Analysis and Design of a High-Performance 28 GHz MIMO Antenna System for Mobile Applications

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ABSTRACT:

A compact 28 GHz MIMO (multiple-input, multiple-output) antenna for mobile applications is designed. The antenna structure is placed at the center of the dielectric substrate. The material of the patch is Perfect Electric Conductor (PEC) and the substrate is Rogers RT 3006(lossy). The antenna is optimized to provide high gain, low correlation, and wide bandwidth for efficient data transmission. The design is simulated using Computer simulation technology (CST) software, and the performance of the antenna is analyzed in terms of S-parameters, radiation patterns, and channel capacity. The outcome of this paper is a high-performance MIMO antenna design that can be used in future mobile communication systems

Keywords: 5G-NR, MIMO, PERFORMANCE ANALYSIS

1. INTRODUCTION:

5G promises to deliver enhanced bandwidth, high data transfer rates, and lower latency to a large number of electronic devices. It is expected to facilitate advancements in self-driving vehicles, virtual reality (VR), and the Internet of Things (IoT).Official specifications or documents for 5G have not been finalized by telecommunication enterprises or regulation bodies like 3GPP, WiMAX, or ITU-R. MIMO (Multiple Input Multiple Output) technology is a key technology in modern wireless communication systems, including 4G LTE and 5G networks, Wi-Fi, and other wireless systems. MIMO technology uses multiple antennas at both the transmitter and receiver ends of a wireless communication link. It increases data rates, improves network capacity, and enhances signal reliability. MIMO achieves this by exploiting the spatial diversity of the radio channel, allowing signals to be transmitted and received through multiple paths. MIMO can be implemented through techniques like spatial multiplexing, diversity, and beamforming. Spatial multiplexing allows multiple data streams to be transmitted simultaneously over the same frequency band, increasing the data rate. Diversity techniques improve reliability by transmitting the same signal over multiple antennas. Beamforming uses multiple antennas to focus the wireless signal in a specific direction, improving signal quality and reducing interference. Overall, MIMO technology has revolutionized wireless communication, enabling higher data rates, greater network capacity, and improved signal quality. It is expected to continue playing a crucial role in the development of future wireless networks, including 5G.In [1] the design and characterization of a compact broadband antenna and its MIMO configuration for 28 GHz 5G applications. The antenna was designed using Rogers RT/5880withathickness of 1.575 mm and has an overall compact size of 30 mm ×30mm. a compact2×2 MIMO antenna with polarization diversity is designed for high channel capacity systems. The mutual coupling between the closely spaced antenna elements are reduced by using two consecutive iterations of defected ground structure (DGS). The proposed MIMO antenna system offers broad bandwidth, high gain, low mutual coupling, and low envelope correlation coefficient along with high diversity gain, low mean effective gain, and low channel capacity loss.[2] explains the design of Multiple Input Multiple Output antenna which resonates at a frequency of 28 GHz. The antenna finally achieves a maximum gain of 11.33 dBi, reflection coefficient is of -48 dB. VSWR of 2:1 and bandwidth of 1.93 GHz is obtained.[3] involves the design of printed antenna for 5G communication. The proposed structure has 7.9*14.71*1.6mm dimension and substrate used in a design is FR-4. The antenna has the operating band from 27.67 GHz to 28.31 GHz band.[4] illustrates the design and analysis of a microstrip patch antenna operating at a frequency of 28 GHz. The obtained beam gain of 7.58 dBi, directivity of 7.509 dBi, the radiation efficiency of 98.214% and bandwidth of 1.046.It is a potential candidate antenna type for 5G communication systems.

2. MIMO ANTENNA:

Modern wireless and mobile applications with low cost and lightweight antennas are integrated within the microwave circuits. MIMO consists of microstrip patch antennas (MPAs) and is implemented on a PCB with a thin layer of perfect electric conductor (PEC) over the dual sides of the dielectric substrate like FR-4 and Rogers RT etc. MIMO antenna technology offers required data rates for base station (BS), automobile, pedestrian, satellite, and radar applications. Modern and smart technologies with MIMO antenna systems are reported for local area network (WLAN) licensed/unlicensed bands, wireless inter-operability for microwave access (WiMAX) bands, global system for mobile communication (GSM), long-term evolution (LTE), global positioning system (GPS) applications, 5G and future generations. The MIMO wireless system has demonstrated the capability to increase the communication spectral efficiency in a multipath environment. By using MIMO technology, So, that designed MIMO antenna. The rectangular MIMO antenna is used in wireless communication due its low profile, small size and light weight. MIMO antenna consist of a radiating patch on one side of a dielectric substrate which as a ground plane on the other side. This antenna depends on the line feeding technique and its performance characteristics which include return loss, bandwidth, gain and VSWR are obtained from the simulation.

3. ANTENNA DESIGN:

1)Operating frequency (fr): The millimetre wave frequency for 5G mobiles and other applications is selected as 28 GHz. 2)Dielectric constant of the substrate (£r): The dielectric material selected for design is Rogers RT 3006 having dielectric constant of 4. A substrate having high dielectric constant should be selected because higher the dielectric constant smaller the dimensions of the antenna. 3)Height of dielectric substrate (h): For the MIMO antenna which are used in cellular phones or hand-held devices it is essential that the antenna is not bulky. Here Rogers RT 3006 substrate of standard height 0.098 mm is selected.

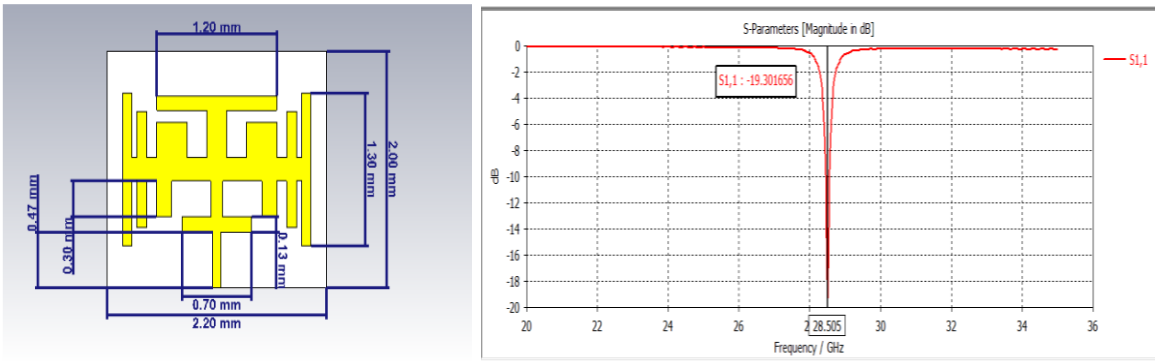

Fig.3.1: Single element antenna and simulated Return loss of stage 1

The return loss of antenna is -19.301 dB, resonating at 28.5 GHz frequency. The bandwidth obtained is 0.115 GHz with VSWR value of 1.2.

The proposed MIMO antenna is realized for 5G&WLAN working at 28 GHz. Generally, mm Wave is regarded as wavelengths from 1 to 10 mm and frequencies from 30 to 300 GHz, but current 5G communications include frequencies below 30 GHz, such as the 28 GHz band, and frequencies up to about 100 GHz as the upper limit. The proposed system involves designing of the antenna at 28 GHz frequency.

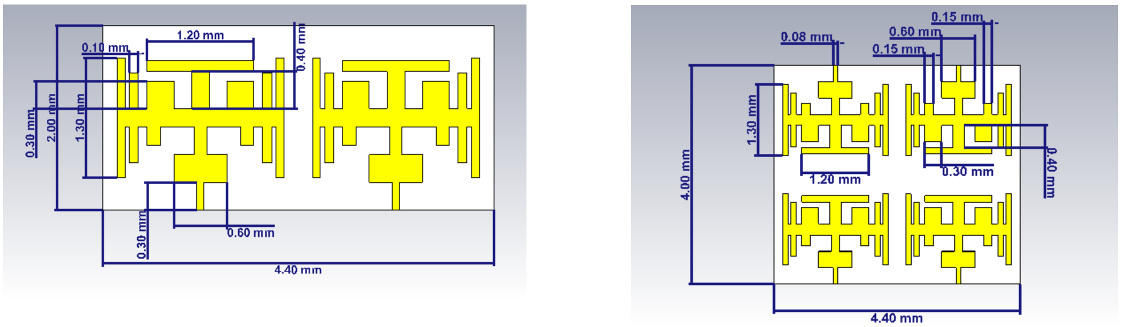

Fig.3.2: 2-Element MIMO antenna - Stage II & 4 -Element MIMO antenna - Stage- III

The proposed antenna has 4-elements arranged in a 2x2 pattern. The width and length of 4-elements MIMO antenna is 4.4 mm x 4 mm. This compact structure works at 28GHz and exhibits improved resonance characteristics.

4.SIMULATION RESULTS:

The return loss of 2-element MIMO antenna is -29.89 dB at 28.29 GHz. The bandwidth is calculated as 0.139 GHz with VSWR value of 1.06

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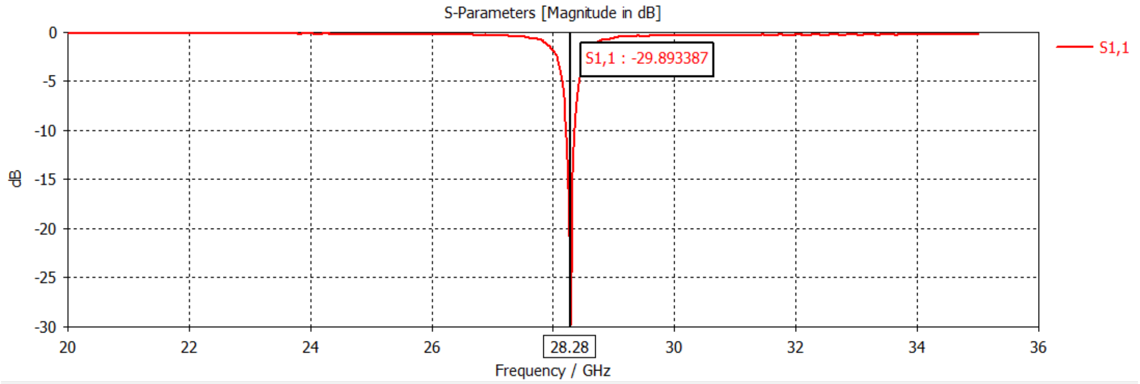

Fig 4.1. Return loss of stage 2- 2 Element MIMO antenna

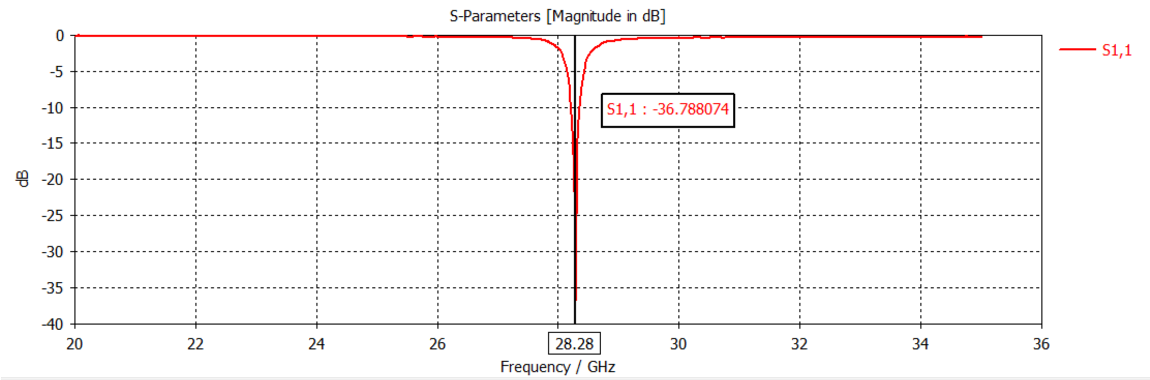

Fig 4.2 Return loss of stage 3- 4 Element MIMO antenna

The return loss of 2x2 :4 element MIMO antenna is –36.78 dB at 28.28 GHz. The bandwidth is calculated as 0.142 GHz with VSWR value of 1.02

5. PERFORMANCE ANALYSIS OF MIMO ANTENNAS:

Performance analysis of MIMO antennas involves evaluating various key metrics to assess their effectiveness in wireless communication systems. Here are some important performance parameters that are commonly analysed:

Channel Capacity: Channel capacity is a fundamental metric that measures the maximum achievable data rate of a MIMO system. It quantifies the amount of information that can be reliably transmitted over the wireless channel. The capacity depends on factors such as the number of antennas, signal-to-noise ratio (SNR), and channel conditions.

Spectral Efficiency: Spectral efficiency measures the amount of data that can be transmitted per unit of frequency bandwidth. It indicates how efficiently the available frequency spectrum is utilized. MIMO antennas can achieve higher spectral efficiency compared to single-antenna systems by exploiting spatial multiplexing.

Diversity Gain: Diversity gain refers to the improvement in signal quality and reliability achieved by using multiple antennas. It helps mitigate the effects of fading and interference in wireless channels. The diversity gain is measured in terms of signal-to-noise ratio improvement and error rate reduction.

Spatial Multiplexing Gain: Spatial multiplexing gain is the increase in data rate achieved by transmitting multiple independent data streams over the same frequency band using multiple antennas. It allows for parallel transmission of multiple data streams, increasing the overall throughput.

Correlation and Condition Number: Correlation measures the similarity between the signals received by different antennas in a MIMO system. Low correlation is desirable to maximize the benefits of spatial multiplexing. The condition number is a measure of the channel matrix's sensitivity to noise and interference. A lower condition number indicates better channel quality.

Beamforming and Directionality: Beamforming is a technique used in MIMO systems to focus the transmitted power in a specific direction or towards a desired user. The beamforming capability and the directivity of the antenna determine the spatial selectivity and coverage of the MIMO system.

Interference Mitigation: MIMO antennas can help mitigate interference by using spatial filtering techniques. The interference rejection capability and the ability to separate desired signals from unwanted interference are crucial factors in the performance of a MIMO system.

Antenna Gain: Antenna gain measures the ability of the antenna to concentrate the transmitted or received power in a specific direction. Higher antenna gain improves the link budget and extends the coverage range of the MIMO system.

These performance parameters can be evaluated through theoretical analysis, computer simulations, and practical measurements. They provide insights into the capabilities and limitations of MIMO antennas, allowing for optimization and improvements in the design and deployment of wireless communication systems.

STAGES / PARAMETERS	I	II	III
Resonant Frequency	28.5 GHz	28.26 GHz	28.28 GHz
Return loss	-19.301 dBi	-29.89 dBi	-36.78 dBi
VSWR	1.243	1.06	1.02

Bandwidth	0.115 GHz	0.139 GHz	0.142 GHz

Table 5.1 – Performance comparison antenna stages

The table explains the performance improvement of 4-element MIMO antenna in comparison with previous stages. 28 MHz improvement in bandwidth is reported with an increase of 17 dB return loss. The proposed antenna gives a VSWR value of 1.02 which is close to 1, the ideal value shows near perfect impedance matching.

6. CONCLUSION

A compact 4-element MIMO antenna with size of 4.4mm x 4mm x 0.098mm is designed and simulated using CST Microwave Studio Software. The resonance behavior of the antenna is improved by increasing the electrical length of the patch. The proposed antenna operates at 28 GHz with a return loss of -36.78 dB and VSWR of 1.02. The proposed antenna is very compact and very easy to fabricate. The 28 GHz band is used for WLAN and 5G applications.

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