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Multi Input Multi Output Antenna Array Design for 5G N78 Applications in Smartphones

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ABSTRACT

This article presents a compact high isolation Multi Input Multi Output (MIMO) Antenna system operating on (3408 - 3760) MHz for the fifth generation N78 Applications in mobile phone terminals. The suggested MIMO antenna system is built from four antenna elements. These antennas are placed over two slim side borders of a mobile device's frame to adhere to the current trend of slim and full-screen smartphone devices. The antenna element is composed of two parts: the front part and the back part. The front part consists of the second iteration of Moore curve fractal geometry and an I-shaped feeding line. The back part is of an L-shaped shorted to the system's ground plane. The desirable antenna diminishment is accomplished based on Moore curve fractal geometry. Low mutual coupling among antennas is attained based on self-isolated and spatial diversity methods, which are less than -16.6 dB. The scattering parameters, antenna gains, antenna efficiencies, and radiation pattern characteristics have all been examined to gauge the performance of the suggested antenna element. In addition, the MEGs and ECCs are examined to understand the MIMO performance of the suggested system. The proposed four-element MIMO antenna system achieves the desired antenna and MIMO characteristics, making it a strong contender for the upcoming 5G mobile devices.

1. Introduction

With the development of wireless communication technologies, there has been a recent increase in demand for smart services and high transmission rates. The 5G wireless communication systems have gained more attention in both academic and industrial domains because of their high transmission rate, high access rate, short latency, and significant spectral efficiency [1]. In 5G mobile devices, the MIMO antenna method has been employed to increase channel capacity and spectrum efficiency without needing extra bandwidth or transmitting power [2]. There are two situations in which the MIMO antenna systems can be used. Since the same data

stream is sent across different antennas to propagate over uncorrelated propagation (spatial) pathways, the first technique is known as a spatial diversity technique. This method strengthens the system's reliability and renders it immune to multipath fading. The second scenario uses a technique known as spatial multiplexing, in which the data stream is split into pieces, and each piece is attached to an antenna for transmission via several propagation channels. This is an intriguing method used in modern communication systems to improve the sent data rate without needing more transmit power or bandwidth [3].

Choosing between these two methods

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depends on how the wireless fading environments work. High SNR (Signal to Noise Ratio) multipath wireless channels effectively use the MIMO system with spatial multiplexing technology. The spatial diversity strategy is the remedy in a wireless channel with poor multipath performance (low SNR) [4]. But if more antennae are added, the isolation issue will worsen due to the mobile terminal device's constrained area. As a result, the influence of this problem will directly affect the performance of the antenna system [5]. Therefore, improving the performance of MIMO antenna systems in terms of low Envelope correlation coefficients (ECCs) and good isolation with a small antenna size is still challenging.

Much work has been done for MIMO antenna systems to perform as desired and improve isolation. A two-element MIMO antenna system using the decoupling network isolation technique was published in [6–9], while a two-element MIMO antenna system using the hybrid electric and magnetic coupling technology was used in [10]. A four-antenna-element MIMO system based on self-decoupled antenna pairs has been given in [11], while a four-antenna-element MIMO antenna system using the spatial diversity technique has been employed in [12]. Other methods have also been used, including the polarization diversity method [13], the hybrid decoupling method (ground slot and neutralization line) [14], the neutralization line method [15], and the self-isolated method [16, 17].

The study provides a compact, high-isolation, four-element antenna design for 5G MIMO mobile phone devices that operate on (3408 - 3760) MHz for N78 band applications. High isolation (greater than 16.6 dB) and very low Envelope correlation coefficients (ECCs) are obtained based on spatial diversity and self-isolated approaches. The entire antenna size printed on the side-edge mobile frame is (9.72 mm and 5.99 mm), which results in the desired antenna reduction and straightforward structure of the proposed antenna element. The suggested antenna system also achieves good antenna and MIMO performances. The proposed four-antenna MIMO system is

modeled and simulated using the CST Microwave Studio software (version 2019).

2. The Proposed Four-Element MIMO Antenna

Figure 1 shows the geometry and dimensions of the four-element MIMO antenna system for 5G mobile phone devices. The four antennas for the proposed MIMO system are positioned at the top four corners of the mobile device and possess identical constructions and dimensions. To comply with the current trend of a full-screen mobile phone device, each antenna element is printed on the inner and outer surfaces of the two long side edges of the mobile frame substrate. The main system board size (150×75) mm² is selected as a representative of a 5.5-inch smartphone. The vertical frame side margins of the mobile device, which are placed on the main system board, are chosen to be 7 mm high to comply with the criteria for a slim smartphone device. The main mobile circuit board and frame are designed using a double-sided FR4 substrate with a height of 0.8 mm, 4.3 relative permittivity, and 0.02 loss tangent. The structure and measurements of a single antenna element, which is separated into front and back sections, are shown in Figure 2. Figure 2(a) demonstrates how the front portion of the antenna element is made up of an I-shaped feeding line and a second iteration Moore fractal monopole antenna. An outstanding antenna compactness is attained by using the endearing Moore space-filling feature. Since the entire planer antenna size (9.72 mm $\times$ 5.99 mm), functioning on the (3408 - 3760) MHz interesting band is printed on the long side frame. Figure 2(b) shows the antenna's back portion, an L-shape connected to the main system ground by a 0.5 mm short stub under the L-shape's vertical stub. The desirable impedance matching of the suggested antenna is caused by coupling capacitance, which is produced by the antenna back portion. A 50 SMA connector is used to feed the antenna components, and it is connected to the antenna feeding lines via holes from the ground of the main system's backside.

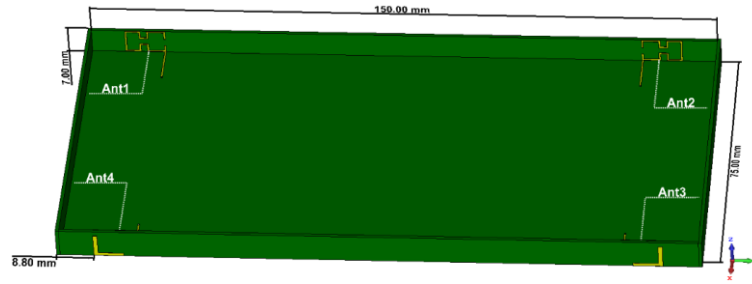
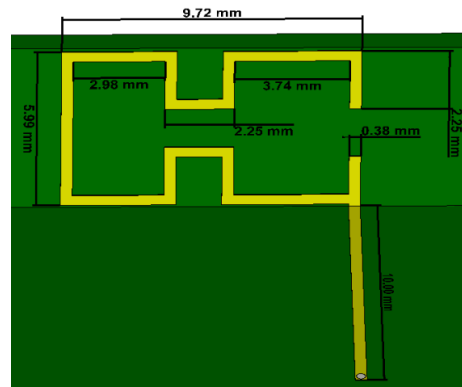
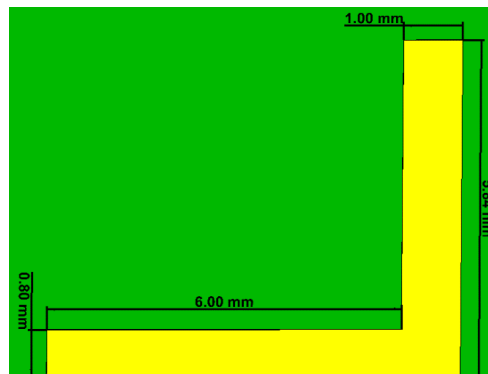


Figure 1: Suggested 4-element MIMO antenna system



(a)



(b)

Figure 2: A single antenna element (a) Front side (b) Back side

3. Results Analysis

3.1 Antenna Performance

Figure 3 illustrates the simulated S parameters of the suggested four-antenna-element MIMO system. A satisfactory impedance matching is attained throughout the entire band of interest (3408 - 3760) MHz, as shown in Figure 3(a). Since the reflection coefficients of all four antennas are less than -10 dB (2:1 VSWR). Figure 3(b) depicts the

transmission coefficients of the proposed antenna system. Very low mutual coupling between antenna elements is attained where $S_{2,1}$ and $S_{4,3}$ are less than -16.6 dB, $S_{3,1}$ and $S_{4,2}$ are less than -27 dB, and the coefficients $S_{4,1}$ and $S_{3,2}$ are less than -17.3 dB. The suggested four-element MIMO antenna system achieves the desired isolation thanks to the self-isolated and spatial diversity approaches. To apply the spatial diversity technique and make the best use of the mobile device's area,

the antenna elements' best orientation and placement have been selected for the top four corners of the device. The self-isolated functionality of the proposed compact antenna elements limits the current flowing via the

excited antenna element and the ground plane of the main system underneath the antenna region.

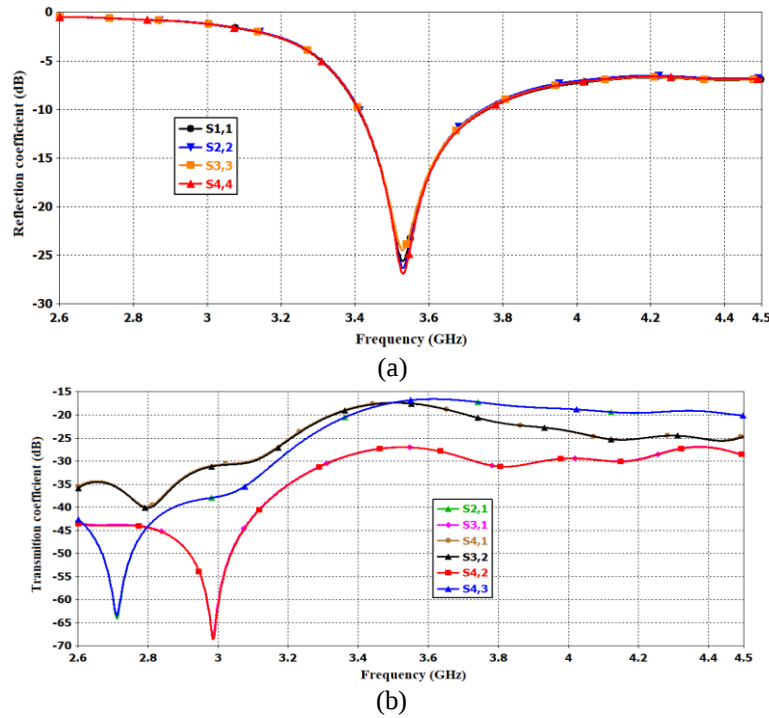


Figure 3: S-parameters (a) Reflection coefficients (b) Transmitting coefficients

Figure 4 shows the four antennas used in the proposed MIMO systems' total and radiation antenna efficiency. Along the operational band, desirable antenna efficiencies are attained, ranging from (62% to 75%) for total efficiencies and from (72% to 82%) for radiation efficiencies. Figure 5 shows the gain over the working band for the four antennas. It can be seen that the gains are nearly constant across the working band and that strong gains are attained for all antennas when the highest gains are about 5 dB. Figures 6(a) and 7(b) display the two- and three-dimensional

radiation patterns for each antenna at the resonance frequency of 3.55 GHz. According to observations, the proposed 4-element MIMO antenna system has an outstanding pattern diversity characteristic because each antenna element has a maximum gain direction that differs from the maximum gain directions of other antennas. Additionally, the radiation patterns from these four antennas totally cover the mobile device board on all sides. The suggested MIMO antenna design thus achieves a desirable radiation coverage performance.

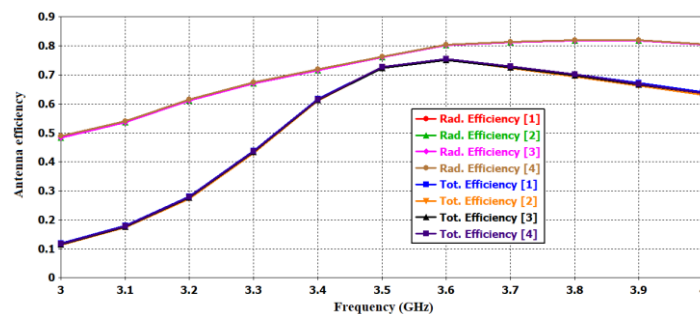


Figure 4: Antenna efficiency

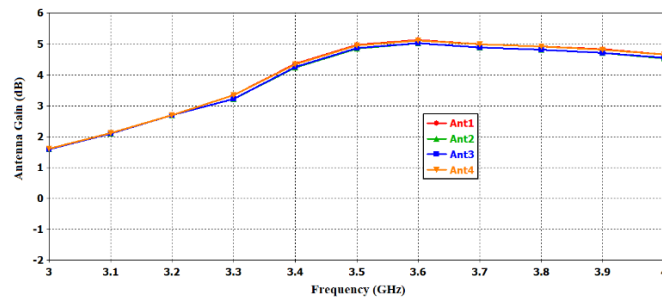
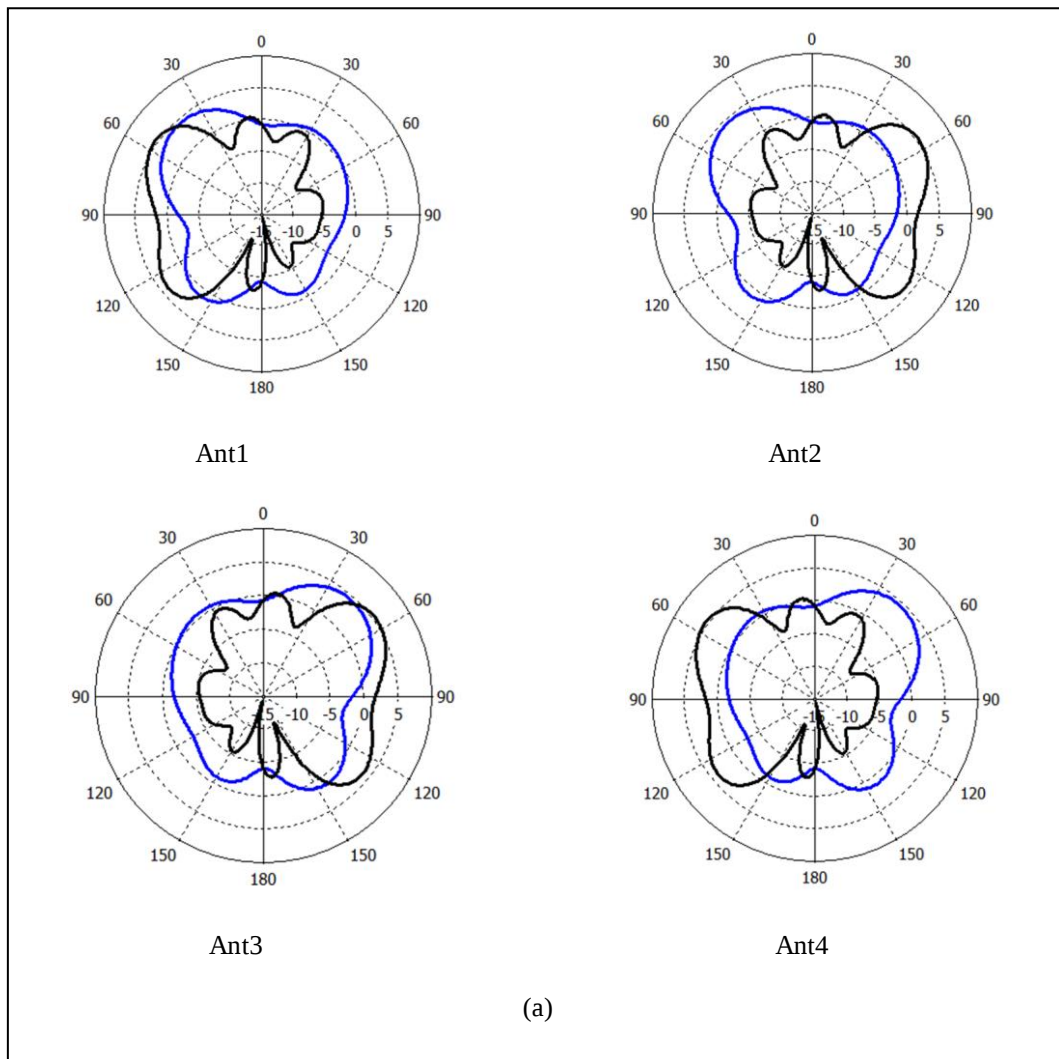


Figure 5: Antenna gain



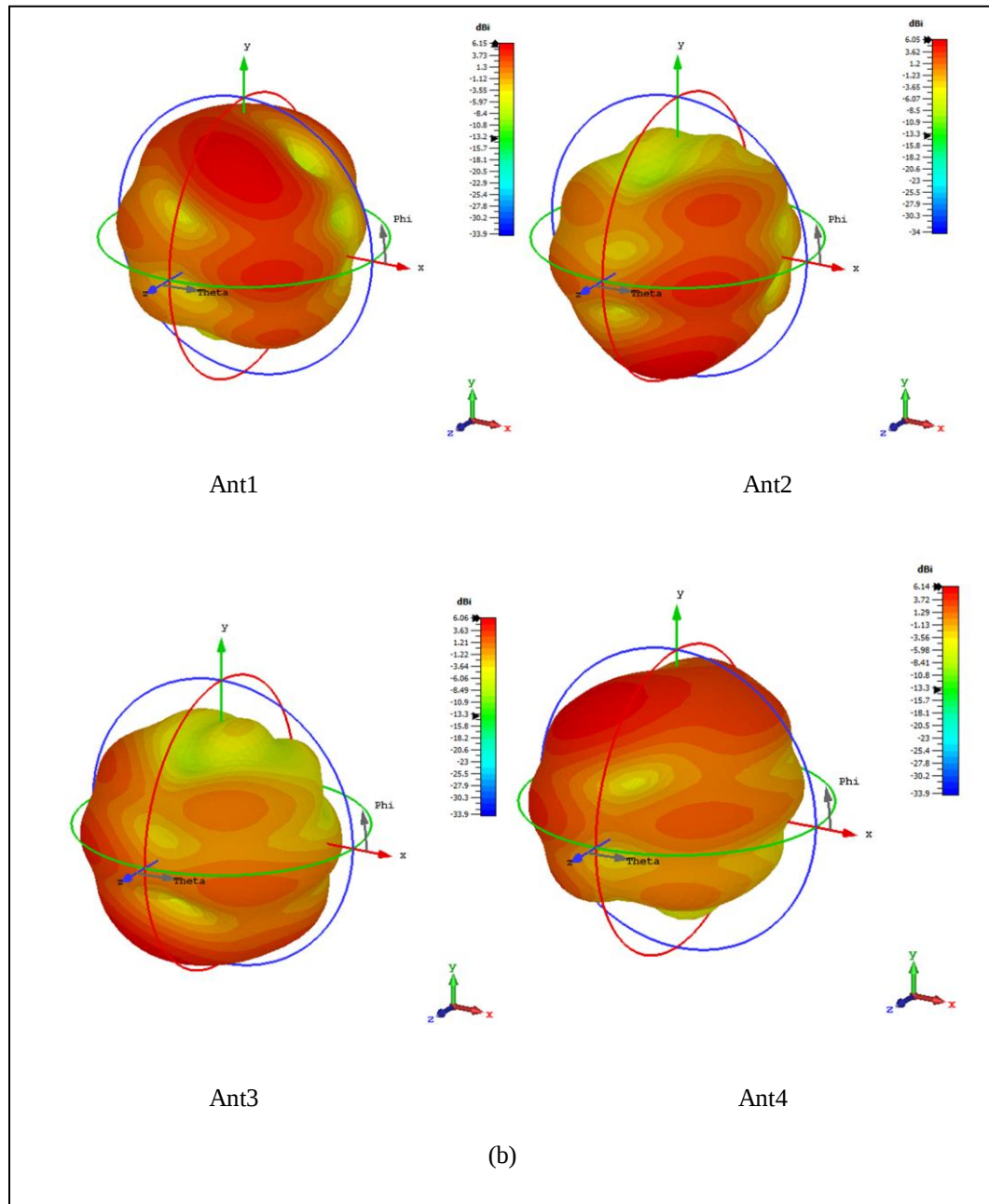


Figure 6: Antennas' radiation patterns at 3.55 GHz (a) 2-D (b) 3-D

3.2. MIMO Performance

The Envelope Correlation Coefficients (ECCs) and Mean Effective Gains (MEGs), which are significant measures, are utilized to assess the MIMO performance of the suggested antenna array. The independent radiation patterns of the antennas are measured by the ECC [18]. Eq. (1) calculates the ECC based on the far-field radiation patterns [19].

4. Conclusion

This study offers a 4-element MIMO antenna system for the 5G mobile phones. Excellent antenna compactness is attained by utilizing the fascinating space-filling property of the Moore fractal geometry. The suggested four-antenna MIMO system achieves the desired isolation (greater than 16.6 dB) using spatial and self-isolated approaches. Very low ECCs are attained (lower than 0.027), resulting

in a great diversity performance for the suggested antenna design. Additionally, good MEGs have been achieved, and the MEGs MIMO antennas' conditions for the best MIMO performance are confirmed. The desired antenna performance is attained, including the antenna gains, efficiencies,

radiation properties and the antenna's scattering parameters. The suggested four-antenna MIMO system can be considered a promising contender for the upcoming 5G mobile phone terminals due to the good antenna and MIMO performance findings.

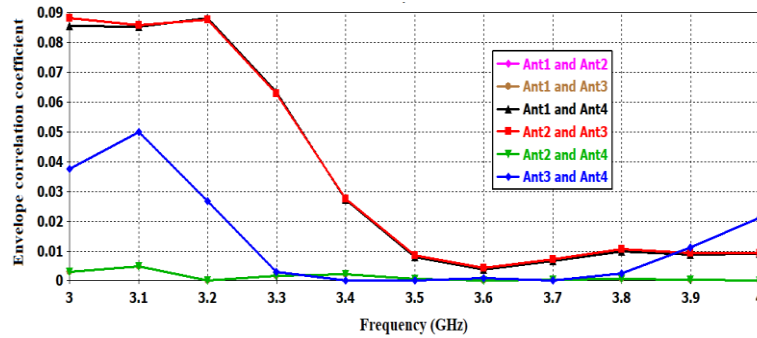


Figure 7: ECCs of the suggested MIMO antenna system

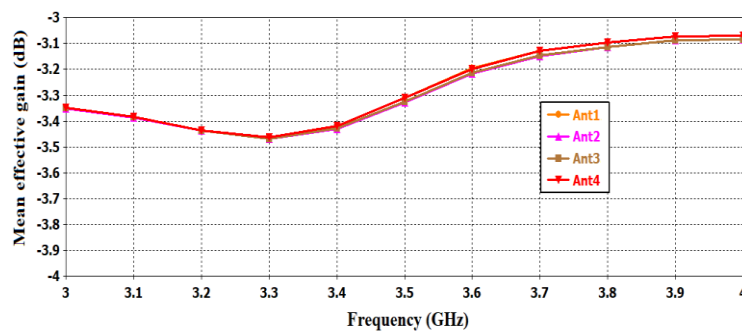


Figure 8: MEGs of the four MIMO antennas

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