Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X Volume 3, Issue 5, 2025

SECRECY CAPACITY AND SIGNAL ENHANCEMENT ANALYSIS USING RECONFIGURABLE INTELLIGENT SURFACES FOR SECURE LINE-OF-SIGHT B5G LINKS

Abdul Haseeb Minhas[*1], Muhammad Ahmed Abbas[2], Syed Muhammad Talal Sherazi[3], Noor Eman Salaha[4], Malik Muhammad Zubair[5], Ahmad Raza[6]

[*1,2,3,4,5,6]*Department of Electrical Engineering, MCS, National University of Sciences and Technology (NUST)*

[*1]hr3030670@gmail.com, [2]muhammadahmedabbas122@gmail.com, [3]stalal.me@gmail.com, [4]noorsalaha42@gmail.com, [5]malikmzubair94@gmail.com, [6]ahmad22004raza@gmail.com

DOI: https://doi.org/10.5281/zenodo.15501525

Keywords
Secrecy Capacity, Line-of-Sight (LOS) Communication, Beyond 5G (B5G) Networks, Secure Wireless Communication, RIS-Assisted Security.

Article History
Received on 16 April 2025
Accepted on 16 May 2025
Published on 24 May 2025

Corresponding Author: *
Abdul Haseeb Minhas

Abstract
This work explores the application of Reconfigurable Intelligent Surfaces (RIS) in achieving physical layer security for next-generation wireless networks. As high-frequency 5G/6G communication systems gain popularity, providing secure and high-capacity links with rising eavesdropping threats is essential. We concentrate on maximizing the secrecy capacity and signal power at the authentic receiver (LR) while minimizing signal quality at possible eavesdroppers (Eve). A mathematical model is formulated to calculate the attainable rates and signal-to-noise ratios (SNRs) for RIS and non-RIS environments. Simulation results show that RIS strongly improves the quality of the signal at LR, resulting in up to 3.3× SNR improvement and a 200% increase in secrecy capacity over LoS transmission. In addition, the Signal Enhancement Ratio (SER) is maintained over a wide range of SNR values, verifying the stability of RIS-assisted communication. These results identify RIS as a promising technology for high-performance and secure wireless communications in beyond-5G (B5G) and 6G scenarios.

INTRODUCTION

The emergence of (B5G) and 6G networks brings unprecedented requirements in terms of ultra-high data rates, minimal latency, extreme connectivity, and high-security standards. These networks are designed to enable crucial real-time applications like autonomous systems, industrial automation, and immersive technologies that necessitate reliable, lossless, and secure communication links. Providing data confidentiality and availability in such settings becomes more challenging with high user density, propagation constraints, and malicious attacks. Thus, sophisticated physical layer security mechanisms are crucial to meet B5G/6G requirements and performance objectives [1], [2].

Safe and lossless transmission of information were recognized as the primary objectives in B5G/6G networks. While B5G/6G networks grew in more crowded regions, the necessity of real-time information exchange that could resist the limitation of transmissions as well as security vulnerabilities—like third-party attackers and interceptors—grew more imperative.

Physical Layer Security (PLS) was investigated for its performance in providing communication privacy by means of randomizing wireless transmission among intended recipients [3]. Line-of-Sight (LoS) communication, where direct visibility exists between the transmitter and receiver with no obstructions in between, was investigated for the potential to enable secure, low-latency transmission [2]. The joint implementation of PLS and LoS was demonstrated to be an important element in the realization of robust performance in B5G/6G networks. Nevertheless, the experimental deployment of LoS communication was greatly limited in urban and high-density scenarios by recurring blockages [4]. The research focused on carrying out a theoretical analysis to overcome the above propagation and security limitations.

Reconfigurable Intelligent Surfaces (RIS) have been proposed as a novel solution in wireless communications to change the propagation environment to fulfill specific transmission requirements [5][6]. RIS is comprised of many passive elements that take advantage of their reflective nature and adaptively control their EM response with on-board PIN diodes [7]. Due to its potential for enhancing the quality of signals without supplying extra energy sources, RIS has been proposed as a green and energy-free solution for future wireless networks [8]

Although the current literature had investigated PLS and RIS separately or together, the research specifically aimed at the possibility of utilizing RIS to facilitate safe LoS communication in city centers where conventional LoS links were disrupted by blockers and where intrusion from a third party was at a higher risk[2].

In particular, the prior work had envisioned a setup wherein RIS was applied initially to modify the primary data link between two WANs, followed by reapplying it in the receive WAN to forward the signal to the target user. The transmission scheme utilized frequency variation to separate the intended receiver (the target user) from third-party unauthorized intruders (eavesdroppers), thereby increasing physical layer security [7].

This framework provided a theoretical basis for employing RIS to address urban communication issues and enhance secure transmission in B5G/6G networks. It highlighted the feasibility of RIS-enabled secure LoS communication as an energy-efficient and scalable solution for use in environments with both physical obstructions and increased security needs[2][7].

The rest of this paper is organized as follows. Section II reviews the relevant work in the field. Section III describes the proposed approach in detail, and Section IV gives the results and discussion. In Section V Finally, the paper is concluded with insights on future research directions.

I. Related Work

Reconfigurable Intelligent Surfaces (RISs) are characterized by their capacity to passively improve wireless communication without the need for active elements like power supplies, signal repeaters, or encoding/decoding units. Through smart reflection of incident signals, RISs have the potential to control the wireless environment to enhance signal propagation. Fig. 1, the mean signal-to-noise ratio (SNR) gets substantially better with more RIS elements, which shows that RIS performance responds well to surface size. Fig. 2 shows comparison of SNR performance in distance for various communication methods. The RIS-assisted system has a higher SNR than the direct link and comes close to the performance of relay-assisted transmission, especially at mid-range distances. This points to the promise of RIS to provide an acceptable balance between performance and energy efficiency in cases where the deployment of active relays is not viable.

Early research along these lines, e.g., [9], began to investigate using RISs to achieve passive beamforming to strengthen wireless connections. The groundbreaking research showed how the use of RISs was able to steer signals towards users, thus enhancing system performance and increasing SNR without an increase in transmission power. This was carried forward by [10], which extended the scope to multi-user scenarios, highlighting the flexibility of RISs to maximize capacity by dynamically controlling signal propagation.

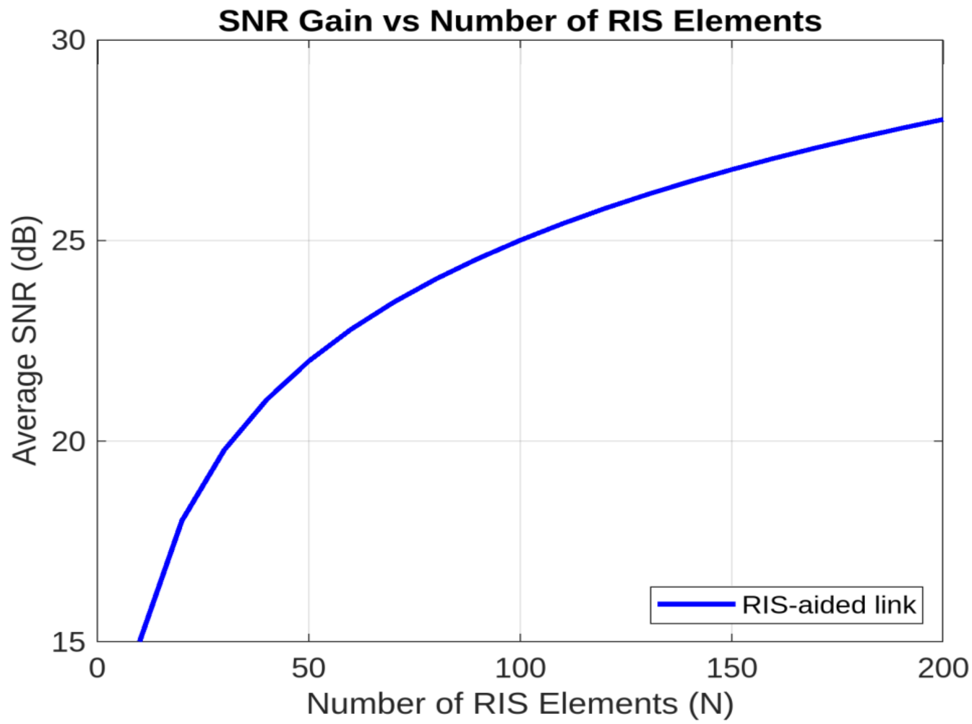

Fig. 1. SNR Gain vs Number of RIS Elements

Different from traditional relaying schemes with active power amplification or decoding-forwarding strategies, RISs make use of passive phase shift control to support signal reception. A comparative study of RISs and conventional relays was discussed in [11], highlighting RISs' reduced power consumption and enhanced spectral efficiency. It concluded that RISs would have similar coverage enhancements without the complexity and energy requirements of active relaying.

Although coverage analysis over RIS-assisted networks has been of interest, it is a relatively new field of study. Initial studies mostly spoke about theoretical deployment in ideal scenarios, with emphasis on coverage gain at the expense of little to no changes in network infrastructure. For instance, [12] examined RIS-enhanced cellular systems and showed that, through optimized phase shifts, RISs were capable of dramatically enhancing signal coverage under high-density urban conditions hampered by extreme path loss. Nonetheless, [13] presented one of the earliest extensive quantitative analyses, pitting RIS-aided communication against relaying and direct transmission schemes.

With respect to SNR performance, the Probability of SNR Gain (PSG) has become a key benchmarking metric for comparing RISs with other systems. Research [14] tested SNR gains realized through relaying, especially in multi-input multi-output (MIMO) settings, illustrating that relays can actually boost SNR even under conditions of reduced diversity than that of single-hop links. Likewise, SNR enhancements in RIS-assisted systems are a function of some important system parameters like the path loss exponent, number of reflecting elements, and metasurface design.

Along this line, [15] introduced a general framework to analyze SNR gain in RIS-assisted configurations in terms of comparisons with direct links and relay-based systems. Their results verified previous results, emphasizing that RISs achieve significant SNR improvement—particularly in high path attenuation scenarios—by virtue of their fine-grained phase adjustment ability to mitigate signal degradation. Their model highlighted the promise of RISs in exceeding conventional methods by both coverage and SNR with minimal or zero energy expense.

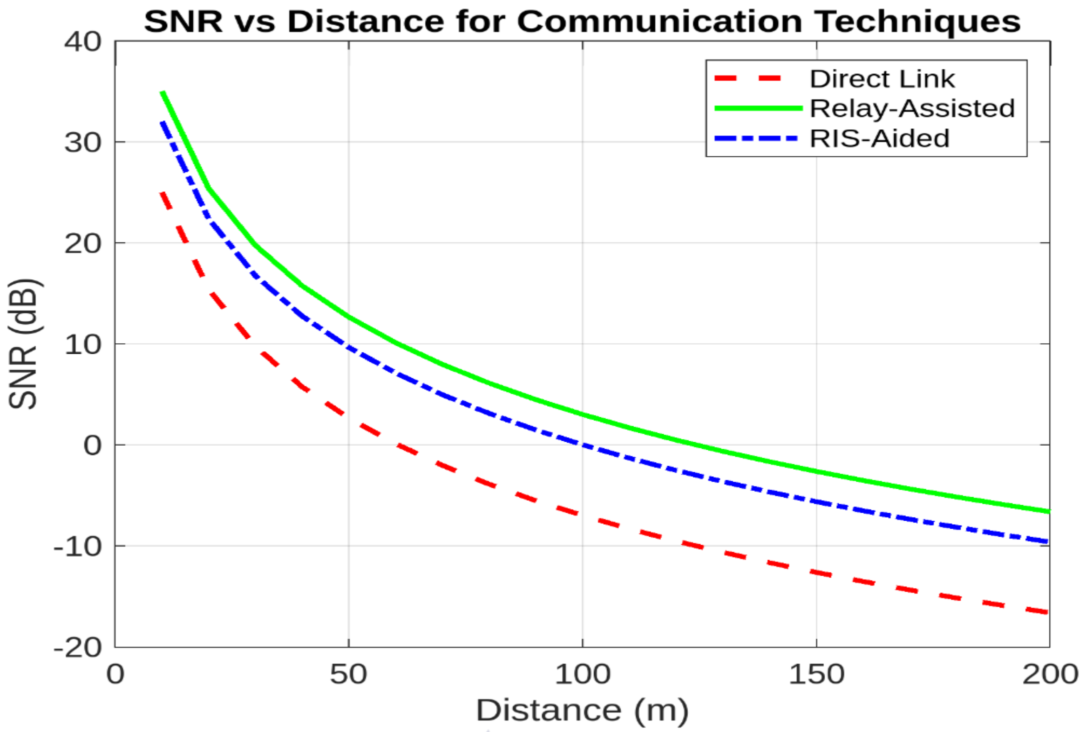

Fig. 2. Comparative SNR Gain (dB) for Different Technologies.

Delay Outage Rate (DOR) is another important parameter, especially for use cases that aim at Ultra-Reliable Low-Latency Communications (URLLC). For this purpose, [16] presented a method to measure DOR in RIS-aided networks. According to their results, RISs, by maximizing signal redirection efficiently, can minimize communication delays and increase reliability—comparable to the relay-based system but at the cost of passive devices, thereby maximizing energy efficiency.

Significantly, [13] presented a comprehensive analysis of coverage, PSG, and DOR for RIS-aided networks. Their paper filled a significant gap in the literature by providing quantitative models that compare RIS performance with direct transmission and relaying approaches. The paper highlighted that RISs can provide extended coverage, improve SNR, and reduce latency all together and hence are a very promising next-generation communication network solution.

(RIS) have come to be considered as a revolutionary technology in wireless communications by virtue of their ability to control the propagation of electromagnetic waves passively. Contrary to conventional active relays, RIS are able to steer signals using smart phase corrections to improve signal strength and reduce energy consumption. The Initial research proved that RIS have the ability to dramatically improve spectral efficiency as well as it can lower power consumption by facilitating passive beamforming [17], [18]. Comparative analysis has indicated that RIS is capable of providing better coverage and energy saving compared to the conventional relaying systems, particularly when its deployed strategically in dense scenarios [19].

Applications of RIS have also been extended to improve non-line-of-sight (NLoS) communication in cities. Researchers examined the RIS coverage advantages in intricate cityscapes, showing that well-designed surfaces are capable of offering virtual LoS links even when there is heavy obstruction [20]. Specifically, probabilistic models of SNR have been constructed to evaluate performance in terms of surface size and configuration [21]. More advanced signal modeling methods demonstrate that RIS can also enhance system reliability in low-diversity scenarios and combat multipath fading [22]. Additionally, RIS is helping to support ultra-reliable low-latency communication (URLLC) by lowering signal processing latency, providing lower delay outage rates (DOR) than conventional relays [23].

Current research has attempted to incorporate RIS with smart and adaptive network control schemes. Deep reinforcement learning has been suggested to adaptively tune the RIS parameters in real-time for high performance in dynamic situations [24]. RIS has also demonstrated good performance at terahertz and millimeter-wave frequencies, where it compensates for heavy path loss by forming efficient LoS links [25]. Green networking research highlights RIS's potential to limit network-wide energy expenditure when coupled with power-aware networking protocols [26]. Hybrid schemes integrating RIS with massive MIMO systems have yielded gains in spatial multiplexing and beamforming efficiency [27].

Security and feasibility of deployment are increasingly focal in RIS research. Physical layer security may be facilitated through RIS-aided secret key generation that leverages channel randomness to thwart eavesdropping, a threat also targeted by adversarial attacks against RIS [28]. Other works concentrate on implementation problems like synchronization, control, and hardware imperfections, and offer solutions for reliable operation in realistic scenarios [29]. Some Stochastic geometry models have also been presented to study RIS performance in the randomly obstructed environments and provide theoretical insights into deployment density as well as in user mobility [30]. Lastly, throughput and coverage performance bounds provide us guidelines for design of large-scale RIS-enabled networks in future 6G systems [31]

In summary, RIS-aided systems have received considerable attention in recent years. While early work focused on the theoretical aspects and benefits of RISs, subsequent studies have made significant progress in analyzing performance metrics like coverage, SNR gain, and delay outage rate. This body of work has established RISs as a promising technology for enhancing future wireless communication systems. The work of [5] marks a significant step forward in providing quantitative analysis for these metrics, demonstrating the potential of RISs to improve communication networks in terms of coverage, SNR, and reliability.

II. Proposed Approach

The envisioned solution uses Reconfigurable Intelligent Surfaces (RIS) to improve wireless communication quality in high-frequency bands (e.g., terahertz and millimeter-wave), especially under situations where LoS paths are blocked by physical obstacles like walls or buildings. High-frequency signals, as much as they can enable ultra-high data rates, suffer greatly from environmental blockages, which complicates robust and secure communication. Traditional remedies, for example, adding extra base stations or relays, are costly, power-hungry, and frequently unsuitable for dense city deployments.

Our approach presents RIS as a passive, programmable, and energy-saving solution. RIS panels are placed at strategic environmental locations like building walls, glass windows, lampposts, or billboards. Incident signals are caught by these surfaces and redirected to the desired receivers through dynamic phase and amplitude tuning of each element in the RIS array. Such redirection forms virtual LoS paths that avoid physical barriers, hence enhancing signal strength and coverage.

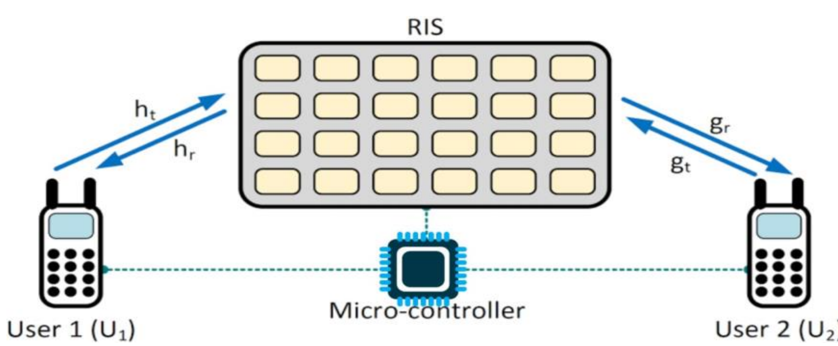

Fig. 3. RIS-assisted transmission scheme for a typical urban setting.

Fig. 3 shows the RIS-assisted transmission scheme for a typical urban setting. As a signal from the transmitter reaches an obstruction, the RIS steers it through smart reflection. The beamforming feature of RIS is adjusted by a central base station or controller with real-time Channel State Information (CSI). RIS provides constructive interference at the intended receiver through adaptive phase alignment, thus ensuring maximum received power as well as stable signal quality.

To achieve optimal performance, the system uses machine learning oriented or iterative optimization algorithms to set RIS parameters dynamically. These algorithms strive to maximize SNR and throughput while reducing delay and interference. In contrast to conventional relaying methods, RIS uses negligible power and lacks the active radio frequency components, providing a sustainable and scalable method for the next-generation networks.

Physical layer security is a major feature of the proposed solution. RIS is employed to defeat signal propagation in any unwanted directions by producing destructive interference at possible eavesdropping sites. Through the accurate phase adjustment of the reflecting elements in accordance with CSI, the RIS system selectively enhances signal transmission towards authorized users and reduces it elsewhere. In contrast to active jamming methods that create extra interference, this passive method enhances security with no energy expenditure, which it makes particularly attractive for the URLLC (Ultra-Reliable Low-Latency Communications) and other 6G-critical applications.

This RIS-aided approach not only overcomes the difficulties of low LoS availability and large path loss, but also improves wireless coverage, energy efficiency, and security in challenging and dynamic scenarios. It is especially useful for urban IoT applications, V2X communication, smart cities, and industrial control. By providing smart control over the wireless propagation channel, the introduced RIS framework is a major step towards sustainable, secure, and high-capacity B5G/6G networks.

III. Results And Analysis

This section summarizes the performance evaluation of the envisioned RIS-enabled secure wireless communication system. We investigate important performance metrics like secrecy capacity and signal enhancement ratio to show the advantages of RIS deployment. The results are derived by using simulations under realistic channel conditions such as path loss, noise variance, and changing SNR levels. Comparative comparison of scenarios with and without RIS emphasizes the dramatic enhancements in secure data communication and signal quality provided by the proposed solution. Quantitative calculations of achievable rates and signal improvement give a clear understanding of how effective the RIS is in improving communication security and reliability.

A. Achievable Rates and Secrecy Capacity

To evaluate the system's secure communication capability, we first calculate the achievable data rates for both the legitimate receiver (LR) and the eavesdropper (Eve) based on their respective signal-to-noise ratios (SNRs):

$$R_{LR} = \log2(1 + \gamma LR), R_{EVE} = \log2(1 + \gamma Eve) \quad (1)$$

where

$$\gamma = \frac{Pt \times G}{d^{\alpha} \times \sigma 2} \quad (2)$$

- Pt : Transmit power
- G: Gain (RIS boost for LR; no boost for Eve)
- d: Distance
- α : Path loss exponent
- σ: Noise variance
- γLR : Signal-to-Noise Ratio at the Legitimate Receiver.

It represents how strong and clear the signal is at the intended receiver's end, possibly boosted by (RIS).

- γEve : Signal-to-Noise Ratio at the Eavesdropper.

It indicates the signal strength that an unintended or malicious receiver (Eve) captures.

The secrecy capacity C_S is calculated as:

$$C_S = \max(0, R_{LR} - R_{EVE}) \quad (3)$$

Table 1: Parameters for Rate Calculation

Parameter	Legitimate Receiver (LR)	Eavesdropper (Eve)
Distance	1 unit	2 units
Path Loss Exponent	0.5	0.5
Noise Variance	1	1
Transmit Power	1 unit	1 unit
RIS Gain	3 (with RIS) / 1 (no RIS)	1

Table 2: Secrecy Capacity C_S at Different SNR Levels

SNR (dB)	**γLR(With RIS)**	**γEve**	C_S (With RIS)	C_S (No RIS)
0	3.0	1.0	1.00	0.00
5	5.0	1.5	1.48	0.26
10	10.0	2.5	2.20	0.55
15	15.0	3.0	2.55	0.74
20	20.0	4.0	2.81	0.92

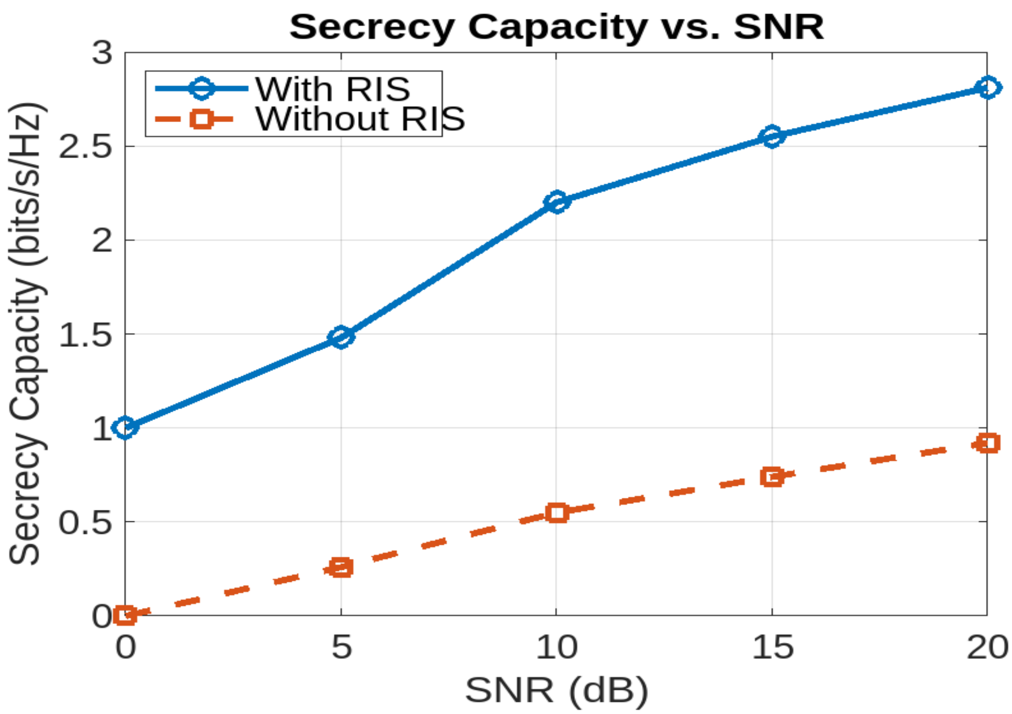

Fig. 4. Secrecy Capacity Comparison With and Without RIS

The Fig. 4. shows the increasing gap in secrecy capacity across the SNR range when RIS is deployed. To evaluate the secure communication performance of the system, we calculate the achievable rates for the legitimate receiver (LR) and eavesdropper (Eve) based on their respective SNRs, as specified in Equations (1) and (2). The secrecy capacity C_S, as expressed in Eq. (3), measures the rate benefit of LR over Eve and depends on RIS-aided signal enhancement. Table 1 lists the simulation parameters, with the LR having an RIS gain of 3 but not Eve. Table 2 provides the calculated secrecy capacities, which trend better with RIS as SNR is increased. Figure 4 shows this graphically, emphasizing the increasing secrecy capacity gap between RIS and non-RIS as SNR grows larger.

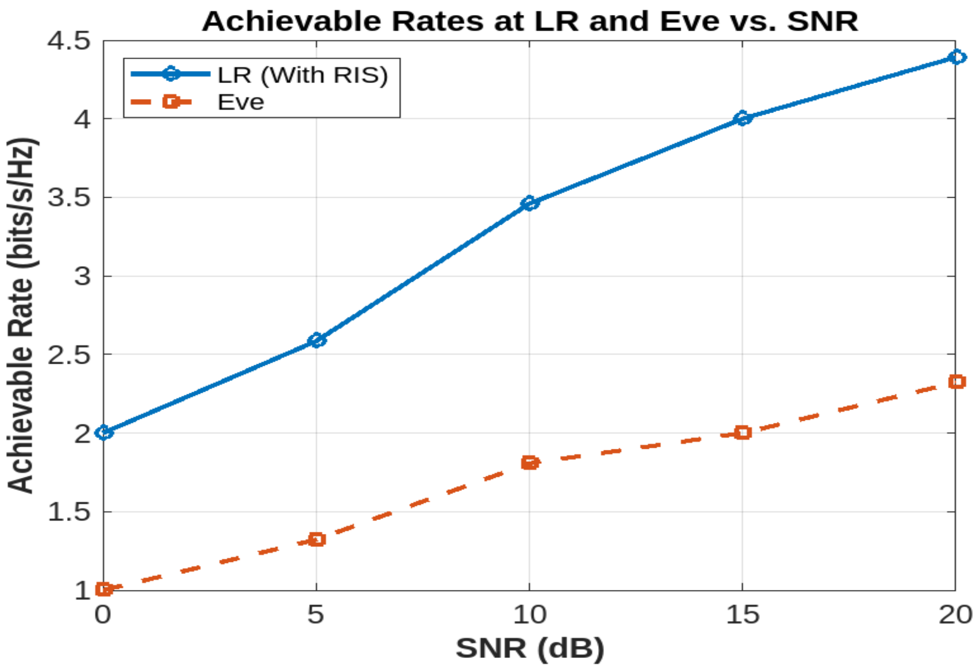

Fig. 5. Achievable Rates $\mathbf{R_{LR}}$ and $\mathbf{R_{EVE}}$ vs. SNR

This Fig. 5. illustrates how the legitimate receiver's rate improves significantly compared to the eavesdropper's due to RIS-assisted gain.

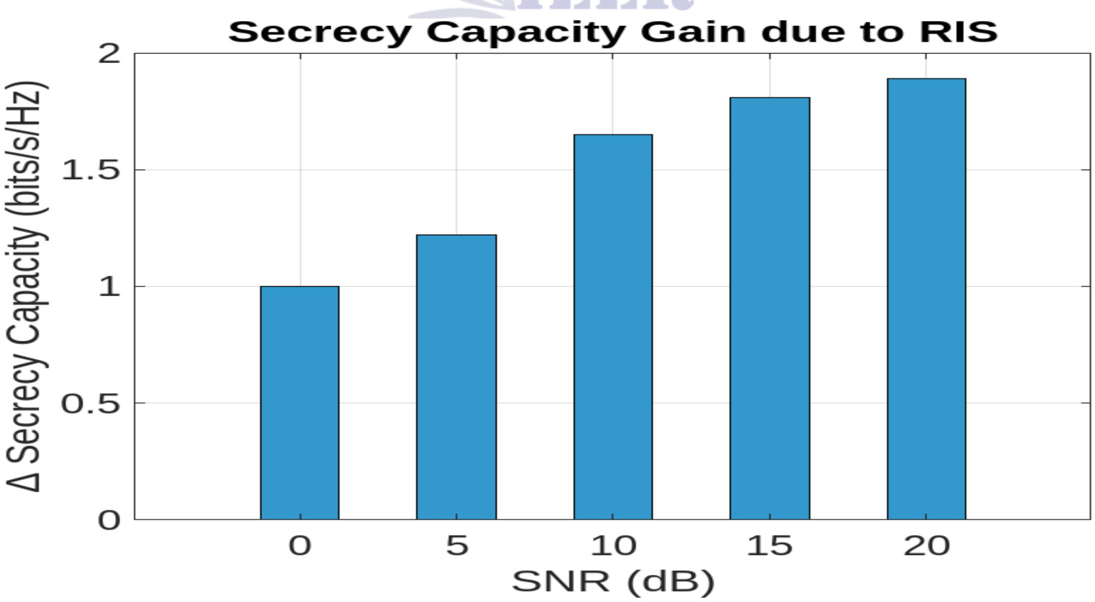

Fig. 6. Secrecy Capacity Gain Due to RIS

The Fig. 6. visualizes the improvement in secrecy capacity achieved by deploying RIS compared to a non-RIS scenario.

The discussion laid out in this section gives a comprehensive analysis of the impact of Reconfigurable Intelligent Surfaces (RIS) on improving the secrecy performance of wireless communication systems. From the system parameters listed in Table 1, we obtained the achievable rates for both the legitimate receiver and the eavesdropper based on their respective SNRs, as indicated in Equation (1). Table 2 presents the resulting secrecy capacities over a variety of different SNR values, demonstrating visibly the benefit of using RIS deployment. Figures 4, 5, and 6 pictorially support these results. Figure 4 underscores the increasing secrecy capacity difference between the RIS and non-RIS cases, Figure 5 indicates the divergence between achievable rates as a consequence of RIS enhanced gain. Figure 6 plots the total secrecy capacity increase facilitated by RIS. Combined, all of these findings affirm that RIS improves physical layer security considerably by enhancing the signal quality of the legitimate receiver while precluding the eavesdropper from intercepting the transmission.

B. Signal Enhancement Ratio (SER) Analysis

The Signal Enhancement Ratio (SER) quantifies the gain in received signal power at the legitimate receiver due to RIS assistance and is defined as:

$$\mathrm{SER} = \frac{\gamma LR(\text{With RIS})}{\gamma LR(\text{No RIS})} \tag{4}$$

This metric highlights the effectiveness of RIS in directing energy toward the LR, improving communication reliability and secrecy.

Table 3. Signal Enhancement Ratio Across SNR Levels.

SNR (dB)	**γLR(No RIS)**	**γLR(With RIS)**	Signal Enhancement Ratio (SER)
0	1.0	3.0	3.0
5	1.5	5.0	3.3
10	3.0	10.0	3.3
15	4.5	15.0	3.3
20	6.0	20.0	3.3

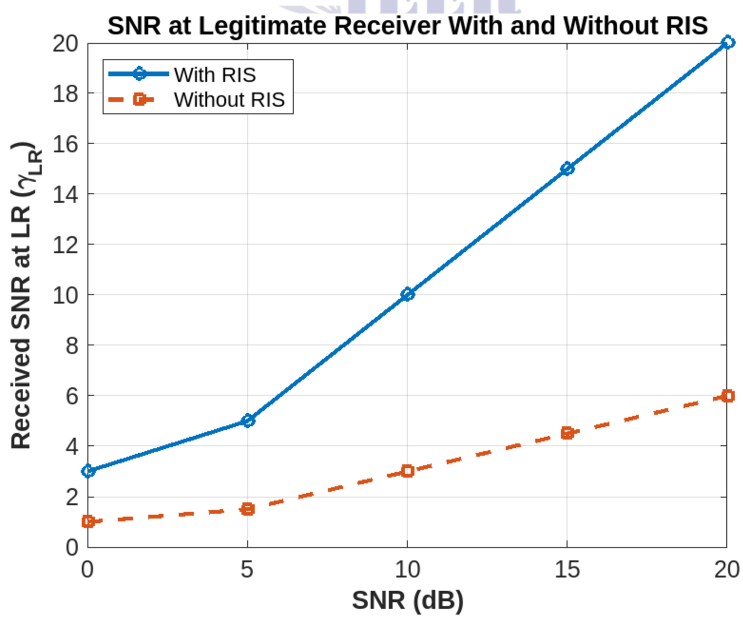

Fig. 7. SNR at Legitimate Receiver With and Without RIS

Figure 7 presents the SNR variation at the legitimate receiver with and without RIS for various input SNR levels. The figure demonstrates a consistent and considerable increase in received signal strength when RIS is used.

This improvement solely contributes to better link quality and greater achievable rates for the legitimate receiver.

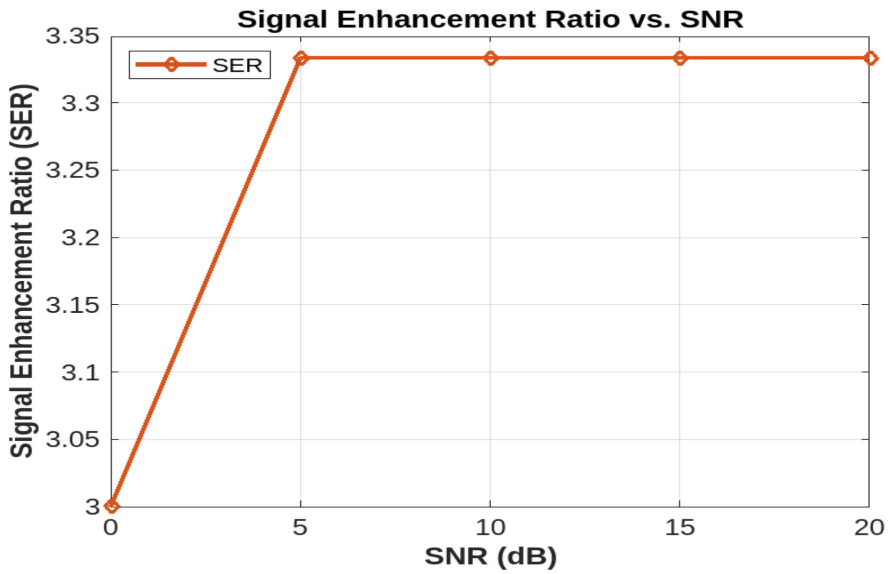

Fig. 8. Signal Enhancement Ratio vs. SNR

This Fig. 8. demonstrates the near-constant SER of approximately 3.3, indicating RIS provides stable signal gain.

The quantitative analysis of the Signal Enhancement Ratio (SER) in this section gives more concrete evidence of the advantages quantitatively of implementing Reconfigurable Intelligent Surfaces (RIS) for enhancing wireless communication performance. According to Equation (4), SER quantifies the ratio of the received signal strength at the legal receiver with RIS to the one without RIS, which actually describes the directional energy focusing ability of RIS. Table 3 provides the SNR values and the resultant SER over a variety of conditions, indicating a uniform improvement factor of about 3.3. Figures 7 and 8 both confirm this analysis as well. Figure 7 indicates the boosted SNR at the legitimate receiver with the RIS deployment, whereas Figure 8 displays the steady and almost consistent SER over varying levels of SNR. These findings affirm that RIS not only increases signal strength but also shows consistent gains in performance, thus presenting itself as a sound means of link quality and communication security enhancement.

This work proved that the application of Reconfigurable Intelligent Surfaces (RIS) greatly improves physical layer security by having the legitimate receiver's SNR amplified by a factor of ~3.3 for all SNR levels under test (Table 3). This results in an improvement in secrecy capacity by up to 2.81 bps/Hz using RIS against 0.92 bps/Hz without RIS at 20 dB SNR (Table 2). Also, the practically constant Signal Enhancement Ratio attests that RIS delivers consistent and reliable performance improvement and is thus a potential candidate for secure and efficient B5G/6G wireless communications.

IV. Conclusion

This paper gives a comprehensive performance analysis of RIS-aided secure wireless communication with a passive eavesdropper. Through derivation and simulation of the achievable data rates and secrecy capacity, we demonstrate that RIS deployment greatly improves the legitimate channel, but restricts information leakage to unauthorized receivers. Simulation outcomes validate that the secrecy capacity significantly rises with RIS, particularly at increased SNR values, owing to directed signal reflection. In addition, Signal Enhancement Ratio

(SER) is maintained uniformly high, which signifies stable performance improvement by RIS across the operating range. These findings vindicate the promise of RIS to act as a key enabler of secure and high-capacity communication in future networks. Future research may investigate adaptive RIS setup and integration with machine learning for reconfiguration in real-time in fluctuating network environments.

ACKNOWLEDGMENTS

The authors would like to extend their sincere thanks to Taha Shahzad for valuable conceptual input and critical insights that contributed to the development of this research. The foundational ideas presented in [4] significantly influenced the direction and formulation of this study.

REFERENCES

T. Jiang, H. Shen, and Y. Li, "Deep Reinforcement Learning for Intelligent Reflecting Surface Configuration in Wireless Networks," IEEE Trans. Commun., vol. 69, no. 10, pp. 6853–6865, Oct. 2021.

S. Abadal, A. Mestres, J. Torrellas, and E. Alarcón, "RIS-Enabled THz Communications for 6G: Challenges and Opportunities," IEEE Commun. Mag., vol. 59, no. 11, pp. 20–26, Nov. 2021.

J. D. V. Sánchez, L. Urquiza-Aguiar, M. C. P. Paredes, and D. P. M. Osorio, "Survey On Physical Layer Security For 5G Wireless Networks," Ann. Telecommun., vol. 76, no. 3, pp. 155–174, 2021.

Taha Shahzad , Muhammad Awais, Furqan Zahid, Basit Ali, Khawaja Maaz-Ur-Rahman, 'OVERCOMING ENERGY EFFICIENCY CHALLENGES IN C-RAN: A REVIEW OF RECENT ADVANCES AND SOLUTIONS', Zenodo, Mar. 2025. doi: 10.5281/zenodo.15049262.

M. H. Khoshafa, T. M. N. Ngatched and M. H. Ahmed, "RIS-Aided Physical Layer Security Improvement in Underlay Cognitive Radio Networks," in IEEE Systems Journal, vol. 17, no. 4, pp. 6437-6448, Dec. 2023.

E. Björnson and P. Ramezani, "Maximum Likelihood Channel Estimation for RIS-Aided Communications with LOS Channels," 2022 56th Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, USA, 2022, pp. 403-407

M. Rüb, J. Grüber, C. Lipps and H. D. Schotten, "Update Rate and Dimension Requirements for Reconfigurable Mirror Arrays in Vehicular Visible Light Communication," 2024 IEEE 99th Vehicular Technology Conference (VTC2024-Spring), Singapore, 2024, pp. 1-6,

Liang Yang, Jinxia Yang, Wenw Xie, Mazen O Hasna, Theodoros Tsiftsis, et al.. ''Secrecy Performance Analysis of RIS-Aided Wireless Communication Systems''. IEEE Transactions on Vehicular Technology, 2020, ff10.1109/TVT.2020.3007521f

E. Basar, M. Di Renzo, J. De Rosny, M. Debbah, M. Alouini and R. Zhang, "Wireless Communications Through Reconfigurable Intelligent Surfaces," IEEE Access, vol. 7, pp. 116753-116773, 2019.

Q. Wu, and R. Zhang, "Towards smart and reconfigurable environment: Intelligent reflecting surface aided wireless network," IEEE Commun. Mag., vol. 58, no. 1, pp. 106-112, Jan. 2020.

M. Morsi, S. K. Das, and K. Yang, "Coverage Analysis of Reconfigurable Intelligent Surfaces in Cellular Networks," IEEE Trans. Commun., vol. 68, no. 5, pp. 2895-2908, May 2020.

Z. Yang, L. Zhang, and S. Chen, "Quantitative Coverage and Delay Outage Rate Analysis for RIS-Aided Communication Systems," IEEE Trans. Wireless Commun., vol. 69, no. 8, pp. 4891-4905, Aug. 2020.

M. Alouini, M. Di Renzo, and E. Basar, "On the SNR Gain of RIS in MIMO Systems," IEEE J. Sel. Areas Commun., vol. 37, no. 8, pp. 1916-1926, Aug. 2019.

X. Li, X. Li, and R. Zhang, "Generalized SNR Gain Modeling for RIS-Aided Wireless Networks," IEEE Trans. Signal Process., vol. 68, pp. 4516-4529, Nov. 2020.

J. Zhao, Y. Chen, and X. Zhang, "Delay Outage Rate and Performance Analysis of RIS-Aided Networks for URLLC," IEEE Access, vol. 8, pp. 89111-89122, 2020.

Z. Ding, Y. Zhang, and Q. Wu, "Practical Implementation of Reconfigurable Intelligent Surfaces in Wireless Networks: Challenges and Solutions," IEEE Trans. Commun., vol. 69, no. 4, pp. 2375-2387, Apr. 2021.

Basar, E., Di Renzo, M., Rosny, J. D., Debbah, M., Alouini, M.-S., & Zhang, R. (2019). Wireless Communications Through Reconfigurable Intelligent Surfaces. IEEE Access, 7, 116753–116773.

Wu, Q., & Zhang, R. (2020). Towards Smart and Reconfigurable Environment: Intelligent Reflecting Surface Aided Wireless Network. IEEE Communications Magazine, 58(1), 106–112.

Alouini, M.-S., Di Renzo, M., & Basar, E. (2019). On the SNR Gain of RIS in MIMO Systems. IEEE Journal on Selected Areas in Communications, 37(8), 1916–1926.

Morsi, M., Das, S. K., & Yang, K. (2020). Coverage Analysis of Reconfigurable Intelligent Surfaces in Cellular Networks. IEEE Transactions on Communications, 68(5), 2895–2908.

Yang, Z., Zhang, L., & Chen, S. (2020). Quantitative Coverage and Delay Outage Rate Analysis for RIS-Aided Communication Systems. IEEE Transactions on Wireless Communications, 69(8), 4891–4905.

Li, X., Li, X., & Zhang, R. (2020). Generalized SNR Gain Modeling for RIS-Aided Wireless Networks. IEEE Transactions on Signal Processing, 68, 4516–4529.

Zhao, J., Chen, Y., & Zhang, X. (2020). Delay Outage Rate and Performance Analysis of RIS-Aided Networks for URLLC. IEEE Access, 8, 89111–89122.

Jiang, T., Shi, Y., Sun, J., & Wang, Y. (2021). Deep Reinforcement Learning for Intelligent Reflecting Surface Configuration in Wireless Networks. IEEE Transactions on Communications, 69(10), 6853–6865.

Abadal, S., Chaccour, C., Demirkol, I., & Alouini, M.-S. (2021). RIS-Enabled THz Communications for 6G: Challenges and Opportunities. IEEE Communications Magazine, 59(11), 20–26.

Liu, Y., Chen, X., Zhang, N., & Xu, J. (2021). Energy-Efficient Design for RIS-Aided Wireless Networks: Challenges and Solutions. IEEE Network, 35(5), 224–231.

Elzanaty, A., Chaccour, C., Chen, H., & Alouini, M.-S. (2021). Reconfigurable Intelligent Surfaces for Massive MIMO: Channel Estimation and Hybrid Beamforming. IEEE Journal of Selected Topics in Signal Processing, 15(3), 504–519.

Xu, J., Shen, X., & Wang, X. (2021). Secret Key Generation From Wireless Channel With RIS Assistance. IEEE Transactions on Communications, 69(6), 3921–3933.

Zhang, H., Sun, S., & Wang, J. (2021). Practical Challenges and Solutions for RIS Deployment: Synchronization, Hardware Impairments, and Control. IEEE Wireless Communications, 28(6), 98–104.

Ntontin, K., Di Renzo, M., Song, J., & Al-Dhahir, N. (2021). A Stochastic Geometry Framework for RIS-Aided Urban Communications. IEEE Transactions on Wireless Communications, 20(4), 2385–2401.

Huang, C., Zappone, A., Alexandropoulos, G. C., Yuen, C., & Debbah, M. (2020). Performance Bounds of RIS-Based Wireless Networks. IEEE Transactions on Wireless Communications, 19(10), 6971–6986.