

Title: 5G Network deployment for Single Leaky Coaxial Cable in Tunnel and Subway/Metro Scenarios.

MCNS is glad to announce the undertaking of a very important project on Single Leaky Coaxial Cable in Tunnel and Subway/Metro Scenarios, outlining a detailed deployment strategy and technical assessment framework for utilizing a **Single Leaky Coaxial Cable (LCX)** in order to provide **5G network coverage and capacity in tunnel and subway (metro) environments**. The goal is to enable reliable, scalable, and efficient 5G services in underground transit infrastructure, balancing cost, complexity, and performance.

This technical project aims to study and provide a comprehensive evaluation framework and deployment strategy for 5G mobile network coverage using a **Single Leaky Coaxial Cable (LCX)** system in **tunnel and subway (metro) environments (figure 1)**. The objective is to assess the feasibility, performance trade-offs, and optimization techniques for delivering enhanced 5G service quality in confined, linear, and interference-sensitive spaces such as underground rail systems.



Figure 1

Leaky coaxial cables, traditionally used in legacy 2G/3G/4G deployments for confined coverage scenarios, are repurposed and evaluated here for 5G NR bands, particularly in the sub-6 GHz range and potential FR2 extensions. The deployment scenario assumes a **single cross polarized LCX per tunnel bore (Figure 2)** to minimize installation complexity and reduce cost, while maintaining reliable service coverage and capacity for a large number of concurrent users typical in public transport systems.

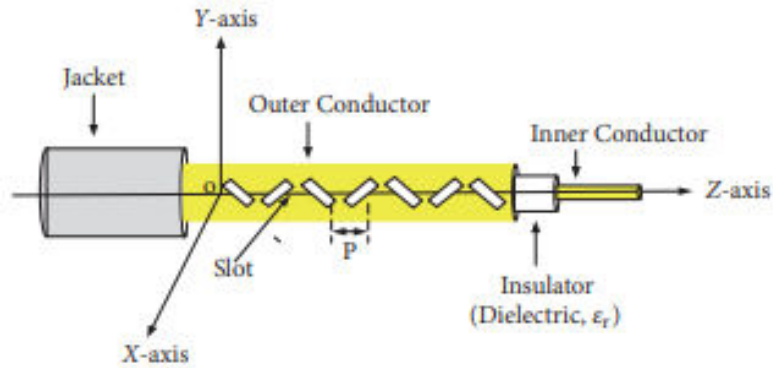


Figure 2

The abstracted system performance is assessed based on key metrics including **5G signal propagation characteristics** (Figure 3) within tunnel constraints (path loss, delay spread, penetration loss), **effective coverage range per LCX section**, and the impact of **LCX coupling loss** and **slot spacing** on received signal strength. The report further examines **cell overlap design**, **handover performance**, and **beam management limitations** in low-scattering tunnel environments.

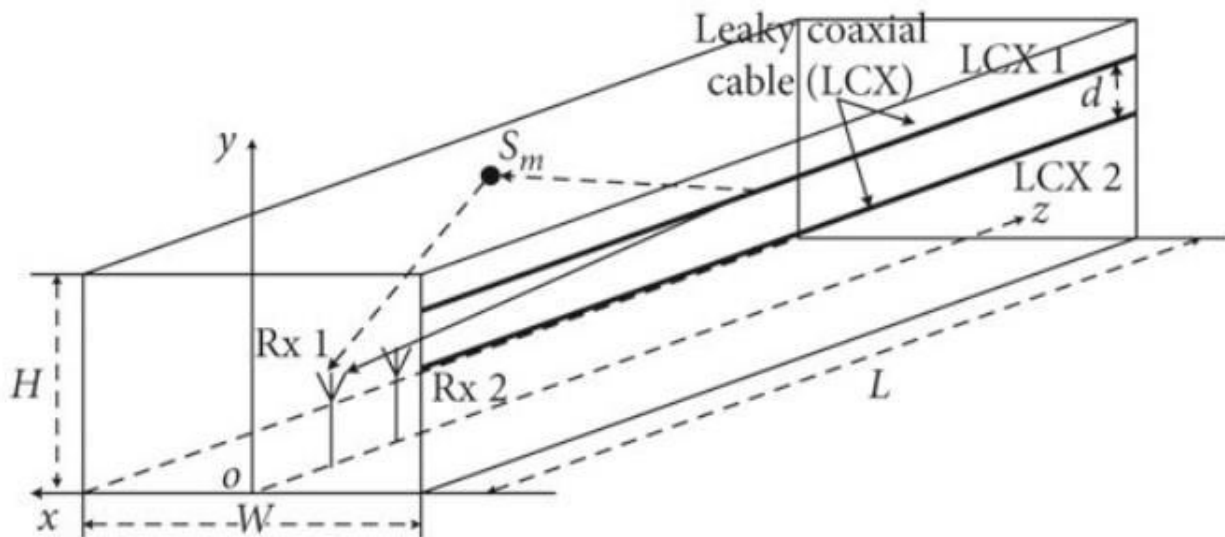


Figure 3

In terms of **5G capacity**, the study evaluates the **number of simultaneously supported users per sector**, accounting for typical train passenger densities, per-user traffic models (eMBB-focused), and TDD resource allocation schemes. It considers limitations imposed by LCX bandwidth constraints, MIMO compatibility (with spatial diversity restrictions), and scheduling inefficiencies due to limited angular resolution in confined spaces.

The project also investigates **uplink power control challenges**, **thermal noise accumulation over long LCX runs**, and **interference scenarios** in multi-train or multi-cell handoff zones. Attention is given to **QoS assurance**, especially for mission-critical or low-latency services (e.g., live CCTV streaming, automated

train control systems). Mitigation strategies such as **LCX-fed small cells**, **low-loss amplification**, and **dynamic resource partitioning** are discussed.

Finally, the document identifies deployment best practices, including LCX routing, repeater/amplifier placement, and synchronization with above-ground 5G gNBs. It outlines a test plan for field measurement validation, KPI benchmarking, and future extensions toward **6G-ready tunnel infrastructures**.

Follows a short presentation of the Project Deliverables

1. Objectives

- To evaluate the feasibility of deploying a single LCX per tunnel for 5G signal distribution.
 - To assess the coverage and capacity performance achievable using LCX-fed infrastructure.
 - To identify key design constraints and mitigation strategies in confined tunnel environments.
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2. Deployment Scenario

- **Environment:** Underground metro tunnels with typical cross-sections of 5–7 meters in diameter.
 - **Architecture:** One LCX installed along the side or ceiling of the tunnel.
 - **Frequency Band:** Sub-6 GHz (e.g., n78) with optional study of FR2 feasibility.
 - **gNB Placement:** Centralized gNB with remote LCX-fed RF heads or repeaters.
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3. Coverage Performance Considerations

- **Path Loss Modeling:** Tunnel-specific models accounting for waveguide effects.
 - **LCX Parameters:** Coupling loss, slot density, attenuation per meter.
 - **Maximum LCX Span:** Determined based on required RSRP/RSRQ at cell edge.
 - **Coverage Uniformity:** Impact of curvature, train metal surfaces, and tunnel material.
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4. Capacity Performance Considerations

- **User Density:** Peak load scenarios during rush hour (e.g., 500–800 users per train).
- **Traffic Profile:** Predominantly eMBB with intermittent URLLC (e.g., control systems).
- **Spectral Efficiency:** MIMO limitations in tunnel (limited angular spread).

- **Scheduler Load:** Resource allocation strategies with constrained coverage.
 - **MIMO over LCX:** 2x2 MIMO can be supported using cross-polarized LCX cables, where orthogonal polarization modes enable spatial separation, improving throughput and reliability within the tunnel constraints.
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5. Radio Planning and Handover

- **Cell Overlap Design:** Minimal overlapping regions to avoid unnecessary handovers.
 - **Mobility Handling:** Intra-LCX handover performance between gNB sectors.
 - **Synchronization:** GPS-free timing sync using PRTC or fiber-distributed timing.
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6. Uplink and Interference Challenges

- **Uplink Power Control:** Mitigating long LCX cable-induced signal losses.
 - **Noise Accumulation:** Impact of multiple amplifiers or repeaters.
 - **Inter-Train Interference:** Scenarios with multiple active UEs per cell.
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7. Enhancement Strategies

- **Inline Repeaters:** For extended LCX coverage (> 300m).
 - **Beamforming Alternatives:** Digital beamforming at gNB with beam selection based on SSBs.
 - **Network Slicing:** Supporting separate slices for public traffic and operational systems.
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8. Testing and Validation Plan

- **KPIs:** RSRP, SINR, throughput, handover success rate, latency.
 - **Drive Testing:** Simulated train movement using controlled UE rigs.
 - **Service Trials:** Real-train environment trials with phased rollout.
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9. Future Evolution

- **6G-readiness:** Potential upgrade path to ISAC and mmWave LCX integration.
- **Digital Twin Integration:** Using tunnel RF models to simulate and optimize planning.

Read the Cellnex's LinkedIn [post](#)

The project has been successfully completed, indicating the maturity of our experience and consulting services