Technologies Used In 5G Antennas (Comprehensive Review)

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Abstract:

In this review, we will shed light on the technology of antennas used in communication within the fifth generation, and we will elaborate on two types of this most advanced technology. The first is Compact Wide-Band Microstrip Patch Antenna; the second type is Four Elements MIMO Antenna.

The world has become a network of interconnected networks, and this communication has resulted in huge and enormous data, and the world of communications has become crowded with transmitted and received data, and this development requires revolutions. In the world of wireless communications until we have now reached the world of the fifth generation and the world of augmented virtual reality, and what it requires to connect what affects human life from the home to the car to the workplace, and in parallel with the revolutions in the world of applications, a revolution occurred in the world of antennas, which is the means through which data is transmitted.

While doing a review of 5G antennas, The MIMO antennas are the best candidate for smartphones while the massive MIMO antennas can be used at base stations. In MIMO metal rim antenna design the use of carrier aggregation reinforces transmission rate. Also, design features like orthogonal polarization boost isolation thereby enhancing the overall efficiency.

Keywords: Fifth Generation antennas, Technologies, MIMO antennas.

1. Introduction:

As a result of the development in the world of technology and discoveries in the world of electromagnetism, wireless communication and called the mobile phone appeared to mankind in the twenties of the nineteenth century (Gupta & Bage, 2020).
Looking at the beginning of the history of mobile phones, communication networks depending on the cable network between cities, including, for example, the communication network that appeared in the United States, specifically between New York and Boston. There was the birth of the first cellular network in about 1970 (Agar, 2003). In addition, the network operators used waiting lists while candidate customers waited hoping to be so lucky to get a mobile phone connection (Agar, 2003). The reason for the waiting list is that the radio spectrum is a limited resource. The advent of modern automated mobile telecommunications systems using cellular structures has helped alleviate scarcity problems by providing more efficient use of frequency space. Two issues are critical in cellular architectures - peregrination and handover. Roaming is required to track calls, and handover is required to allow user to conduct phone conversations as they move from one cell to another (Dunnewijk & Hulte´n, 2007).

The fifth generation of mobile networks, or 5G, is the most recent cellular generation that is facilitated by the new radio (NR) technology, which is based on Orthogonal Frequency Division Multiple Access (OFDMA) (Ahmadi, 2019).

5G is extremely efficient and capable of supporting a large number of devices, which can help many industries modernize. It can also work in a wide range of frequency ranges 4 including both great and slight frequencies. Although the 5G higher-frequency bands devise limited penetration, they have exceptionally minimum latency (less than 1 ms), making them excellent intended for real-time services (Xiang et al., 2016).

With this development in networks accompanied by a huge development in the antenna system used, in this research, we will present a brief history of the antennas and details will be given about three examples of the latest antennas used in the fifth generation

Antenna is a specialized transducer or conductor by which electromagnetic waves are sent out or received. It also use to receive and transform electromagnetic signal into electrical signal.

Practically antennas are the device use to send information inform of electromagnetic wave signal to communicate wireless or unguided way (Dhande, 2009).

The antennas are of various kinds and having different characteristics according to the need of signal transmission and reception, in this review, we will explain two types of antennas in the fifth generation

1. Compact Wide-Band Microstrip Patch Antenna:

The antenna is designed over a ground plane, having a minimal size of 0.308λo × 0.308λo × 0.009λo with design centre frequency 22 GHz. In order to enhance the antenna bandwidth, a T shaped slotted Patch and rectangular notch has been introduced. The antenna is covering a wideband of frequency range 23.60 GHz to 44.20 GHz, with a gain of 4.198 dB at 27.30 GHz and 4.703dB at 39.90 GHz centre frequency. antenna is compact as well as suited for higher band of 5G communications. In addition, the designed antenna exhibits omni-directional radiation pattern which is required for 5G applications (Gupta & Bage, 2020).

Antenna Design:

Figure (1) shows that the top and bottom view of the proposed patch antenna with their design steps and respective dimensions. The antenna is designed at printed Roger RT/Duroid 5880 dielectric substrate having thickness of value 0.127 mm, copper cladding 0.035 mm, loss tangent 0.009 and dielectric constant of 2.2

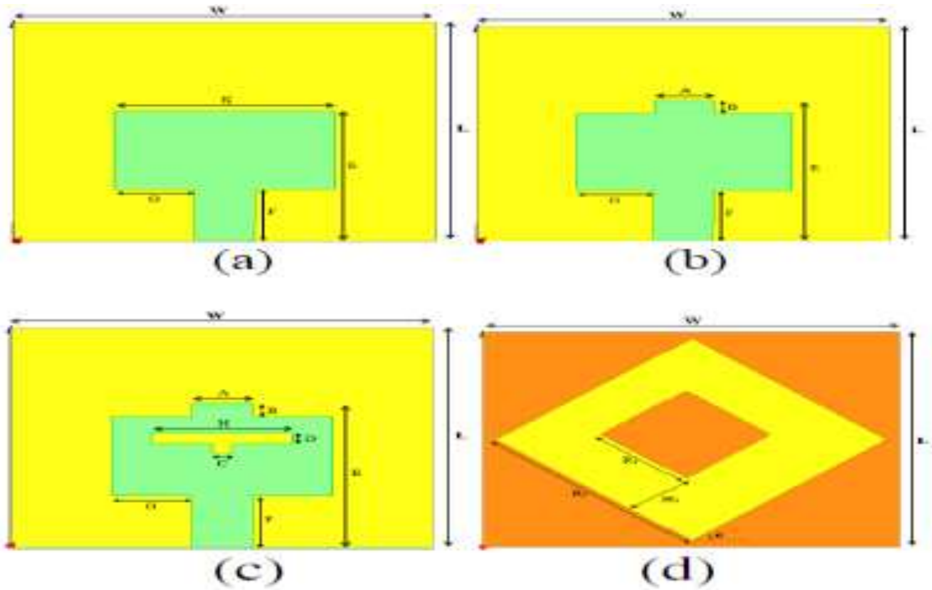

Figure 1. Designed antenna with defected ground structure of size 4.20 x 4.20 x 0.127 mm3 (a) conventional rectangular patch antenna having patch size 2.75 x 2.20 mm2; (b) Rectangular patch antenna with rectangular notch of size A = 0.60mm, B = 0.25 mm; (c) Top view of the proposed antenna having values C = 0.20mm, D = 0.20mm, E = 2.75mm, F = 1mm, G = 0.80mm, H = 1.4mm; (d) Bottom view of proposed antenna with parameters R1 = 1.2mm, R2 = 2.80mm, R3 = 1.23mm.

The antenna has been simulated using Ansys HFSS (v.15), and energized with microstrip line feed.

Figure 2 shows the |S11| vs. frequency graph. It has been observed that, proposed antenna shows wideband characteristics which cover a 10dB frequency range from 23.60–44.20 GHz and resonated at frequencies of 27.30 GHz and 39.90 GHz. The figure also shows that, the return loss of the proposed antenna at resonant frequency is 14.085 dB and 18.254 dB. The impedance bandwidth of the proposed design is 20.60 GHz (60.77%).

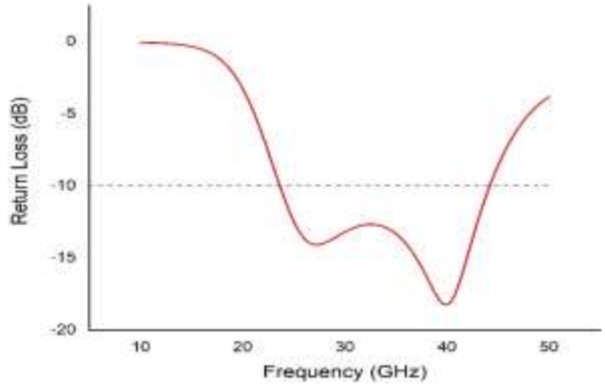

Figure 2. Simulated |S11| of antenna.

Current Distribution:

Figure (3). Shows surface current distribution of the antenna at two different resonant frequencies. Figure (3) (a), shows that the surface current at lower frequency i.e. 27.30 GHz. The figure reveals a current magnitude is stronger near the bottom of the patch and around the feed line. The figure also shows that surface current is stronger behind the line feed and vertex of the slotted square on the ground plane.

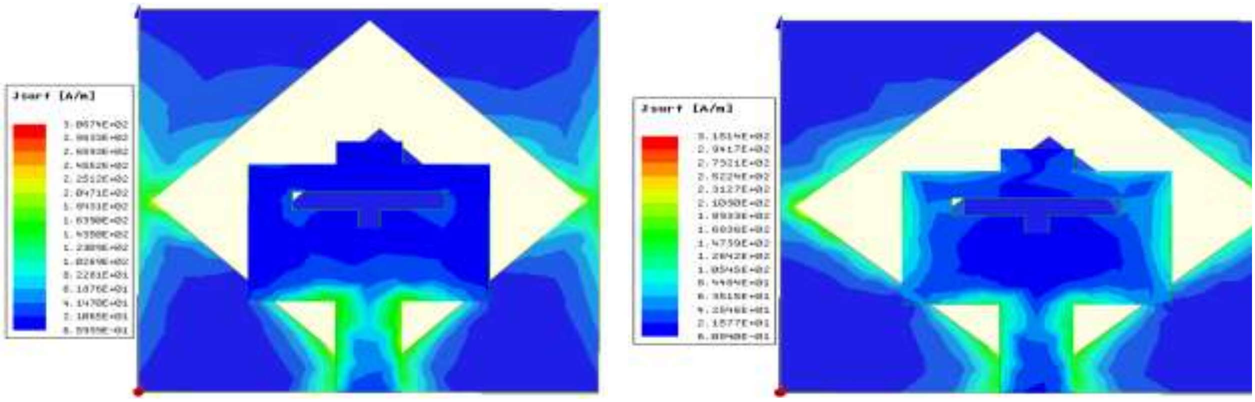

Figure 3. Current distribution of proposed antenna (a) at resonant frequency of 27.30 GHz and (b) resonant frequency of 39.90 GHz.

The Figure 3 (b) shows the surface current density at higher resonant frequency i.e. 39.90 GHz. The amplitude of the current magnitude is stronger near the bottom and sides of the rectangular patch and around the feed. The figure also shows that amplitude is stronger behind the line feed and vertex of the slotted square on the ground plane.

Radiation Pattern:

The E- plane and H-plane radiation patterns of the antenna at two different resonant frequencies are shown in Figure 4 (a) and (b).

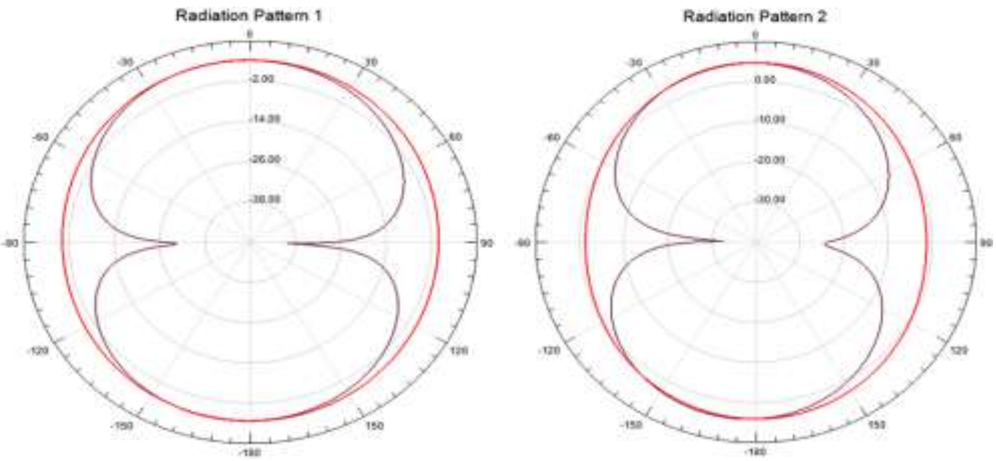

Figure 4. Radiation Pattern of proposed Antenna with phi = 00 & 900 at resonant frequency (a) 23.70 GHz and (b) 39.90 GHz.

The omni directional radiation patterns are achieved at both resonant frequencies i.e. 27.30 and 39.90 GHz. The omni directional radiation patterns are the necessary requirement for the 5G mobile communications.

Comparison Table:

The comparison between this antenna with the few other antennas [2, 3, 4, 5] is tabulated in Table 1. The table shows that, this antenna has small in size from other antenna. The table also reveals that, the proposed antenna has higher gain other than ref (Jilani & Alomainy, 2016).

Ref.	Antenna Type	BW in GHz	Freq. GHz	gain in dB	Size mm3
[2]	L-shaped patch	5/6	28/38	2.06/ 4.76	8 x 7.5 x 0.127
[3]	T-shaped patch	3.60	28/38	3.61/ 5.36	20 x 20 x 1.575
[4]	π-shaped patch	1.02/ 3.49	38/40	3.86/ 1.86	N.A.

[5]	CPW	N.A.	32/37.5	6.06	16 x 16 x 0.135
This antenna	T-slotted patch	20.60	27.3/39.9	4.198/ 4.703	4.2 x 4.2 x 0.127

Table 1. Comparison of characteristics of this antenna with few other antennas.

2. Four Elements MIMO Antenna:

Antenna Design:

The design of a four-element dual-band 28/38 GHz printed slotted microstrip antenna for the upcoming 5G mobile networks is introduced. By precisely employing two antennas of a similar variety at the lower verge and employing two antennas of a similar variety at the higher edge situated on the same 110 × 55mm2 PCB of the mobile substrate, the four-element MIMO antenna is formed. The four-port MIMO antenna is considered as displayed in Fig. 5.

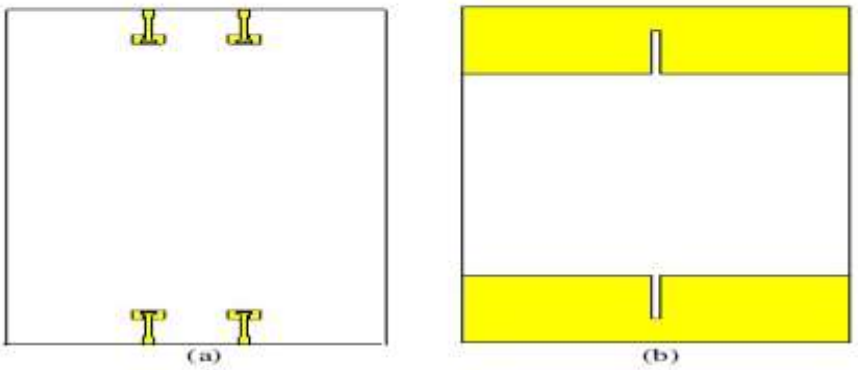

Figure 5. Four-element MIMO antenna. (a) Top view and (b) bottom view.

Return Loss and Mutual Coupling:

The reflection coefficients |*S*11| for the introduced four-element 5G MIMO antenna intended from simulation and measurement are illustrated in **Fig 6**. It is obvious that the introduced MIMO antenna has moral matched impedances at the two wanted frequency bands of 28/38 GHz for |*S*11| smaller than −10 dB. Due to the similarity between the four elements, only *S*11, *S*21, *S*31, and *S*41 coefficients are displayed in figures.

The isolation is superior to −28.32 dB and −26.27 dB for the higher and lower frequency bands, respectively. It is distinguished that inter-element mutual coupling values are reduced from the two elements MIMO system introduced in this work.

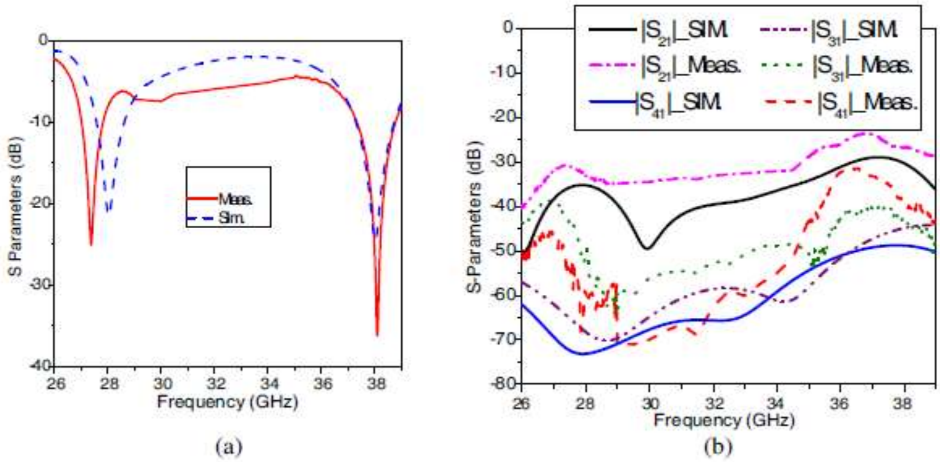

Figure 6. Four-element MIMO antenna. (a) Reflection coefficients and (b) transmission coefficients.

Surface Current Distribution:

Figure 7. Demonstrates the surface current distributions of the four-element MIMO antenna at frequencies of 28 and 38GHz.

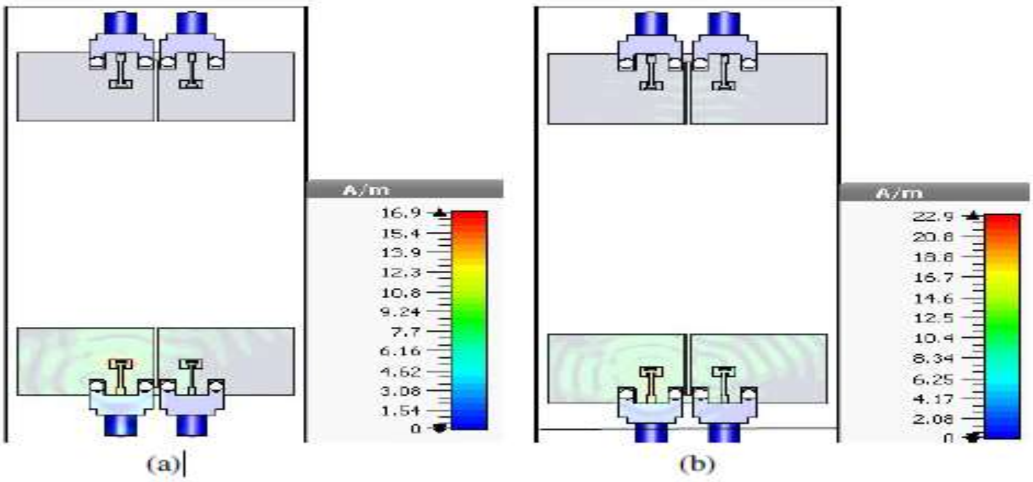

Figure 7. Current distributions of introduced four element MIMO antenna at (a) 28GHz and (b) 38 GHz.

Gain and Radiation Pattern:

The radiation pattern of the introduced four-element MIMO antenna outcomes from the simulation is obtained in **Fig. 8**. The antenna system shows available maximum and stable directivity, gain, and radiation efficiency of 8.409 dBi 7.946 dBi and 89.89% for the first band of 28 GHz and 8.808 dBi, 8.265 dBi and 88.25 % for the second band of 38 GHz, respectively. The attained sidelobe levels are −18.2dB and −3.5 at 28GHz, 38GHz, respectively.

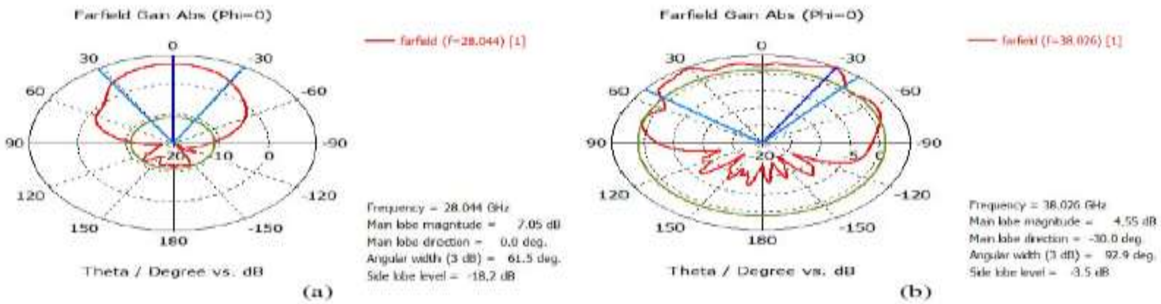

Figure 8. Simulated gain of introduced four element MIMO antenna for (a) 28GHz and (b) 38GHz.

Envelope Correlation Coefficient:

For the introduced four-element MIMO antenna system, ρ is intended at the two frequencies 28 GHz and 38GHz, and the equivalent gained values are 2.46 × 10−5 and 7.65 × 105, respectively as exhibited in Fig. 9. It is noticeable that the considered MIMO antenna system gratifies the requirements for decent MIMO operation for 5G mobile applications. Fig. 10 displays the fabricated four-element MIMO 5G antenna. Such designs are very smart to be combined in the upcoming mobile terminals for short-range 5G mobile communications. The simulated reflection and mutual coupling coefficients, gain, and envelope correlation coefficient values of the introduced two and four elements antennas at the two wanted frequencies are exposed in Table 2.

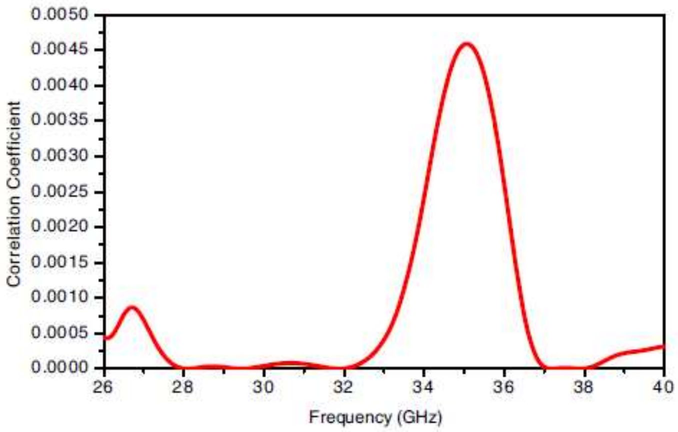

Figure 9. Envelope correlation coefficient of 4-element MIMO antenna.

Figure 10. Photograph of introduced four element MIMO 5G antenna.

Table 2. Final parameters of the introduced antennas.

Antenna Design	Resonance Frequency (GHz)	Reflection Coefficient (dB)	Mutual Coupling (dB)	Gain (dBi)	Envelope Correlation Coefficient
Two Element Different Antennas	27.946	-27.84	-30.21	7.18	-
	37.83	-18.35	-29.91	9.24	-
Two Element Symmetric Antenna	28.044	-19.91	-29.34	7.88	1.36×10^{-5}
	37.928	-26.12	-27.28	9.49	3.86×10^{-5}
Four Element MIMO Antenna	28.044	-21.57	-28.32	7.95	2.46×10^{-5}
	38.04	-24.59	-26.27	8.27	7.65×10^{-5}

Conclusion:

In conclusion, it becomes clear to us the tremendous development in the world of communications, especially the antenna sector used in the fifth generation, a comprehensive review of different 5G antennas Technology done with the comparison and analysis of their performance enhancement techniques. Also, 5G communication requirements are elaborated. While doing a review of 5G antennas, The MIMO antennas are the best candidate for smartphones while the massive MIMO antennas can be used at base stations. In MIMO metal rim antenna design the use of carrier aggregation reinforces transmission rate. Also, design features like orthogonal polarization boost isolation thereby enhancing the overall efficiency.

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