Project: IEEE P802.15 Working Group for Wireless Speciality Networks (WSN)

Submission Title: Requirements on RIS in THz NLOS Backhaul-Links Applications
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Abstract: The use of THz frequencies around 300 GHz is an attractive option to provide wireless backhaul links in ultra-densified Beynod5G/6G networks to replace fiber links. In the recently finished Horizon 2020 EU-Japan project ThoR the feasibility of 300 GHz backhaul links have been successfully demonstrated. In the same project automatic methods to plan THz backhaul links have been developed, showing that even in case of NLOS between two nodes wireless connections are possible by exploiting reflections on building walls. The use of Reflective Intelligent Surfaces with defined properties, which may be even designed for the specific purpose may significantly increase the degrees of freedom in this application. This contribution presents a simulation studies to determine the requirements

Purpose: Information of IEEE 802.15 SC THz

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On the Requirements on Reflective Intelligent Surfaces in THz NLOS Backhaul Links

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- This contribution has based on the paper presented at *URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023* and is presenting results from the Terrameta and 6G-RIC projects.
- Terrameta has received funding from Horizon Europe, the European Union’s Framework Programme for Research and Innovation, under grant agreement 101097101. The project is supported by 6G SNS and its members (including top-up funding by UK Research and Innovation (UKRI) under the UK government’s Horizon Europe funding guarantee). Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union, 6G SNS or UKRI. The European Union, 6G SNS or UKRI cannot be held responsible for them.
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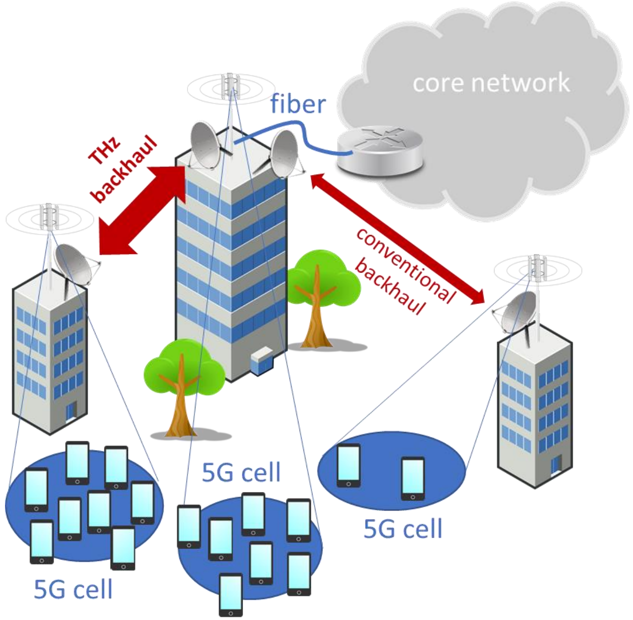
Outline

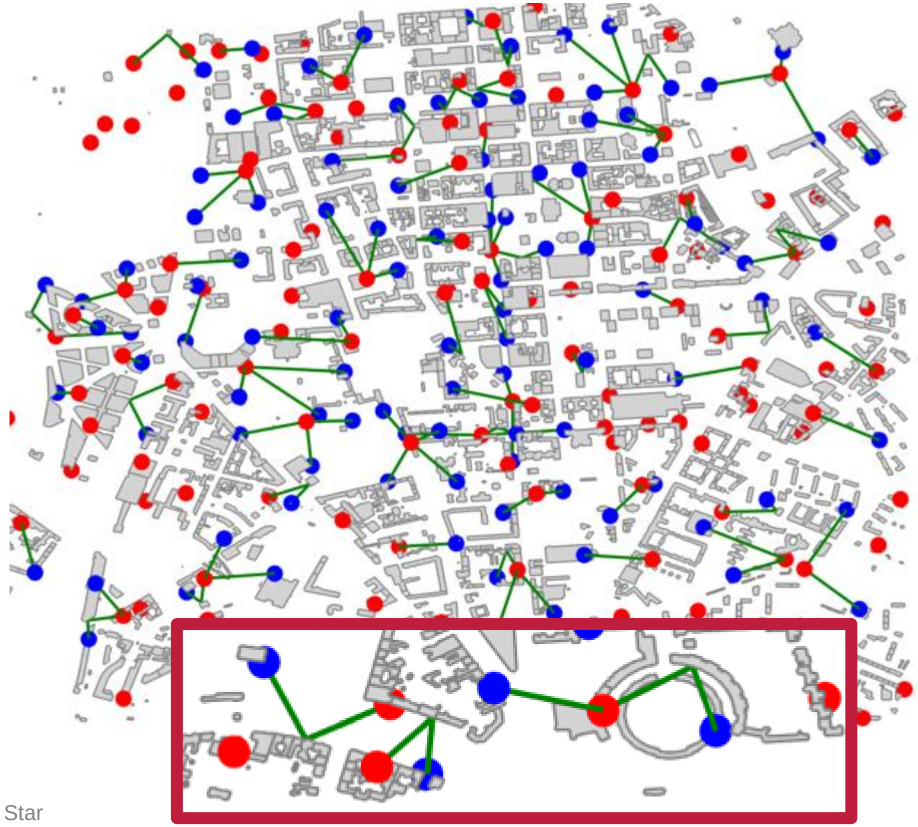
- Motivation for RIS @ THz NLOS-Backhaul-Links
- Simulation set-up
- RIS Path Loss Model
- Impact of RIS size on the Link Distance
- Impact of the Angle of Incidence
- Consideration of Near-/Far-Field Distance
- Conclusions

Starting Point H2020-EU-Japan-Project ThoR

THz end-to-end wireless systems supporting ultra-high data Rate applications

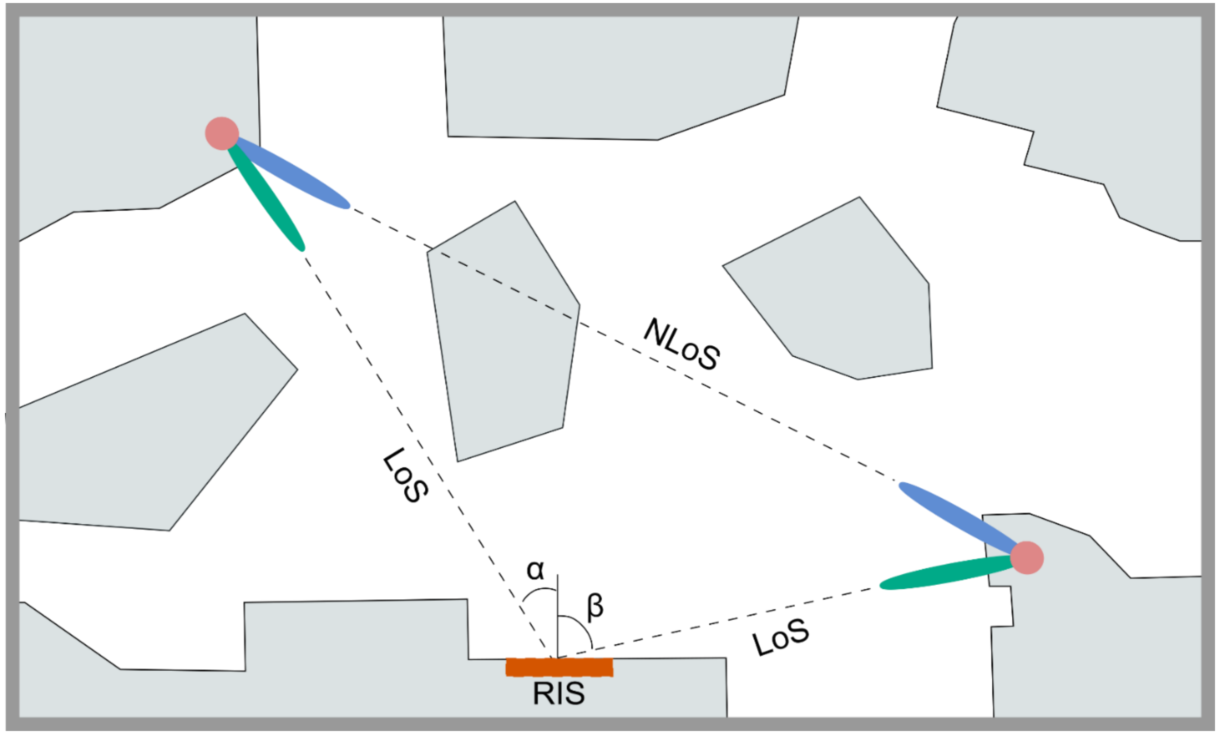
- ThoR has demonstrated a THz backhaul link and has worked on solutions for automatic planning of THz backhaul networks

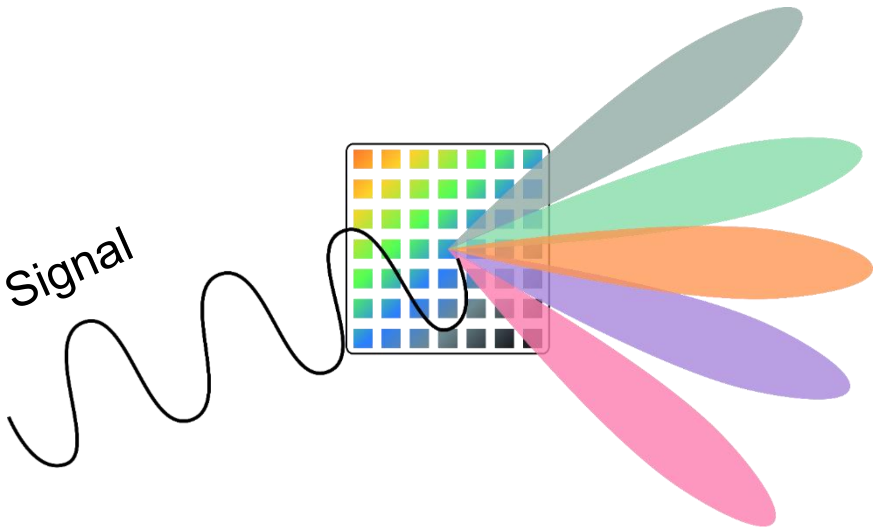




T. Kürner and B. K. Jung, "Automatic Planning of NLOS Backhaul Links at 300 GHz arranged in Star Topology," 2021 XXXIVth General Assembly and Scientific Symposium of the International Union of Radio Science (URSI GASS), 2021, pp. 1-3, doi: 10.23919/URSIGASS51995.2021.9560305.

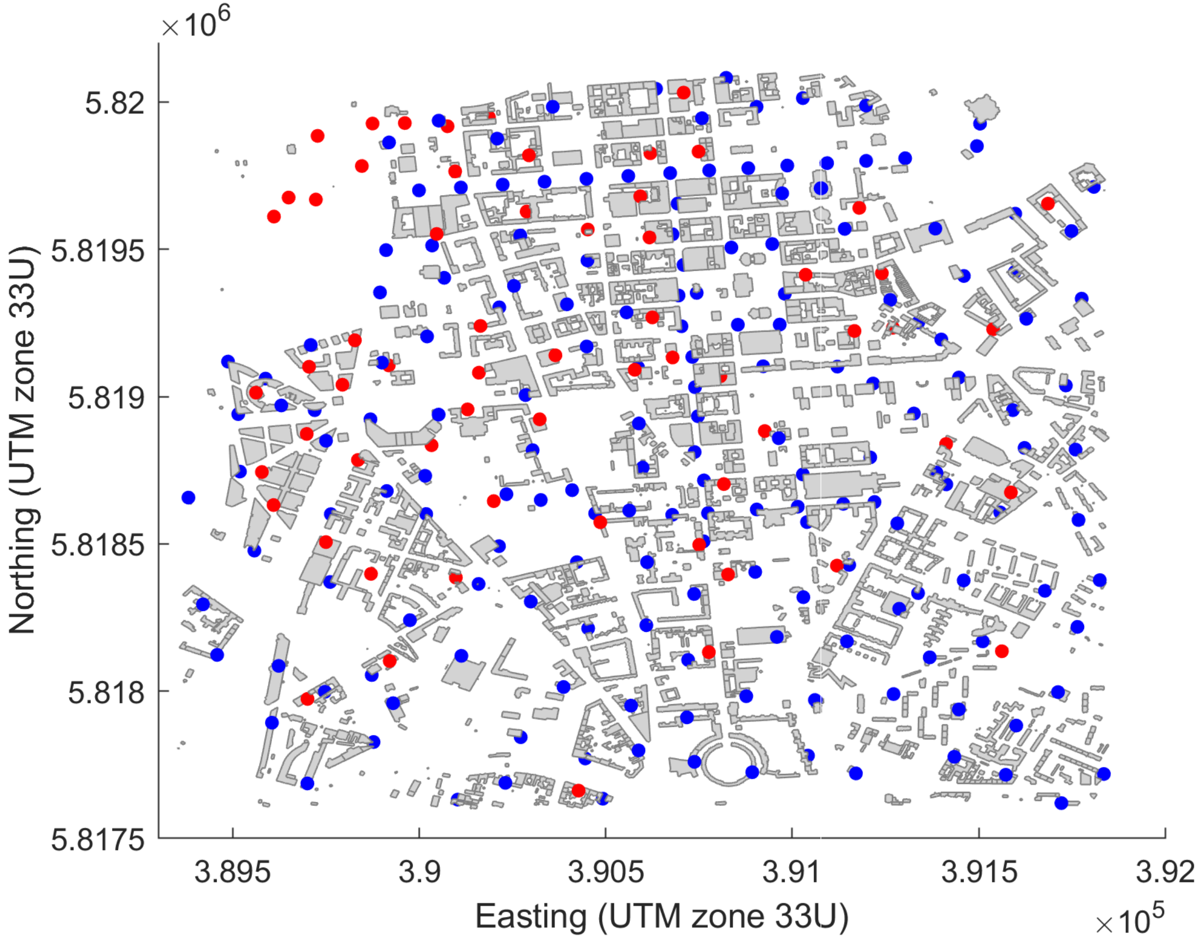
Motivation RIS in THz NLOS Backhaul Links





What are the requirements on RIS for this application ?

The question will be answered by Ray Tracing Simulation in one of the ThoR Scenarios at Berlin



- City center of Berlin
  - 62 macro cell sites (red)
  - 176 small cell sites (blue)
- 50% of small cell sites
  - Lamp post sites 4m above the ground
- 50% of small cell sites
  - 1m above the roof top of buildings

Data Processing

1. Do ray tracing simulation using a given scenario

2. Identify all cell pairs between which no LOS path has been found

3. Find points on the surfaces which have LOS condition to TX and RX at the same time

4. Sort out the points P, where the path length Tx-P-Rx is larger than a specified maximum distance (in this study: 300 m)

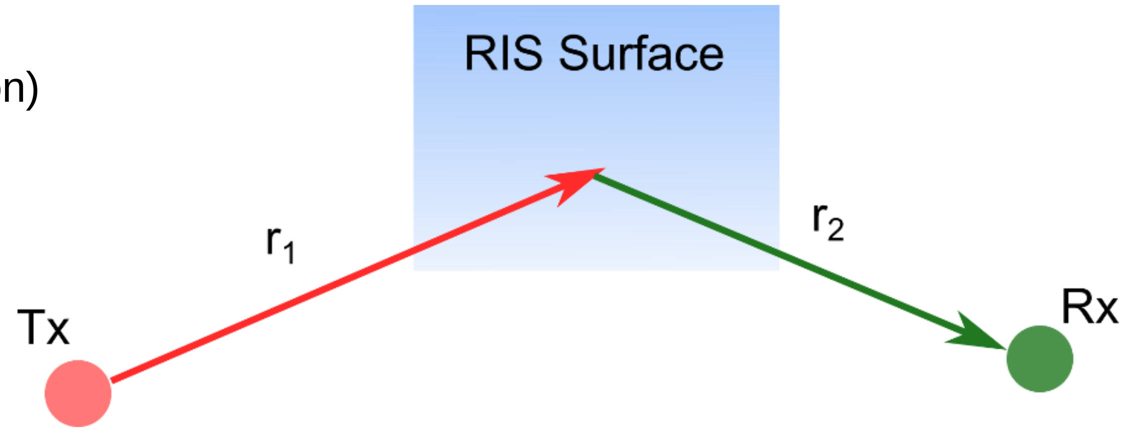
5. Select only one point on each surface, which has the smallest difference between the angle of incidence and the angle of reflection

RIS Path Loss Model

$$P_{RX} = \frac{P_{TX} G_{TX} G_{RX} \lambda^2 \sigma}{(4\pi)^3 {r_1}^2 {r_2}^2 L}$$

L: additional loss (atm. attenuation)

σ: radar cross section



$$\sigma = \frac{4\pi A^2}{\lambda^2} \cos(\theta_i)\, \eta_{ab}$$

$$\eta_{ab} = \frac{A_{eff}}{A}$$

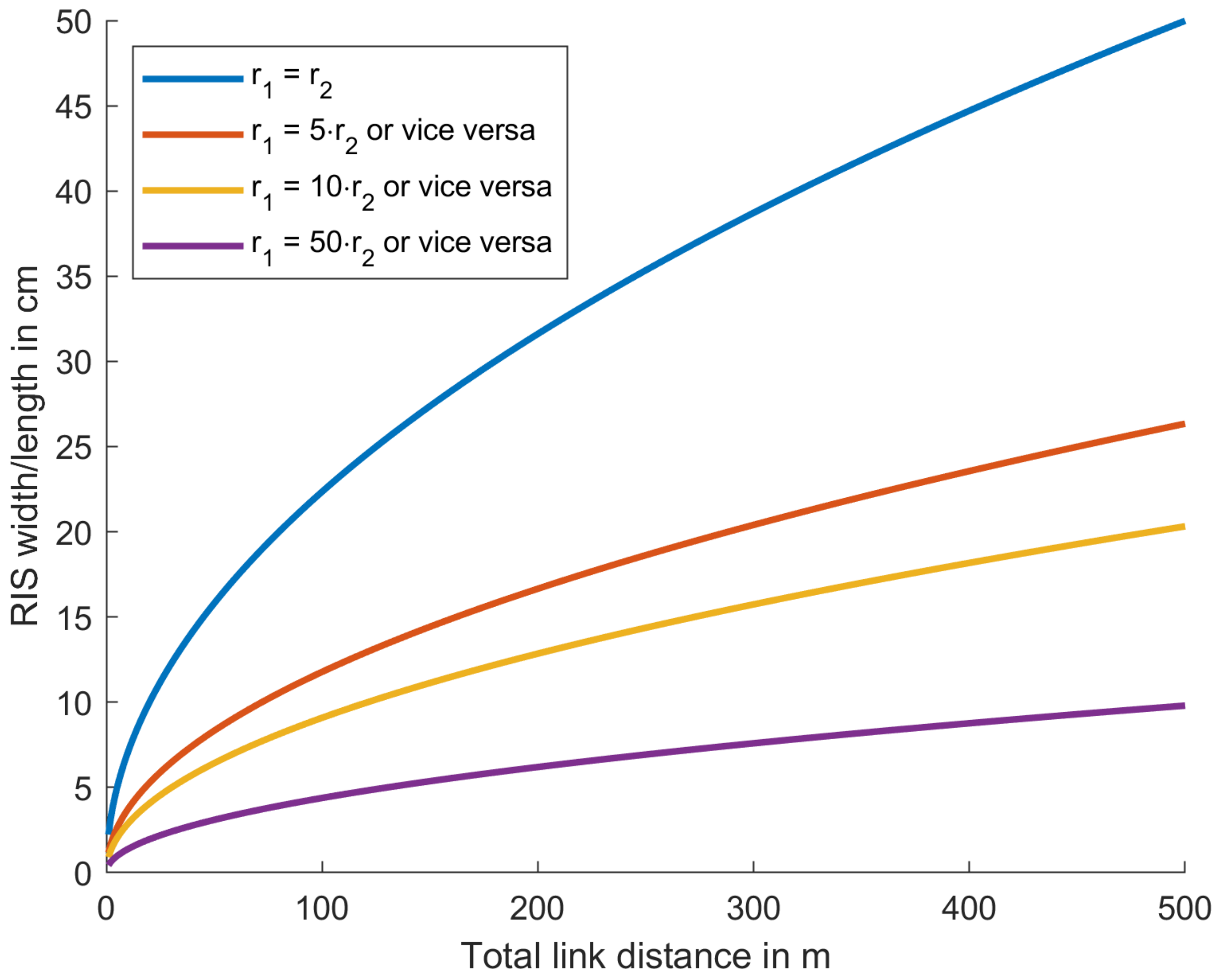
$\eta_{ab}: aperture\ efficiency$

Not the full RIS area will contribute to radio cross section (assumption here: 25%)

$$\frac{P_{RX}}{P_{TX}} = G_{TX} + G_{RX} + G_{RIS} + 20\log(A) + 10\log\big(\cos(\theta_i)\big) + 10\log(\eta_{ab})$$

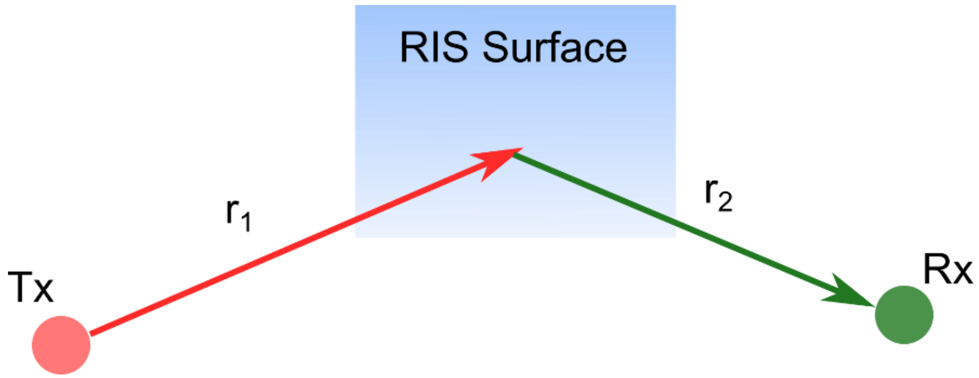
$$-20\log(4\pi) - 20\log(r_1) - 20\log(r_2) - \left(\gamma_{Gas} + \gamma_{Rain}\right) * \frac{r_1 + r_2}{1000}$$

Investigation on RIS Size

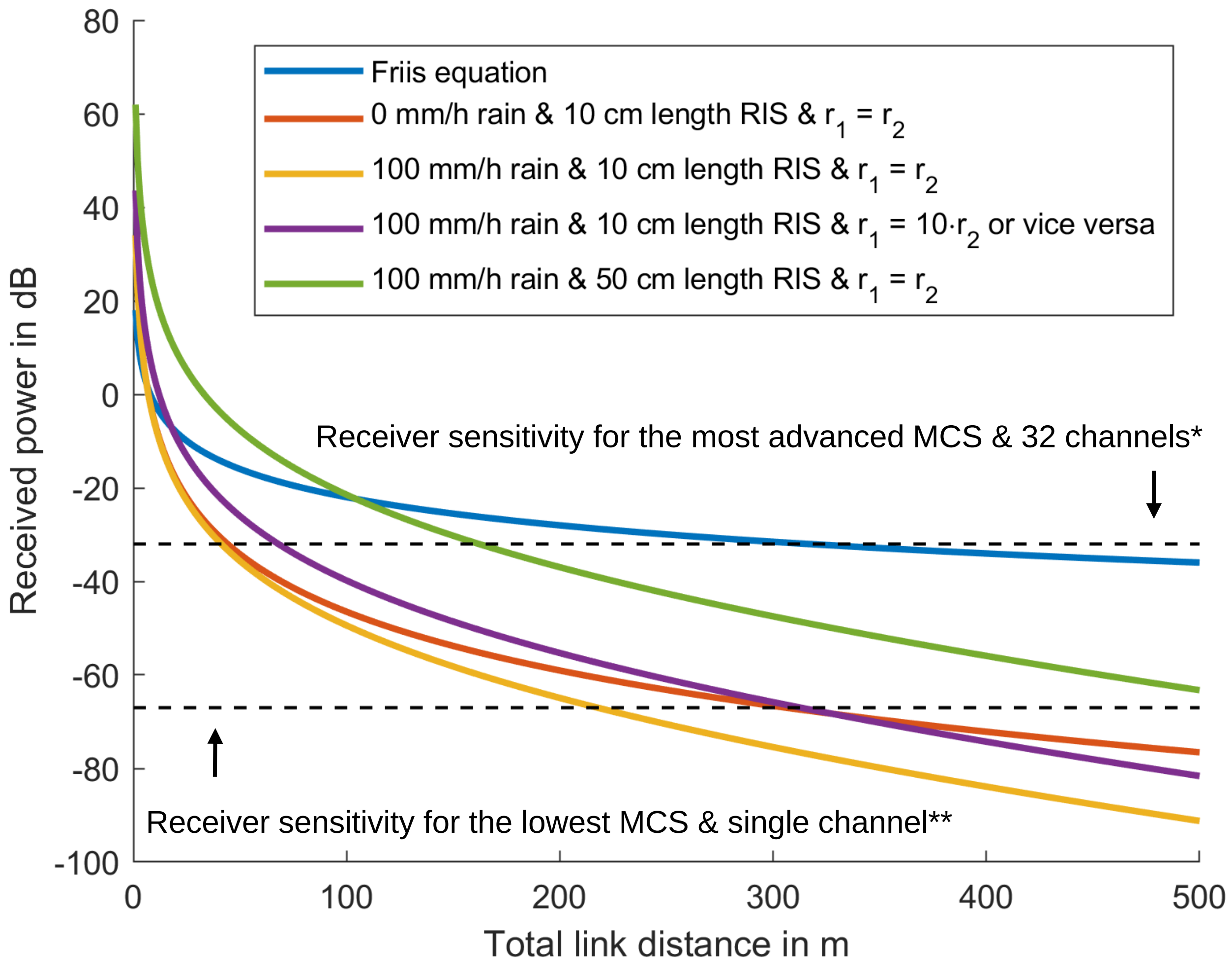


- Required size of RIS to achieve that the entire path loss including RIS equals to the free space path loss of the same total path length $(r_1 + r_2)$

- $\mathrm{A} = \frac{\lambda \cdot r_1 \cdot r_2}{r_1 + r_2}$ A is the surface area of RIS



Received Power at Rx

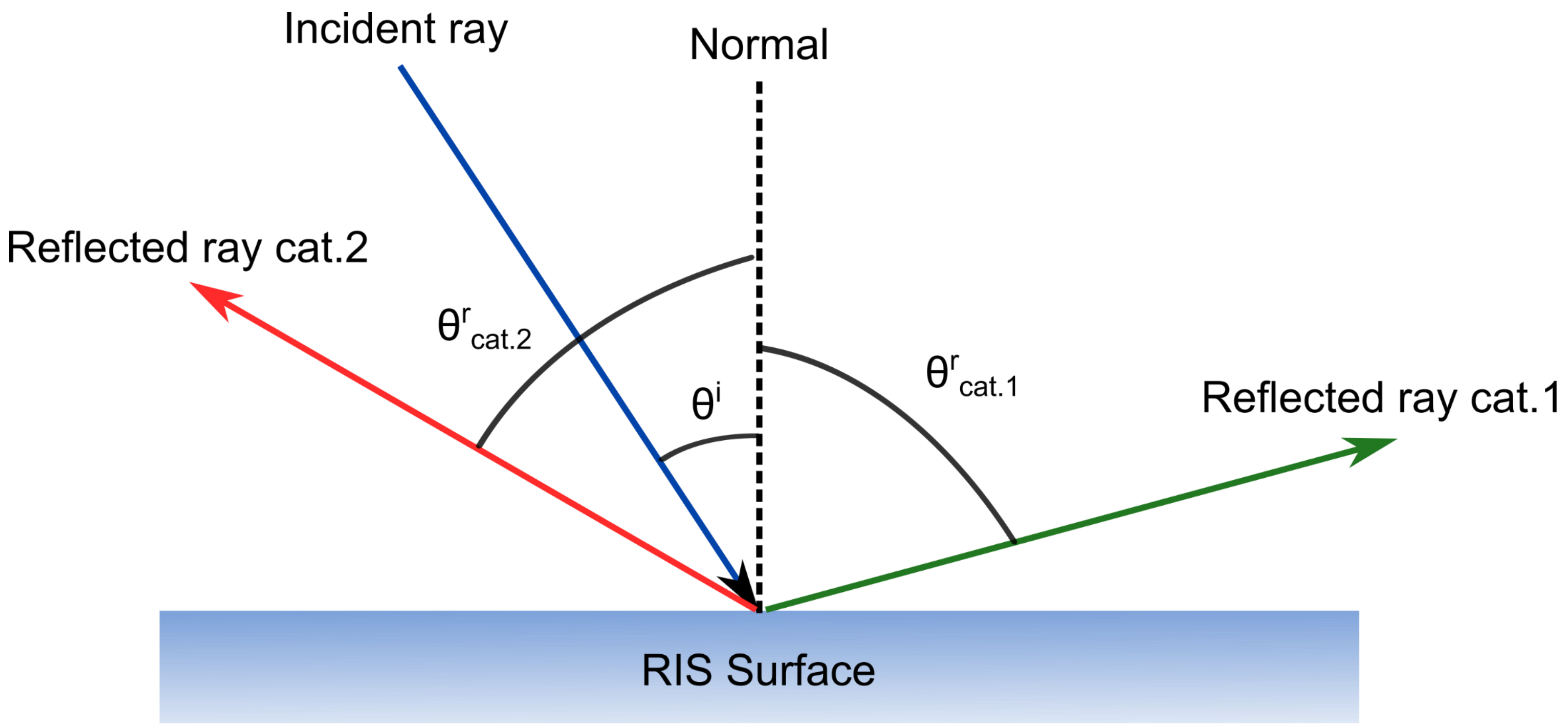


- Considering various system configurations
  - Rain rate
  - Size of RIS
  - Portion of path length r1 and r2

- P_{TX} : 0 dBm
- $G_{TX}, G_{RX} = 50\ dBi$
- η_{ab} = 25%
- 10 dB system margin is considered

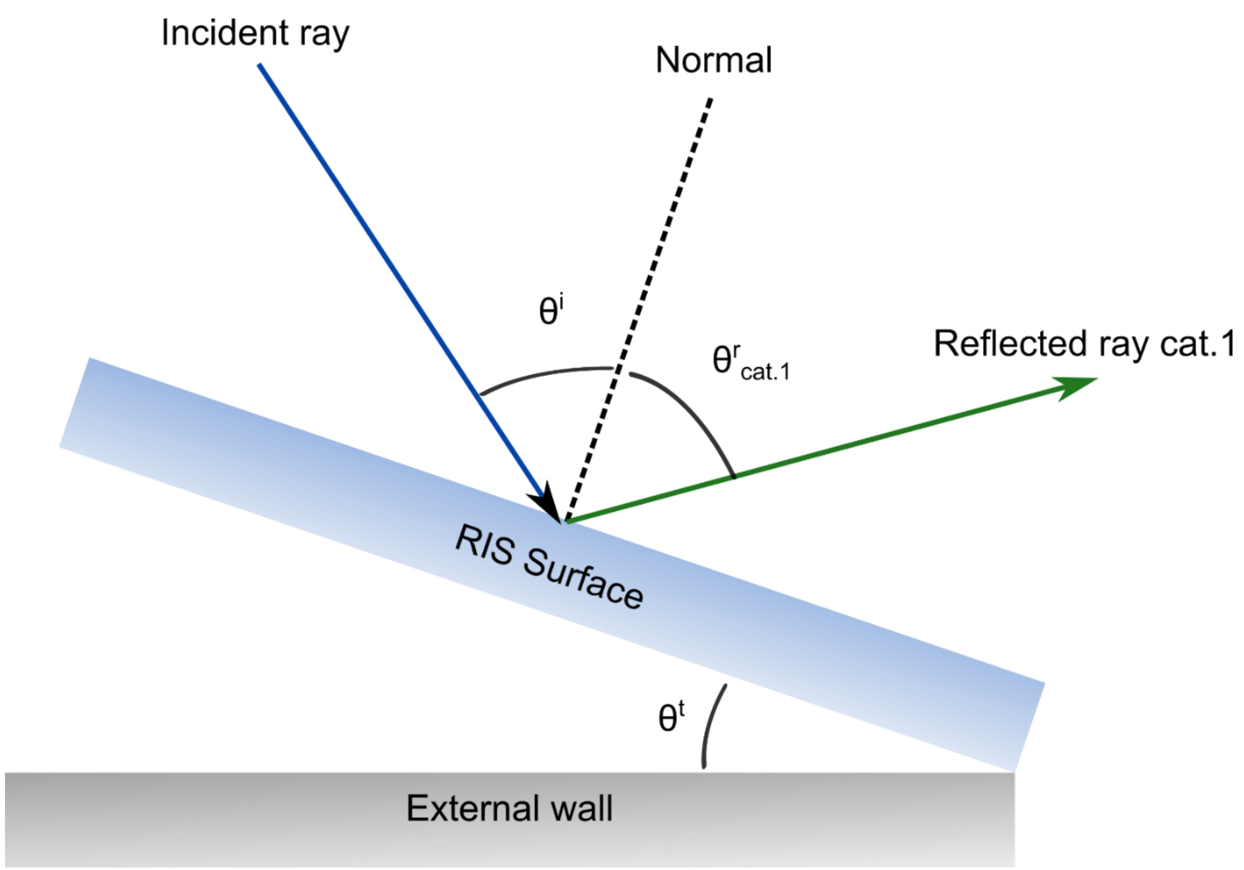
* 64 QAM & 14/15 FEC defined in IEEE Std. 802.15.3d-2017
** BPSK & 11/15 FEC defined in IEEE Std. 802.15.3d-2017

Introduction of Reflection Categories

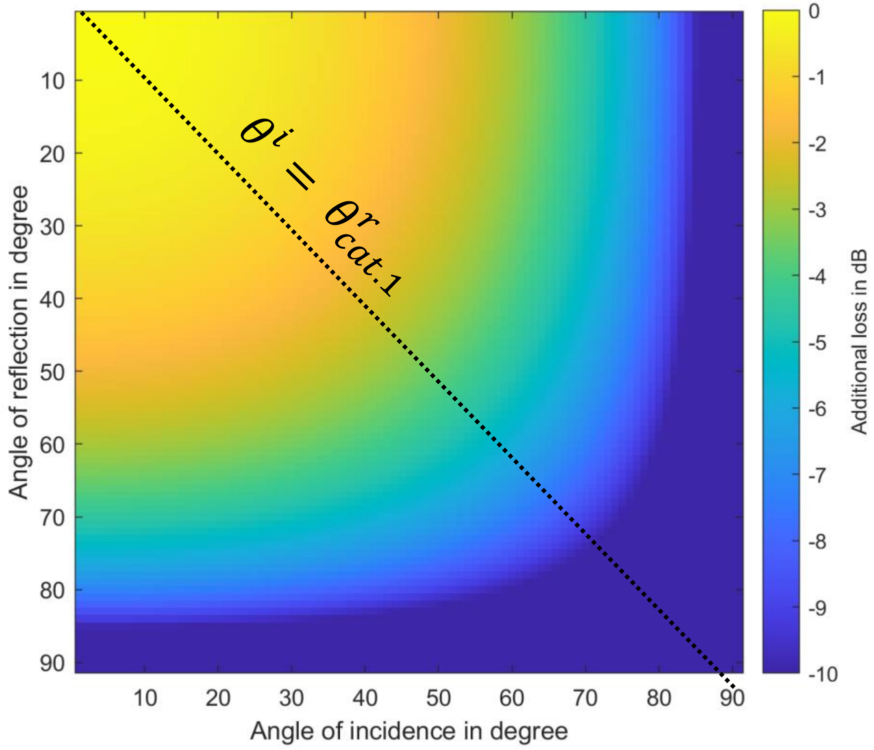


Tilting of RIS Surface to reduce the Loss caused by the Difference between the Angle of Incidence and the Reflection Angle

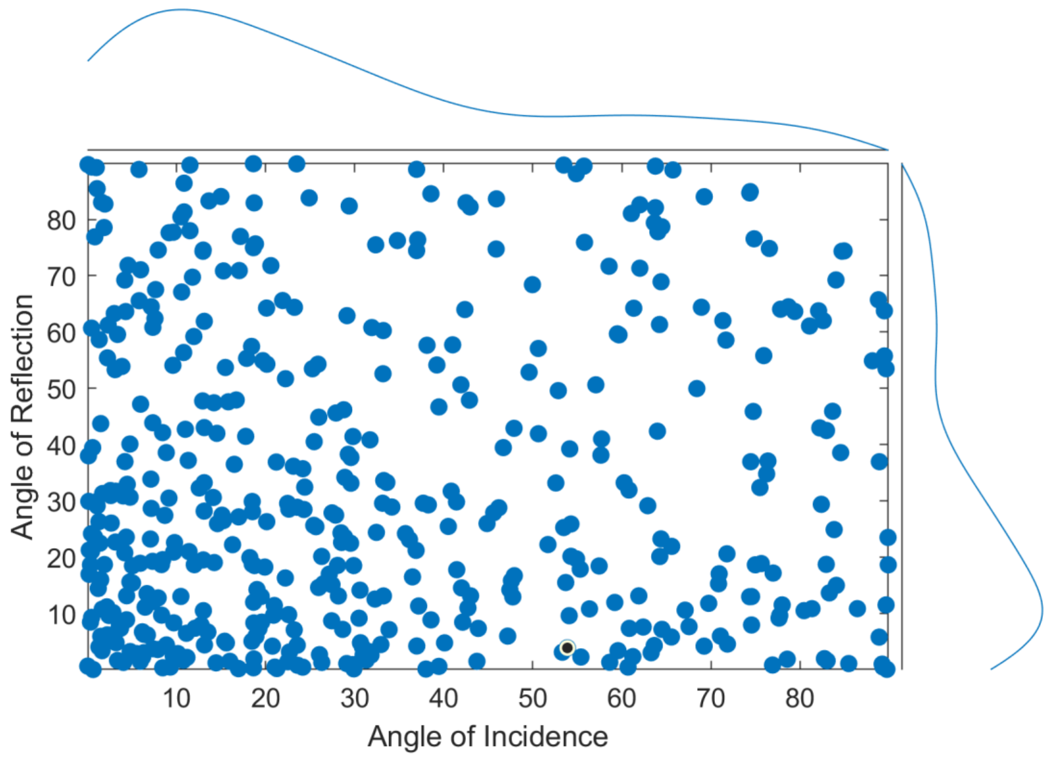
Tilting to achieve $\theta^i = \theta^r_{cat.1}$



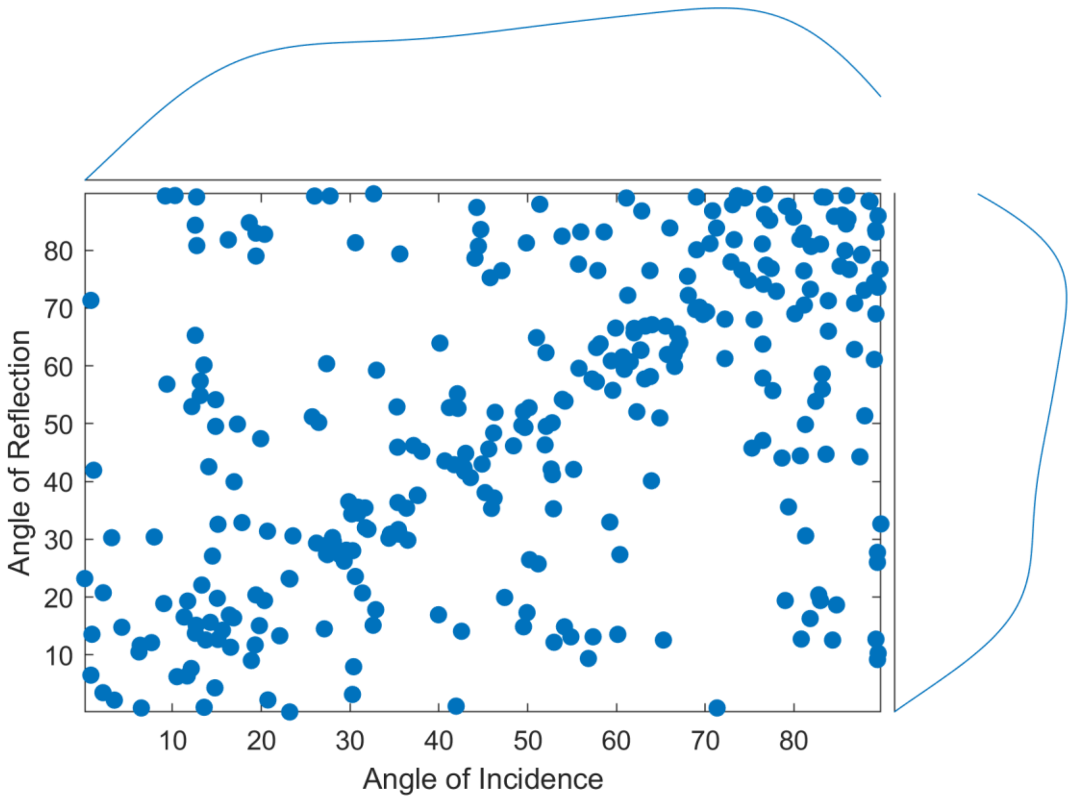
$$\sigma_{RCS} \leq \frac{4\pi}{\lambda^2} D^4 \cos(\theta_i)\cos(\theta_o)$$



Distribution of Angles of Incidence and Reflection at the Berlin Scenario

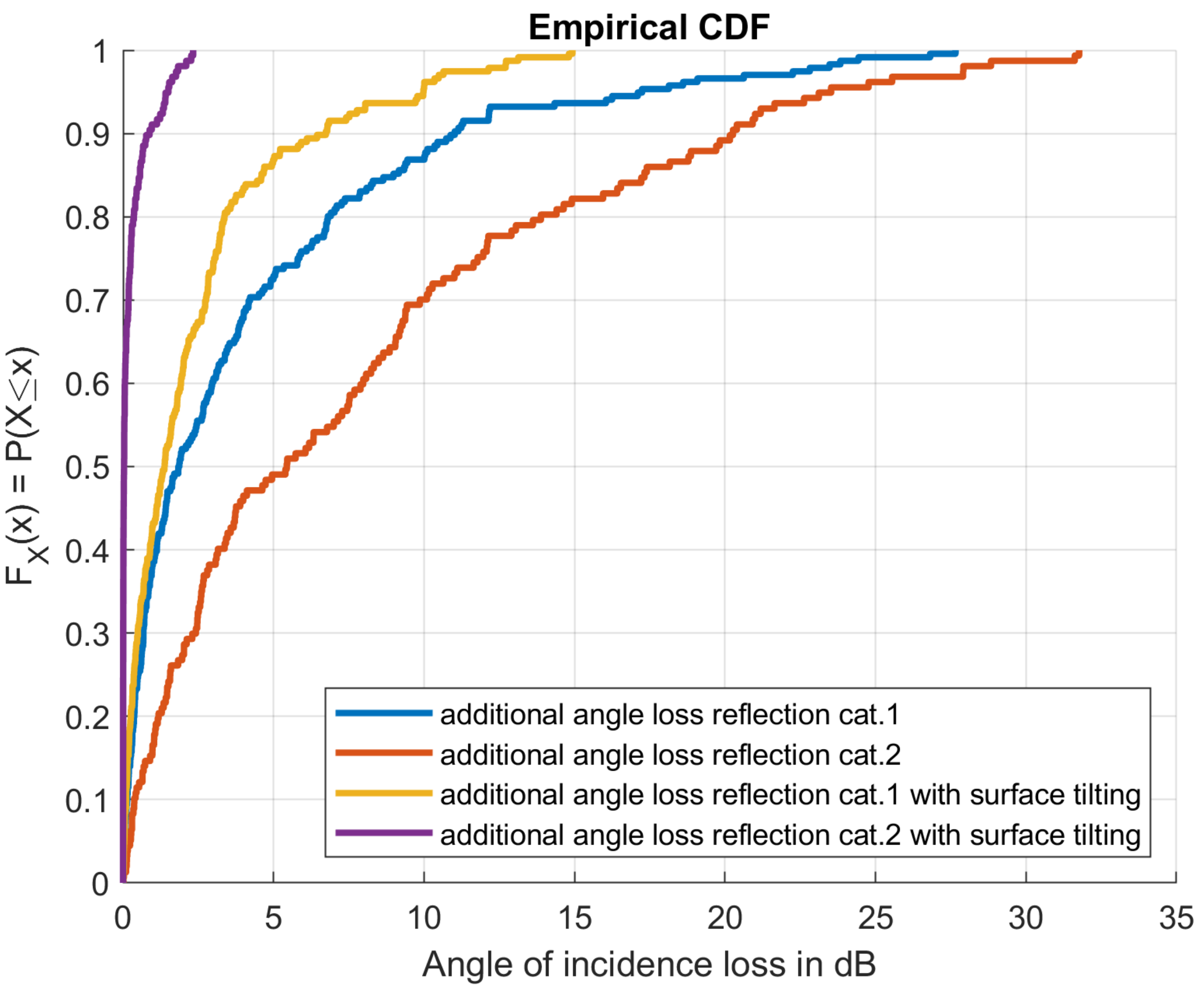


Reflection category 1



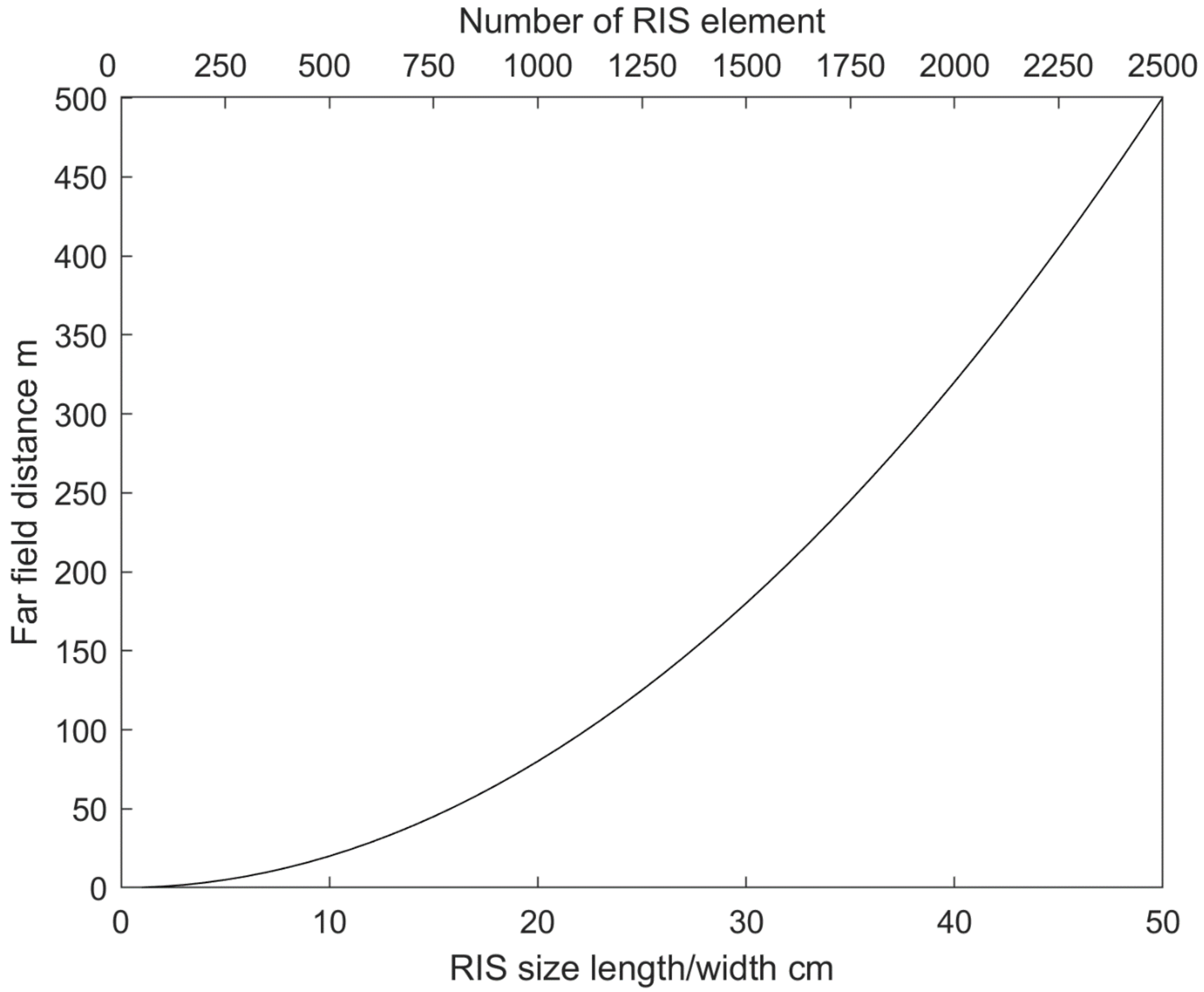
Reflection category 2

Additional Loss due to Angle of Incidence



- Tilting angle is adaptively set to achieve same angle of incidence (AOI) and angle of reflection (AOR)
  - $\theta_i = \theta_r$ after tilting RIS surface
- Surface tilting has a great impact on the reduction of the additional AOI loss, especially in the case of the reflection category 2.

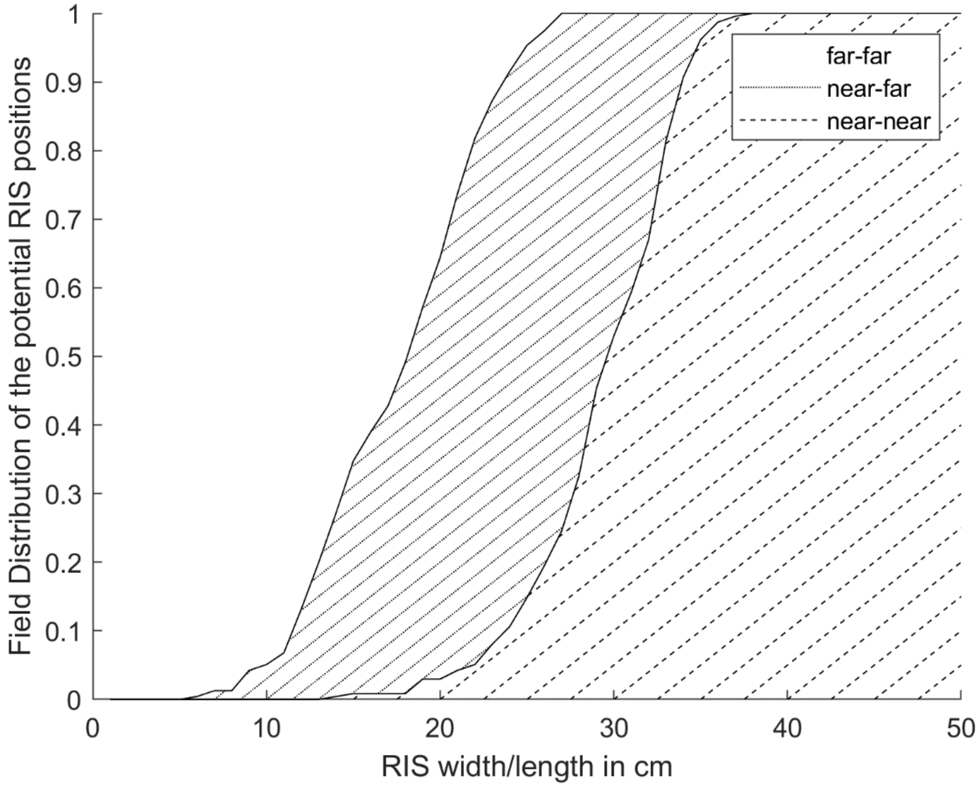
Near-/Far-Field Distance Depending on RIS Size



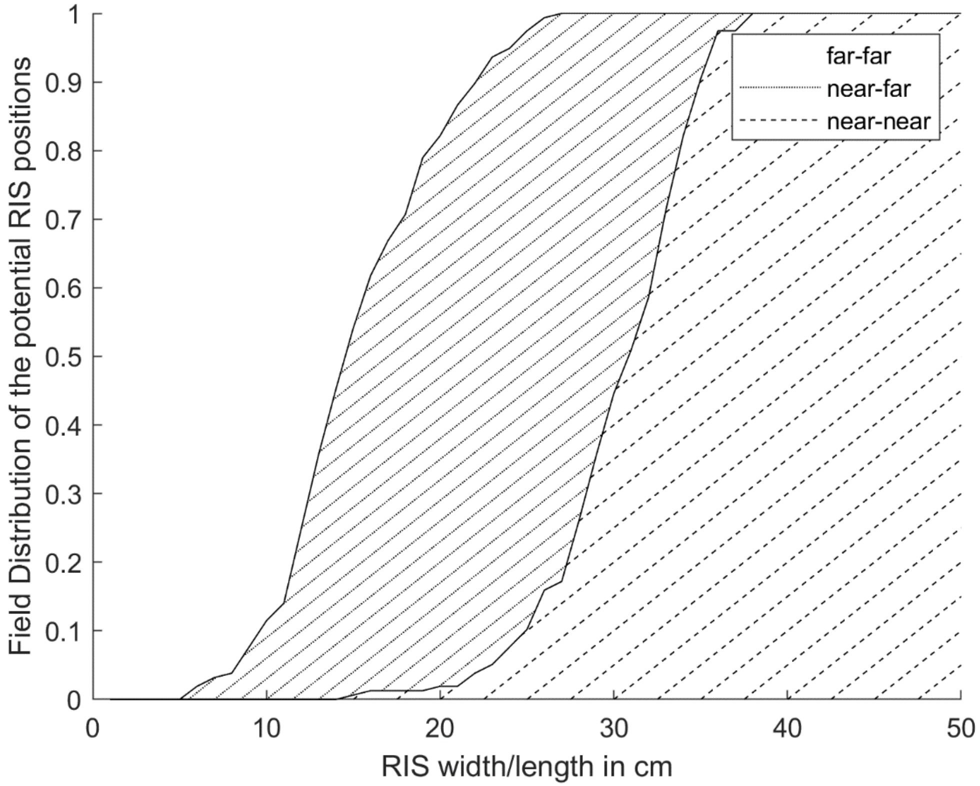
- $R = \frac{2L^2}{\lambda}$
  - Far-field at distance > R
  - Near-field at distance < R
  - L length and width of RIS
- Size of element $\frac{\lambda}{2}$
- Spacing $\frac{\lambda}{2}$
- Carrier frequency 300 GHz

Since backhaul links are bi-directional links near-/far-field conditions may be different wrt to both ends of the backhaul link!

Near/Far Field Distance Distribution of Backhaul Links in the Berlin Scenario



Reflection category 1



Reflection category 2

Conclusion

- Pathloss model including RIS has been discussed
- Two categories of reflections using RIS have been identified
- Tilting of RIS may be required to mitigate high loss caused by the incident angle
- Size of RIS should be selectively chosen due to far-/near-field constraint
  - RIS lenghts of up to 10 cm x 10 cm results in most of the cases the Backhaul links satisfied the far field condition wrt both ends of the link
- Simulation results taking into account typical weather conditions showed that wireless backhaul links up to few hundreds meters using RIS are feasible

Results of this study will be used to dimension RIS for THz Backhaul Links

Thank you for your kind attention.

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