MIMO antenna for mm-wave 5G application

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Abstract

Paper introduces a MIMO (multiple inputs multiple outputs) antenna for the 5G (Fifth generation) application. This antenna is a low-profile antenna and has a low cost. This antenna has a compact size of 24 x 12 x 1.5. Simulated results of the antenna introduce a 10dB impedance bandwidth of 2.75 GHz (24.38 GHz to 27.13 GHz). This antenna provides a total gain of more than 2.79 dBi for the entire bandwidth. This antenna structure provides minimum isolation of less than -20db for operating bandwidth. Radiation efficiency received is 99%. ECC for proposed antenna is 0.0005. Diversity gain for proposed work is 9.99. These important features make it appropriate for 5G applications.

Keywords. MIMO, mm-wave (Millimeter wave), 5G (Fifth Generation).

1. INTRODUCTION

In recent years there is a demand for maximum throughput, high data rate and, a wide spectrum, and smart home life. As a result, 5G technology come up which is the most promising technology. Big challenge for 5G device is to provide high gain, minimum radiation losses, and enhance bandwidth. The 5G technology required an antenna with minimum path loss, good radiation pattern, and low latency [1]-[6]. Millimeter wave frequency band was provided for different 5G application.Now a days the mm-Wave (Millimeter-wave) technology has attracted the industry and academia for its various advantages. It's a promising technology for applications like the Internet of Things (IoT) used for smart cities, Machine to Machine (M2M) communication, and 5G wi-fi routers and repeaters. 26 GHz spectrum used in 5G technology cover band from 24.25 GHz and 27.5 GHz is used for different application like mobile communication, fixed Links, and Satellite Receiver Earth stations. Further 5G antenna design requires an antenna with improved performance. That can be achieved by using MIMO antenna structure. The use of multiple antennas at the transmitting and multiple antennas at the receiving end further improves link reliability, data rate, and channel capacity [7]. MIMO utilizes more than one transmits and receive antennas which multiplies the capacity of the link. This is the technique that simultaneously transmits and receives multiple channels over the radio link. One key feature of the MIMO antennas is without enhancing signal power it increases transmission range. As compared to an array antenna system Multiple antennas are preferred because it makes the system simpler. MIMO antennas are applied in 5G communication to gain maximum throughput, high efficiency, high data rate, and minimum latency. One of the factors of the 5G antenna design is compact size. But if the spacing between the antennas is reduced then it leads to enhance in mutual coupling. This mutual coupling linking multiple antenna structure gets increased because of the huge flow of current from the exciting port to the non-excited port or because of space radiation. The main question in the 5G antenna design is to lessen mutual coupling between multiple antennas by maintaining the compact size. Different mutual coupling reduction techniques are used like Frequency selective surface [8], meta surface shields [9], defected ground planes [10][11], and EBG structure [12] to improve isolation between two antenna elements. Ansys HFSS software is used to simulate a Single patch and MIMO antenna structure. In proposed work wide bandwidth is achieved. The paper is arranged like this: In section II single patch antenna geometry is presented. This section provides Simulation results for the evolution steps of antenna design, return loss, gain, and radiation pattern. In section III MIMO antenna geometry and simulated results of return loss, and isolation is presented. Finally, in section IV work is concluded.

2. SINGLE PATCH ANTENNA DESIGN IN TEXT

The mm-wave 5G antenna is designed using Roger RT duroid 5880 substrates with tan δ = 0.0009 and ε_r = 2.2. The single patch antenna is designed with a substrate dimension of 12 x 12 mm2. Fig. 2.1 (a) demonstrate the evolutionary stage of the suggested mm-wave single-patch antenna.

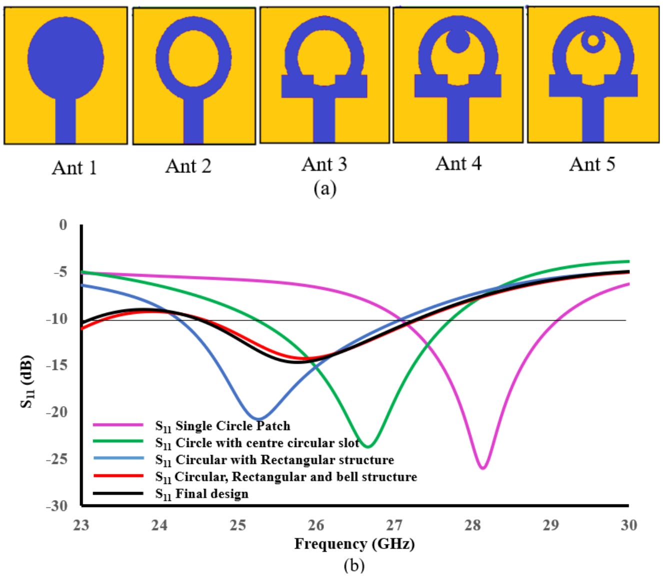

Figure 2.1 (a) Sigle patch antenna evolution stages. (b) S_{11} for each stage of antenna design.

Fig. 2.1 (b) represents the S_{11} of each evolutionary stage of the antenna design. In the first stage of antenna design Ant 1 which is resonating at 28GHz. Further to resonate at a lower frequency circular slot is inserted in the circular patch. Now antenna resonates at 26. 5GHz. Further to improve the bandwidth and to resonate at a lower frequency rectangular structure is inserted in the bottom corner of the circular patch as represented by Ant 3 and Ant 4. In the final stage of the antenna design Ant 5 one more circular slot is inserted to further improve bandwidth which covers lower mm-wave 5G frequency band. Fig 2.2 (a) and (b) represents the mm-wave single patch antenna. The optimized value of the designed structure is presented in table I. The scattering parameter result is shown in fig. 2.2 (c). From the simulated result presented in Fig. 2.2 (c), bandwidth achieved for the antenna is 2.75 GHz

(24.38 GHz to 27.13 GHz). Figure 2.3 depicts the total gain. The total antenna gain is more than 2.79 dBi and the maximum gain achieved is up to 4.44 dBi. Fig. 2.4 (a) and (b) represents E-plane cross-polarization and co-polarization for single patch antenna. The simulated result of the antenna radiation pattern is presented in fig. 2.4 (c).

Table 1. ANTENNA DESIGN

Parameter	Dimension (mm)	Parameter	Dimension (mm)	Parameter	Dimension (mm)
A	12	d	5	i	2
B	12	c	1	j	3
h	1.5	e	2.2	l	3.9
c	7.4	g	1	m	2

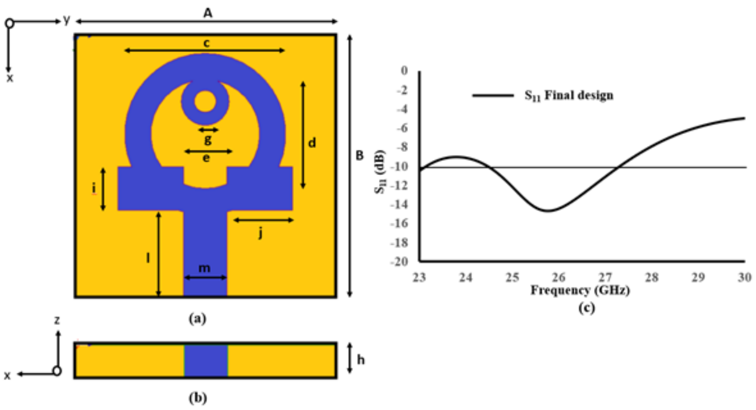

Figure 2.2 (a) Mm-wave 5G antenna structure. (a) Top view. (b) Side view. (c) S_{11} for single patch antenna.

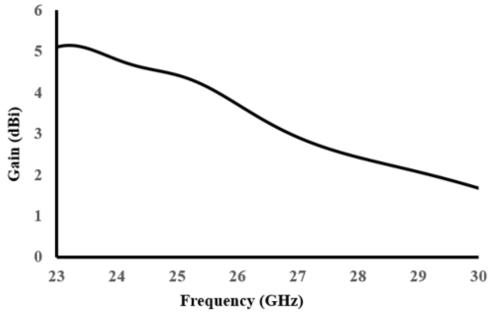

Figure 2.3 Gain for the single antenna structure.

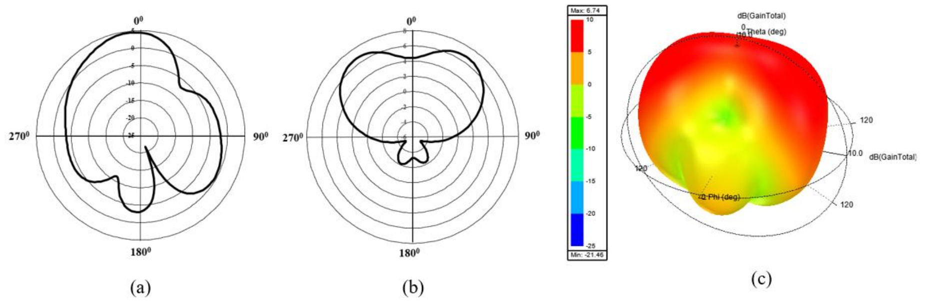

Fig. 2.4. Single patch antenna structure E-Plane (a) Co-polarization. (b) Cross Polarization (c) Radiation pattern.

3. MIMO ANTENNA DESIGN AND RESULT

As now a days because of the increase in demand for IoT devices and smart devices 5G devices are recommended to provide link reliability, much faster data

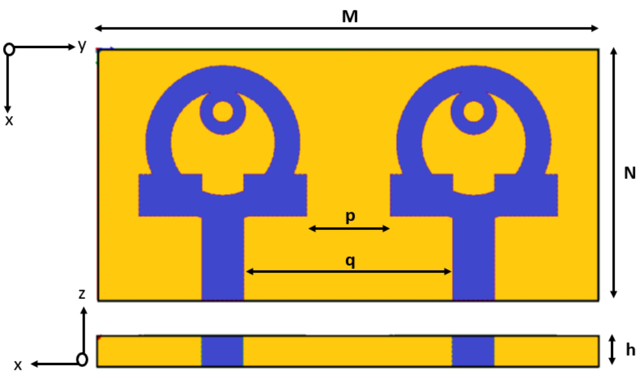

Figure 3.1 MIMO antenna geometry M = 24 mm, N = 12 mm, h = 1.5 mm, p = 4 mm, q = 10 mm.

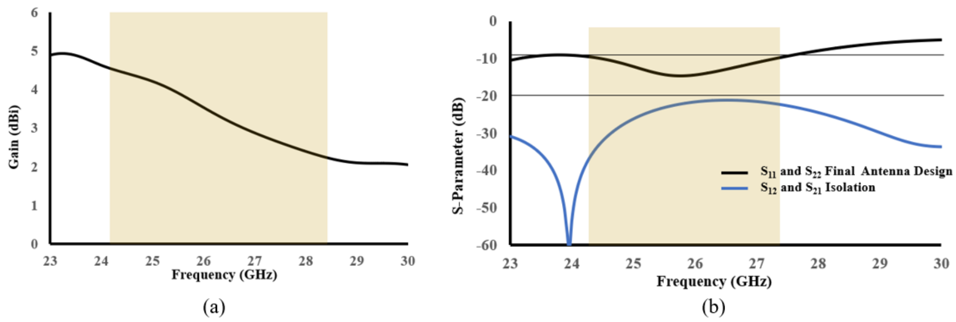

Figure 3.2 (a) Gain of MIMO antenna geometry. (b) S-parameter for MIMO antenna (S11, S22, S12 and S21).

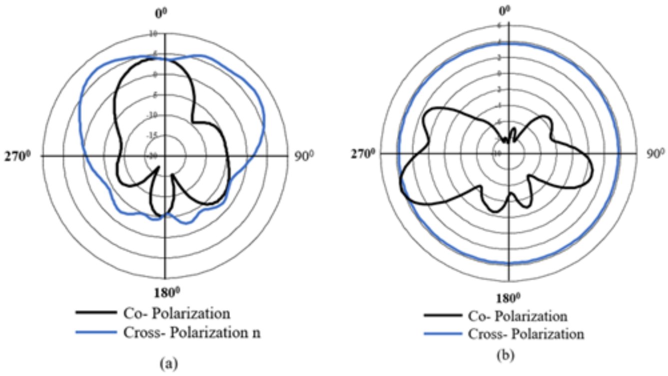

Figure 3.3 (a) Cross - Polarization and Co – Polarization for E-Plane (b) Cross - Polarization and Co – Polarization for H-Plane.

rate, and improved capacity. The main requirement of a 5G antenna is a MIMO antenna. A Two-port MIMO structure is designed as presented in fig. 3.1. Two antennas are sharing the same substrate. With substrate size of 24 mm x 12 mm. Fig. 3.2 (a) shows the gain of the MIMO antenna. As the geometry of all two antennas is kept similar so there is no change in bandwidth received for antennas. This bandwidth received is remaining the same as bandwidth received for a single patch antenna in between 24.38 GHz to 27.13 GHz.

Table 2. ANTENNA DESIGN COMPARISON OF VARIOUS PARAMETERS

Ref	Size (mm2)	Substrate	Center freq. (GHz)	No. Of ports	Radiation Efficiency (%)	BW (GHz)
[13]	20 × 27.7	Rogers RO4003C	28.45	2	91	3.8
[14]	60 x 60	PET	26	4	61	-
[15]	20 x 20	Rogers 5880	28	2	-	0.85
[16]	157 x 70	Rogers 5880	28	8	60	1.62
[17]	31.77 × 39	Rogers 6010	26	2	-	1.9
[18]	35 x 35	Rogers 6003	26	4	96	3
[19]	50 x 50	Rogers 4350	28	2	86	1
This work	24 x 12	Rogers 5880	25.7	2	99	2.74

One of the factors of the 5G antenna design is compact size. But if the spacing between the antennas is reduced then it leads to increase in the mutual coupling. Mutual coupling must be less than -20dB. In the proposed design isolation achieved is less than -20 dB for entire bandwidth. Fig. 3.2 (b) shows the reflection coefficient and mutual coupling between antenna. Fig. 3.3 presents E-Plan and H-plane radiation pattern. Simulated radiation efficiency received is 99%. Envelope correlation coefficient (ECC) for proposed antenna is 0.0005. Diversity gain achieved is 9.99 for antenna presented.

4. CONCLUSION

This mm-wave antenna is a low profile, low-cost antenna, and which can be used for the 5G application. The size of the MIMO antenna is 24 mm x 12 mm x 1.5 mm. Simulated results show that the maximum impedance bandwidth provided by a single patch as well as a MIMO antenna is 2.74 GHz (24.38 GHz to 27.31 GHz). Antenna provide maximum gain of 4.4 dBi. Simulated results provide minimum isolation between antenna is less than -20dB. ECC value received for proposed antenna is 0.0005. Radiation efficiency received is 99%. Diversity gain for proposed work is 9.99. Because of all these features, this antenna design is useful for 5G applications.

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Biographies

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