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A Comprehensive Systematic Review of Reflection Intelligent Surfaces (RIS) in Free-Space Optical (FSO) Systems: Atmospheric Impacts and Advanced Communication Strategies

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ABSTRACT

Free Space Optic (FSO) communication systems offer high data rates and cost efficiency. Nevertheless, their performance is significantly hindered by adverse weather conditions like fog, rain, and snow, which result in scattering, absorption, and attenuation of optical signals. To address these challenges, integrating Reflection Intelligent Surface (RIS) technology is seen as a promising solution to enhance the performance and reliability of FSO systems. This review focuses on the impact of weather conditions on RIS-assisted FSO communication systems, using a comprehensive analysis based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework. Scholarly articles from Scopus, Web of Science (WoS), and Institute of Electrical and Electronics Engineers (IEEE), published between 2024 and 2026, were analysed, yielding 34 relevant studies. The findings were organised into three key themes: (1) RIS in FSO systems, (2) Effects of Atmospheric and Environmental Conditions on RIS and FSO Systems, and (3) Advanced Communication Strategies in Optical Networks. The analysis highlights that RIS technology can mitigate some of the detrimental effects of weather on FSO systems by dynamically adjusting the phase and direction of optical signals, improving Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), and data throughput under moderate weather conditions. However, extreme weather events still present significant challenges that RIS alone cannot fully overcome. In conclusion, while RIS significantly enhances FSO system performance in mild-to-moderate weather conditions, extreme conditions necessitate further research into innovative designs and adaptive control mechanisms that can provide robust communication across all weather scenarios.

1. Introduction

The increasing demand for high-capacity, low-latency communication systems has

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driven significant research into advanced wireless technologies [1], [2]. Free Space Optics (FSO) has emerged as a promising solution for high-speed data transmission, especially in urban environments where the Radio Frequency (RF) spectrum is limited [3]. Other than that, FSO communication leverages the line-of-sight transmission of optical signals through the atmosphere, offering several advantages, such as high bandwidth, immunity to electromagnetic interference, and secure data transfer [4], [5]. However, the performance of FSO systems is highly susceptible to environmental factors, particularly weather conditions such as fog, rain, snow, and turbulence, which can severely degrade the signal quality [4], [5] (figure 1). In parallel with the evolution of FSO, the concept of Reflection Intelligent Surface (RIS)-assisted communication has gained considerable attention to enhance the reliability and efficiency of wireless networks [4], [6]. RIS technology involves the use of programmable surfaces, typically composed of a large array of passive reflective elements, which can be adjusted to control the phase, amplitude, and direction of incoming electromagnetic waves. By intelligently manipulating these properties, RIS can effectively mitigate signal blockages, improve signal strength, and extend the coverage area, making it a valuable addition to FSO systems [7].

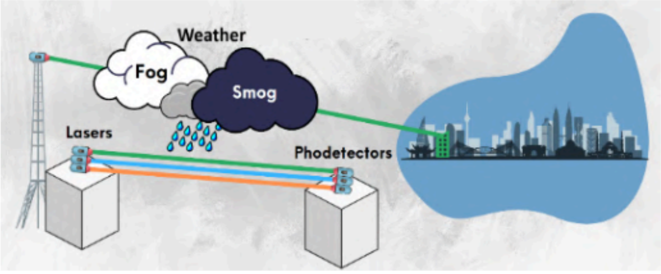

Fig. 1. FSO Communication System [8]

The integration of RIS into FSO communication systems holds significant potential to overcome some of the inherent limitations of FSO, particularly in adverse weather conditions [9]–[15]. Moreover, RIS can be strategically deployed to optimize the path of optical signals by passing obstructions and compensating for signal degradation caused by scattering and absorption in the atmosphere [9], [14], [16]–[18]. This synergy between FSO and RIS could lead to more resilient communication systems that maintain high performance even in challenging environmental scenarios [12], [15], [19]. Despite its promising advantages, the performance of RIS-assisted FSO systems under varying weather conditions remains a critical area of investigation [20]–[22]. Note that different weather phenomena affect the propagation of optical signals in distinct ways, necessitating a comprehensive analysis to understand their impact on the overall system performance [14], [20], [21]. For instance, fog can cause severe attenuation of the optical signal due to scattering, while rain and snow primarily contribute to absorption and scattering [11], [12], [20], [21]. Additionally, atmospheric turbulence can induce random fluctuations in the signal phase and amplitude, further complicating the transmission [6], [11], [12], [15], [20], [21]

This research addresses key questions about the impact of weather on RIS-assisted FSO communication systems. It examines weather-induced issues, the implementation of adaptive strategies, and their effects on system performance in both real-world and simulated environments. Additionally, it explores the challenges of long-term, large-scale deployments under diverse weather conditions and potential solutions. By analyzing how RIS mitigates weather-related impairments, this study aims to optimize FSO systems for real-world use, contributing to the development of resilient, high-performance next-generation communication networks.

2. Literature review

The impact of weather on FSO RIS-assisted communication systems has received significant attention, with research highlighting key challenges like fog, rain, and turbulence that degrade signal quality [23]. While FSO links offer high-speed, secure communication, they rely on a direct Line of Sight (LoS) and are greatly affected by adverse weather [24], [25]. RIS can enhance signal quality by intelligently reflecting it towards the receiver, significantly improving the error performance analytical and simulation studies confirm that RIS-assisted MIMO/FSO substantially lowers outage and bit error rates under turbulence and misalignment [9], [18]. This integration can mitigate weather-related issues, increasing robustness (Simbarashe et al., 2025). Additionally, RIS has been introduced in hybrid FSO systems with RF or other links to further address these challenges and improve secrecy and reliability in mixed RF/FSO networks [26]. Research also highlights RIS's potential in Satellite–Aerial–Ground–type architectures and quantum FSO networks, enhancing reliability by overcoming blockages, cloud cover and turbulence, particularly in hybrid or RIS-assisted FSO/RF and quantum setups that dynamically adjust or optimize paths for stable connections [11].

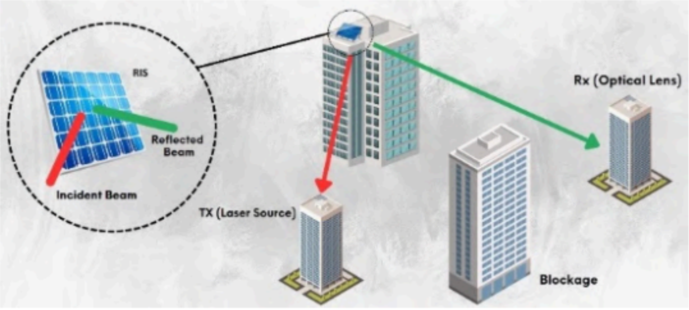

Fig. 2. FSO Communication Systems Enhanced by RIS [8]

Recent studies have focused on the impact of weather on hybrid FSO/THz systems, particularly the performance of RIS-assisted hybrid systems under weather-induced impairments like fog and atmospheric turbulence [27], [28]. The performance of a hybrid FSO/THz system is analyzed using Maximal Ratio Combining (MRC) and Selection Combining (SC), showing that RIS technology significantly improves system resilience by optimizing the Signal-to-Noise Ratio (SNR) and reducing outage probability, even under severe atmospheric conditions [27], [28]. Integrating RIS into mixed THz/FSO systems enhances reliability and mitigates the adverse effects of fog and turbulence, common in FSO systems. These studies confirm RIS's critical role in maintaining communication performance during weather-related disturbances [29]. Research on RIS-assisted FSO systems focusing on atmospheric turbulence and pointing errors for smart city applications shows that RIS improves the Bit Error Rate (BER) and outage probability by compensating for signal blockages and turbulence-induced fading with closed-form expressions for these metrics [30]. Increasing RIS elements enhances system robustness against adverse weather conditions, emphasizing RIS's potential in ensuring reliable FSO communication in densely populated urban environments.

The integration of RIS with FSO systems has also been explored in multi-link configurations, where optimal placement of RIS elements plays a crucial role in system performance. [31] presents a model for a multi-link terrestrial RIS-assisted FSO system, considering key degrading factors such as pointing errors and atmospheric turbulence. Their results suggest that the optimal placement of RIS elements, particularly closer to the transmitter or receiver depending on conditions, can substantially improve system performance by mitigating channel impairments and jitter effects [31]. This study highlights the importance of strategic RIS placement in maximizing the benefits of RIS technology in FSO systems, especially under dynamic environmental conditions where weather and other factors significantly impact signal quality [32], [33]. Furthermore, [34] investigated transmission challenges in IRS-assisted FSO systems coexisting with direct FSO links and proposed schemes optimizing performance under varying weather conditions, demonstrating that RIS integration can improve system reliability by up to 40% [35]. The ability of RIS to dynamically manipulate optical signal propagation has been shown to improve average symbol error rates and overall system reliability; however, current research often relies on theoretical models with limited empirical validation, indicating a need for further practical studies and exploration of hybrid technologies and security implications in FSO channels [26], [34].In conclusion, integrating RIS into FSO systems significantly enhances their performance under adverse weather conditions, such as fog, rain, and turbulence. RIS technology mitigates signal degradation by optimizing the signal path and improving metrics like Signal Error Rate (SER), Bit Error Rate (BER), and outage probability. Additionally, strategic placement of RIS elements and advanced optimization techniques, such as machine learning, further enhance system reliability, making RIS a crucial component in maintaining robust FSO communication in challenging environmental conditions.

3. Material and methods

The PRISMA framework enhances transparency and rigor in systematic literature reviews through its four phases—identification, screening, eligibility, and data abstraction—focusing on randomized trials to reduce bias. This review used Web of Science, Scopus, and IEEE databases for comprehensive coverage. PRISMA’s structured approach improves research quality and reliability.

3.1 Identification

This study employed systematic review procedures to gather relevant materials, expanding keywords using dictionaries, thesauri, encyclopaedias, and prior research. Search strings were then developed for IEEE, WoS, and Scopus databases, leading to the identification of 374 relevant papers (see Table 1).

Table 1
The Search String

Scopus	ALL ((“free space optic*” OR “FSO”) AND (“reflect* intelligent* surface*” OR “Intelligent* reflection* surface*” OR “reconfigure* intelligent* surface*” OR “reflect* Intelligence* Surface*” OR “Intelligence* reflect* surface*” OR “RSI” OR “IRS”) AND (“weather*” OR “atmospheric*” OR “turbulence*” OR “rain*” OR “haze*”)). Date of Access: February 2026
IEEE	((“free space optic” OR “FSO”) AND (“reflect* intelligent surface” OR “Intelligent* reflection* surface” OR “reconfigure* intelligent surface” OR “reflect* Intelligence* Surface” OR “Intelligence* reflect* surface” OR “RSI” OR “IRS”) AND (“weather” OR “atmospheric” OR “turbulence” OR “rain” OR “haze”)). Date of Access: February 2026
WoS	TS= ((“free space optic*” OR “FSO”) AND (“reflect* intelligent* surface*” OR “Intelligent* reflection* surface*” OR “reconfigure* intelligent* surface*” OR “reflect* Intelligence* Surface*” OR “Intelligence* reflect* surface*” OR “RSI” OR “IRS”) AND (“weather*” OR “atmospheric*” OR “turbulence*” OR “rain*” OR “haze*”)). Date of Access: February 2026

3.2 Screening

During the screening phase, 249 duplicate publications were excluded, leaving 123 papers aligned with the research question on weather's impact on FSO RIS-assisted communication systems (see Table 2). The review focused on English-language literature from 2024 to 2026, including reviews, meta-analyses, and conference proceedings. A total of 21 publications were rejected due to duplication.

Table 2
The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2024 – 2026	< 2024
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Subject	Engineering	Besides Engineering
Keyword	Optical, RIS, FSO	others

3.3 Eligibility

In the eligibility phase, 102 articles were thoroughly reviewed, focusing on titles and key content to ensure alignment with the research objectives. 68 articles were excluded due to irrelevance or lack of full-text access, leaving 34 articles for further review.

3.4 Data Abstraction and Analysis

An integrative analysis was conducted to synthesize various quantitative research designs, focusing on data collection and theme development. Figure 3 shows the detailed analysis of 34 publications on weather effects in FSO RIS-assisted systems. The authors collaboratively developed themes, documented insights, and resolved any inconsistencies during the process.

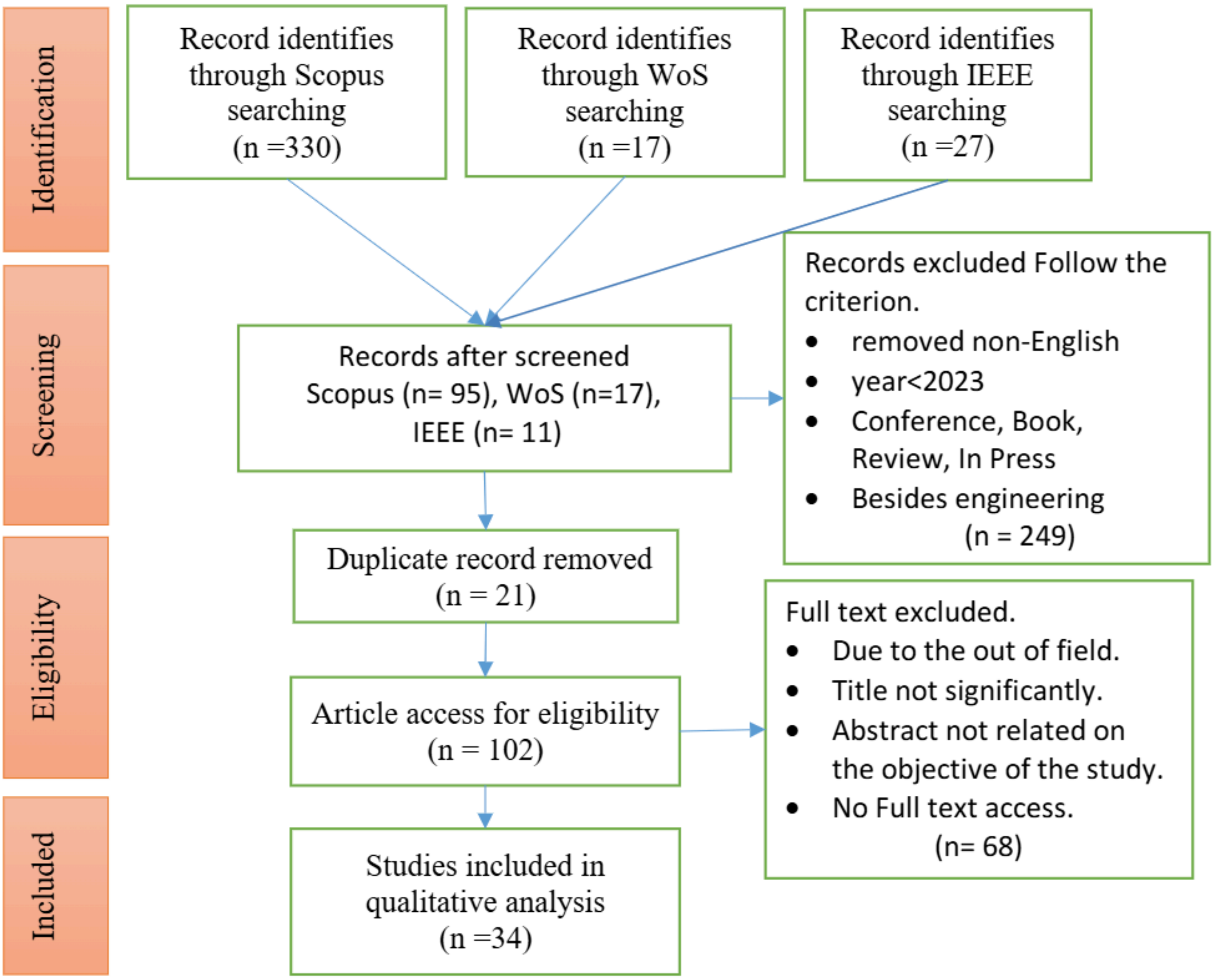

Fig. 3. Flow diagram of the proposed search (PS) study

4. Quality of Appraisal

According to the guidelines proposed by Kitchenham and Charters [36], once we had selected PSs we had to assess the quality of the research they presented and quantitatively compare them. In this study, we apply Quality Assessment (QA) from A.AbouZahra [37], which consists of five QAs for our Systematic literature review (SLR). The scoring procedure for evaluating each criterion involves three possible ratings: “Yes” (Y) with a score of 1 if the criterion is fully met, “Partly” (P) with a score of 0.5 if the criterion is somewhat met but contains some gaps or shortcomings, and “No” (N) with a score of 0 if the criterion is not met at all.

Table 3
The table outlines a Quality Assessment (QA) process used to evaluate a study based on specific criteria

Quality Assessment	Expert 1	Expert 2	Expert 3	Total Mark
Is the purpose of the study clearly stated?	Y	Y	Y	3
Is the interest and the usefulness of the work clearly presented?	Y	Y	Y	3
Is the study methodology clearly established?	Y	Y	Y	3
Are the concepts of the approach clearly defined?	Y	Y	Y	3
Is the work compared and measured with other similar work?	Y	Y	Y	3

Here's a detailed explanation:

1. Is the purpose of the study clearly stated?
   This criterion checks whether the study's objectives are clearly defined and articulated. A clear purpose helps set the direction and scope of the research.
2. Is the interest and usefulness of the work clearly presented?
   This criterion evaluates whether the study's significance and potential contributions are well-explained. It measures the relevance and impact of the research.
3. Is the study methodology clearly established?
   This assesses whether the research methodology is well-defined and appropriate for achieving the study's objectives. Clarity in methodology is crucial for the study's validity and reproducibility.
4. Are the concepts of the approach clearly defined?
   This criterion looks at whether the theoretical framework and key concepts are clearly articulated. Clear definitions are essential for understanding the study's approach.
5. Is the work compared and measured with other similar work?
   This evaluates whether the study has been benchmarked against existing research. Comparing with other studies helps position the work within the broader academic context and highlights its contributions.

Each expert independently assesses the study according to these criteria, and the scores are then totalled across all experts to determine the overall mark. For a study to be accepted for the next process, the total mark, derived from summing the scores from all three experts, must exceed 3.0. This threshold ensures that only studies meeting a certain quality standard proceed further.

5. Result and Finding

The produced themes were eventually tweaked to ensure consistency. The analysis selection was conducted by two experts specializing in communication systems, especially in FSO-RIS-assisted Communication Systems, to determine the validity of the problems. Note that the expert review phase ensures the clarity, importance, and suitability of each subtheme by establishing the domain validity of the problems. The expert review phase ensures the clarity, importance, and suitability of each subtheme by establishing the domain validity. The author also compared the findings to resolve discrepancies in the theme-creation process. Note that if any inconsistencies on the theme arose, the authors addressed them with one another.

5.1 Reflection Intelligent Surfaces (RIS) in Free-Space Optical (FSO) Systems

RIS has shown significant potential in enhancing the performance of FSO systems, particularly by mitigating the effects of atmospheric turbulence, pointing errors, and misalignments. Studies highlight the importance of RIS in improving Average Symbol Error Rate (ASER) and outage probability in turbulent conditions using advanced models such as gamma-gamma and Fisher-Snedecor F-distribution [9]. Ishida et al. (2024b) further explore the optimization of IRS placement to maximize performance by considering pointing errors and system jitter, offering valuable insights for system design [9]. Additionally, Ajam et al. (2024) propose various IRS-sharing protocols to address non-uniformity and misalignment issues in multi-link FSO systems, demonstrating the impact of IRS configurations on BER and overall system reliability [68]

The impact of atmospheric turbulence and environmental conditions on RIS-assisted FSO systems has been widely examined, with studies confirming their significance in real-world applications and showing that these systems maintain performance under adverse weather modeled by Malaga and Fisher-Snedecor distributions [48], [69]. Advanced strategies like phase-shift optimization and multihop relaying further improve system performance, enabling reliable communication across varying distances and conditions [68], [70].

5.2 Effects of Atmospheric and Environmental Conditions in Reflection Intelligent Surfaces (RIS) and Free-Space Optical (FSO) Systems

RIS significantly enhances FSO systems by mitigating atmospheric challenges like turbulence, fog, and pointing errors. Meanwhile [71] demonstrated that addressing the transmitter beam waist radius and pointing error displacement reduces the ASER in RIS-assisted FSO systems. Similarly, [72] highlighted the severe impact of atmospheric turbulence on data transmission, emphasising the challenge of maintaining reliable communication. Various studies, including those by [73] and [74], explored optimisation and error-control strategies, such as PSO and retransmission protocols, to improve FSO performance under adverse conditions. Therefore, [75] introduced SIMO techniques to mitigate jamming, verifying their effectiveness through Monte Carlo simulations.

Table 4
Summary of Results on Atmospheric and Environmental Effects in RIS and FSO Systems

Reference	Methodology	Results on Atmospheric and Environmental Conditions
[76]	Numerical simulations investigating pointing errors and atmospheric turbulence on RIS-aided FSO links using log-normal distribution for weak turbulence and SC-QAM modulation.	Atmospheric turbulence and pointing errors significantly impact the ASER, with the performance degrading with increased turbulence.
[77], [78]	Theoretical analysis of ASER using log-normal turbulence channels for FSO links with RIS. The study considers variables like link distance, transmitted power, and QAM scheme.	Atmospheric turbulence and signal attenuation result in substantial ASER degradation, particularly over long distances and with increased optical power.
[47]	Analysis of a mixed IRS-aided RF-FSO system using Nakagami-m distribution for RF and F distribution turbulence for FSO, incorporating Monte Carlo simulations.	Atmospheric turbulence and pointing errors reduce performance metrics such as BER and SNR. However, the IRS mitigates some of these adverse effects.

[79]	Investigation of the effects of environmental conditions on FSO data and power transmission under normal and turbulent conditions.	Turbulent atmospheric conditions degrade data and power transmission. Nevertheless, FSO outperforms RF communication under similar conditions.
[80]	Proposal of a PSO method for optimising UAV trajectories in FSO communications, considering atmospheric loss due to fog and pointing errors.	Atmospheric losses, particularly due to fog, create inhomogeneous media affecting laser propagation, and pointing errors exacerbate these losses. Optimised UAV trajectories reduce some of these losses.
[33]	Study of IRS-assisted UAV FSO systems affected by atmospheric turbulence, pointing errors, and jamming, using Monte Carlo simulations.	Atmospheric turbulence and pointing errors, when combined with jamming, drastically reduce system performance. Nonetheless, the IRS helps mitigate some of these effects.
[75]	Investigation of jamming impacts on RIS-assisted dual-hop FSO systems using SIMO configuration and Monte Carlo simulations.	Environmental conditions such as atmospheric turbulence, pointing errors, and jamming significantly impact the Average Bit Error Rate (ABER).

5.3 Advanced Communication Strategies in Optical Networks

RIS and hybrid FSO/RF systems have shown substantial promise in overcoming performance limitations associated with conventional FSO communication systems. [81] discuss the effectiveness of cognitive RF-FSO fronthaul assignment strategies in Cell-Free massive MIMO (CF-mMIMO) networks. The research emphasises how energy efficiency is improved by 198% in the presence of adverse weather conditions and FSO misalignment, particularly when the RF-FSO hybrid link is deployed. [82] further contribute to the field by exploring hybrid FSO/sub-THz vertical networks designed for the Internet of Vehicles (IoV). The findings underscore the importance of optimising switching techniques, showing that both soft-switching and hard-switching methods can significantly enhance performance metrics, such as outage probability and TCP throughput, especially under challenging atmospheric conditions such as rain and fog. Consequently, [83] present a similar hybrid approach by incorporating optical IRS into a dual-hop mixed FSO/RF system for Cloud Radio Access Networks (C-RAN). The results demonstrate that using polar codes and beamforming techniques significantly reduces turbulence-induced fading and misalignment errors, improving data rates and reliability, as confirmed by Monte Carlo simulations.

Environmental impediments, particularly atmospheric turbulence and adverse weather conditions, remain among the most critical challenges in maintaining signal integrity in FSO communication systems. Correspondingly, [84] propose a RIS-UAV relay-assisted hybrid FSO/RF system for Satellite Aerial-Ground Integrated Networks (SAGIN), focusing on mitigating the effects of cloud coverage and atmospheric turbulence. The study introduces a novel link-switching design that adapts to different weather conditions, such as fog and rain, effectively maintaining high-speed connections. This system improves upon traditional FSO systems by diversifying the FSO link, thereby reducing the impact of cloud blockage. Consequently, [33] highlight the importance of diversity techniques such as Signal Space Diversity (SSD) in improving system performance under fading conditions. Their analysis of distributed RIS-assisted dual-hop mixed RF-FSO systems shows that the combination of SSD and IRS can enhance spectral efficiency and diversity order, particularly when dealing with atmospheric turbulence modelled by Gamma-Gamma and Nakagami-m fading distributions. Similarly [85] provides a detailed performance analysis of hybrid FSO/RF systems under adverse climatic conditions, confirming that the deployment of IRS significantly reduces the outage probability and ASER. The Monte Carlo simulations conducted in these studies consistently validate the theoretical models, proving that hybrid techniques are key to maintaining communication reliability in a complex environment.

6. Discussion and Conclusion

The integration of Reflection Intelligent Surfaces (RIS) into Free-Space Optical (FSO) systems presents a significant advancement in mitigating environmental challenges, particularly those caused by atmospheric turbulence, pointing errors, and misalignments. RIS technology has proven effective in enhancing performance metrics such as Average Symbol Error Rate (ASER) and outage probability under turbulent conditions, utilizing advanced models to optimize system resilience, even in harsh environmental conditions. One key area where RIS adds value is through the precise placement and configuration of RIS to counter pointing errors and system jitter. Optimizing RIS placement significantly improves system performance by maximizing beam alignment and minimizing signal distortions caused by environmental factors.

Additionally, RIS-sharing protocols have been proposed to address non-uniformity and misalignment issues in multi-link FSO systems, which reduces the Bit Error Rate (BER) and enhances overall system reliability. Despite these advancements, atmospheric turbulence and environmental conditions remain a critical challenge for FSO systems. RIS has demonstrated the ability to maintain system performance even under adverse weather conditions by employing strategies such as phase-shift optimization and multihop relaying. These methods enhance system performance and ensure reliable communication across longer distances and varying weather conditions. However, while these strategies significantly improve system reliability, they require advanced computational resources and precise system design, making large-scale deployment a complex task. Environmental factors like atmospheric turbulence, fog, and pointing errors are crucial considerations. By controlling the transmitter beam waist radius and minimizing pointing error displacement, it is possible to reduce ASER in RIS-assisted FSO systems. Atmospheric turbulence can severely impact data transmission, particularly under non-optimal environmental conditions.

However, FSO communication still outperforms traditional RF communication under similar conditions, suggesting that with proper optimizations, RIS-assisted FSO systems offer a superior alternative for weather-resilient communication. Several advanced methodologies, including diversity combining techniques like Maximal Ratio Combining (MRC) and cognitive RF-FSO strategies, show promise in overcoming environmental challenges. Hybrid FSO/RF systems that incorporate RIS technology significantly improve system energy efficiency and reliability, particularly in dense urban environments and challenging atmospheric conditions.

In conclusion, the integration of Reflection Intelligent Surfaces (RIS) into Free-Space Optical (FSO) systems offers significant advantages in enhancing system performance, particularly under challenging atmospheric conditions. RIS technology not only improves key metrics such as Bit Error Rate (BER), Signal-to-Noise Ratio (SNR), attenuation, and channel capacity but also increases energy efficiency and extends communication range. Additionally, RIS enhances link reliability and reduces latency, making it essential for maintaining robust communication links. The combination of RIS with hybrid FSO/RF systems further addresses the complexities posed by environmental factors, enabling adaptive network designs that ensure consistent, high-speed communication even in adverse weather. These systems also benefit from enhanced spectral efficiency and reduced outage probability. As ongoing research continues to refine these technologies, RIS emerges as a crucial innovation, providing substantial benefits in reliability, efficiency, and overall system resilience for FSO communication networks.

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Background of selected study:

No	Authors	Title	Year	Journal	Scopus	WoS	IEEE
1	Dabiri, M.T.; Hasna, M.; Qaraqe, K.A. [38]	From Idealized Optical IRS Models to Realistic Lens-Based Architectures	2026	IEEE	/		/
2	Rahman, T.U.; Li, G.; Ali, F.; Khan, A.D.; Rehman, A.; Ouyang, Z.; Afsar, H.; Alshamrani, A.; Roslee, M. [39]	Fiber-array beamforming and modulation scheme with hybrid switching techniques for U2G-free space optical communication	2026	Elsevier	/	/	
3	Zhang, Q.; Yue, D.-W.; Jin, S.-N.; Xu, X.-Y.; Wang, M. [40]	Performance Analysis of Multi-RIS-Assisted UWOC Systems: Full Receiving Scheme and Selective Receiving Scheme	2026	IEEE	/		/
4	Liu, Z.; Yang, F.; Song, J.; Han, Z. [32]	Optical Intelligent Reflecting Surface-Assisted Visible Light Covert Communication With NOMA: An Effective Covert Spectral Efficiency	2026	IEEE	/		/
5	Salam, R.; Ashok Bohara, V. [41]	LC-OSTAR-IRS: Tunable Liquid Crystal Surfaces for High-Performance UWOC	2026	IEEE	/		/
6	Ajam H., Najafi M., Jamali V., Schober R.[42]	Optical IRSs: Power Scaling Law, Optimal Deployment, and Comparison with Relays.	2026	IEEE	/		/
7	Ata, Y.; Al-Sallami, F.M.; Gökçe, M.C.; Vegni, A.M.; Rajbhandari, S.; Baykal, Y. [43]	Optical Wireless Communication in Atmosphere and Underwater: Statistical Models, Improvement Techniques, and Recent Applications	2026	IEEE	/		/
8	Vishwakarma, N.; Premanand, R.; Swaminathan, R.; Madhukumar, A.S. [44]	RIS-Assisted MIMO THz Communication Systems with Spatial Modulation: A Performance Analysis	2026	IEEE	/		/
9	Guo, X.; Lin, Y.; Pang, D.; Li, X.; Song, Y.; Dong, K. [45]	Beam-Deviation Compensation of FSM via Beam-Tracing Modeling in Dynamic Optomechanical Systems	2026	IEEE	/		/
10	Ajam, H.; Rittler, A.; Jamali, V.; Papanikolaou, V.K.; Schmauss, B.; Schober, R. [46]	Modeling and Mitigation of Intersymbol Interference in High-Rate IRS-Assisted FSO Links	2026	IEEE	/		/
11	Shang, S.; Zedini, E.; Kammoun, A.; Alouini, M.-S. [47].	Optical Intelligent Reflecting Surfaces Empowering Non-Terrestrial Communications	2026	IEEE	/		/
12	Kumar, R.; Shukla, M.K.; Kumar, V.; Tripathi, R. [48].	UAV-Enabled SAGIN: Investigating Multi-RIS Systems for Mixed FSO-RF Communication	2026	IEEE	/	/	/

No	Authors	Title	Year	Journal	Scopus	WoS	IEEE
13	Shang, S.; Zedini, E.; Kammoun, A.; Alouini, M.-S. [49]	A Novel Hybrid Optical and STAR IRS System for NTN Communications	2026	IEEE	/		/
14	Chen, C.; Li, K.; Ji, J.; Zhao, H. [50]	A heterogeneous RIS-assisted all-optical ocean-air integrated network: Channel modelling and performance analysis	2025	Elsevier	/		/
15	Wang, J.; Gao, D.; Zhang, X.; Ding, D. [33]	ABER and outage probability of FSO systems under UAV-assisted symbol-level jamming over turbulent channels with pointing errors	2025	Elsevier	/		/
16	Xie, J.; Zhang, J.; Li, J.; Ding, X.; Wang, S.; Xie, Y.; Pan, G. (Xie et al.,	Covert communications for dual-hop FSO–RF systems with NOMA	2025	Optica (OSA)	/		
17	Li, H.; Pang, W.; Li, S.; Wang, P.; Li, H.; Hao, W.; Hui, X. [51]	Performance analysis of Dual-Client FSO communication system with UAV-Mounted STAR-RIS considering ES protocol over atmospheric IGGG distribution	2025	Elsevier	/		/
18	Kumar, A.; Dewangan, K.; Krishnan, P. (Kumar et al., 2025)	Channel capacity enhancement of RIS-assisted FSO communication system for high-speed trains access connectivity	2025	Elsevier	/		/
19	Raamesh, L.; Anitha, S.; Radhika, S.; Chandra Sekar, A. [52]	A Quantum-Crossover Gravitational Search Algorithm for Energy-Efficient Power Allocation in Serial Relaying Underwater Wireless Optical Communication Systems	2025	Wiley	/		
20	Khatiwoda, N.R.; Dawadi, B.R.; Joshi, S.R. [53]	Phase-Shift Design and Channel Modelling for Focused Beams in IRS-Assisted FSO Systems. Joint Placement Optimization and Sum Rate Maximization of RIS-Assisted UAV with LEO-Terrestrial Dual	2025	MDPI	/		
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