Review-I

DESIGN AND SIMULATION OF RADIO-OVER-FIBER(ROF) SYSTEM FOR 5G BACKHAUL 6G TERAHERTZ EXTENSIONS USING OPTISYSTEM

AY 2025-26

Capstone Project – Introduction (PROJ2999)

GITAM
DEEMED TO BE UNIVERSITY

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Objective and Goals

•Objective:

•To design and simulate a Radio-over-Fiber system for 5G backhaul using OptiSystem.

•Goals:

•Investigate system performance with varying fiber lengths (2-40 km) and RF carrier frequencies (10-60 GHz).

•Analyze 64-QAM and 256-QAM modulation schemes in OFDM systems.

•Extend the RoF architecture for 6G Terahertz links (140-300 GHz).

•Evaluate performance metrics including Error Vector Magnitude (EVM), Bit Error Rate (BER), and Q-factor.

•Propose improvements for real-world deployment.

Project Plan

Gantt Chart - Milestones and Activities

Task ID	Task Name	Duration	Start Date	End Date
1.0	Project Initiation & Planning	1 Week	Sep 1, 2025	Sep 7, 2025
1.1	Finalize Problem Statement & Objectives	3 Days	Sep 1, 2025	Sep 3, 2025
1.2	Develop Project Plan & Gantt Chart	4 Days	Sep 4, 2025	Sep 7, 2025
2.0	Literature Survey	2 Weeks	Sep 8, 2025	Sep 21, 2025
2.1	Research RoF for 5G/6G	7 Days	Sep 8, 2025	Sep 14, 2025
2.2	Study OptiSystem & Relevant Components	7 Days	Sep 15, 2025	Sep 21, 2025
3.0	System Design & Architecture	2 Weeks	Sep 22, 2025	Oct 5, 2025
3.1	Design 5G RoF Transmitter/Receiver	7 Days	Sep 22, 2025	Sep 28, 2025
3.2	Design 6G THz Extension Architecture	7 Days	Sep 29, 2025	Oct 5, 2025
4.0	Review-I Preparation & Submission	1 Week	Oct 6, 2025	Oct 12, 2025
4.1	Prepare Report and Presentation	7 Days	Oct 6, 2025	Oct 12, 2025
5.0	Implementation & Simulation (Planned)	5 Weeks	Oct 13, 2025	Nov 16, 2025
5.1	Build Baseline 5G RoF System	2 Weeks	Oct 13, 2025	Oct 26, 2025
5.2	Simulate Parameter Variations	2 Weeks	Oct 27, 2025	Nov 9, 2025
5.3	Simulate 6G THz Extension	1 Week	Nov 10, 2025	Nov 16, 2025
6.0	Final Report & Submission (Planned)	2 Weeks	Nov 17, 2025	Nov 30, 2025
6.1	Analyze Results and Draw Conclusions	7 Days	Nov 17, 2025	Nov 23, 2025
6.2	Finalize Project Report and Deliverables	7 Days	Nov 24, 2025	Nov 30, 2025

Literature Survey

Key Publications:

Agrawal, G. P. (2012): Provided foundational knowledge on fiber-optic communication systems.

Seeds, A. J., & Williams, K. J. (2006): Introduced microwave photonics, the basis of RoF technology.

Saleh, A. A. M., & Simmons, J. M. (2019): Discussed network architectures relevant to 5G multi-tier cellular networks.
Koenig, S., et al. (2013): Demonstrated high-data-rate wireless communication in the sub-THz range.

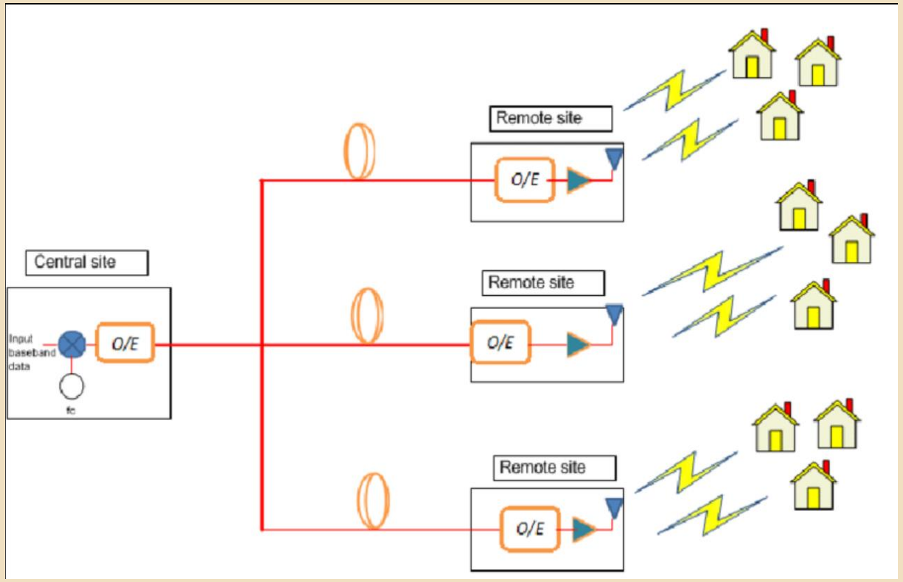
Rappaport, T. S., et al. (2019): Outlined the challenges and opportunities for wireless communications at THz frequencies for 6G.

Key Resources:

Software: Optiwave Systems Inc. OptiSystem 17 is used for its comprehensive optical and RF component libraries.

Existing Implementations:
The literature confirms that RoF is a mature candidate technology for 5G backhaul applications.
Photonic THz generation is identified as a strong potential technique for 6G systems.

Diagrams


Central site
Input baseband data
O/E
Remote site
O/E
Remote site
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Remote site
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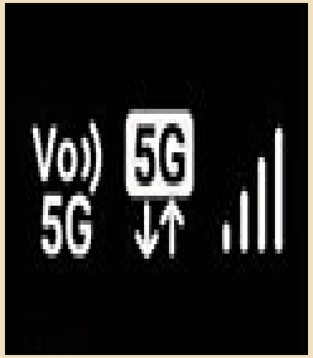
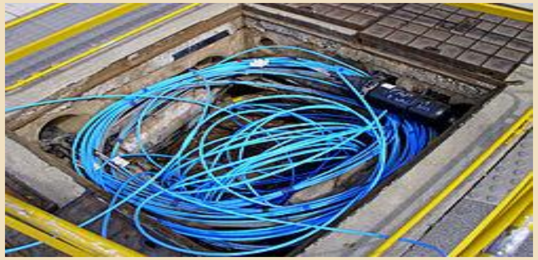
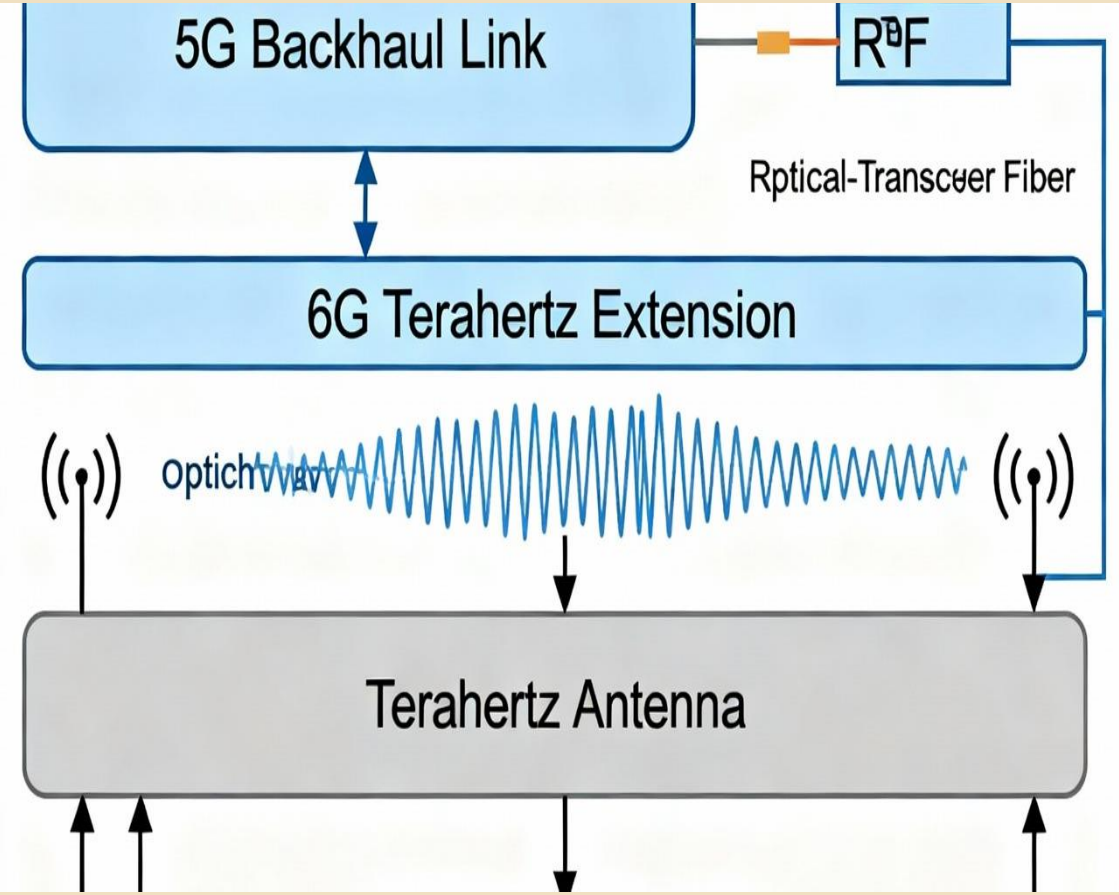
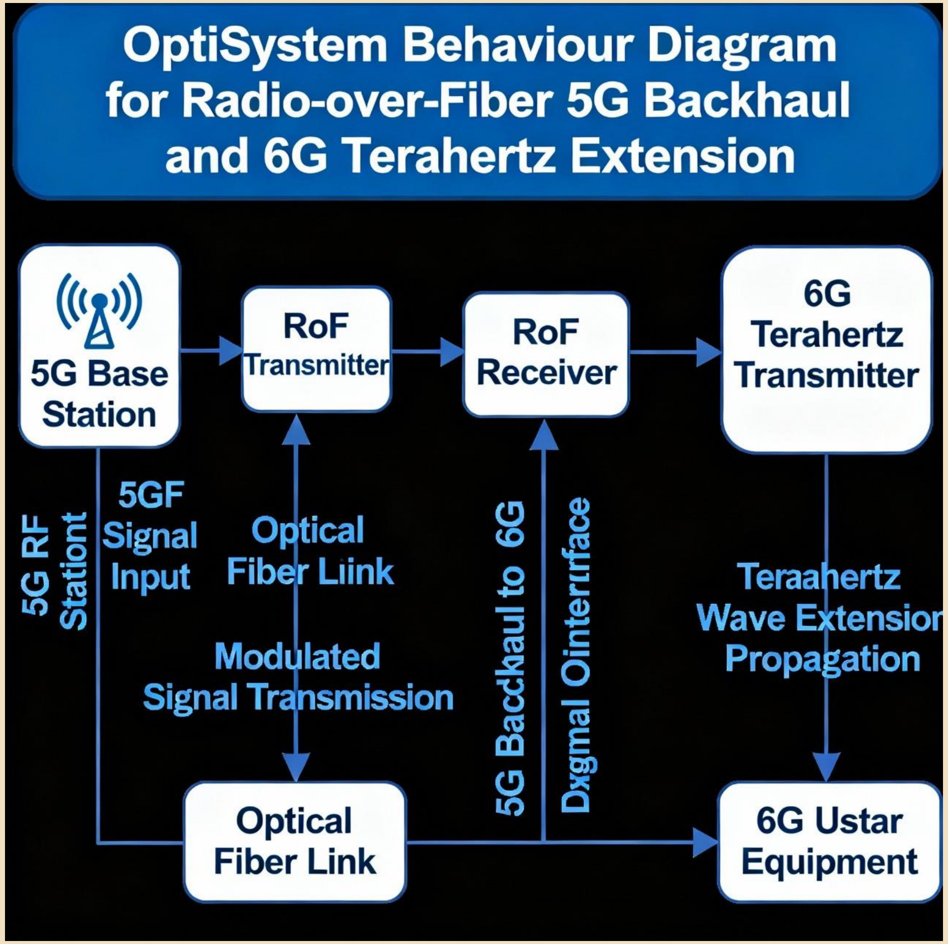

Vo)) 5G
5G



Architecture





Use Cases & Testing

Use Cases

•**5G Backhaul/Fronthaul:** RoF is a key enabler for C-RAN (Cloud/Centralized Radio Access Network) and distributed antenna systems (DAS). It centralizes complex baseband processing, allowing simpler, lower-cost Remote Antenna Units (RAUs) to be deployed closer to users, improving signal quality and capacity in dense urban areas, stadiums, and large buildings.

•**6G Terahertz Links:** As we move towards 6G, RoF is the most promising technology for generating and distributing ultra-high-frequency Terahertz signals. It overcomes the high atmospheric attenuation and free-space path loss of THz waves by converting the signal to a THz frequency only at the final point of transmission. This enables ultra-high-speed, short-range indoor and outdoor wireless links.

•**Satellite Communications:** RoF links are used to connect ground-based satellite dishes to a central processing station, providing low-loss, high-bandwidth communication over long distances.

•**Military and Radar Systems:** The ability to distribute high-frequency RF signals with high fidelity and low latency makes RoF ideal for phased-array radar systems and electronic warfare applications.

Testing Methodologies

•**Simulation-Based Testing (OptiSystem):** This project uses OptiSystem to perform "virtual" testing. This is a cost-effective and efficient way to analyze system performance under a wide range of parameters (e.g., varying fiber length, RF frequency, and modulation schemes) and to model fiber impairments like chromatic dispersion and nonlinearities.

•**Performance Metrics:** The primary metrics for evaluating system performance include:

- **Bit Error Rate (BER):** Measures the number of erroneous bits received, indicating the overall quality of the digital link.
- **Q-factor:** A measure of the signal-to-noise ratio in a digital communication system, directly related to the BER.
- **Error Vector Magnitude (EVM):** Quantifies the difference between the ideal and measured constellation points in a QAM-modulated signal, revealing impairments caused by noise, distortion, and phase noise.

•**Experimental Validation:** While our project is simulation-based, a crucial next step would be hardware prototyping. Experimental testing involves:

- Building a physical setup with real lasers, modulators, fiber spools, and photodiodes.
- Using test and measurement equipment (e.g., spectrum analyzers, oscilloscopes, and BER testers) to validate the simulation results in a real-world environment.
- This step is vital for uncovering real-world impairments not captured in simulation.

Implementation Plan

Iteration 3: 6G Terahertz Extension

•**Plan:**

- Modify the transmitter architecture to implement photonic THz generation.
- **Optical Heterodyning:** Use two laser sources with a precise frequency offset (e.g., 140 GHz).
- Modulate one of the lasers with the data signal before combining them at the photodiode to generate the THz carrier.
- Simulate a short-range wireless hop by modeling free-space path loss for the THz link.

•**Objective:**

- To successfully generate a stable THz carrier at the target frequency (140-300 GHz).
- To demonstrate and analyze the feasibility of transmitting data over the photonic-generated THz link.

Conclusion & Future Work

Expected Conclusion:

The simulation is expected to validate that RoF is a viable and scalable backhaul solution for 5G mmWave networks, supporting links up to 20-40 km with acceptable performance.
A clear trade-off between robustness (64-QAM) and spectral efficiency (256-QAM) will be demonstrated, showing the impact of modulation schemes on system performance.
The extension to 6G will show that photonic heterodyning is a viable technique for generating stable THz carriers for short-range, ultra-high-speed wireless hops. The simulation will reveal the unique challenges and opportunities of this technology.

Future Work:

Digital Signal Processing (DSP) Implementation: Implement advanced DSP algorithms to compensate for channel impairments. This includes adaptive equalization to mitigate chromatic dispersion and phase noise compensation techniques, which could significantly extend the system's reach and improve performance.
Integration with Other Technologies: Investigate the integration of RoF with technologies like Free Space Optics (FSO) or Free Space Terahertz (FST) to create a hybrid fiber-wireless network. This would allow for flexible deployment in environments where physical fiber links are impractical.
Cost and Power Analysis: Conduct a comprehensive analysis of the cost and power consumption of the proposed system compared to traditional backhaul solutions. This is a critical factor for real-world deployment and commercial viability.
Multi-User and Multi-Cell Simulation: Expand the current single-link simulation to a more complex network-level scenario to analyze performance in a multi-user, multi-cell environment. This would provide more realistic insights into network-wide performance.

THANK YOU

Have a Great Day !