



OPTI-6G

Optical access enabling buildings to communicate and sense simultaneously

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6G SNS

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Why Do Buildings Need New Network Infrastructure?

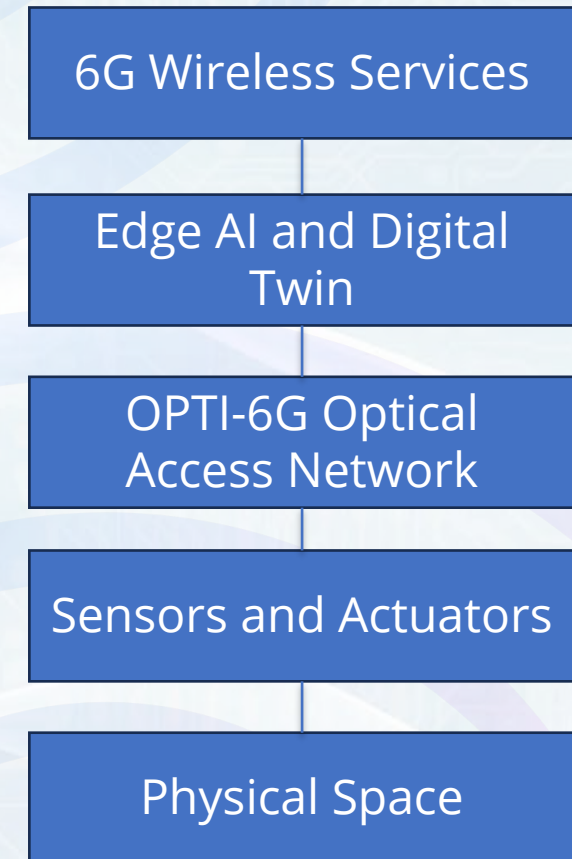
- Emerging 6G Applications have demanding new requirements
 - Extended Reality (XR) – increased indoor traffic and high accuracy localisation
 - Digital Twins
 - Autonomous Robots - Real-time sensing and control and high accuracy localisation
 - Smart Manufacturing - Massive indoor traffic and Ultra-low latency requirements
 - Intelligent Healthcare - Dense wireless deployments and ultra secure communications
 - Human-AI Collaboration - increased indoor traffic and high Energy efficiency
- **Wireless (radio) alone cannot meet future indoor communication and intelligence requirements**

Vision of the 6G Intelligent Building - From Connected Buildings to Cognitive Buildings

Future Building Characteristics

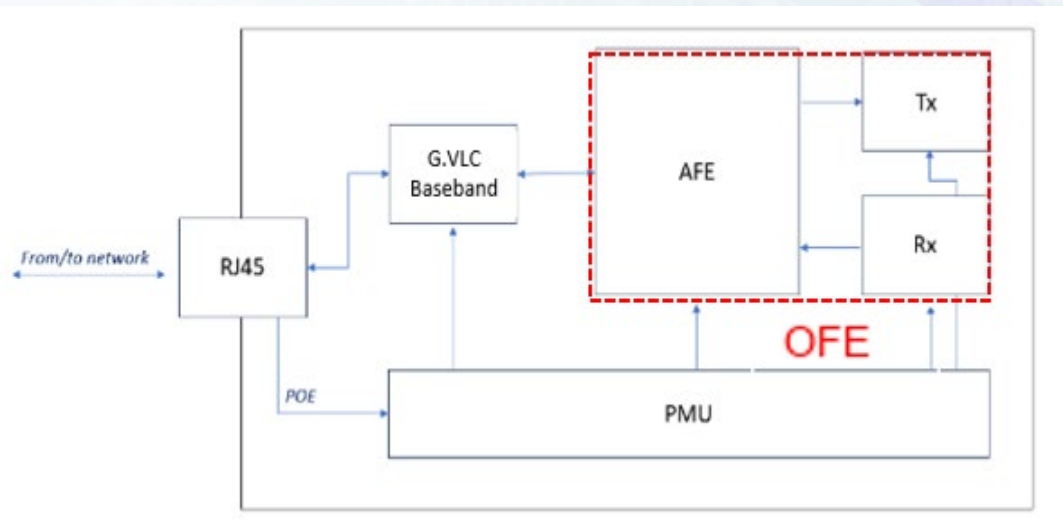
- Connectivity everywhere
- Continuous sensing
- Intelligent decision-making
- Autonomous operation
- Human-centric services

OPTI-6G Optical access system forms the nervous system of the smart building.

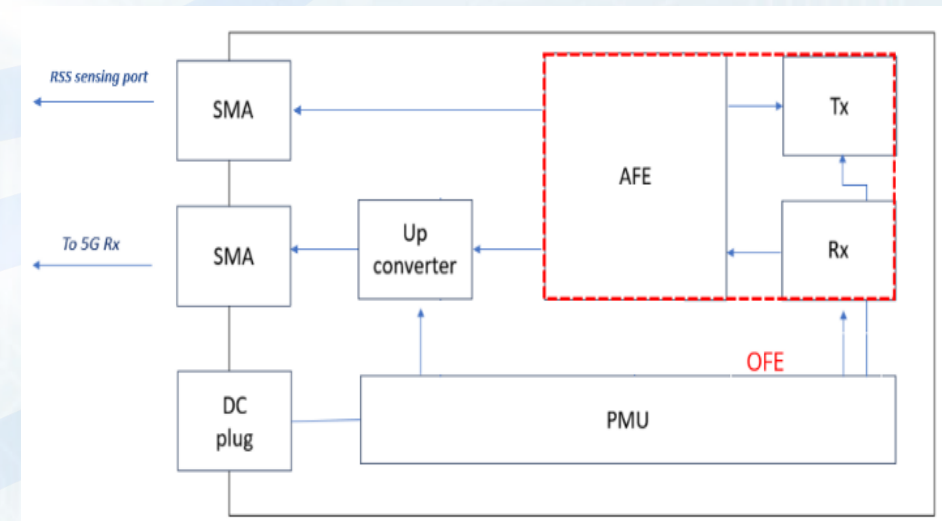


Adaptation of LiFi OWC Antenna to 5G OWC Antenna

- The OWC system 5G building blocks have been adapted from baseband part of an existing G.vlc LiFi system.

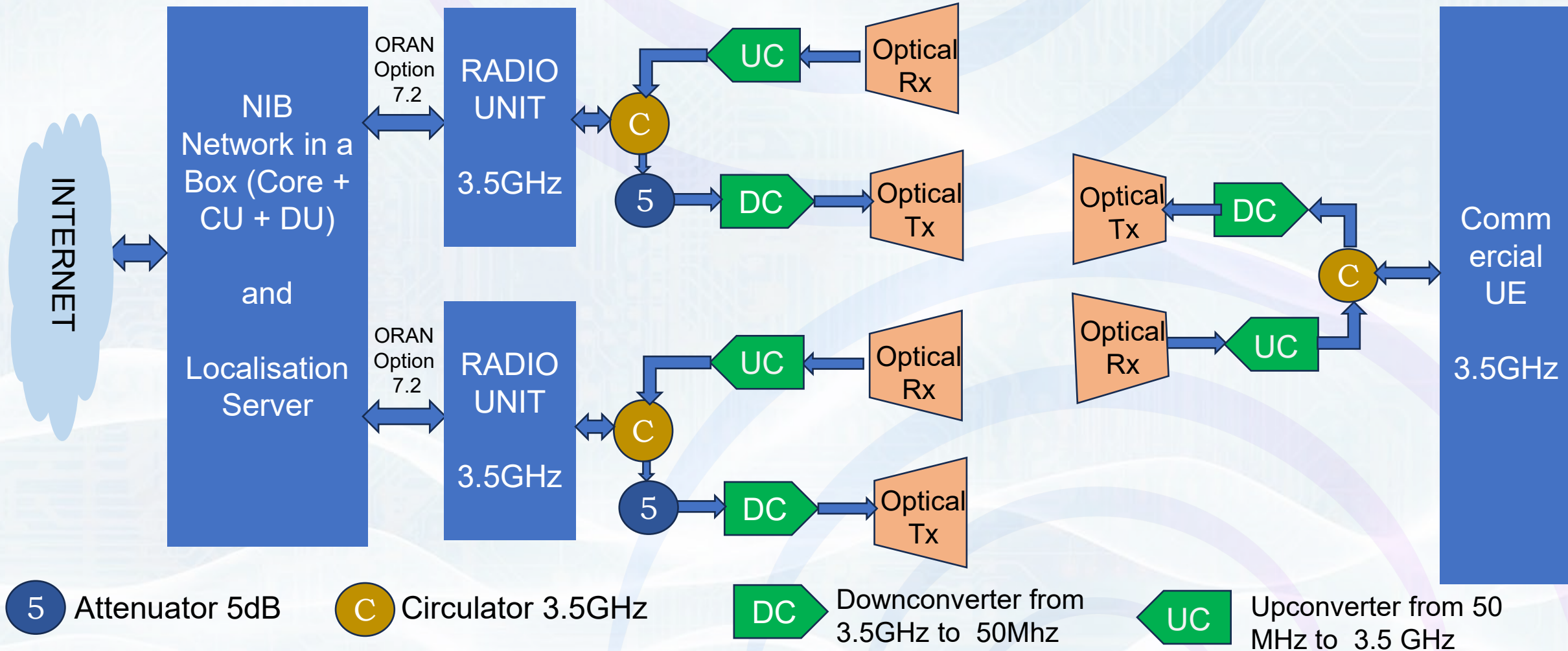


ADAPTATION

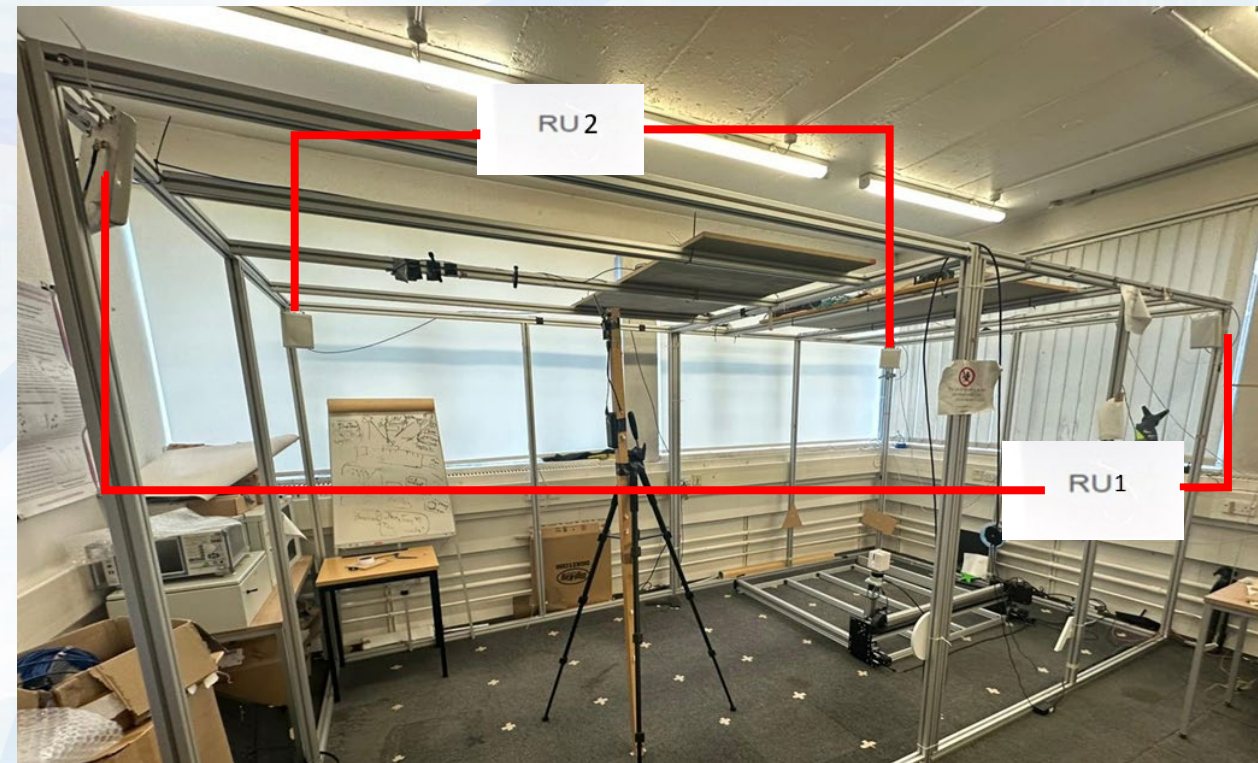
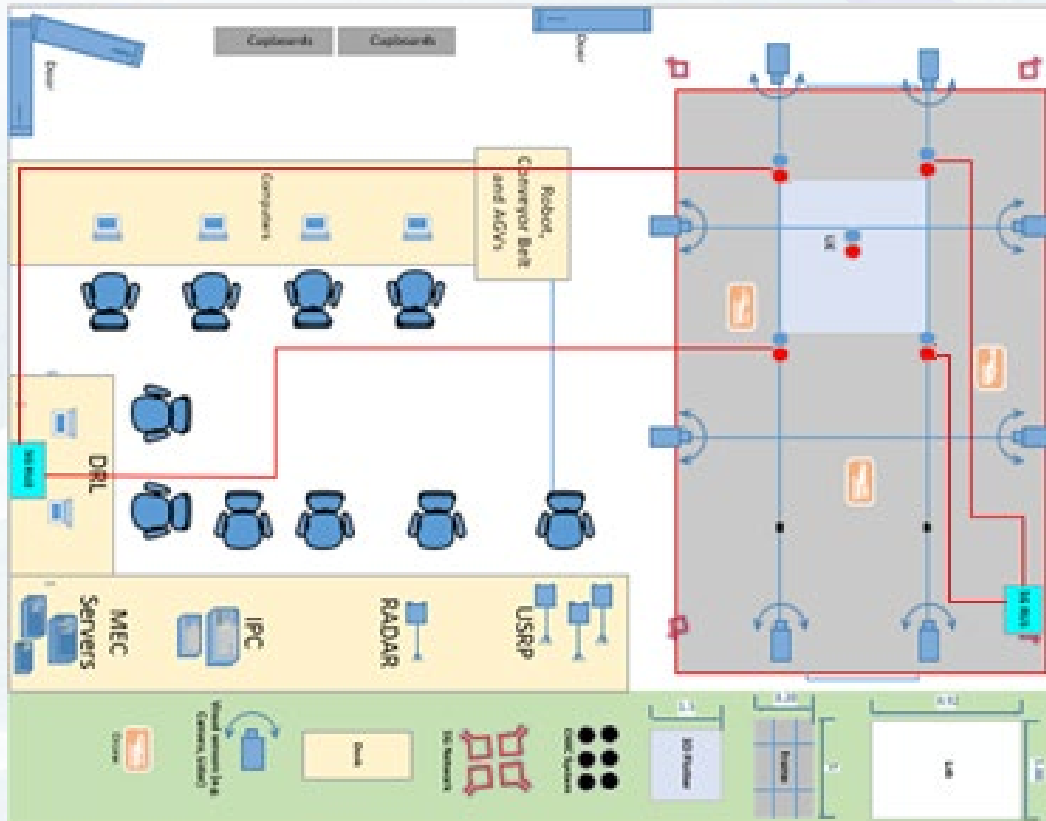


- The G.vlc baseband and the PHY Ethernet has been replaced by an up/down converter (using an RF mixer) to allow using OWC to interface with the 5G network.

Integration of 5G OWC Antenna for OPTI-6G Cellfree Test



Cellfree Lab Configuration



Preliminary Cellfree Streaming Performance Tests

- The preliminary experimental setup uses a laptop receiver and a Raspberry Pi camera streamer connected through a private 5G-box setup.
- The laptop uses a Telit Remote NDIS6 air interface and has local Telit LAN address 192.168.225.150.
- The Raspberry Pi uses a Quectel device on wwan0 and has address 192.168.2.2.
- The experiment will be repeated using 5G OWC antenna system

Pi-to-Laptop vs Pi-to-Pi Comparison

Overlay comparison using the same first 720 received frames



Note: Pi-to-Pi delay includes sender/receiver clock-offset effects; jitter and throughput are receiver-side measurements.

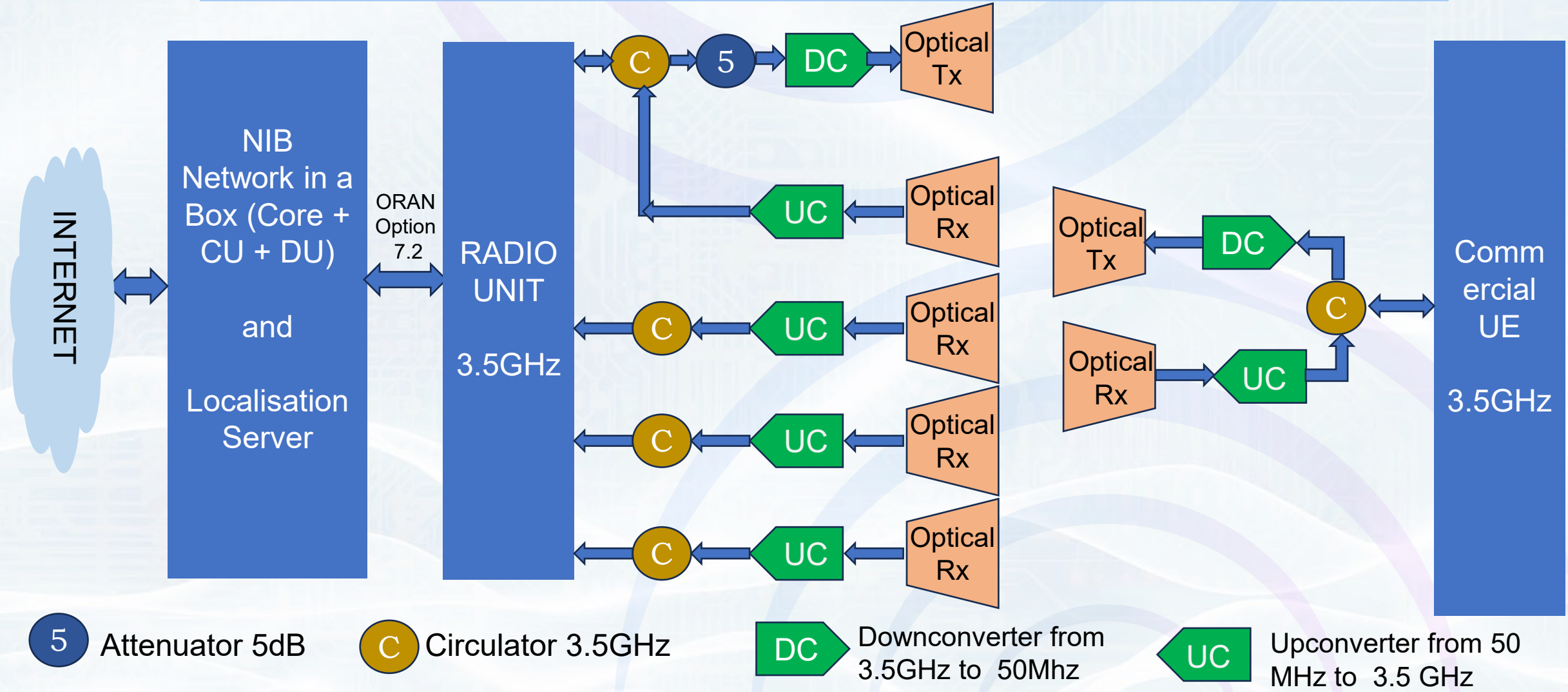
Metric	Pi-to-laptop	Pi-to-Pi, first 720 frames
Frames compared	720	720
Duration	29.96 s	23.98 s
Lost frames	0	0
Avg. delay	55.62 ms	3.56 ms*
Max delay	182.04 ms	95.12 ms
Avg. jitter	5.42 ms	10.31 ms
Max jitter	19.55 ms	16.06 ms
Avg. throughput	1.376 Mbps	1.163 Mbps
Avg. FPS	24.10	29.85

Proposed Common Metrics for Future Sub-6 GHz and Infrared OWC Network Comparison

- Proposed metrics for 5G OWC antenna system

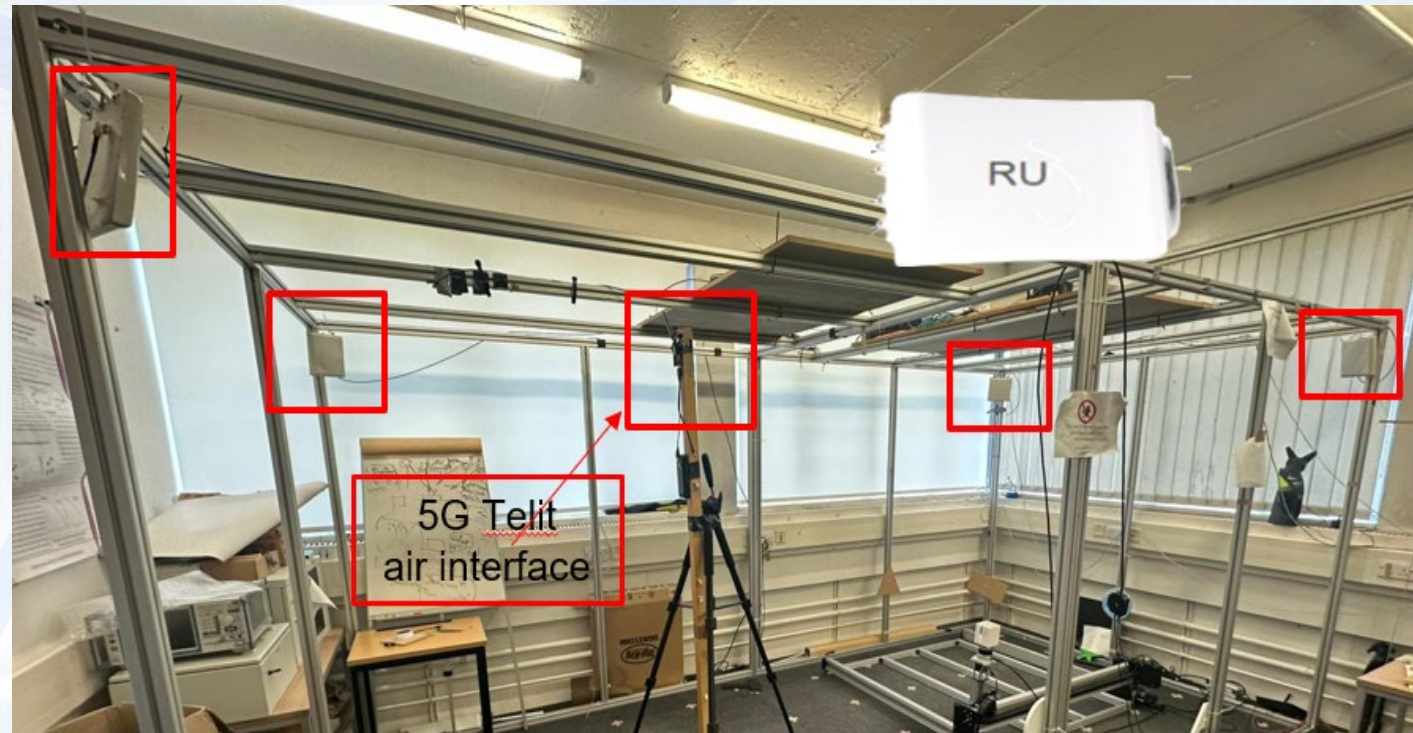
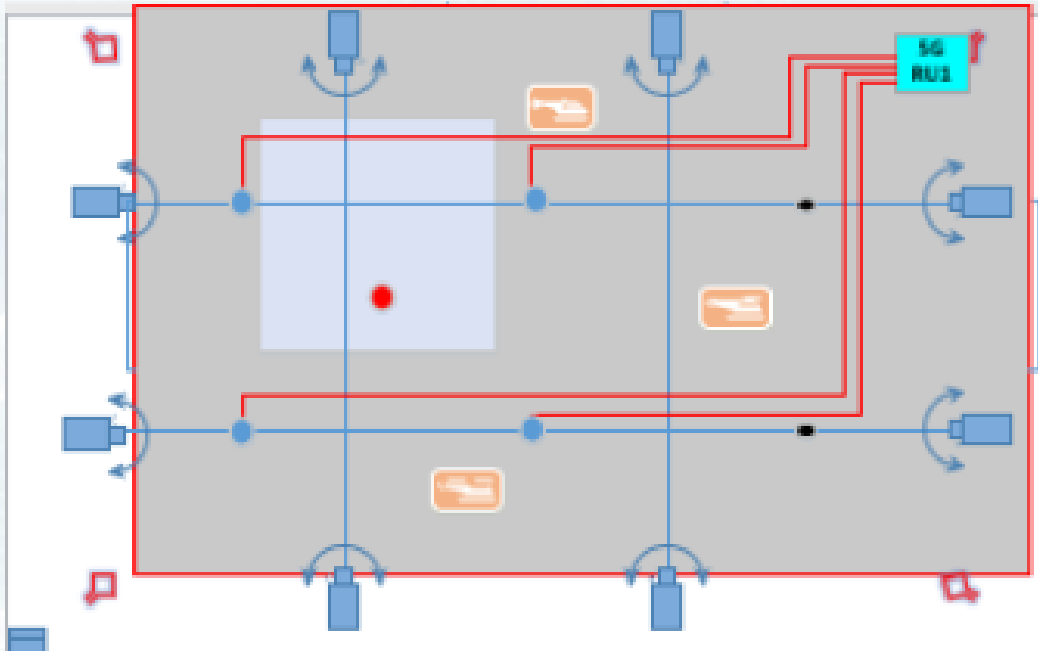
Metric	Baseline tool	Reason for inclusion
Throughput	iperf3, video logs	Capacity under controlled and application traffic
Latency / RTD	ping, packet traces	Responsiveness and control-loop feasibility
Jitter	packet/video logs	Temporal stability for streaming
Packet/frame loss	iperf3 UDP, frame IDs	Reliability under load and mobility
FPS	receiver logs	Application-level continuity
Connection setup	script logs	Session establishment and NAT/association effects

Integration of 5G OWC Antennas for OPTI-6G TDoA Localisation Test



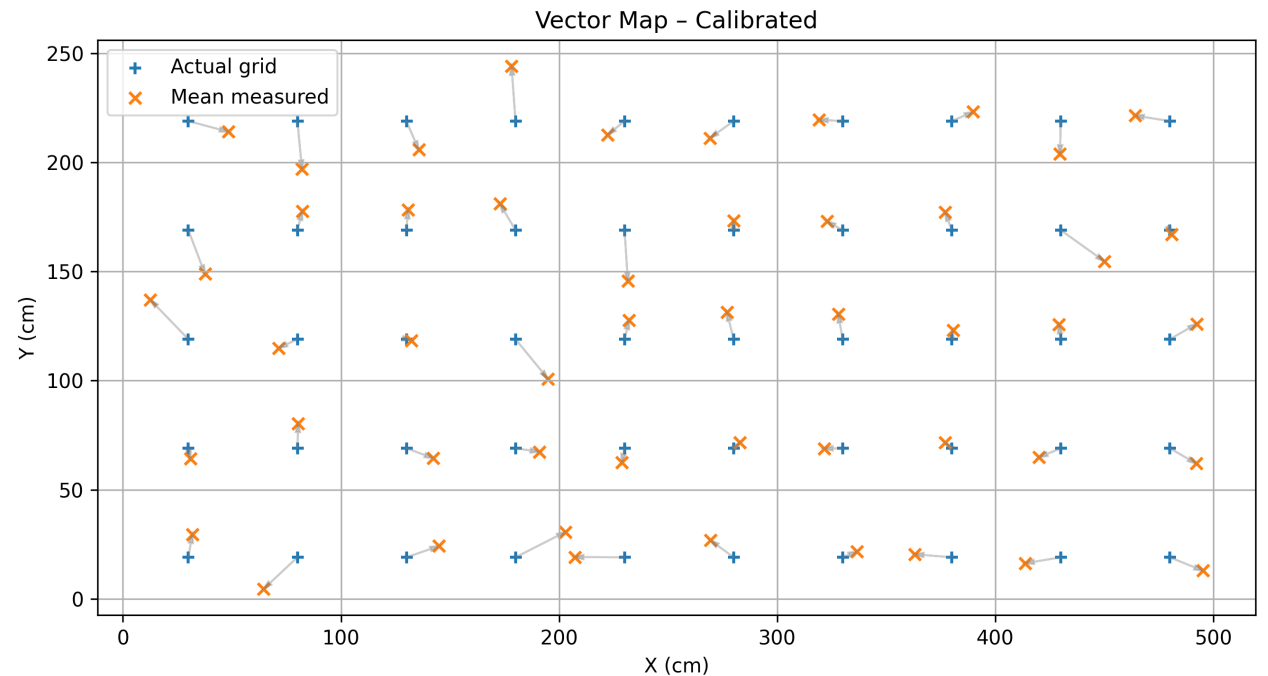
Lab setup for 5G OWC Antennas for OPTI-6G TDoA Localisation Test

- Four panel antennas connect to RU
- One 5G Telit Air interface for UE



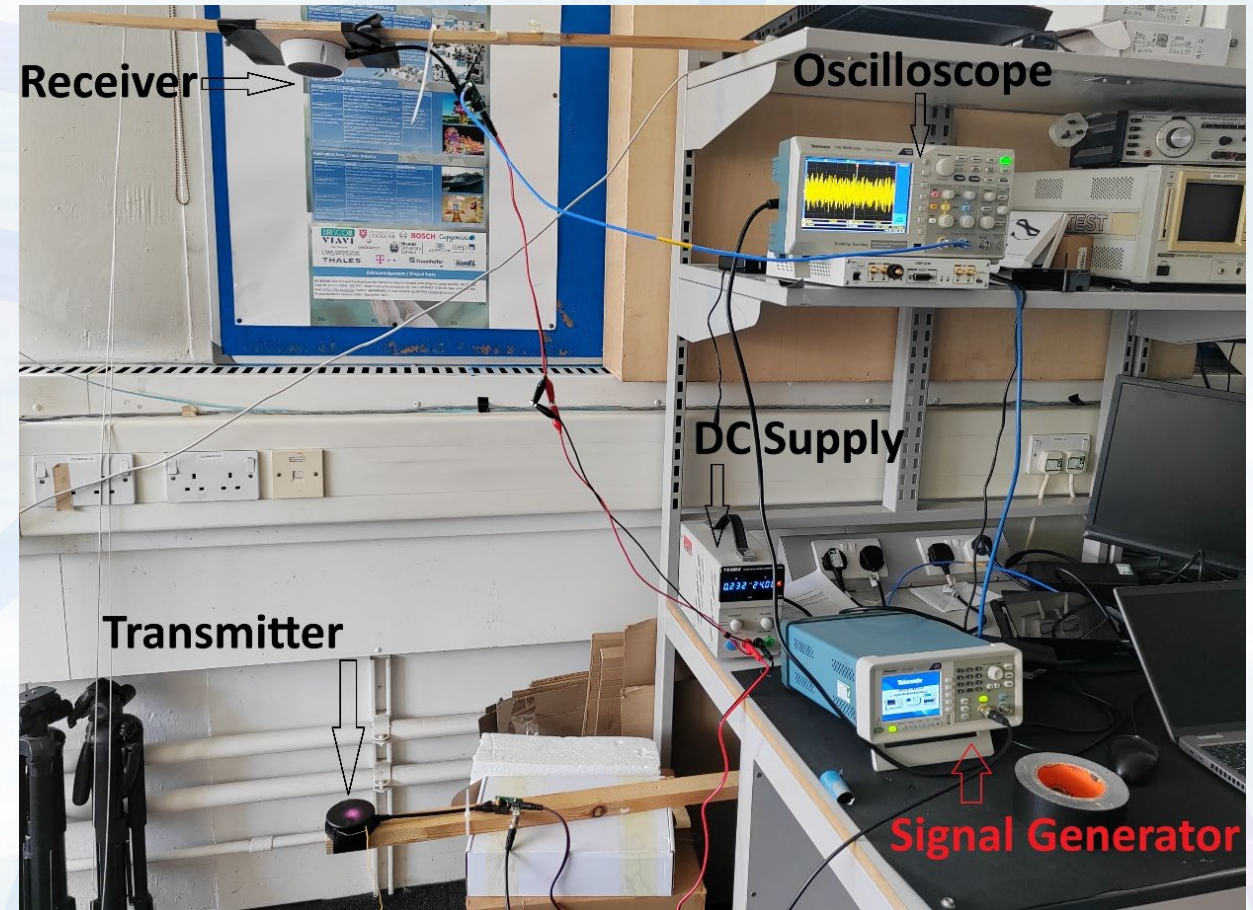
Preliminary Reference Indoor TDoA-Based Localisation Test Results Using Sub-6 GHz

- Across the full 50-point grid, the uncalibrated data produced an overall RMSE of 14.7 cm, as computed from the full 2500 sample dataset.
- The central region of the grid exhibits the tightest confidence bounds, typically within ± 1.2 – 2.8 cm, reflecting high measurement consistency and favourable geometric conditions.
- The experiment will be repeated using 5G OWC antenna system



Validate RSS Testbed

- Scenario 1: Impact of varying transmit power on the received signal. A 30 MHz sine wave is used as the transmit signal, applied at three different power levels: 20 mVrms, 30 mVrms, and 40 mVrms and the resulting received signal is then studied using the TBS 1052B-EDU digital oscilloscope.
- Scenario 2: Impact of varying transmit distance on the received signal. It considers different distances between the TX and RX – D1 = 1.522 m, D2 = 1.284 m, and D3 = 1.090 m – whereas the transmit power of the transmitted 30 MHz sine wave is kept constant (20 mVrms).
- Scenario 3: This scenario tests the lab setup in with a processing platform in place of the TBS 1052B-EDU digital oscilloscope to process measurements from multiple optical antennas simultaneously in real time.

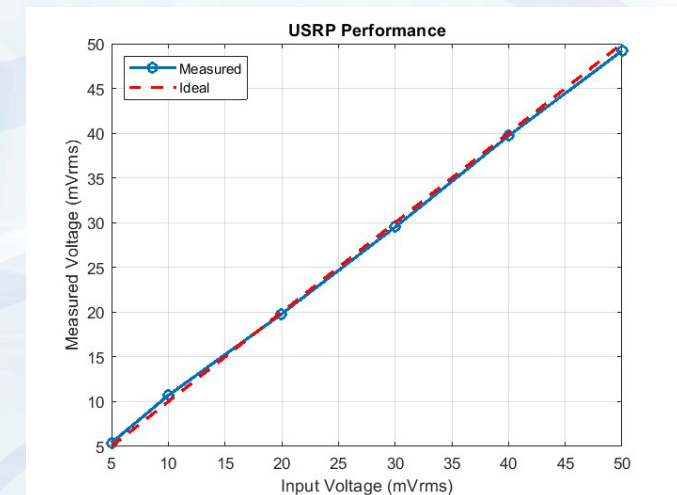


RSS Test Results

- Scenario 1: measurements confirm that the optical wireless link provides a nearly linear gain response with modest compression at higher input levels. The effective voltage gain is ~ 21.3 V/V (≈ 26 – 28 dB), and the received power levels (5–13 mW into 50 Ω) are consistent with expectations for the tested conditions.
- Scenario 2: The results confirm that the RSS is distance-dependent, with higher amplitudes observed at shorter separations. The system demonstrates the expected trend of stronger coupling as TX and RX move closer. However, the deviations from an ideal propagation law suggest that the measurement setup is affected possibly by multipath or near-field effects. The values of G are not constant, which implies that the system does not strictly follow the inverse square law as assumed.
- Scenario 3: About the accuracy: The relative error between input and measured RMS is small. For example:
 - 5 mV $\rightarrow$ 5.4 mV (+8%)
 - 10 mV $\rightarrow$ 10.7 mV (+7%)
 - 50 mV $\rightarrow$ 49.2 mV (–1.6%)

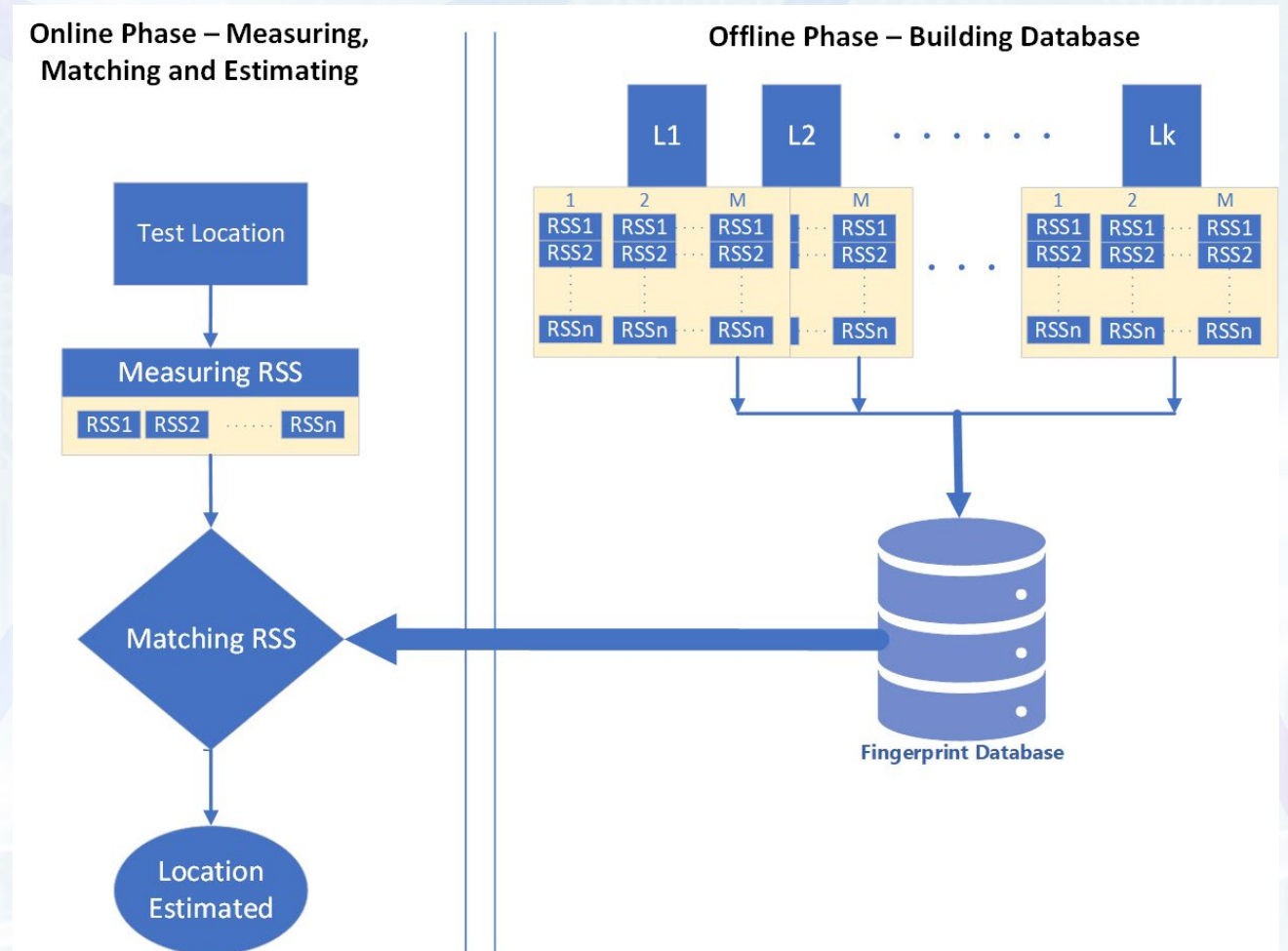
TX Power	Output RMS Voltage	Voltage Gain	Received Power
20 mVrms	0.496094 V	27.89 dB	0.004922 W 6.92 dBm (50 Ω)
30 mVrms	0.650815 V	26.73 dB	0.008471 W 9.28 dBm (50 Ω)
40 mVrms	0.806959 V	26.10 dB	0.013024 W 11.15 dBm (50 Ω)

Accuracy improves at higher amplitudes because quantization noise and offset errors are less significant compared to signal power.



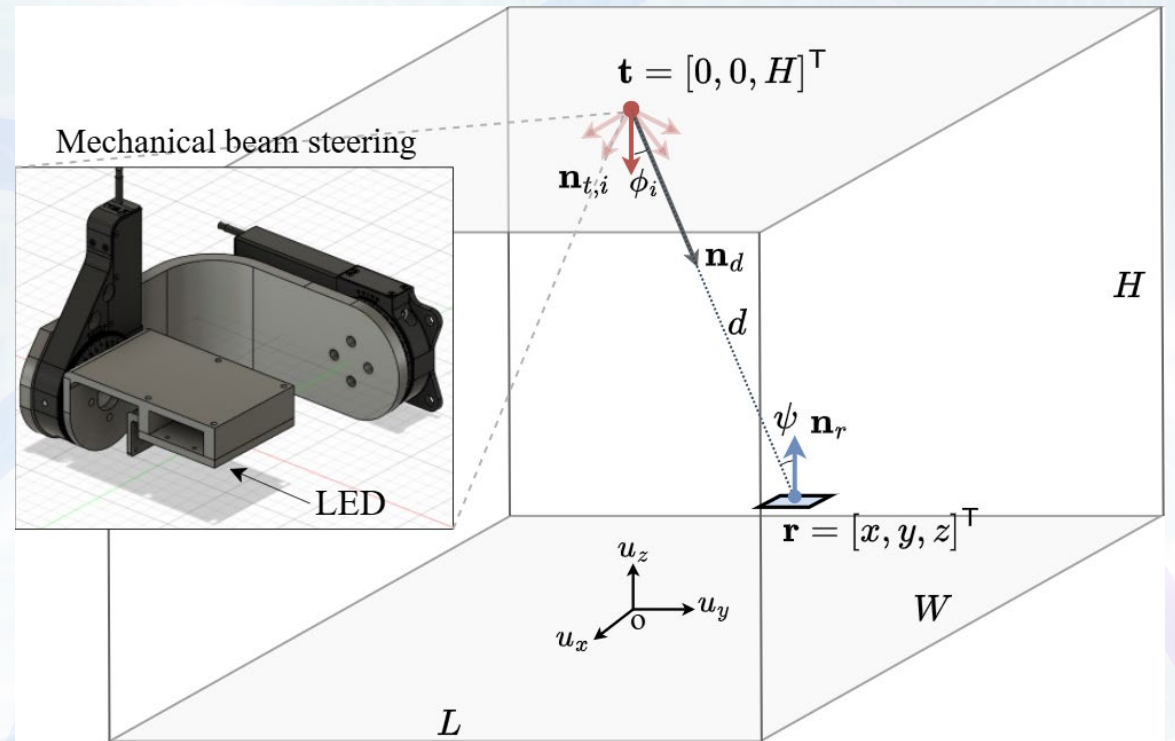
Applying RSS Test Results to AI Fingerprint Process to Estimate Location

- RSS-based localization involves non-linear relationships between the RSS values from multiple LEDs and the physical location of the receiver.
- ANN models are well-suited to model these non-linear relationships because they can “learn” from data to map RSS measurements to positions.
- AI RSS fingerprinting process in OWC systems involves two main phases: the offline phase (training) and the online phase (testing or real-time localization).



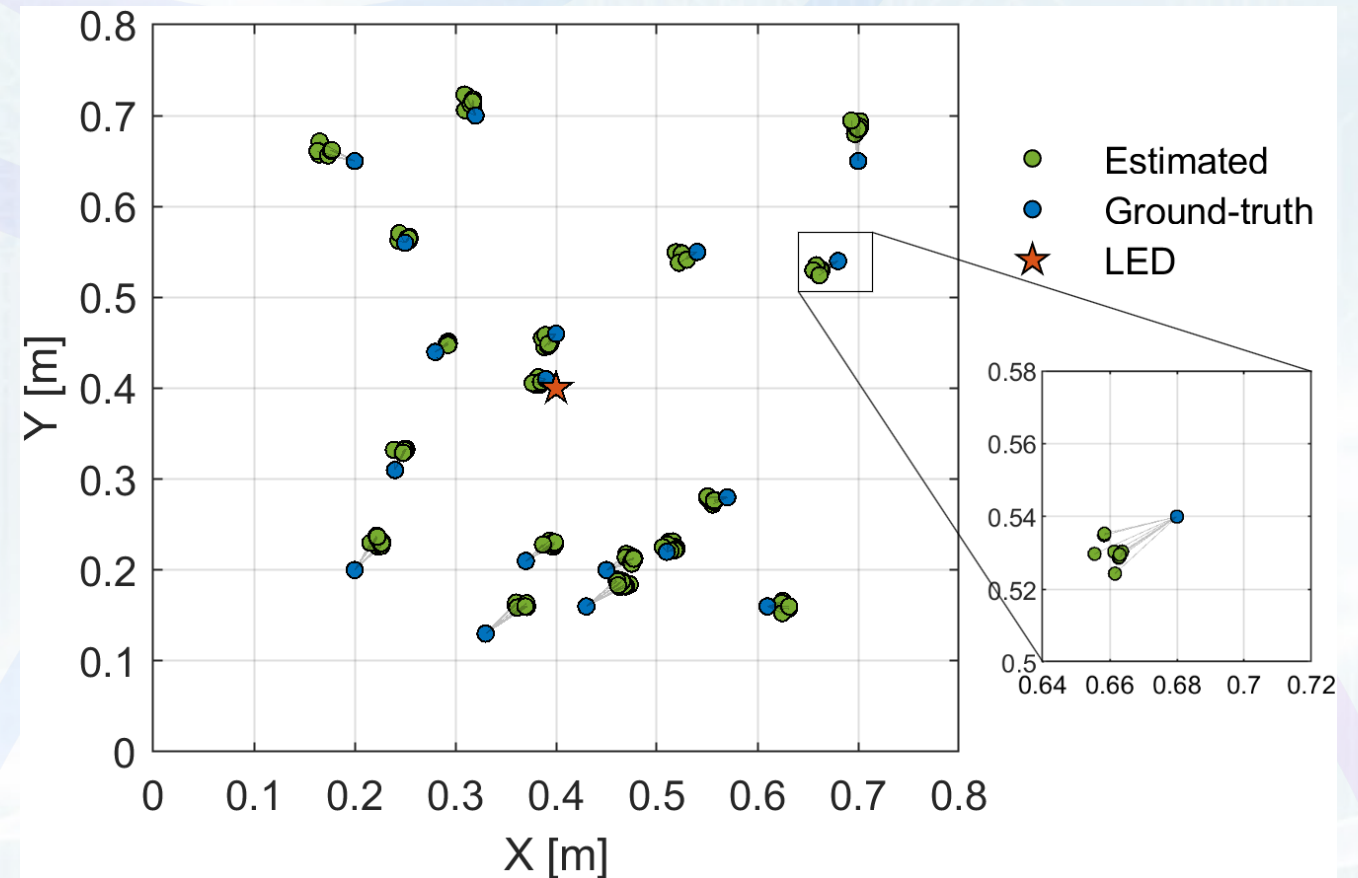
Beamsteering-Based Localisation

- An optical source, modelled as a Lambertian emitter or order m_t , is placed at point $\mathbf{t} = [0, 0, H]^T$
- UE, equipped with at least one photodiode (PD), is located at the unknown position $\mathbf{r} = [x, y, z]^T$.
- The orientation of the optical source, with orientation vector $\mathbf{n}_{t,i}$, may be modified using a mechanical beamsteering platform on which it is installed.
- UE records the corresponding RSS, which also depends on its own position $\mathbf{r}$ and on its orientation, noted $\mathbf{n}_r$.
- This Singular Value Decomposition (SVD) estimator, supports not only two-dimensional (2D) positioning but also 3D positioning with enhancements.



SVD Localisation First Results

- Two-dimensional position estimates obtained with the SVD estimator have then been computed.
- In the workspace plane the ground-truth positions (in blue) and the resulting estimated positions (in green).
- Each cluster of estimated positions around a ground-truth position corresponds to the ten different estimates obtained from the ten different orientations of the UE.
- From these tests, we can deduce that across all tested locations and orientations of the UE:
 - The $RMSE_{global}$ is 2.66 cm,
 - APE is 2.35 cm,
 - 90-th percentile error $\varepsilon_{90\%}$ is 4.32 cm,
 - This is in line with the target accuracy KPI of 5 cm





<https://opti-6g.sns-ju.eu/>

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Thank you for your attention!

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