MTH2175
Supervised by:Dr.Samah El-Shafiey

NEXT-GEN

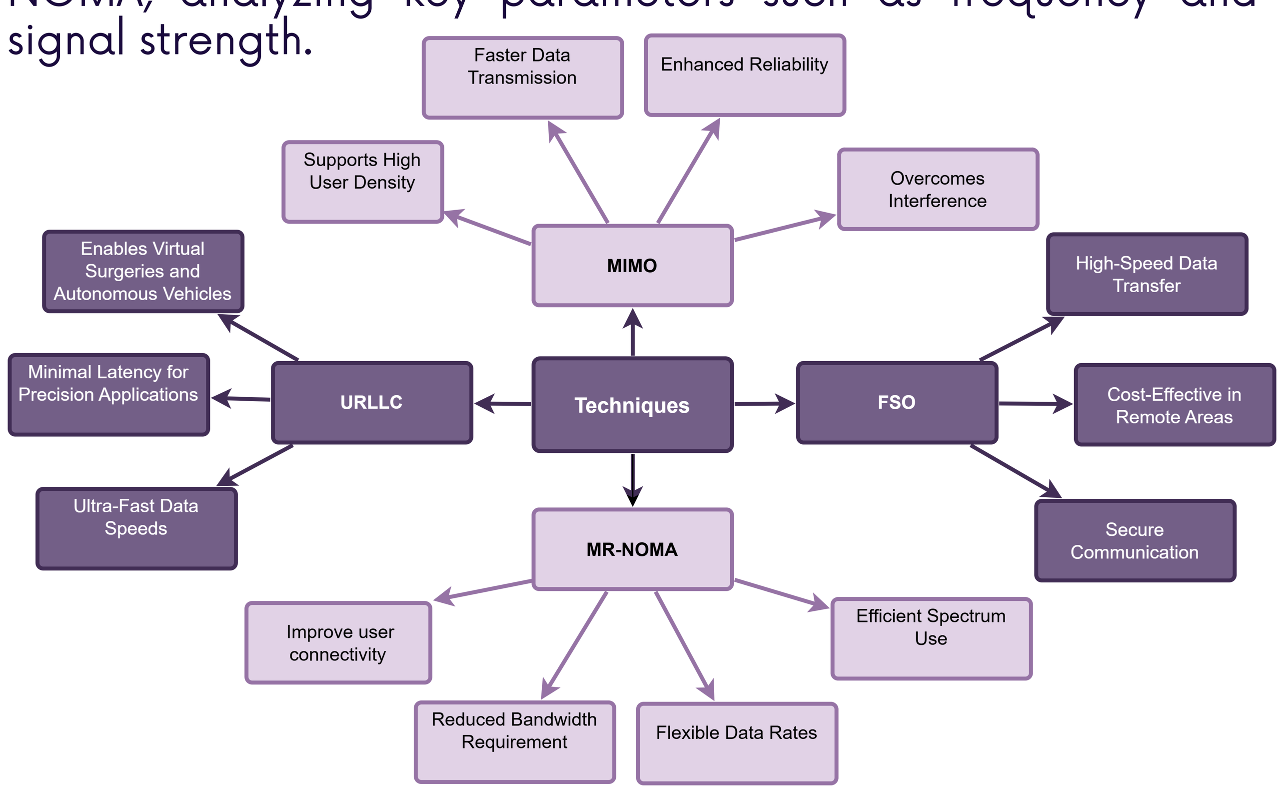
Wi-Fi's down? 5G takes the crown!

Abstract

The evolution of wireless communication from 1G to the anticipated 6G networks highlights significant advancements in speed, reliability, and efficiency, transitioning from analog systems to the cutting-edge 5G era. In this project, a MIMO ring antenna was designed to function as both a transmitter and receiver. MIMO transmitters, typically colocated, operate across a wide frequency range, enabling higher data rates. The project includes the simulation of this antenna design and an evaluation of its coverage, specifically tested around Cairo University's Faculty of Engineering campus.

Litrature review

The growing demand for mobile communication requires networks with higher data rates, reliability, and low latency. This review examines advanced techniques like MIMO, MR-NOMA, URLLC, and FSO to tackle challenges such as interference and bandwidth limitations. While each technique addresses critical needs, they have their limitations. The main focus is on enhancing MIMO with MR-NOMA, analyzing key parameters such as frequency and signal strength.



Methodology

-Wave Equations
To analyze the propagation of Electromagnetic fields, we start with the wave equations for the Electric field E and the Magnetic field B:

$$\nabla^2 \mathbf{E} - \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = 0 \qquad \nabla^2 \mathbf{B} - \frac{1}{c^2}\frac{\partial^2 B}{\partial t^2} = 0$$

-For MIMO:
Our project focuses on a 4-element MIMO ring elliptic antenna in order to run a simulation and produce the results we aim for. The design process involves defining the antenna geometry and simulating its performance using electromagnetic software. Key performance metrics, such as radiation patterns, impedance matching, and isolation between elements, are analyzed. The MIMO performance is evaluated by calculating channel capacity, diversity gain, and array gain.

-Next formula describes that MIMO uses multiple antennas at the transmitter and receiver to transmit multiple data streams simultaneously over the same frequency.

$$y = Hx + n$$

-The elements of matrix is the complex channel gains between transmit and receive antennas

$$\begin{pmatrix} h_{11} & \cdots & h_{1,nt} \\ \vdots & \ddots & \vdots \\ h_{nr,1} & \cdots & h_{nr,nt} \end{pmatrix} \qquad h_{ij} = g_{ij} \cdot e^{i\emptyset_{ij}}$$

-The channel capacity in MIMO represents the (bits/second) transmitted data so that it is important factor to be calculated, and we can calculate it from this equation

$$C(t) = \log_2\left[\det\left(I_N + \frac{P_T}{N_T N_0} H(t)H(t)^H\right)\right]$$

-Spectral Efficiency (SE) is a measure of how well a communication system makes use of the bandwidth that is available

$$\mathrm{SE} = \frac{\text{Throughput(bps)}}{\text{Channel bandwidth(Hz)}}$$

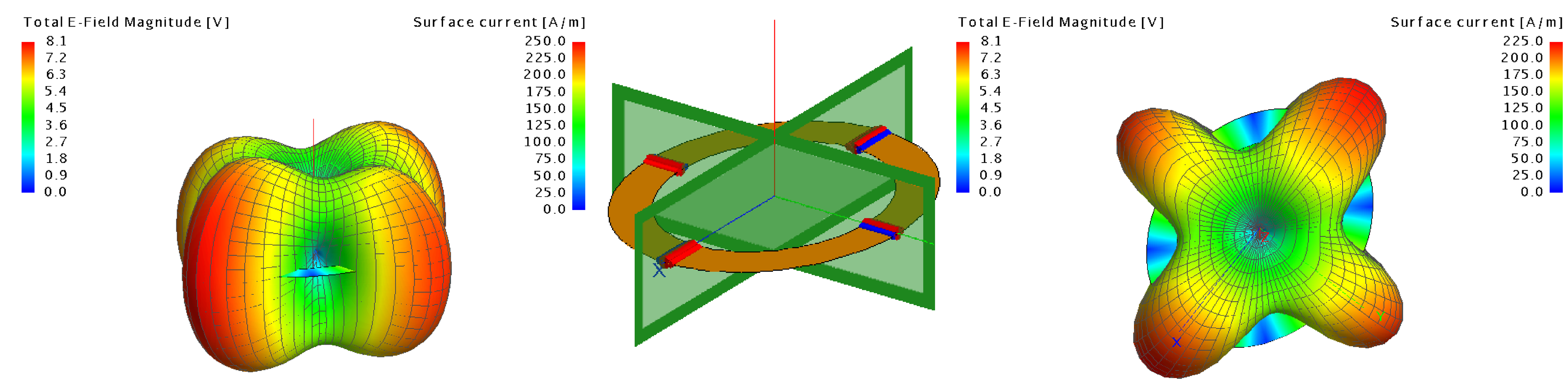
-Far-Field Radiation Pattern
The far-field radiation pattern is crucial for understanding the antenna's performance. It can be expressed as:

$$\mathbf{E}\,(\theta, \phi) = \frac{jk}{4\pi r}\int_{-\pi}^{\pi}\int_{0}^{\pi} \mathrm{F}(\theta', \phi')\, e^{-\mathrm{j}kr\cos\theta'} \sin\theta' d\theta' d\phi'$$

For more details
Check this

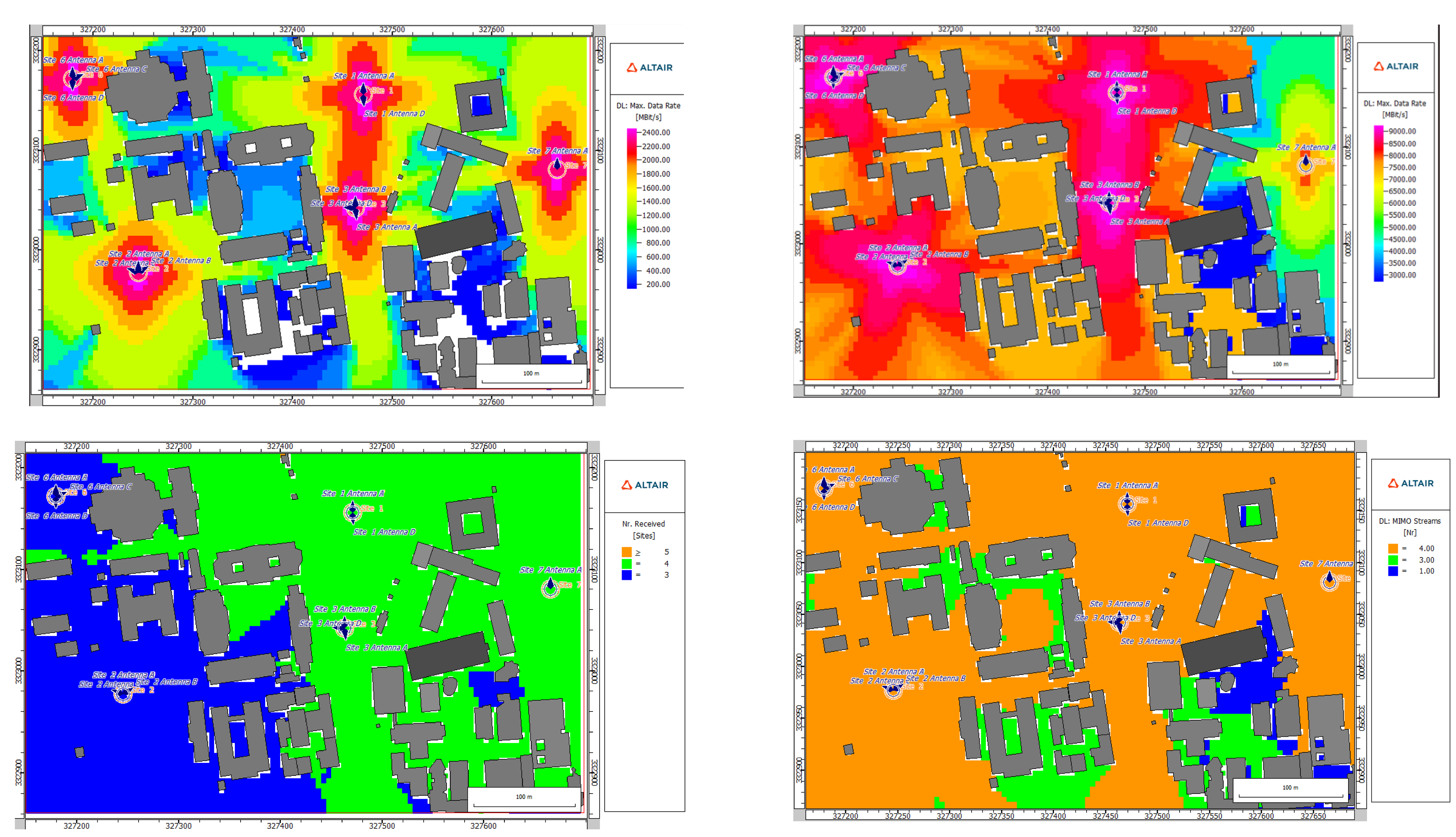
Results

5G technology supports high data rates, low losses, and minimal latency, making it ideal for modern applications like VR. This project incorporates MIMO (Multiple-Input Multiple-Output) technology, which uses multiple antennas at both transmitter and receiver to enhance data throughput and connection reliability. A 4x4 MIMO elliptical ring antenna design is chosen to optimize network performance.



We design a ring Mimo Whose system consists of 4 radiation elements arranged in the form of an oval ring. This choice helps achieve better spatial diversity, which increases their quality of being making it suitable for higher frequencies.

The far field of an antenna is where electromagnetic waves propagate with perpendicular electric and magnetic fields, enabling simplified radiation analysis. It is essential for optimizing directional energy radiation and evaluating antenna efficiency, gain, and performance.



The 4x4 MIMO system significantly enhances throughput by leveraging spatial multiplexing, enabling the simultaneous transmission of multiple data streams.

Conclusion

The results confirm the theoretical advantages of MIMO technology in enhancing wireless communication. The improvements in data rate and connectivity highlight the potential of MIMO systems for applications in high-density environments, such as college campuses. Challenges like SNIR degradation in obstructed areas were addressed through beamforming and adaptive channel allocation techniques. However, it is important to acknowledge the study's limitation to simulations. Further experimental validation in real-world conditions is recommended to account for factors like weather and hardware imperfections. In conclusion, the 4x4 MIMO system demonstrates substantial improvements in wireless communication performance, proving its effectiveness for next-generation networks.

Future work

In conclusion, our results were largely influenced by the capabilities and limitations of the software used. With greater flexibility, we would have explored simulations involving larger MIMO setups, such as 8x MIMO transmitters, and incorporated advanced features like MIMO-NOMA and network slicing with AI. Using deep learning, these methods could optimize data distribution based on user-specific data usage patterns. Additionally, we aimed to experiment with 6G data rates and visualize the impact on applications like VR headsets, which require high data rates and ultra-low latency for smooth user experiences, minimizing health risks like nausea or headaches.

PRESENTED BY:

MOHAMED ABDELHAFEZ — MOSTAFA FARHAN — OMAR ELASHKAR — AHMED TAHA
AHMED MOHAMED — MAZEN REFAEY — AMR HAMDY — YOUSSEF HANY