# Motivation of study on Reconfigurable Intelligent Surface

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# Motivation

- One of the breakthroughs in 5G is to use mmWave (i.e., FR2) for cellular communication.
- FR2 provides significant gain for system capacity, which contributes to eMBB and URLLC use cases.
- On the other hand, FR2 deployment is struggling with its weak coverage.

- For FR2 deployments, 3GPP developed multiple tools for coverage extension:
  - Rel-16 introduced Integrated Access and Backhaul (IAB), comprised of IAB-DU and IAB-MT.
  - Rel-17 introduced NR Repeaters, which is just amplify-and-forward (AF) repeater.
  - Rel-18 introduced Network-controlled repeaters (NCR), comprised of NCR-Fwd and NCR-MT.
- The existing tools, however, still have disadvantages, e.g., complexity and limitations such as power consumption, etc.

- Reflector is a commonly used method in wireless systems (e.g., satellite communications) to make the signal path to be seen as “quasi” line-of-sight through constructive addition.
- Metamaterial is widely used in products such as antenna, reflector and refractor (i.e., meta-surface).
- Stand-alone meta-surface with fixed beamforming is close to mass-production.
- Reconfigurable Intelligent Surface (RIS) is in PoC phase.

- In Rel-19 RAN workshop, the channel modeling for RIS was identified as a potential area for study, in RWS-230488.
  - It was an open issue whether other aspects can be included in Rel-19 study, which is discussed in this paper.

- Therefore, RIS, as a low-complexity coverage extension method, should be studied to maximize 5G’s potential abilities.

***Study on RIS should start in Rel-19, in order to encourage & accelerate mmWave deployment/usage***


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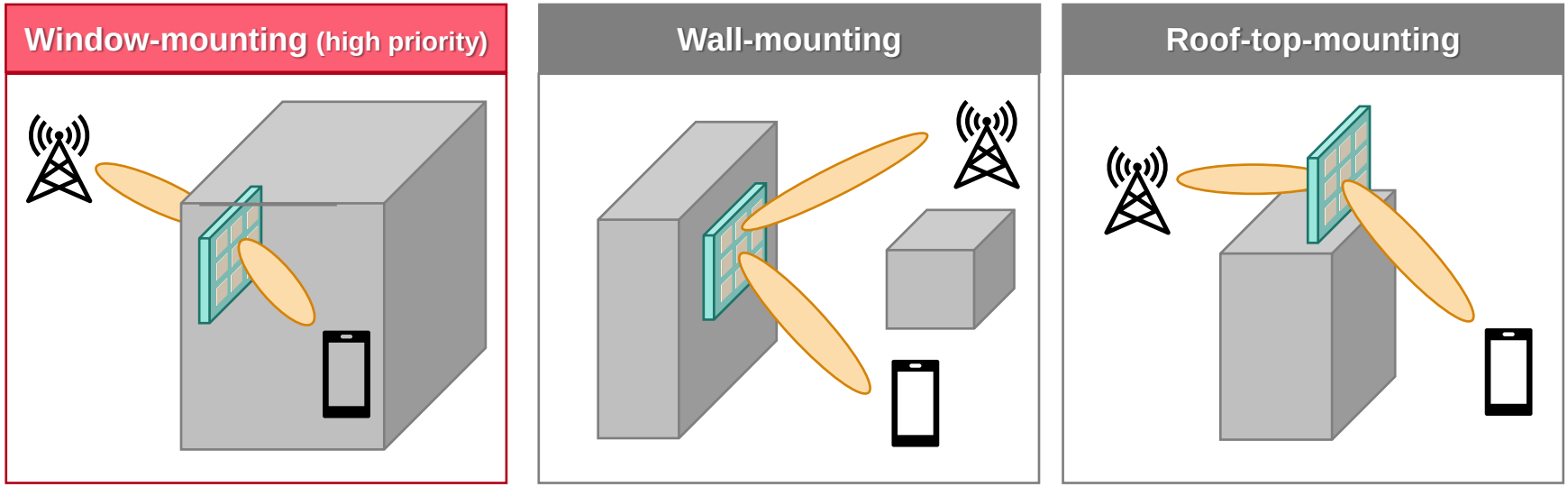
# Deployment scenarios and use cases (1)

Typical use case is coverage extension in urban area.




- Outdoor-to-indoor coverage extension is enabled by window-mounting (high priority scenario, esp. for FR2).
  - Installation is easier with “cooperative user”.
  - In many situations the RIS requires no site acquisition.
- Shadowing avoidance (“quasi” line-of-sight) is enabled by wall-mounting and roof-top-mounting

***Coverage extension in urban area should be considered in Rel-19***



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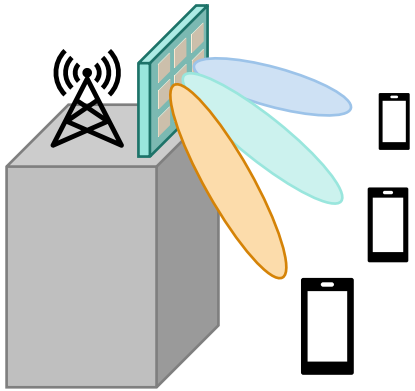
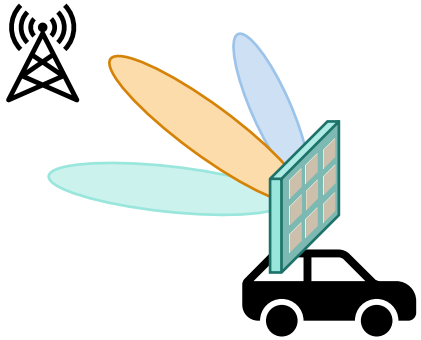
# Deployment scenarios and use cases (2)

Advanced use cases can enable low-complexity network-nodes and devices, and UAV coverage.

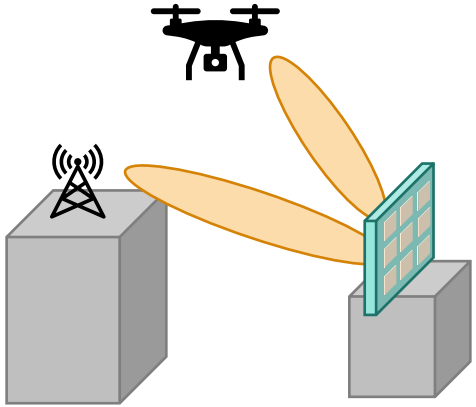
**gNB-equipping**



**UE-equipping**



**UAV coverage by down-tilting cell**



- Low-complexity analog beamformer and high gain antenna are enabled by gNB/UE-equipped RIS.
- Down-tilting cell, which is usually for terrestrial UEs, are reused for UAV coverage on the air.

***RIS as analog beamformer for gNB/UE should be included in Rel-19***



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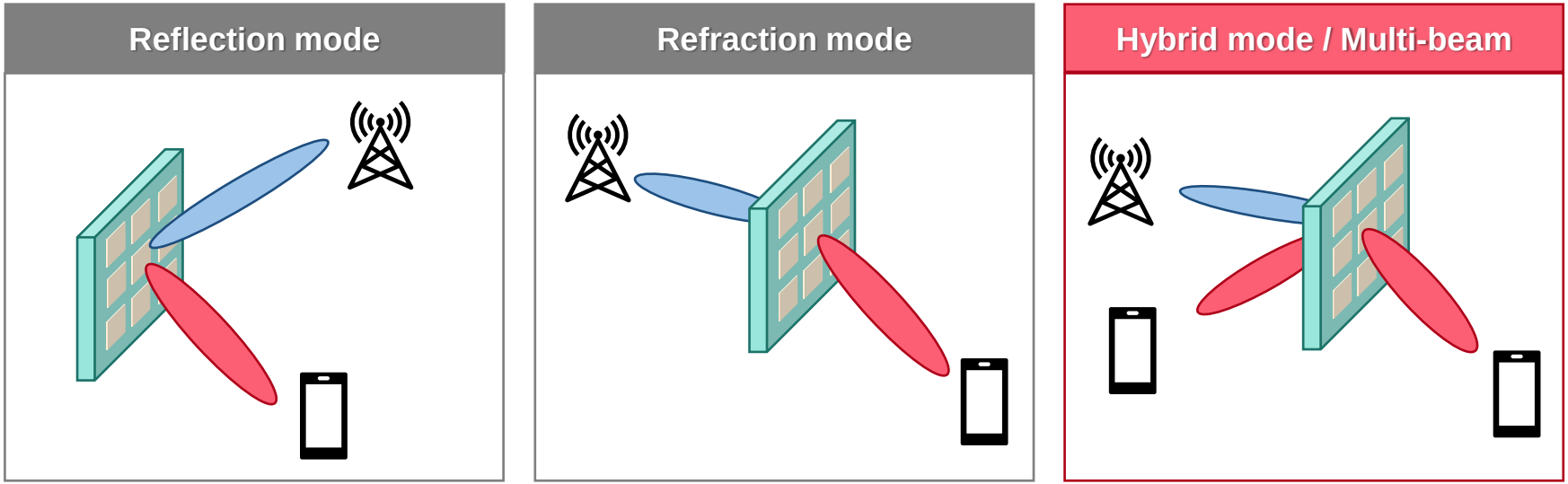
# Operational characteristics (1)

Reflection and refraction are basic characteristics of RIS.




- Reflection and Refraction modes are the basic operation modes, which are common with fixed surface.
- Hybrid mode can be ensured, i.e., reflection and refraction are seamlessly reconfigured.
- Multi-beam can be controlled by dynamic/semi-static separation/aggregation of partitions on meta-surface.

***Hybrid mode and multi-beam operation should be studied in Rel-19***



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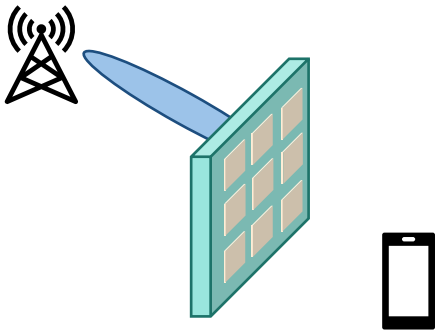
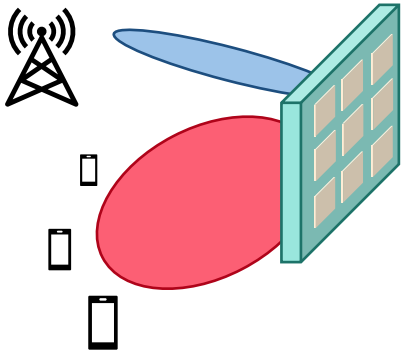
# Operational characteristics (2)

Absorption, backscattering and transmission/reception modes are other applications of RIS.

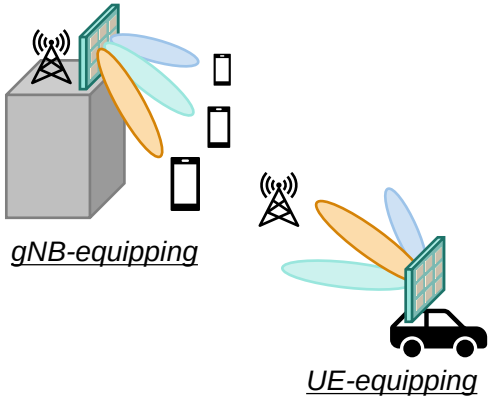
**Absorption mode**



**Backscattering mode**



**Tx/Rx mode**




- Absorption mode is useful for blocking interference to the UEs in other cells.
- Backscattering mode can cover wider area, instead of “pencil beam”, to cover multiple UEs in an area.
- Tx/Rx mode is a kind of meta-surface antenna with capable of dynamic beamforming.

***Other operational modes can be considered in the study***



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# Operational characteristics (3)

Other characteristic is delay of response for beamforming, depending on device performance.

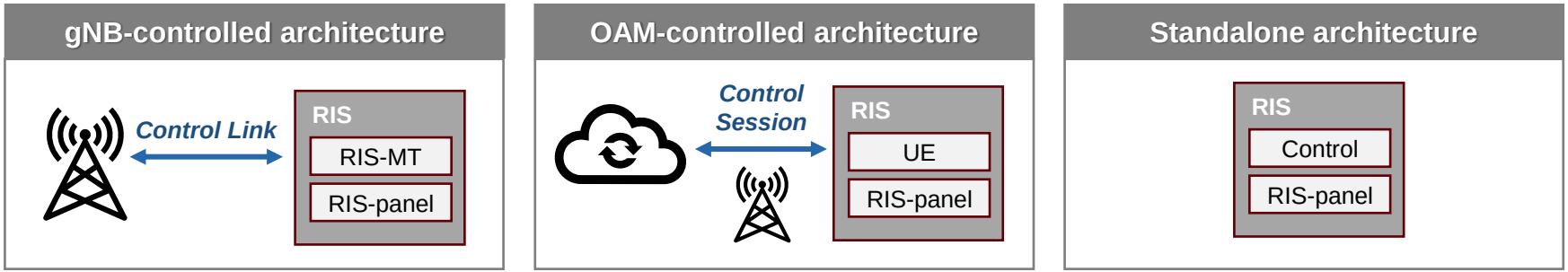
Hardware implementations and characteristics (Table 5.3.1-1 in [4])

| | RF-MEMS | PN diodes | Varactor diodes | MOSFET | Photo-conductive | Ferro-electric | Liquid crystal |
|---|---|---|---|---|---|---|---|
| Working frequency (GHz) | < 40 | < 110 | < 20 | < 200 | / | / | > 20 |
| Working Voltage | High | Medium | High | High | Low | Very High | High |
| Power consumption | Low | Medium | High | Low | Medium | Low | Low |
| Time to change codebook | μs | ns | ns | ns | μs | ms | ms |
| Insertion loss | Low | Medium | High | Medium | Medium | / | High |
| Digital/analog control | D | D | A | D | D | A | A |
| Cost | Medium | Low | High | Medium | / | High | / |

Total response time =
device response (see left table)
+ controller delay (e.g., usec order)
+ signalling delay (e.g., ms order)

For FR2 or URLLC deployment, larger SCS/shorter symbol time should be assumed.

System architecture may depend on response time of beamformer




***RIS system architectures, considering response time performance, should be studied in Rel-19***



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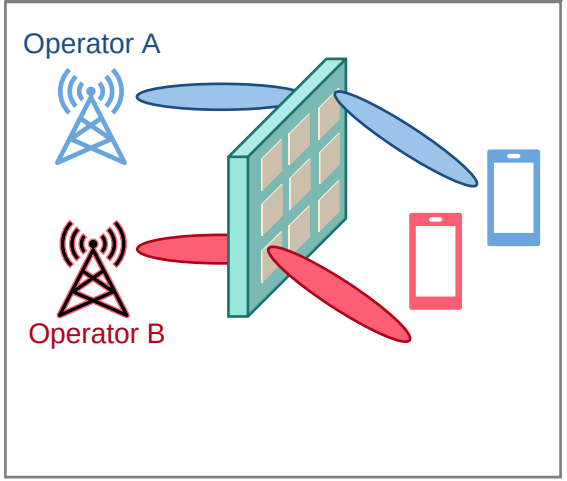
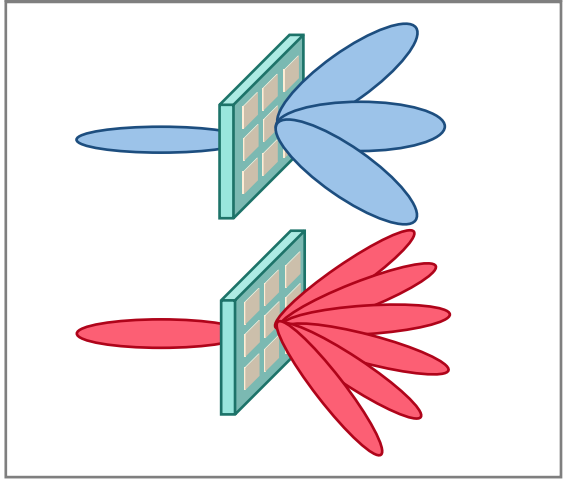
# Other considerations

Potential issues to be studied (informative)

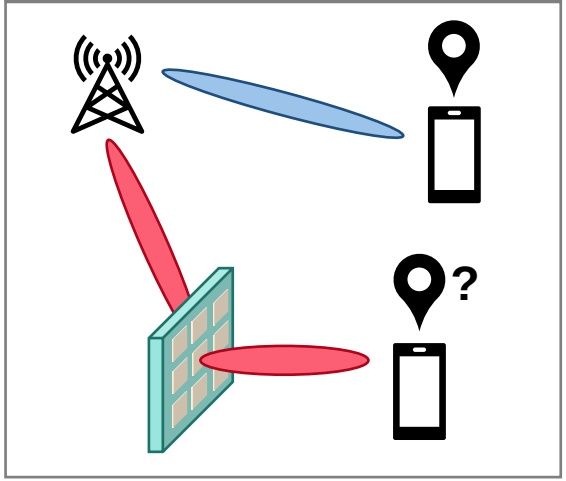
**Out-of-band effects**




**Beamforming resolutions**



**Impacts to positioning**




- Out-of-band reflection/refraction may impact other operations on different frequencies/operators.
- Beamforming resolutions (e.g., element's degree of freedom) will impact product designs and costs.
- RIS-involved channel may impact the positioning accuracy.

***Other potential issues will be discussed in the study item, if time allows***



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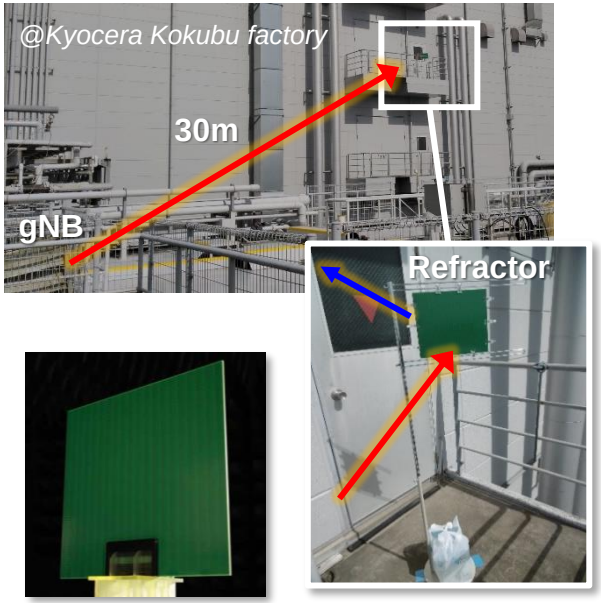
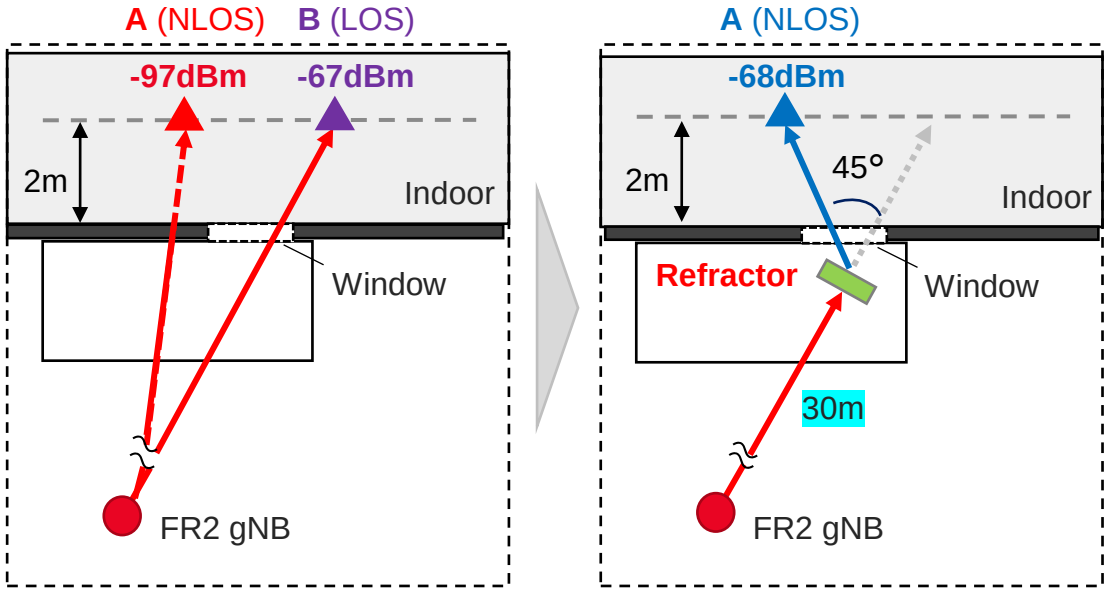
# Performance evaluation (Outdoor-to-Indoor coverage: high priority case)

Experimental trial at 28GHz in our factory environment shows refractor provides “quasi” line of sight path.
Refractor size is 300mm x 300mm, with 6,000 elements. *The size can be changed depending on situations




Passive refractor (prototype)

Trial setup




***RSRP at point A (NLOS) with refractor is almost same with one at point B (LOS), i.e., O2I loss is 1dB***

***System-level performance evaluation on “quasi” LoS path should be studied in Rel-19***



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# Summary – Key takeaways

3GPP should at least study the following:

- Key scenarios for RIS deployment (e.g., see [2], section 6 and [3], sections 4.4, 5.2.1)
  - We think the outdoor-to-indoor scenario to enhance FR2 coverage (e.g., RIS window-mounting) may be one such scenario (see [3], Fig. 36 and corresponding link budget in Table 7)
- Develop evaluation methodology to assess RIS performance
  - Channel modeling (e.g., see [3], sections 6 and 7)
  - Key performance indicators (coverage improvement, data rate increase, etc.) for single user and multi-user scenarios (e.g., see [3], section 8)

***3GPP should prioritize studying O2I coverage scenario, channel modelling and KPIs***


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# Summary – Key takeaways

***The outdoor-to-indoor is the most potential scenario, thus it should be prioritized***

*. as Scenario I captured in [3] below, or as Window-mounting in slide 3 above*

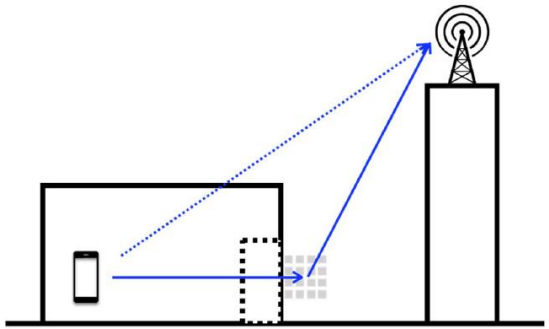

**Figure 36: Scenario I - Using RIS to avoid penetration loss**

**Table 7: Link budget analysis assumptions and results corresponding to Scenario I**

| Link | UE-BS | UE-RIS-BS |
|---|---|---|
| Number of RIS elements | N/A | 900 (16,1 cm x 16,1 cm) |
| Channel model | UMa NLOS O2I | InH LOS + UMa NLOS |
| LLS channel model | CDL-A with 300 ns delay spread, doppler shift 77,78 Hz (i.e. UE speed is 3 km/h) | UE-RIS: CDL-E with 30 ns delay spread, doppler shift 77,78 Hz<br>RIS-BS: CDL-A with 300 ns delay spread |
| O2I loss (dB) | 22,8 | 0 |
| 2-D distance (m) | 110 | UE-RIS: 5<br>RIS-BS: 105 |
| Path loss (dB) | 145,44 | 195,32 |
| Rx SNR (dB) | -6,62 | 0,68 |
| SNR required (dB) | -7,1 | 0,2 |
| Excess SNR (dB) | 0,48 | 0,48 |

. The analysis for Scenario 1 in [3] is proven by our performance evaluation in real field, as in slide 9 above.

***RIS has considerable gain for FR2 coverage enhancement, especially O2I penetration loss elimination***



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# Summary – Details of study objectives

***RIS is expected to improve FR2 deployments with 5G-Advanced, i.e., Do not assume it only for 6G.***

Potential objectives of Rel-19 study on RIS are proposed as follows.

- Study channel modelling, involving “intentional” reflection/refraction due to RIS [RAN1]
- Study the deployment scenarios and use cases of RIS, including but not limited to: [RAN1]
  - Outdoor-to-Indoor coverage extension, e.g., by window-mounting refractor (high priority).
  - Outdoor-to-Outdoor coverage extension, e.g., by roof-top-mounting refractor/reflector.
  - Indoor-to-Indoor coverage extension, e.g., by wall-mounting reflector.
  - RIS as analog beamformer at gNB side, at UE side and at intermediate position between gNB and UE.
- Study the operational characteristics and their applicable architectures of RIS [RAN2, RAN1, RAN3]
  - Reflection mode, Refraction mode, Absorption mode and Hybrid operation of the three modes.
  - Single beam operation and Multi-beam operation (RIS partitioning).
  - Delay/response performance of beam re-forming/switching.
  - Control plane options such as gNB-controlled (dynamic operation), OAM-controlled (semi-static operation) and Standalone (i.e., no control from outside, automatic operation).
- Evaluate the system-level performance, based on identified scenarios/use cases. [RAN1]
  - Especially, it’s preferable to identify the performance gain from dynamic operation and semi-static operation, with reference to fixed/traditional reflector.

***Study on Reconfigurable Intelligent Surface with wider scope should be started in Rel-19***


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## References

[1] H. Hashida et al., “Intelligent Reflecting Surface Placement Optimization in Air-Ground Communication Networks Toward 6G,” IEEE Wireless Communications (Volume: 27, Issue: 6, December 2020). pp. 146-151.

[2] Reconfigurable Intelligent Surfaces (RIS); Use Cases, Deployment Scenarios and Requirements, ETSI GR RIS 001 V1.1.1 (2023-04)

[3] Reconfigurable Intelligent Surfaces (RIS); Communication Models, Channel Models, Channel Estimation and Evaluation Methodology, ETSI GR RIS 003 V1.1.1 (2023-06)

[4] Reconfigurable Intelligent Surfaces (RIS); Technological challenges, architecture and impact on standardization, ETSI GR RIS 002 V1.1.1 (2023-08)



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