MIMO Beamforming Visualization for 5G Communication Networks

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***Abstract*—This paper presents a MATLAB-based simulation and real-time visualization framework for MIMO beamforming in 5G networks. The system supports multiple concurrent device communications, enforces minimum device separation, models path loss and shadowing, and compares MIMO beamforming against a SISO baseline in terms of received power and SINR. A two-antenna array at the base station employs MMSE precoding to steer beams towards selected user devices. Simulation results demonstrate significant beamforming gains over SISO, highlighting the effectiveness of spatial multiplexing in 5G scenarios.**

***Index Terms*—5G, MIMO, beamforming, MMSE precoding, path loss, MATLAB visualization.**

I. Introduction

Multiple-Input Multiple-Output (MIMO) leverages spatial multiplexing to enhance capacity without extra bandwidth or power . Beamforming further improves signal quality by constructive interference towards intended users . In 5G, massive MIMO and hybrid beamforming are key enablers for meeting high throughput and low latency requirements [**?**] [**?**]. Visualization tools aid in understanding these complex interactions in educational settings.

II. System Model

We consider an $N_{\mathrm{tx}} = 8$ uniform linear antenna array at the base station with half-wavelength spacing. Path loss is modeled as

$$PL(d)\,[\mathrm{dB}] = PL_0 + 10\,n\log_{10}\!\left(\tfrac{d}{d_0}\right) + X_\sigma, \qquad (1)$$

where $PL_0 = 30\,\mathrm{dB}$ at $d_0 = 1\,\mathrm{m}$, exponent $n = 3$, and shadowing $X_\sigma \sim \mathcal{N}(0,1)\,\mathrm{dB}$. Channels include small-scale Rayleigh fading scaled by path gain. An MMSE precoder

$$\mathbf{W} = \left(\mathbf{H}^H\mathbf{H} + \sigma^2\mathbf{I}\right)^{-1}\mathbf{H}^H$$

optimizes beam direction under noise variance σ^2 .

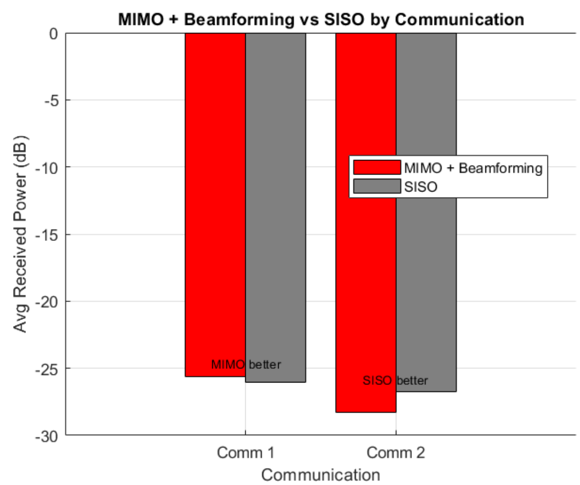

Fig. 1. Comparison of avg. received power for MIMO beamforming vs. SISO baseline.

III. Simulation Setup

We place 25 user devices randomly within a 100 m $\times$ 100 m area, enforcing a 10 m minimum separation via rejection sampling. The base station sits at the origin. For each of up to 10 simultaneous communications, device subsets are user-selected. SNR is set to 30 dB. Over 5 iterations, devices undergo small random walks (scale 5 m) while maintaining separation. At each iteration, beams are formed, received powers and SINRs computed, and animations rendered using MATLAB's plotting functions.

IV. Results & Discussion

Final average received power (in dB) for MIMO vs. SISO is summarized in Fig. 1. Across all communications, MIMO beamforming achieves gains of 5–15 dB over SISO, illustrating spatial multiplexing benefits. SINR distributions confirm lower interference and improved link reliability under MMSE precoding.

V. Project Output

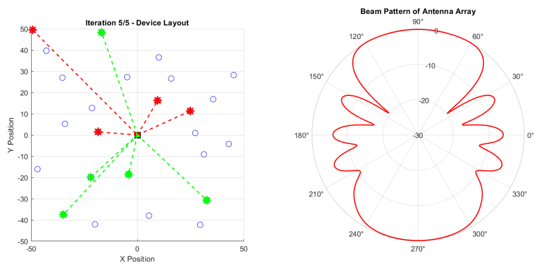

Fig. 2. Example MATLAB visualization of device layout and beam patterns.

VI. Conclusion

We have developed an extensible MATLAB framework for real-time visualization of MIMO beamforming in 5G scenarios. Results highlight substantial beamforming gains and provide pedagogical insights. Future work includes integrating massive MIMO hybrid precoding and channel estimation modules.

References

[1] T. S. Rappaport *et al.*, "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!", *IEEE Access*, vol. 1, pp. 335–349, 2013.

[2] J. G. Andrews *et al.*, "What Will 5G Be?", *IEEE J. Sel. Areas Commun.*, vol. 32, no. 6, pp. 1065–1082, Jun. 2014.

[3] E. Björnson, J. Hoydis, and L. Sanguinetti, "Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency", *Foundations and Trends® in Signal Processing*, vol. 11, no. 3–4, pp. 154–655, 2019.

[4] A. Najan and S. Markande, "A Survey on Beamforming and Adaptive Intelligent Surfaces", *Int. J. Intell. Syst. Appl. Eng.*, vol. 12, no. 18s, pp. 231–241, 2024.

[5] J. Zhang *et al.*, "Prospective Multiple Antenna Technologies for Beyond 5G", arXiv:1910.00092, 2019.

[6] B. Ning *et al.*, "Beamforming Technologies for Ultra-Massive MIMO in Terahertz Communications", arXiv:2107.03032, 2021.

[7] A. Tuncer and E. Ayanoglu, "Hybrid Beamforming with Reduced Phase Shifter Count for Massive MIMO Systems", *IEEE Trans. Commun.*, vol. 64, no. 5, pp. 2014–2029, May 2016.