Practical mmWave UE Performance in RIS-Assisted Wireless Network

C. Larmour*, M. A. B. Abbasi* D. Zelenchuk*, N. Buchanan*, V. Fusco*,
*Centre for Wireless Innovation (CWI), School of Electronics, Electrical Engineering and Computer Science (EEECS), Queen's University Belfast, Belfast, UK, clarmour04@qub.ac.uk

***Abstract*—This paper investigates the incorporation of Reflective Intelligent Surfaces (RIS) into mmWave wireless networks for enhancing user equipment (UE) performance. Specifically, it delves into the previously unexplored effect of user interaction with a steerable handheld mm-wave device on system bit rate performance in the presence of RIS, especially in non-line-of-sight conditions and when obstructed by a user's hand. The results emphasize the capacity of RIS to enhance both spectral efficiency and link reliability, contingent on the UE antenna array steering its beam towards the base stations or the RIS. Moreover, the investigation highlights the importance of practical UE for realistic network insights, crucial for effective optimization efforts.**

***Index Terms*—antennas, mmWave, RIS, spectral efficiency, user equipment**

I. Introduction and Contribution

The pursuit of better data rates and more reliable wireless communication has led to the exploration of cutting-edge technologies like Reflective Intelligent Surfaces (RIS). These surfaces redirect radio waves from base stations (BS) to user equipment (UE) located beyond the direct line-of-sight (LOS), enhancing signal quality and overall network performance. Particularly, they are beneficial for high-frequency signals prone to obstruction. By enabling non-LOS signal transmission to UE, RIS technology can extend signal coverage and boost network performance [1], [2]. However, integrating RIS technology into wireless networks comes with its own set of challenges. One such challenge is understanding the performance of a UE operating at 28 GHz, both in free space and when a user's hand is present. Additionally, this study investigates the performance and data rates when steering the UE towards the BS versus the RIS, determining the optimal configuration for a given UE location. This research provides valuable insights into RIS performance in realistic mmWave wireless network scenarios, highlighting its advantages.

II. Simulation Setup

The RIS assisted wireless environment system model, including both the BS and RIS, used for these simulations is presented in [1], [2], whereas the UE model within these simulations is a design from a previous study for a handheld mmWave device [3]. The simulation setup developed in MATLAB [4] is detailed in Fig. 1. The setup showcases a UE receiving signal from both the BS and RIS, enabling calculation of the spectral efficiency. It is also possible to remove the LOS path and determine the performance of the RIS when it is operating independently. Additionally we can also steer the UE directivity beam towards either the BS or RIS to determine which case is optimal. Furthermore, adjustments made to the UE location along the x-axis, allow assessment of a practical application where a UE is moving in relation to the BS and RIS and how this affects performance. Note that it is assumed that mmWave UE can have omnidirectional radiation at all times, however, this is untrue since UE phased antenna array can only focus towards limited directions around the UE, studied more extensively in [3], [5]

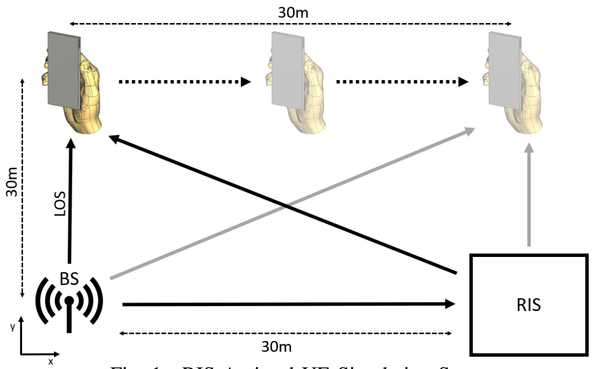

Fig. 1. RIS-Assisted UE Simulation Setup

III. Results and Discussion

Results provide valuable insights into the spectral efficiency at various UE locations. We evaluate two key performance metrics: *LOS+RIS*, where the UE receives signals from both the BS and RIS simultaneously, and *RIS Only*, where the UE solely relies on signals from the RIS in the absence of LOS connectivity. In the case of *LOS+RIS* shown in Fig. 2, steering the UE towards either the BS or RIS leads to a substantial improvement in spectral efficiency compared to an isotropic source in most scenarios. One observation is the impact of introducing a user's hand to the UE, which generally results in reduced spectral efficiency compared to the hand-free scenario. Notably, when steering the UE towards the RIS, a significant reduction in performance occurs within the 12-18m range. This can be attributed to the central positioning of the UE, potentially causing destructive interference between the signals from the BS and RIS, thereby decreasing spectral efficiency. It is also plausible that certain blind spots in the UE radiation patterns emerge when focusing on the RIS at these specific locations. In such cases, it becomes evident that directing the UE towards the BS yields optimal performance, offering significantly higher spectral efficiency. Furthermore, the highest spectral efficiency for a given scenario is achieved when closely aligned with either the BS or RIS. For instance, when the UE is positioned at 0m, aligned with the BS, for *wo\Hand BS Focused*, spectral efficiency reaches 11.68

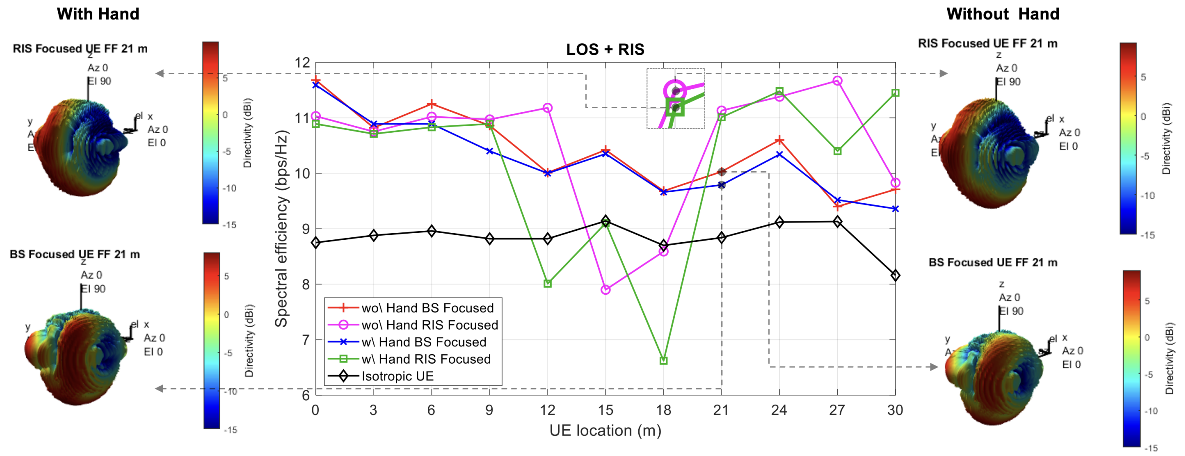

Fig. 2. Spectral Efficiency of UE at different locations for *LOS+RIS*.

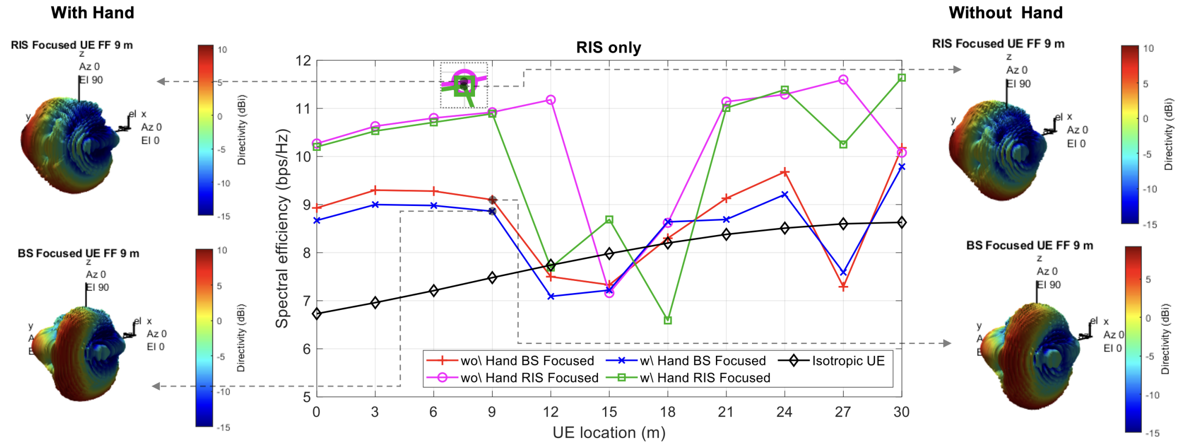

Fig. 3. Spectral Efficiency of UE at different locations for *RIS Only*.

bps/Hz. Similarly, at 27m, closely aligned with the RIS, for *wo\Hand RIS Focused*, spectral efficiency remains high at 11.67 bps/Hz. This emphasizes the importance of strategic RIS placement to maximize spectral efficiency when a practical UE is used instead of an ideal isotropic radiator.

In the context of *RIS Only* shown in Fig. 3, we observe similar trends to the *LOS+RIS* scenario. Once again, a user's hand results in a general reduction in spectral efficiency. Notably, it becomes evident that directing the UE signal towards the BS does not yield the same benefit as directing the UE signal towards the RIS, this is reasonable as there is no LOS link available to the BS in this scenario. Close to the centre point where the distance from BS and RIS is almost the same, UE focusing towards the BS is bound to achieve spectral efficiency even below the isotropic counterpart. The performance enhancements are only plausible when UE is steering the maximum directivity beam towards the RIS. The highest spectral efficiency values are also attained when the UE aligns itself with the RIS.

Excluding the spectral efficiency reduction at the centre point, it is clear that the *RIS Only* scenario can offer comparable spectral efficiency with the *LOS+RIS* scenario. This is significant for mmWave wireless networks, providing a viable alternative when LOS transmission is not available, highlighting the adaptability and promise of RIS technology in various network conditions. Importantly, this investigation underscores the significance of employing practical UE in assessing the performance of RIS in mmWave wireless networks. This offers more realistic network parameters, thereby contributing to the effectiveness of network optimization efforts.

IV. Acknowledgement

This work was partially supported by Project REASON sponsored by the Department of Science Innovation and Technology (DSIT).

References

[1] M. A. ElMossallamy, H. Zhang, L. Song, K. G. Seddik, Z. Han and G. Y. Li, "Reconfigurable Intelligent Surfaces for Wireless Communications: Principles, Challenges, and Opportunities," in *IEEE Transactions on Cognitive Communications and Networking*, vol. 6, no. 3, pp. 990-1002, Sept. 2020.

[2] Q. Wu, S. Zhang, B. Zheng, C. You and R. Zhang, "Intelligent Reflecting Surface-Aided Wireless Communications: A Tutorial," in *IEEE Transactions on Communications*, vol. 69, no. 5, pp. 3313-3351, May 2021.

[3] C. Larmour, M. Megarry, N. Buchanan, V. Fusco and M. A. Babar Abbasi, "Quasi-Omnidirectional Millimetre Wave 5G Handset Antenna," 2023 17th European Conference on Antennas and Propagation (EuCAP), Florence, Italy, 2023, pp. 1-4.

[4] Introduction to Reconfigurable Intelligent Surfaces (RIS) - MATLAB and Simulink, https://www.mathworks.com/help/phased/ug/introduction-to-reconfigurable-intelligent-surfaces.html (accessed Feb. 2, 2024).

[5] C. Wang, C. Larmour, V. F. Fusco and M. A. B. Abbasi, "Can a mmWave 5G Handset have Quasi-Omnidirectional Coverage?," 2022 16th European Conference on Antennas and Propagation (EuCAP), Madrid, Spain, 2022, pp. 1-5.