanned aerial vehicle (UAV), commonly known as drones, has become an intensive topic of research over the past few years because of its flexibility, autonomy, and wide range of application fields [1], [2]. The use of UAVs for general multi-dimensional performance and low cost has been increasing rapidly in civilian domain applications such as public safety, surveillance, and monitoring, rescue operations, internet of things (IoT) communication, and telecommunications [1]-[3].

Natural disasters such as a tornado, hurricanes, and floods occur tragically almost in all the countries. Still, when they occur extensively, the existing terrestrial communication network can be destroyed

or damaged. In this scenario, to ensure public safety, communication is essential for search and rescue operations, UAV deployment can do that operation [3], [4]. UAVs can be used for information dissemination and connectivity enhancements of the terrestrial network due to the advantages of a line of sight (LoS) communication and mobility. UAV can also be used as a base station for mobile ad-hoc networks and information dissemination of device to device (D2D) communication [3], [5], [6]. D2D communication is an effective solution for offloading data traffic, which increases coverage and network capacity [3]. UAV is the key enabler for mm-wave communication. The UAV with mm-wave communication capability can establish LoS connection with ground users, which can reduce propagation loss at a higher frequency [5], [6].

The rapid growth of mobile users and applications is creating demand for fast data rate, high bandwidth, low latency communication, which can be met through the use of a 5G frequency spectrum. The third generation partnership projects (3GPP) divided 5G frequency band into below 6 GHz and above 24 GHz, (24 GHz, 26 GHz, 28 GHz, and 38 GHz) [7], [8]. UAV can help the network provider on-demand deployment of quality wireless communication with LoS.

UAVs are categorized based on their altitudes such as HAP (high altitude platform) and LAP (low altitude platform). HAP is generally quasi-stationary and altitude above 17 km. On the other hand, LAP can move very fast and flexibly, where its height is 10 meters to a few kilometers [5], [9]. The altitude of LAP can be covered with a high directive microstrip patch antenna (MPA) [10].

Antenna design is a crucial part of any UAV deployment for wireless communication. The proper shape and size of the antenna to fit it within the body of UAV is a top research arena for innovation in UAV technology. The microstrip patch antenna can be a useful tool for UAV as a base station or UE [11]-[20].

The microstrip patch antenna for 5G wireless communication is extremely desirable because it is a low cost, low profile easy to design, compact size, and easy installation process [11]. The flat and small antenna is preferable for UAV applications for being easy to implant on the surface area of the UAV. Antenna arrays enhance directivity and gain. A highly directive antenna is preferred as it reduces co-channel interference and covers long distances [21]. For designing UAV antenna papers [11]-[20], [22]-[28] has been reviewed.

Yusuf *et al.* [11], an E-shaped dual-band UAV antenna has been designed whose resonant frequency is 5.8 and 9.6 GHz, respectively, but it is quite bulky, and due to the dual-band behavior gain of the antenna is less which is 9.11 dBi and 5.37 dBi respectively. Deo *et al.* [12] introduced a dipole antenna for a resonant frequency of 5.09 GHz, but its gain and bandwidth are 4.36 dBi and 120 MHz, respectively, which is extremely low. A rectangular shape 2×2 microstrip patch antenna array for 3.8 GHz resonant frequency has been proposed by Sajjad *et al.* [13] where the gain is 13.5 dB, but bandwidth is only 72 MHz which does not meet the minimum bandwidth requirement of 5G communications. Kang *et al.* [14], a planar square segment antenna is designed for the UAV application of four resonating frequencies, which are 0.95 GHz, 1.6 GHz, 2.05 GHz, and 2.4 GHz respectively but antenna gain is meager because it resonates on multiple frequency bands. Horizontal polarized tri-band antenna of 57.7×117×29.6 mm size has been designed in [15] for the UAV application where gain and bandwidth are extremely low due to omnidirectional behaviors. A coaxial feed line rectangular microstrip patch antenna has been proposed by the Arpaio *et al.* [16] for 3.6 GHz resonant frequency whose size is extremely large where bandwidth is 400 MHz, and the average gain is 12 dBi. In work [17], a 12-element planer printed array antenna at 2.45 GHz resonant frequency presented with a good gain but bandwidth and return loss are lower. In [18], authors proposed a coaxial feed annular ring slot antenna at 2.76 GHz resonant frequency with radius 47.2 mm and Arlon AD250A with dielectric constant 2.5 used as a substrate where bandwidth and gain are poor. Safaron *et al.* [19] proposed a cloverleaf antenna by using FR-4 substrate material at 2.45 GHz resonant frequency. An integrated feed 12-element planer antenna array is presented in [20] which resonate at 2.47 GHz frequency with 11 dBi gain but bandwidth is only 40 MHz. The antenna arrays designed for higher 28 GHz frequency are reviewed below.

A corporate series feed rectangular patch antenna array is presented for 28 GHz resonant frequency by Mohamed and Ammor [22] where antenna gain is only 17.1 dB but antenna size is large. Ndip *et al.* [23], has been designed a four elements antenna array of 28 GHz operating frequency whose gain and bandwidth are 12.2 dBi and 0.9 GHz, respectively, where the size of the antenna is not specified. A rectangular patch antenna array has been proposed in paper [24] that has a gain of only 11.2 dBi and coaxial feed used to feed the antenna where Arizaca-cusicuna *et al.* [25] introduced a corporate series feed 16-element rectangular patch antenna for 28 GHz resonant frequency with 17 dB gain, but return loss and bandwidth are only 16.37 dB and 0.3 GHz respectively. Khabba *et al.* [26], A 10 elements beam-steering antenna array has been designed whose resonant frequency is 28 GHz, where the gain is 16.5 dB, but the antenna size is hefty and feed by microstrip line. line feed technique is also used in 2×2 U slot patch antenna array projected by Yoon and Seo [27] for 28 GHz resonant frequency where the gain is only 14.3 dBi. Gharbi *et al.* [28], recommended two 4×1 and 2×2 rectangular patch antennas where the gain is 13.2 and 13.3 dBi respectively.

Generally, UAV uses a fixed operating frequency for communication. Presently 5.8 GHz is one of the popular choices for the designer. In paper [11]-[20], there has been taken a vital step for designing antenna below 6 GHz frequency but due to multi-band or feedline impedance mismatch, the gain of the antenna degrades or reduced antenna operational bandwidth due to inapt design parameter. A single band antenna with proper feed-line impedance matching can achieve higher gain and better operational bandwidth. A UAV, which is operated at 5.8 GHz, may satisfy the 5G wireless communication requirements. But soon, we will have to move towards higher frequency for achieving more lower latency and wider bandwidth so that we can meet 5G requirement completely, 28 GHz is one of the most attractive higher frequency bands. In paper [22]-[28] there has been designed different microstrip patch antenna array for future upcoming 5G application for the 28 GHz frequency spectrum.

In this perspective, we have presented a microwave and mm-wave antenna with their parameters to focus on UAV deployment in 5G wireless communication. A comparative analysis is also stated to prioritize mm-wave communication with research findings. A compact size, high directional microstrip patch antenna array of 5.8 GHz and 28 GHz resonant frequency is proposed in this paper. The design addressed a nice mix up of high directivity as well as wide bandwidth with a compact size which is achieved by inset feed technique [29], [30], substrate material with lower dielectric constant [23] and optimize design parameters. Only high directivity and fixed operating frequency can mitigate the co-channel interference for an Unmanned Aerial Vehicle of complex implementation procedures and handoff scenarios for 5G wireless communications [21]. Notably, wide bandwidth will increase coverage and capacity where small size reduces cost and antenna installation space, which is a vital point for small size UAV.

The rest of the paper is arranged in the following way. Section 2 discusses the antenna design in detail. In section 3, the output of the proposed antenna is presented with analysis and section 4 draws a comparison of the proposed antenna with recent work [11]-[20], [22]-[28]. Section 5 concludes the paper.

## 2. ANTENNA DESIGN

The rectangular patch antenna is chosen as the antenna shape because it provides better results [31]. The antenna parameters have calculated by using equation (1)-(11) [29], [32]. Width of the antenna,

$$W_p \approx \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

where,

$f_r$  = Resonant frequency

$c$  = Velocity of light

$\epsilon_r$  = Substrate dielectric constant

Antenna length calculated by,

$$L_p \approx L_{eff} - 2\Delta L \quad (2)$$

The effective length  $L_{eff}$  and its deviation calculated by using the equation.

$$L_{eff} \approx \frac{c}{2f_r \sqrt{\frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[ 1 + \frac{12h}{W_p} \right]^{\frac{1}{2}}}} \quad (3)$$

$$\Delta L \approx 0.412 \left( \frac{\epsilon_{eff} + 0.3}{\epsilon_{eff} - 0.258} \right) \left( \frac{\frac{W_p}{h} + 0.264}{\frac{W_p}{h} + 0.8} \right) \quad (4)$$

Hight of the Substrate calculated by (5).

$$h \approx \frac{0.0606\lambda}{\sqrt{\epsilon_r}} \quad (5)$$

Where wavelength,

$$\lambda \approx \frac{c}{f_r} \quad (6)$$

In the case of antenna design, feeding technique is very important because proper impedance matching in the feed line can ensure no reflection back from antenna which increases antenna efficiency [29]. Inset feed technique provides lowest return loss and highest gain [30].

Inset feed depth and notch gap calculated by (7), (8),

$$Fi \approx \frac{0.822 \times Lp}{2} \tag{7}$$

$$Gap \approx \frac{c}{\sqrt{2\epsilon_{eff}}} \times \frac{4.65 \times 10^{-12}}{f_r} \tag{8}$$

Width of 50Ω feed line calculated by (9),

$$Wf \approx \frac{120\pi}{\sqrt{\epsilon_{eff}} \left( 1.393 + \frac{Wp + \frac{2}{3}}{h} \ln \left( \frac{Wp + 1.444}{h} \right) \right)} \tag{9}$$

Single antenna ground plane dimension calculated by (10) and (11), width of the ground is  $W_g$  length of the ground is  $L_g$ .

$$W_g \approx 6h + Wp \tag{10}$$

$$L_g \approx 6h + Lp \tag{11}$$

The Roger RT5880 (lossy) is chosen as substrate material because of its low dielectric constant, which provides higher directivity and low cost with availability [23]. Dielectric constant and loss tangent of the substrate is 2.2 and 0.0009, respectively. Table 1 shows the parameters list of single antennas for both 5.8 GHz and 28 GHz resonant frequency, and Figure 1 shows the front view of a single antenna for both frequencies. CST microwave studio used for designing and simulating all the antennas.

Table 1. Single antenna parameter list for both 5.8 GHz and 28 GHz resonant frequency

Parameters	Value for 5.8 GHz (mm)	Value for 28 GHz (mm)	Parameters	Value for 5.8 GHz (mm)	Value for 28 GHz (mm)
$Wp$	20.65	4.8	$Wf$	2	0.31
$Lp$	15.81	3	$Gap$	0.82	0.1
$Wg$	33.62	8.78	$hp$	0.035	0.035
$Lg$	28.79	7	$h$	2.16	0.66
$Fi$	4.1	0.51			

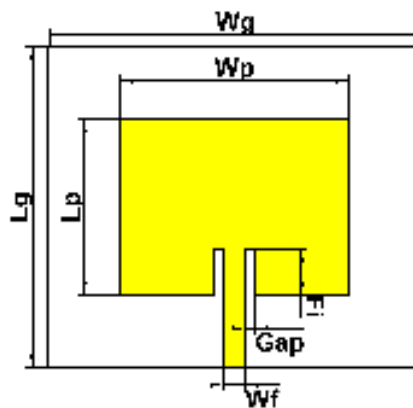


Figure 1. Front view of single antenna for both 5.8 GHz and 28 GHz resonant frequency

To achieve high directivity and gain, we have designed an antenna array too. Figure 2 shows front view of 2x2 antenna for both 5.83 GHz and 28 GHz frequency. In Table 2 parameters list of 2x2 antenna array is given. The attenuation due to rain, cloud, and fog increases exponentially with the increase of

operating frequency [33]. The problem, as mentioned earlier, can be solved by increasing antenna gain [34]. That's why we have designed another 4×4 microstrip patch antenna for 28 GHz frequency. Figure 3 shows the front view of the antenna. Where  $x=2.32$  mm,  $y=4.39$  mm,  $Wf4=0.6$  mm,  $Wf5=1.01$  mm, and the dimension of the antenna is  $30.14 \times 32.04$  mm<sup>2</sup>.

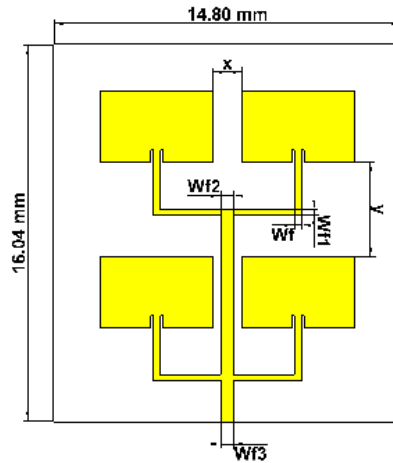


Figure 2. Front view of 2×2 antenna array for both 5.83 GHz and 28 GHz frequency

Table 2. List of 2×2 antenna array parameters for both 5.8 GHz and 28 GHz frequency

Parameters	Value for 5.8 GHz (mm)	Value for 28 GHz (mm)	Parameters	Value for 5.83 GHz (mm)	Value for 28 GHz (mm)
$x$	13.4	1.2	$Wf2$	1.02	0.57
$y$	15.66	4	$Wf3$	5.12	0.57
$Wf1$	1.63	0.24	$W$	67.67	14.80
$L$	65.52	16.04			

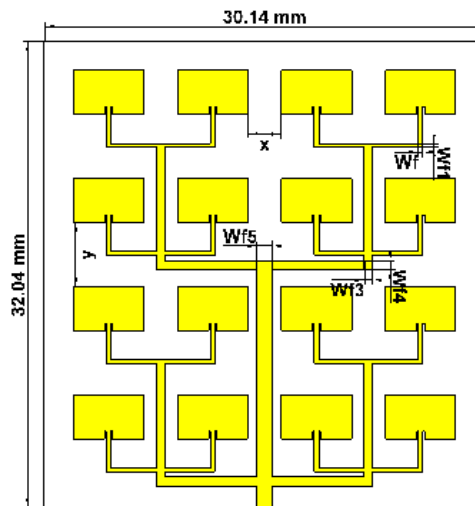


Figure 3. Front view of 4×4 antenna array at 28 GHz frequency

### 3. RESULTS AND DISCUSSION

In this section, we discuss the antenna return loss, voltage standing wave ratio, directivity, gain, and radiation pattern. Comparison of different element antenna for 5.8 GHz and 28 GHz shown in Tables 3 and 4, where an assessment of the existing antenna sets with the recommended 5.83 GHz 2×2 antenna array and the 28 GHz 4×4 antenna array is shown in Tables 5 and 6.

Table 3. Comparison of a single element and 2×2 antenna array for 5.8 GHz frequency band

Antenna	Size mm <sup>2</sup>	Resonant Frequency (GHz)	Return loss (dB)	Bandwidth (MHz)	Directivity (dBi)	Gain (dB)
single	33.62×28.79	5.8	45	280	7.81	8.02
2x2 Array	67.67×65.52	5.83	45	702	12	12

Table 4. Comparison of a single element, 2×2 antenna array, and 4×4 antenna array for 28 GHz frequency band

Antenna	Size mm <sup>2</sup>	Return loss (dB)	Bandwidth (MHz)	Directivity (dBi)	Gain (dB)
single	8.78×6.99	41	2.351	8.23	8.37
2×2 Array	14.78×16.04	28.5	1.95	13.2	12.8
4×4 Array	30.13×32	30.3	1.596	18.4	17.9

Table 5. Comparison of existing below 6 GHz UAV antenna and proposed 5.83 GHz 2×2 antenna array

Ref.	Antenna Description	Size	Resonant frequency (GHz)	Return loss (dB)	Bandwidth (MHz)	Gain (dBi)
[11]	1×4 E-Shape MPA	22×4.6×0.167 cm <sup>2</sup>	5.8	20.36	189.8	9.11
			9.65	19.26	545.8	5.37
[12]	Dipole antenna including metallic reflector	48×40×22.52 mm <sup>2</sup>	5.09	32	120	4.36
[13]	2×2 MPA array	--	3.8	26	72	13.5
[14]	Segmented loop antenna	75×75×0.8 mm <sup>3</sup>	0.95	20	20	0.9
			1.6	20>	1179	3.94
			2.05			3.05
			2.61			2.52
[15]	Folded patch antenna with vertical slot inside metal box	57.7 ×117×29.6 mm <sup>3</sup>	0.843	16	7	1.5
			1.4445	25	45	3
			2.4	18	261	4
[16]	2×2 MPA array	100×100 cm <sup>2</sup>	3.6	20	400	12
[17]	12-element antenna array	39.6×11.6 cm <sup>2</sup>	2.45	17	50	21.4dB
[18]	Annular ring slot antenna	Radius 47.2 mm	2.67	31	70	2.5
[19]	4-blade cloverleaf antenna	Radius 88 mm	2.45	19	100	6.38
[20]	12-element antenna array with integrated feed	458.8×161×1.27 mm <sup>3</sup>	2.47	14	40	11
Proposed	2×2 MPA array	67.67×65.51 mm <sup>2</sup>	5.83	45	702	12dB

Table 6. Comparison of the existing 28 GHz microstrip patch antenna array and proposed 4×4 antenna array

Ref.	Antenna Description	Size (mm <sup>3</sup> )	Resonant frequency (GHz)	Return loss (dB)	Bandwidth (GHz)	Gain (dBi)
[22]	16-element rectangular patch antenna array	88×25×0.78	27.85	62.31 dB	2.52	17.1 dB
[23]	2×2 MPA array	-	28	36 dB	0.9	12.2
[24]	2×2 MPA array	7.07×31.677 mm <sup>2</sup>	28	21.44	-	11.2
[25]	4×4 MPA array	30.65×39.3 mm <sup>2</sup>	28	16.37	0.3	17 dB
[26]	1×10 MPA array	60×100×0.7	28	35	1.2	16.5
[27]	2×2 U-slot MPA array	41.3×46×0.5	28	40	4.14	14.3
[28]	1×4 MPA array	21.6×31.6×0.508	28	62	2.15	13.2
	2×2 MPA array	22.8×19.2×0.508		34	1.3	13.3
proposed	4×4 MPA array	30.13×32×0.5	28	30.3	1.596	17.9 dB

### 3.1. Return-loss

Antenna return loss or S11 parameter is a plot that denotes the ratio of the reflected power to the incident power with a dB unit. At the same time, it describes how much antenna matches with transmission line or device, the lower it is, the better the match will be [32]. Figure 4 shows the return loss plot of 5.8 GHz single and 2×2 array antenna where the array antenna resonant frequency moves slightly towards upper at 5.83 GHz due to array antenna feed-line mismatch but it still in acceptable level. With S11 <-10dB criteria the bandwidth of the 2×2 array antenna is 702 MHz. Figure 5 shows the return loss plot of 28 GHz antenna for different elements where the bandwidth of the 4×4 antenna array is 1.596 GHz using S11<-10 dB criteria. Figures 4 and 5 shows that the return loss at the resonant frequency of 2×2 antenna array at 5.83 GHz is -45 dB, on the other hand, the 4×4 antenna array at 28 GHz has a -30 dB return loss. It clarifies that radiation at 5.8 GHz and 28 GHz resonant frequency is quite acceptable and high.

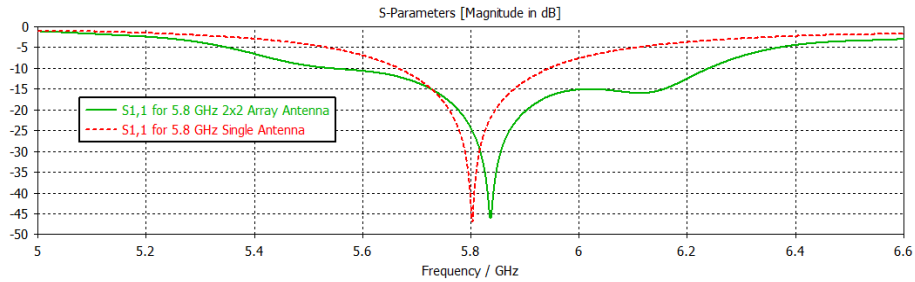


Figure 4. Return-loss plot of single and 2×2 antenna array for 5.8 GHz frequency

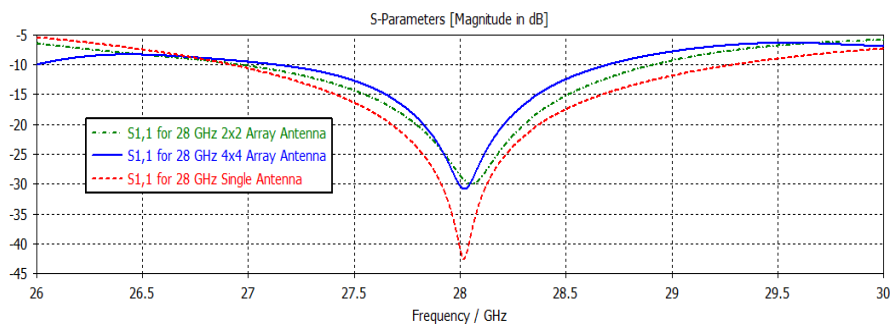


Figure 5. Return-loss plot of single, 2×2 and 4×4 antenna array for 28 GHz frequency

### 3.2. Voltage standing wave ratio

The voltage standing wave ratio (VSWR) parameter of the antenna indicates how much of an antenna is impedance matched with its radio or transmission line [32]. For 5G wireless communication, the value of VSWR should be between 1-2, and the lower the value, the better the antenna will match with the transmission line. The value of the ideal field is 1, which indicates that no power is reflected from the antenna. Figures 6 and 7 show the VSWR plots of all designed 5.83 GHz and 28 GHz antenna respectively, were in all fields VSWR is close to 1 which is an ideal value.

### 3.3. Directivity and gain

Directivity of the antenna indicates the maximum gain in a direction. If an antenna radiates evenly in all directions, then it has zero directionality, and the directivity is 1 or 0 dB. In contrast, the antenna gain shows how much power the antenna can transmit towards peak radiation compared to the isotropic source [32]. 5G communication requires high directivity and gain for overcoming attenuation and increasing communication range. The proposed 5.83 GHz 2×2 antenna array and 28 GHz 4×4 antenna array, have achieved 12 dBi and 18.4 dBi directivity respectively, and 12 dB and 17.9 dB gain correspondingly. Higher directivity is achieved because the antenna resonates at optimum frequency band towards a single direction and substrate material is used with lower dielectric constant [23]. Tables 3 and 4 show the gain and directivity of the all 5.8 GHz and 28 GHz antennas.

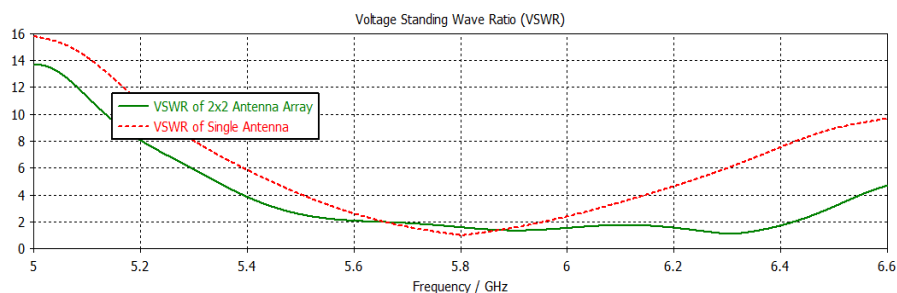


Figure 6. VSWR plot of single and 2×2 antenna array for 5.8 GHz frequency

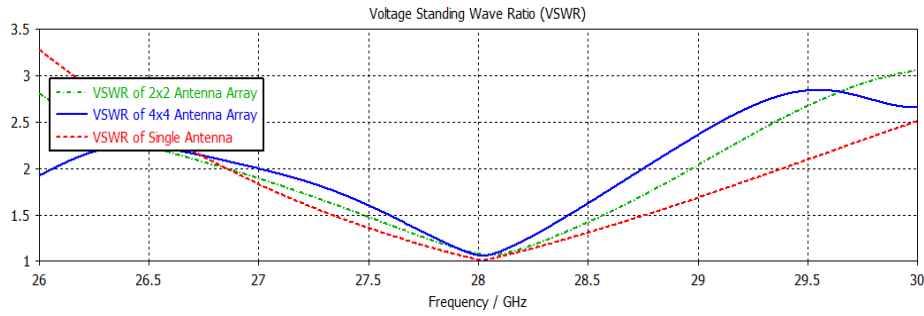


Figure 7. VSWR plot of single, 2×2 and 4×4 antenna array for 28 GHz frequency

### 3.4. Efficiency

The antenna efficiency is the ratio of the power delivered to the antenna and the radiated power from the antenna. High efficiency means that the maximum input power of the antenna has been radiated [32]. For 5G wireless communication, efficiency needs to be above 70%. The efficiency of the recommended 5.83 GHz 2×2 antenna array is 99%, and the efficiency of 28 GHz 4×4 antenna array is 88.5% which is a good value where inset feed technique with proper impedance matching play a vital rule [29], [30]. Figures 8 and 9 show the efficiency vs frequency plot for 5.8 GHz and 28 GHz frequency respectively.

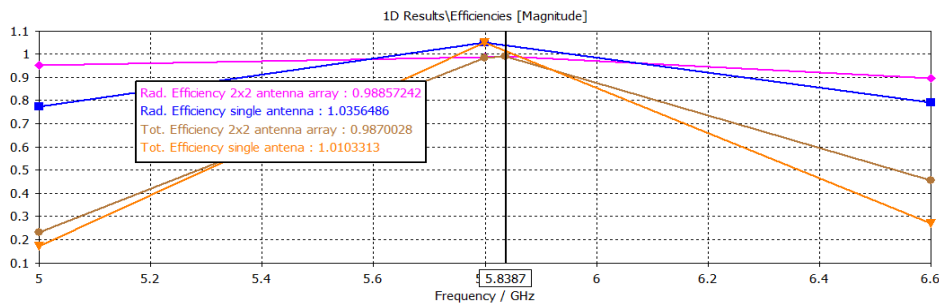


Figure 8. Efficiency vs frequency plot for 5.83 GHz frequency

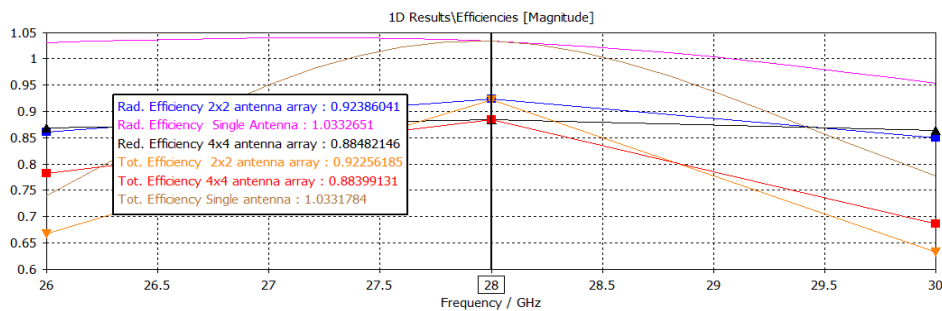


Figure 9. Efficiency vs frequency plot for 28 GHz frequency

### 3.5. Radiation pattern

The radiation pattern of the antenna indicates the directional (angular) dependence of the strength of radio waves [32]. The 3-dimensional (3D) radiation pattern of the proposed 5.83 GHz 2×2 antenna array and 28 GHz 4×4 antenna array has been shown in Figure 10(a) and 10(b), respectively. Figure 11 shows a 2-dimensional (2D) radiation pattern of 5.83 GHz 2×2 antenna array for  $\Phi=0^\circ$  and  $90^\circ$  where angular width is 39.2 and 42 degrees, sidelobe level is -19.0 dB and -5.2 dB respectively. Figure 12 shows a 2D radiation pattern of 28 GHz 4×4 antenna array for both  $\Phi=0^\circ$  and  $90^\circ$  where angular width is 19.7 degree and 20.4 degree, sidelobe level is -14.2 dB and -11.4 dB.



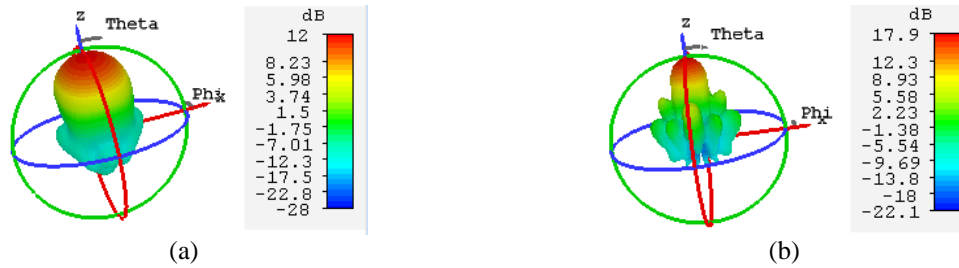


Figure 10. 3D radiation pattern, (a) at 28 GHz resonant frequency for 4x4 antenna array, (b) at 5.83 GHz resonant frequency for 2x2 antenna array



Figure 11. 2D radiation pattern at 5.83 GHz for 2x2 antenna array where Phi=0° and 90°



Figure 12. 2D radiation pattern at 28 GHz frequency for 4x4 antenna array where Phi=0° and 90°

#### 4. COMPARISON

Firstly, a single element 5.8 GHz rectangular patch antenna designed than a 2x2 array antenna designed using by the single element where gain and directivity increases significantly also bandwidth is wider compare to the single antenna but resonant frequency shifted 5.8 GHz to 5.83 GHz where return loss remain constant shown in Table 3. 28 GHz frequency is considered as high gain and directivity is required for UAV but higher frequency introduces higher attenuation in the air [33], [34]. So a 4x4 array antenna also designed at 28 GHz frequency which provides better gain and directivity than single and 2x2 array antenna shown in Table 4. Although there is a reduction of bandwidth and return loss, but enough for 5G communications of UAV.

The proposed 5.83 GHz 2x2 antenna array has a compact size than all antenna listed in Table 5 with a simple rectangular patch where microstrip line feed [11], [12] quarter-wavelength transmission line [13] and coaxial feed technique [14]-[20] has been used to feed the antenna. Designed inset-fed antenna has achieved a high gain better than the entire antennas listed in Table 5 except [13], [17] and also has realized a wider bandwidth with good return loss which will be more effective for UAV application. The recommended 28 GHz 4x4 antenna has higher gain than antenna enlisted in Table 6 although has lesser bandwidth than [22], [27]. Still, size reduction is significant, which reduce the fabrication cost and also weight, which allow UAV to carry the antenna effortlessly.

## 5. CONCLUSION

UAV deployment for wireless communications is not a regular case rather it is used for emergency support to an accident or event. Obviously, in consideration of flight time and battery lifetime, all must encourage getting a handsome bandwidth to cover more people to make the deployment cost-effective. The high directive and wide bandwidth microstrip patch antenna are preferable for UAVs because of its lightweight, low cost, and ease of fabrication. In this paper, two compact size planes 5.8 GHz 2×2 antenna array and 28 GHz 4×4 antenna array are proposed, where higher directivity has been achieved because antennas resonate in a single direction. The high directivity increases the antenna's coverage as well as reduces co-channel interference with the surrounding UAVs or UEs, which enable smooth UAV deployment through 5G network. Tables 5 and 6 show that the proposed antennas are smaller than the existing antenna, which can be set to any surface of the UAV because of its flat shape. Also, small size will reduce fabrication cost and provide scope to attach more payloads to the UAV. The proposed work has found wider bandwidth at 28 GHz than 5.8 GHz. Use of 28 GHz can aid high speed and low latency at 5G communications than 5.8 GHz. 5G specifications had adopted higher frequencies as a key enabler due to the aforementioned advantages.

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