**PROJECT**

**SYNOPSIS**

RECONFIGURABLE INTELLIGENT SURFACE-ASSISTED  
FREE-SPACE OPTICAL COMMUNICATION SYSTEM UNDER  
THE INFLUENCE OF SIGNAL BLOCKAGE FOR SMART-CITY  
APPLICATIONS

*Submitted by*

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*Under the guidance of*

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Description generated with very high confidenceDEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING**

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| **Date of commencement of the project:** | **JAN 2024** |
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1. **Introduction**

The project focuses on the performance analysis of a proposed Reconfigurable Intelligent Surface (RIS)-assisted Free-Space Optical (FSO) communication system for smart-city applications. The system's performance is evaluated in the presence of atmospheric turbulence, blockage, and pointing errors. The study aims to understand the impact of these environmental factors on the system's performance and assess the effectiveness of RIS in mitigating their effects. Through the analysis of bit error rate (BER), outage probability, and channel capacity, the paper provides insights into the advantages of the RIS-based FSO system over conventional direct FSO systems in challenging urban environments.

1. **Need for the project**

The need for this project arises from the increasing demand for reliable and high-speed communication systems in smart cities. Free-Space Optical (FSO) communication is a promising technology for providing high-speed connectivity in urban environments. However, atmospheric turbulence, blockage, and pointing errors can significantly degrade the performance of FSO systems. The proposed Reconfigurable Intelligent Surface (RIS)-assisted FSO system aims to mitigate the effects of these environmental factors and improve the system's performance. The study provides insights into the advantages of RIS-based FSO systems over conventional direct FSO systems in challenging urban environments, making it a valuable contribution to the field of smart city communication systems which finds a variety of applications in:

* **SMART CITY INFRASTRUCTURE**: The project's outcomes can be applied to enhance communication infrastructure in smart cities, facilitating various applications such as smart transportation, surveillance, and infrastructure monitoring.
* **EMERGENCY RESPONSE SYSTEMS**: Reliable communication systems are crucial for emergency response systems in urban environments. The project's
* findings can contribute to improving communication reliability in critical situations.
* **URBAN CONNECTIVITY**: As cities evolve into smart cities, there is a growing need for efficient and reliable communication networks to support IoT devices, autonomous vehicles, and other smart city technologies.
* **INTERNET OF THINGS (IOT):** Supporting IoT applications in smart cities, the system can enable efficient and reliable data transmission for various IoT devices and sensors.
* **URBAN SURVEILLANCE AND SECURITY**: The high-speed connectivity facilitated by the system can support urban surveillance and security systems, enhancing public safety in smart city environments.

1. **Objective**

This project aims to develop and assess a communication system integrating reconfigurable intelligent surfaces (RIS) with free-space optical (FSO) technology for smart city environments. The focus is on evaluating the system's performance under urban signal blockage conditions. Key activities include literature review, system design, prototype construction, testing under simulated urban conditions, and theoretical analysis. The project will provide insights into the system's effectiveness in overcoming signal blockage challenges and offer recommendations for optimized system design and deployment strategies in smart cities.

1. **Methodology**

The project is carried out in into following parts

* **Literature Review**:
* Conduct an extensive review of existing literature on Free-Space Optical (FSO) communication systems, atmospheric turbulence modeling, signal blockage effects, pointing errors, and Reconfigurable Intelligent Surfaces (RIS) technologies.
* Analyze previous research to understand the current state-of-the-art techniques, challenges, and advancements in FSO communication systems, particularly in urban environments.
* **System Design**:
* Design a Reconfigurable Intelligent Surface (RIS)-assisted Free-Space Optical (FSO) communication system tailored specifically for smart-city applications.
* Consider the impact of atmospheric turbulence, signal blockage effects due to buildings and obstacles, and pointing errors on system design.
* Develop a conceptual framework for integrating RIS technology into the FSO communication system to mitigate signal blockage and enhance communication reliability.
* **Mathematical Modeling:**
* Develop a comprehensive mathematical model to characterize the behavior of the FSO channel in the presence of atmospheric turbulence, signal blockage, and pointing errors.
* Incorporate realistic models for atmospheric turbulence effects, including scintillation, beam wandering, and beam spreading.
* Model signal blockage effects using path loss models that account for the obstruction caused by buildings and obstacles in urban environments.
* Integrate pointing error models to simulate the misalignment between transmitter, receiver, and RIS elements.
* **Performance Evaluation:**
* Derive the probability density function (PDF) and cumulative distribution function (CDF) of the direct and RIS-assisted FSO links under various environmental conditions.
* Simulate the performance of the proposed system in terms of key metrics such as bit error rate (BER), outage probability, and channel capacity using binary phase shift keying (BPSK) modulation.
* Evaluate the impact of varying parameters such as RIS configuration, atmospheric turbulence intensity, blockage levels, and pointing error magnitudes on system performance.
* **Comparative Analysis:**
* Conduct a comparative analysis between the performance of the direct FSO link and the RIS-assisted FSO link under different scenarios and levels of signal blockage.
* Investigate how the number of RIS elements and their configurations affect the system's BER, outage probability, and channel capacity.
* Compare the reliability and efficiency of the proposed RIS-assisted FSO system with conventional direct FSO systems, highlighting advantages and limitations.
* **Impact Analysis:**
* Analyze the impact of atmospheric turbulence, signal blockage, and pointing errors on the overall performance and reliability of the proposed RIS-assisted FSO system.
* Investigate how environmental factors and system parameters influence the system's ability to maintain reliable communication links in urban environments.
* **Insights and Recommendations:**
* Provide comprehensive insights into the advantages of employing RIS technology in FSO communication systems for smart-city applications, particularly in mitigating signal blockage effects.
* Offer recommendations for optimizing system design parameters, RIS configurations, and operational strategies to enhance the reliability and efficiency of RIS-assisted FSO communication in urban environments.
* Suggest future research directions for further advancements in RIS-assisted FSO systems, including experimental validations, field trials, and scalability for large-scale smart city deployments.

1. **Result**

* **Performance Analysis**:

Bit Error Rate (BER): The BER performance of the system was analyzed under different scenarios, including direct FSO links and RIS-assisted FSO links. BER values were computed for varying numbers of RIS elements and signal-to-noise ratio (SNR) levels.

Outage Probability: The probability of system outage was determined for different configurations, considering varying levels of atmospheric turbulence, signal blockage, and pointing errors.

Channel Capacity: The channel capacity, indicating the maximum data rate that can be reliably transmitted over the FSO link, was calculated for different environmental conditions and RIS configurations.

* **Environmental Factors Impact**:

Atmospheric Turbulence: The code simulated the impact of atmospheric turbulence using parameters alpha\_turbulence and beta\_turbulence, affecting the system's performance in terms of BER, outage probability, and channel capacity.

Signal Blockage: Varying levels of signal blockage were considered (weak, moderate, strong) to assess the system's resilience and performance degradation under obstructed communication paths.

Pointing Errors: The effect of pointing errors, controlled by parameters pointing\_error\_zeta and pointing\_error\_A0, on system performance metrics was analyzed to understand their influence on communication reliability.

* **Effectiveness of RIS**:

RIS Configuration: The code evaluated different RIS configurations (static and dynamic phase shifts) to determine their impact on system performance, particularly in mitigating the effects of environmental factors on FSO communication.

* **Sensitivity Analysis:**

Critical Parameters: Sensitivity analysis was conducted to identify critical parameters (alpha\_turbulence, beta\_turbulence, pointing\_error\_zeta, pointing\_error\_A0) that significantly affect system performance. The analysis helped in understanding parameter ranges that optimize system reliability and efficiency.

* **Visualization**:

Plotting: The code generated various plots and visualizations to illustrate system performance metrics such as received signal constellation, BER performance, outage probability analysis, and channel capacity analysis. These visualizations aid in interpreting and analyzing the simulation results effectively.

* **Snr Vs (Tx and Rx) Positions:**

he "TX and RX vs SNR" result plot visualizes the Signal-to-Noise Ratio (SNR) as a function of the transmitter (TX) and receiver (RX) positions in the communication system. This plot provides valuable insights into how the SNR varies based on the geographical locations of the transmitter and receiver within the smart city environment.

Here's a breakdown of what the plot represents:

* X-Axis (TX Position): This axis represents the positions of the transmitter along a specific axis within the smart city environment. The positions are usually measured in meters or kilometers, depending on the scale of the simulation or real-world scenario.
* Y-Axis (RX Position): Similarly, this axis represents the positions of the receiver along a specific axis within the smart city environment. Like the TX position, RX positions are also measured in meters or kilometers.
* Z-Axis (SNR): The Z-axis represents the Signal-to-Noise Ratio (SNR) in decibels (dB). SNR is a crucial metric in communication systems as it quantifies the ratio of the received signal power to the background noise power. Higher SNR values indicate better signal quality and, consequently, better communication performance.
* **Insights and Recommendations**:

System Advantages: The results provide insights into the advantages of using RIS-assisted FSO communication systems over conventional direct FSO systems in smart city environments, highlighting their potential to enhance reliability and efficiency in urban communication scenarios.

Future Research Directions: Based on the findings, recommendations for future research directions are proposed, aiming to further improve the design and performance of RIS-assisted FSO communication systems for smart city applications.

1. **Project Schedule**

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| *Jan 2024* | * Conduct an extensive review of literature on FSO communication systems, atmospheric turbulence, signal blockage effects, pointing errors, and RIS technologies. * Gather relevant research papers, articles, and conference proceedings. * Design the conceptual framework for the RIS-assisted FSO communication system. * Define system requirements, considering smart-city applications and environmental factors. |
| *Feb 2024* | * Develop mathematical models for the FSO channel in the presence of atmospheric turbulence, signal blockage, and pointing errors. * Integrate realistic models for atmospheric turbulence effects and signal blockage. * Set up the simulation environment to replicate real-world conditions encountered in smart city scenarios. * Configure parameters for simulating the FSO communication system and its environment. |
| *Mar 2024* | * Implement simulation algorithms to evaluate the performance of the proposed system. * Simulate the system's performance in terms of BER, outage probability, and channel capacity under various scenarios. * Conduct comparative analysis between the direct FSO link and the RIS-assisted FSO link. * Investigate the impact of RIS configurations and environmental factors on system performance. |
| *Apr 2024* | * Analyze the impact of atmospheric turbulence, signal blockage, and pointing errors on the overall system performance. * Evaluate the system's ability to maintain reliable communication links in urban environments. * Provide comprehensive insights into the advantages of the RIS-assisted FSO system for smart-city applications. * Offer recommendations for optimizing system design parameters and operational strategies. * Compile all findings, analyses, and recommendations into a comprehensive project report. * Proofread, edit, and finalize the report for submission by the project deadline. |

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| *Project Details* | | | |
| **Project Title** | Reconfigurable intelligent surface-assisted free-space optical communication system under the influence of signal blockage for smart-city applications | | |
| Project Duration | 4 months | Date of reporting | Jan 2024 |
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