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

Submission Title: Heuristic Path Loss Modeling for RIS Links

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Source: Thomas Kürner, TU Braunschweig
Address Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice:+495313912416, FAX: +495313915192, E-Mail: t.kuerner@tu-braunschweig.de

Re: n/a

Abstract: In this contribution an approach for a heuristic path loss model for RIS links at THz frequencies based on the bistatic radar equation is proposed, which accounts for the altered path gain progression due to near field effects.

Purpose: Information of IEEE 802.15 SC THz

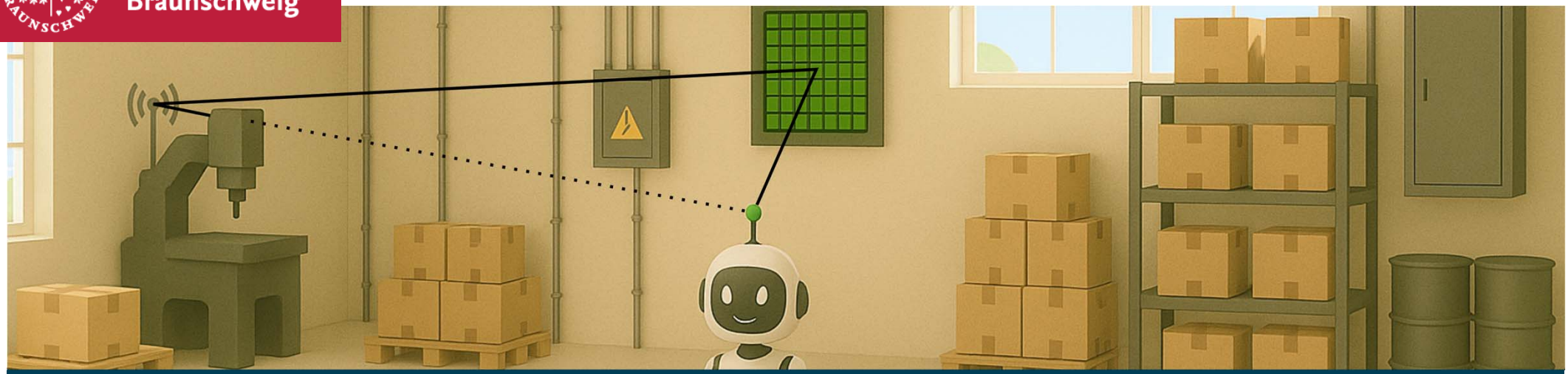
Acknowledgement

- The material presented here is a modified version of following publication:
  - L. H. W. Loeser, and T. Kürner, „Towards a Heuristic Path Loss Model for RIS Links," in Proc. URSI-B EMTS 2025, Bologna, 23–27 June 2025; also presented at ETSI ISG THz as THz(25)00027r3 on 10 June 2025
  - Modifications have been made wrt the proposed path gain model (see slide 11 impacting also slightly the results shown on slide 14)

- This work has been performed within the TERRAMETA project. The TERRAMETA project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101097101, including top-up funding by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee.

Technische Universität Braunschweig

Institut für Nachrichtentechnik



Heuristic Path Loss Modeling for RIS Links

Lorenz Loeser, Thomas Kürner

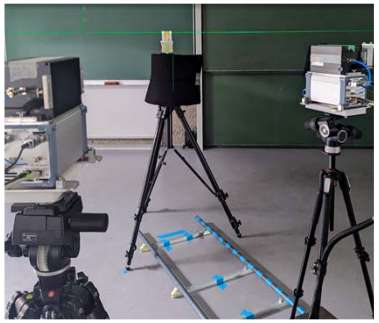
Thomas Kürner
Institute for Communications Technology
Technische Universität Braunschweig, Germany

Agenda

Motivation

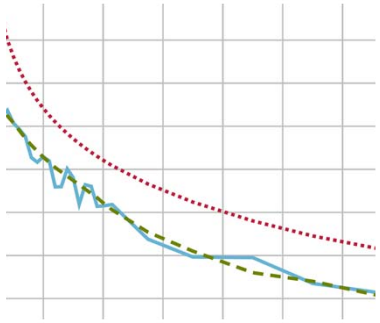
Why bother with RIS?

Measurements



Conducted measurement campaign

Model

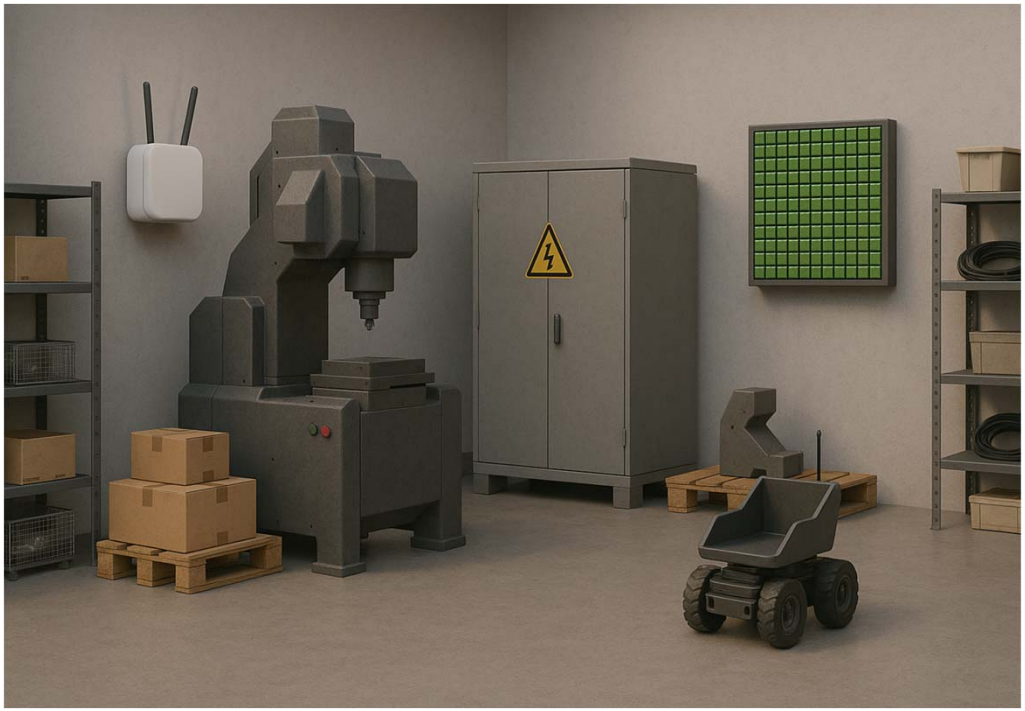


Modeling path gain and illumination

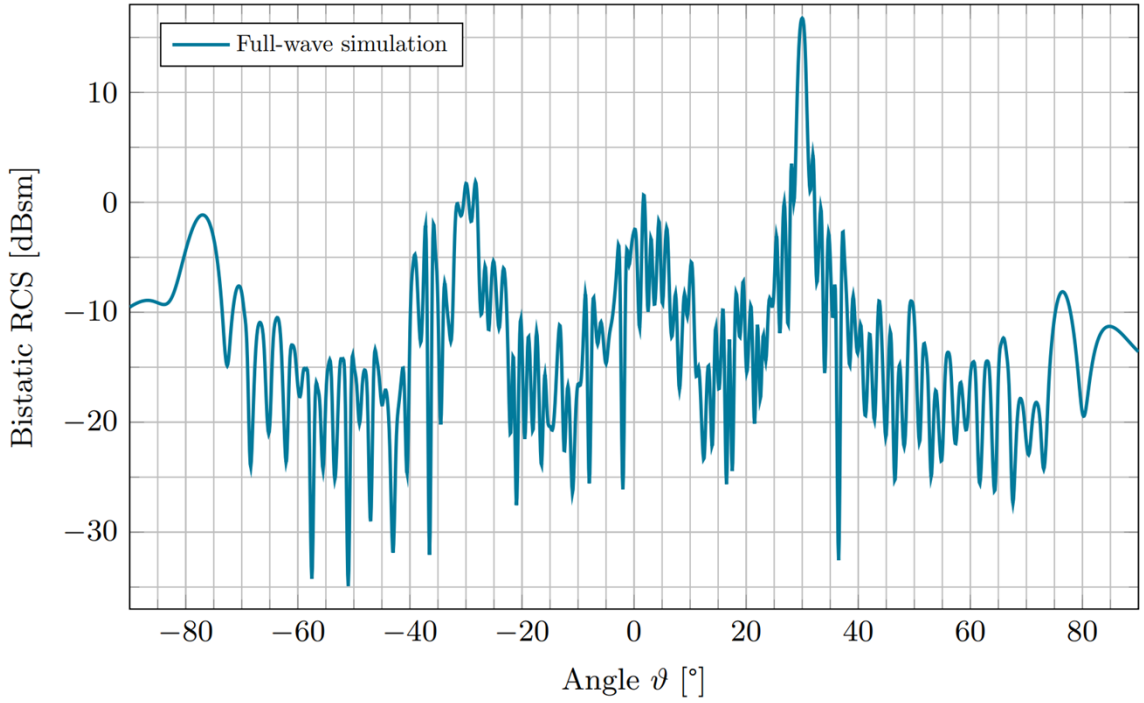
Conclusions

Key points and scope

Motivation



Potential use case of RIS



RCS of 3-bit static RIS within Terrameta project

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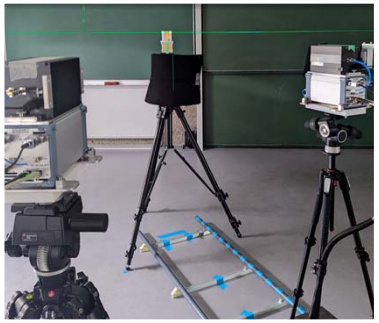
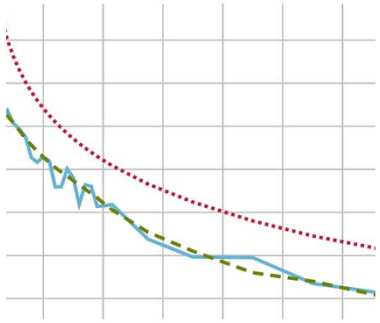


Conducted measurement campaign

Model



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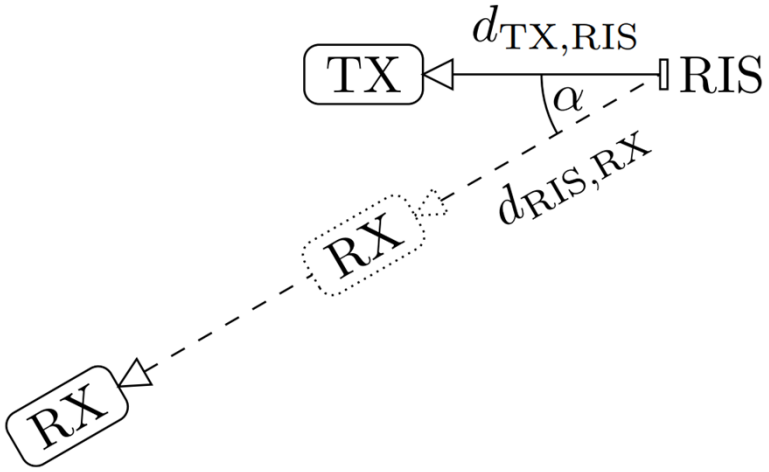


Schematic of meas. setup

Photo of meas. setup

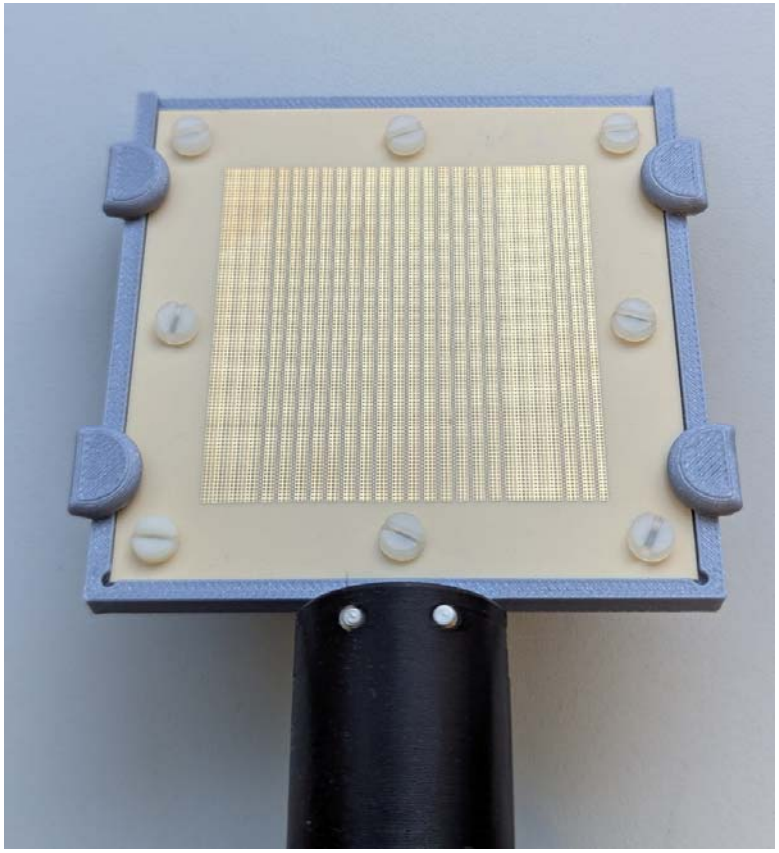
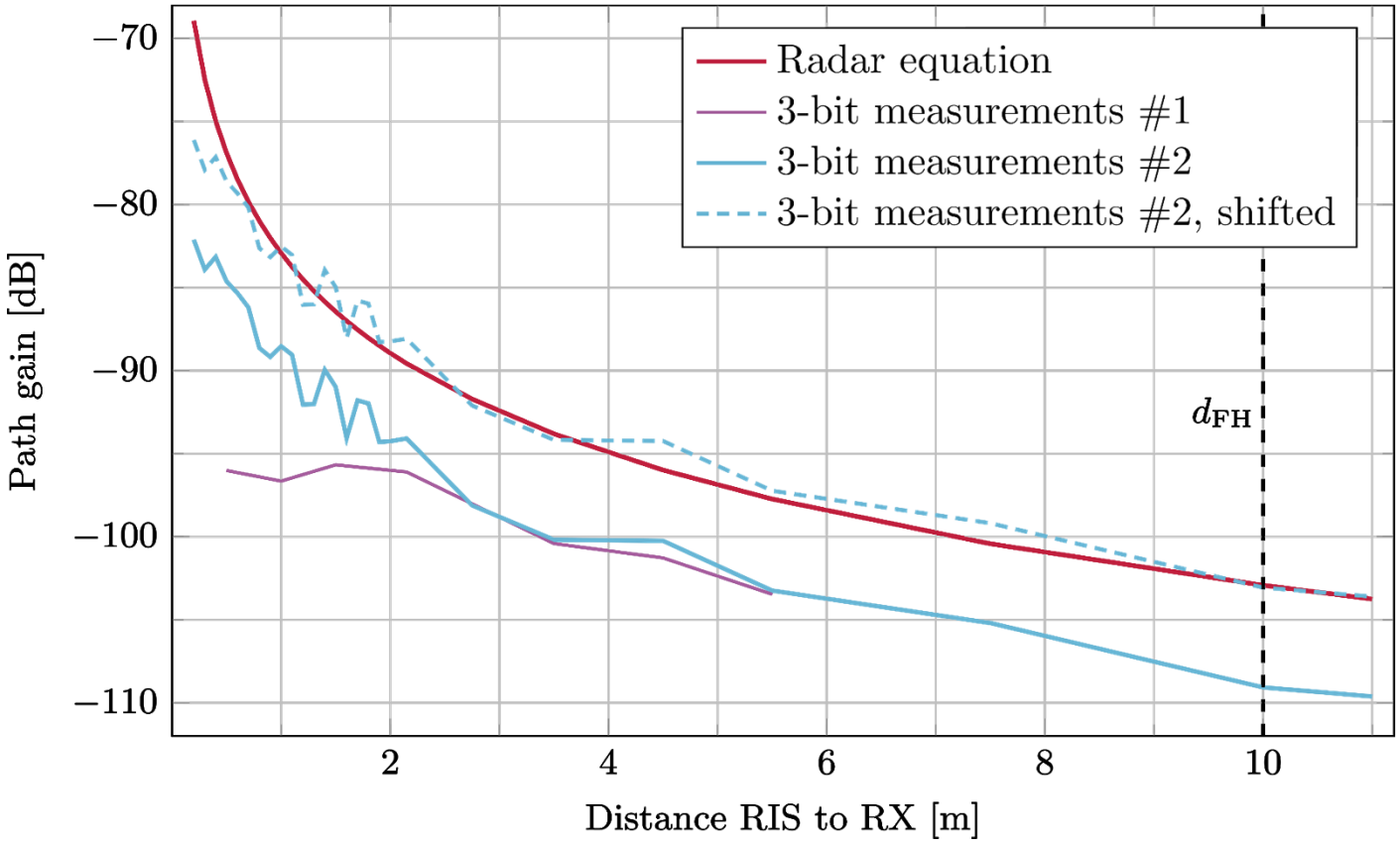


Photo of used RIS

Measurement Results

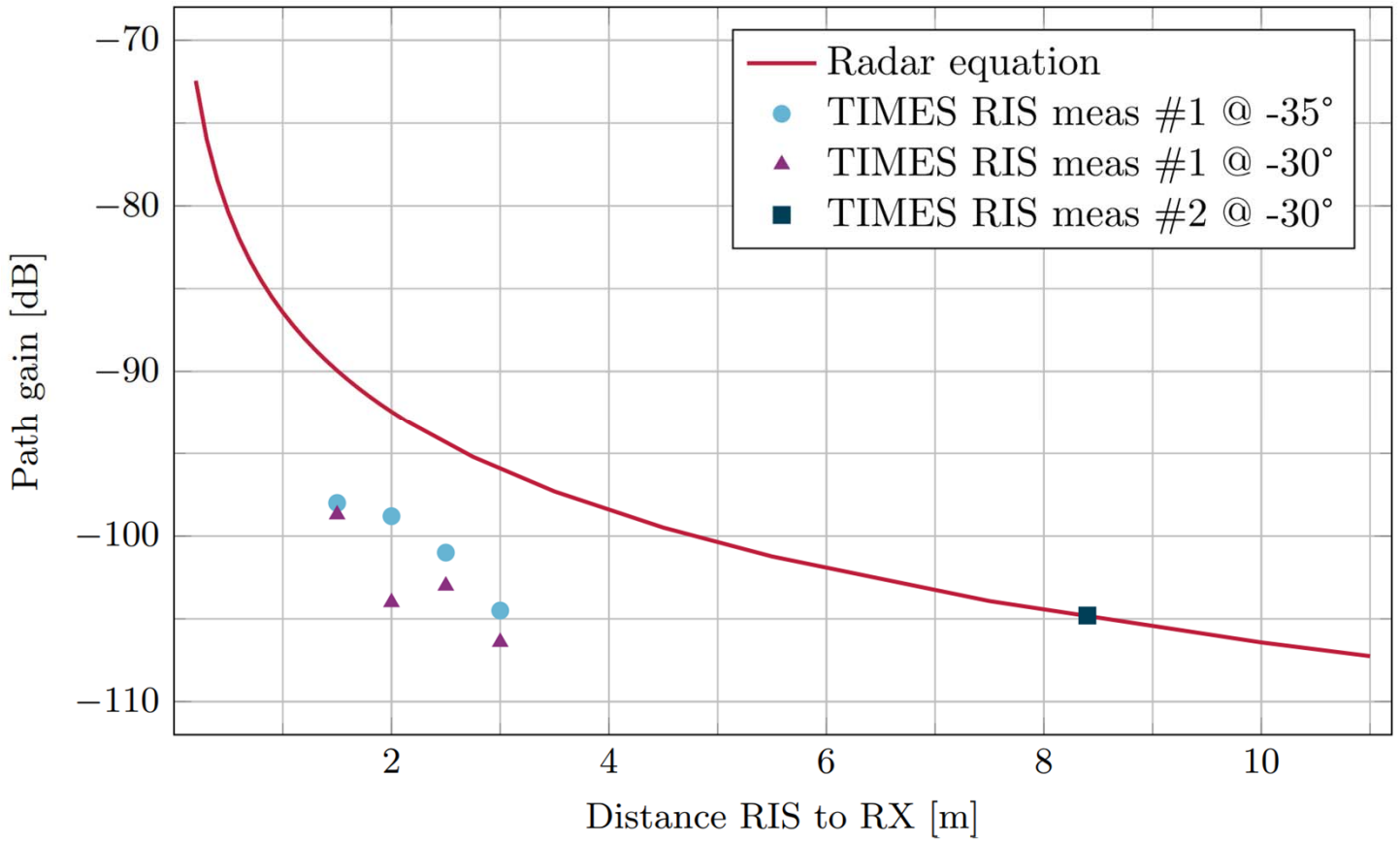


Path gain over RIS-RX distance

- Path gain progressions very similar
- Deviation of progression only very close to RIS
- Systematic offset
- Alignment process tedious

Measurement Results

- TIMES RIS shows similar behavior



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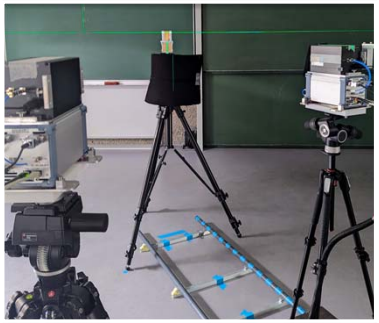
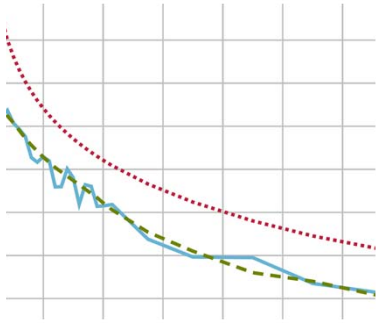


Conducted measurement campaign

Model



Modeling path gain and illumination

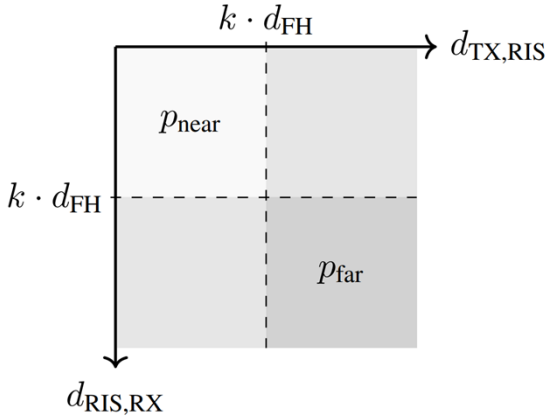
Conclusions

Key points and scope

Proposed Path Gain Model

- Radar equation with adjusted power loss exponents

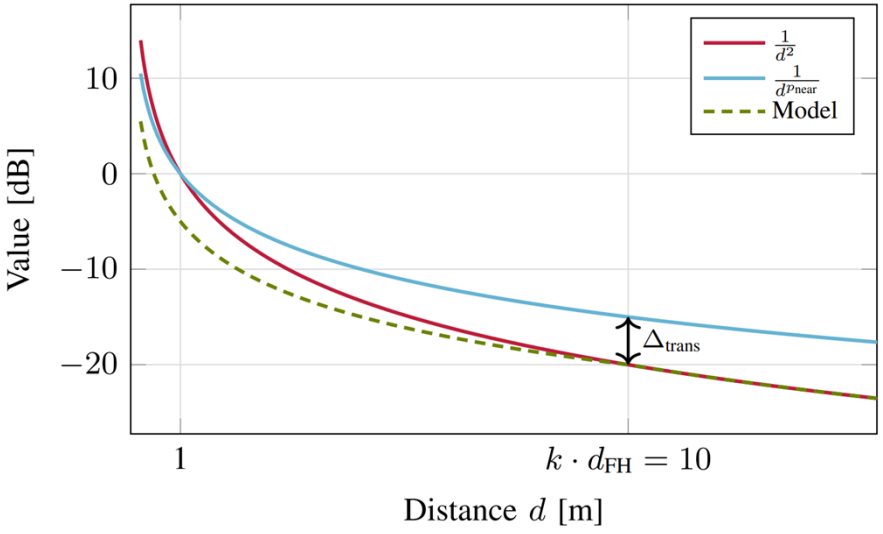
$$G = \sigma_{\text{RIS}} \cdot \frac{\lambda^2}{(4\pi)^3} \cdot \frac{\Delta_{\text{trans}}(d_{\text{TX,RIS}}) \cdot \Delta_{\text{trans}}(d_{\text{RIS,RX}})}{d_{\text{TX,RIS}}^{p_{\text{TX}}} \cdot d_{\text{RIS,RX}}^{p_{\text{RX}}}}$$



Schematic for adjustment of power loss exponents

- Correction factor for smooth transition

$$\Delta_{\text{trans}}(d) = \begin{cases} (k \cdot d_{\text{FH}})^{(p_{\text{near}}-2)} & , \; d \leq k \cdot d_{\text{FH}} \\ 1 & , \; \text{else} \end{cases}$$



Schematic for explanation of transition factor

Radar Cross Section

- PEC as upper boundary

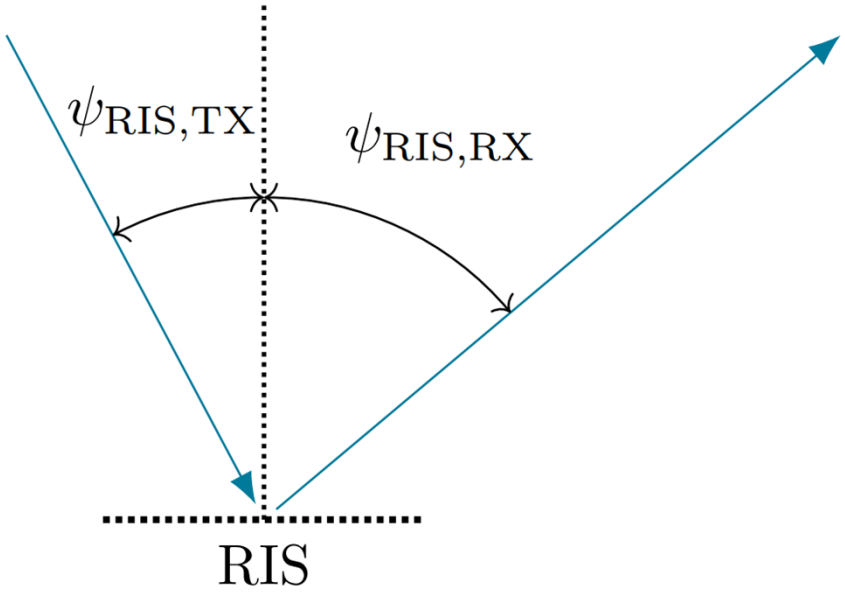
$$\sigma_{\mathrm{PEC}} = \frac{4\pi}{\lambda^2} \cdot A_{\mathrm{RIS}}^2$$

- RIS RCS

$$\sigma_{\mathrm{RIS}} = \sigma_{\mathrm{PEC}} \cdot \cos(\psi_{\mathrm{RIS,TX}}) \cdot \cos(\psi_{\mathrm{RIS,RX}}) \cdot \eta_{\mathrm{RIS}}$$

- RIS efficiency

$$\eta_{\mathrm{RIS,dB}} \approx - \left\{ \begin{array}{ll} 1.5\,\mathrm{dB}, & \text{3-bit} \\ 3\,\mathrm{dB}, & \text{2-bit} \\ 6\,\mathrm{dB}, & \text{1-bit} \end{array} \right\} - \left\{ \begin{array}{ll} 1\,\mathrm{dB}, & \text{reconf.} \\ 0\,\mathrm{dB}, & \text{static} \end{array} \right\}$$



Definition of angles

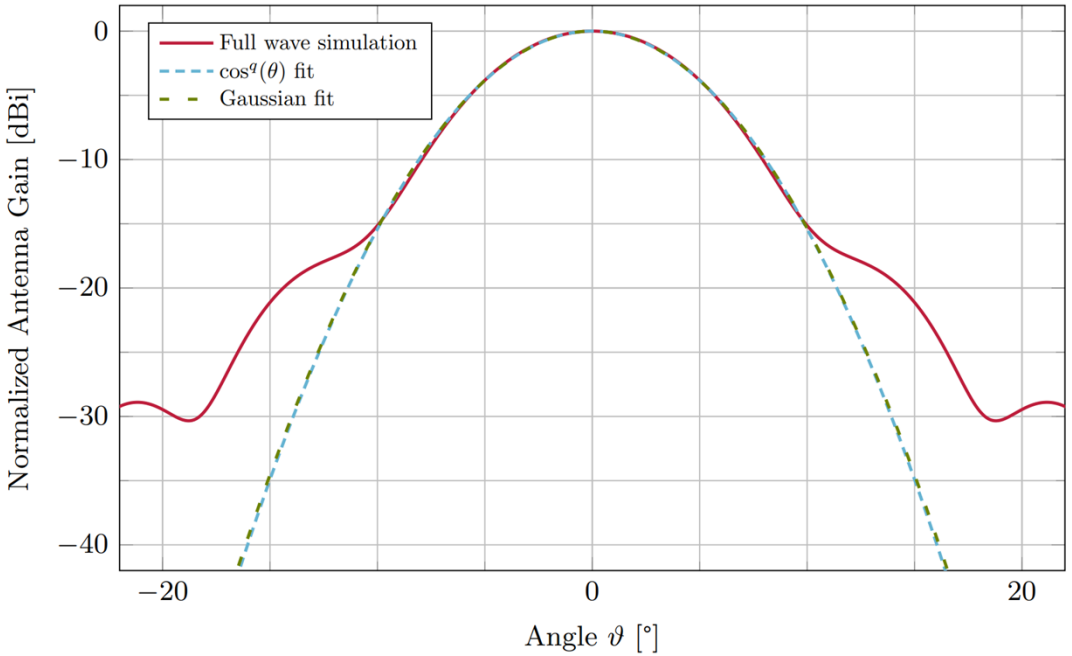
Illumination Loss

- TX/RX main lobes as cosine or Gaussian
- Discretize RIS surface

$$\eta_{\text{illu}} = \frac{\sum_i G_{\text{TX,norm}}(\psi_{\text{TX,RIS},i}) \cdot G_{\text{RX,norm}}(\psi_{\text{RX,RIS},i})}{I}$$

- Overall model

$$G = \sigma_{\text{RIS}} \cdot \frac{\lambda^2}{(4\pi)^3} \cdot \frac{\Delta_{\text{trans}}(d_{\text{TX,RIS}}) \cdot \Delta_{\text{trans}}(d_{\text{RIS,RX}})}{d_{\text{TX,RIS}}^{p_{\text{TX}}} \cdot d_{\text{RIS,RX}}^{p_{\text{RX}}}} \cdot \eta_{\text{illu}}$$

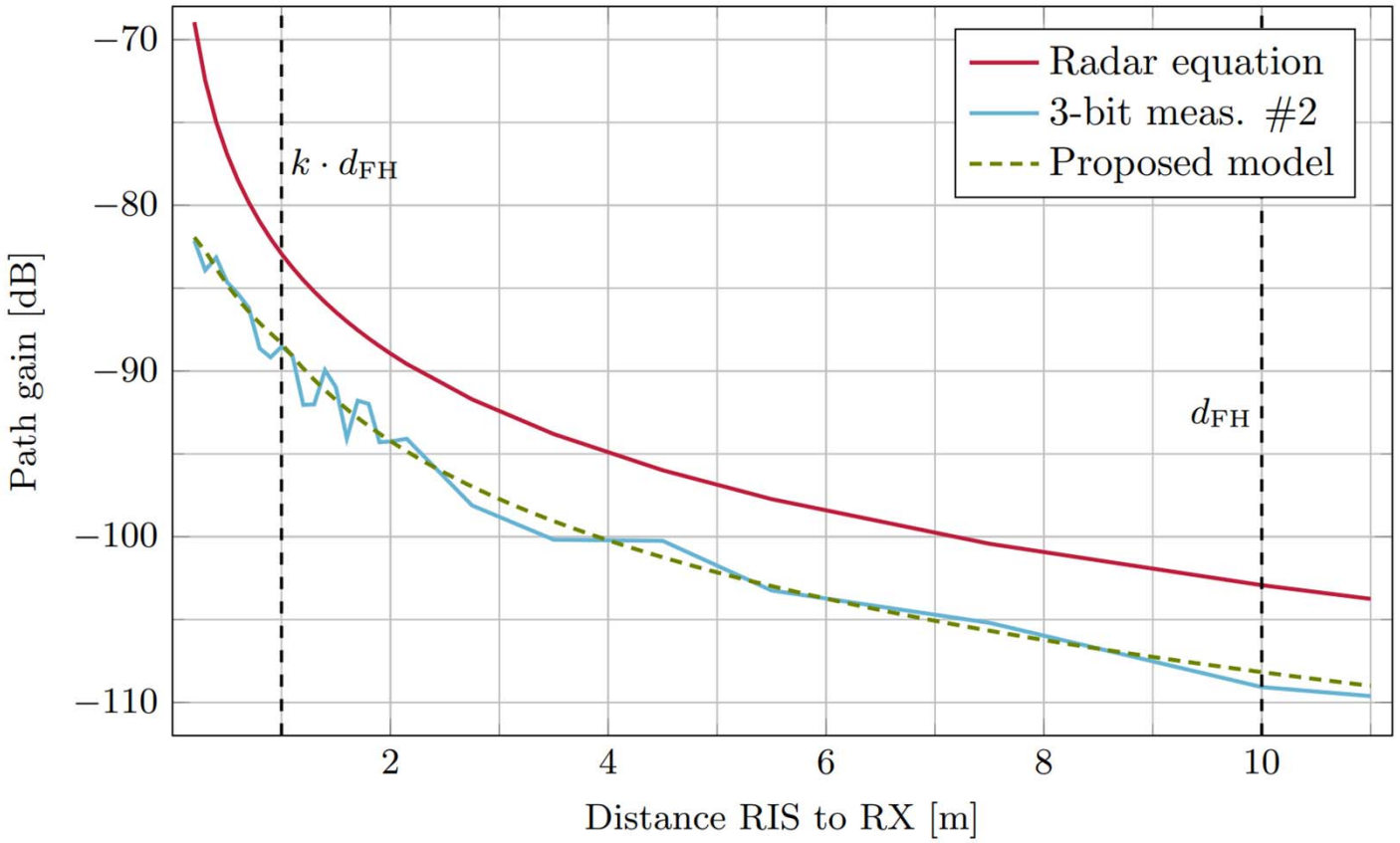


Approximations of main lobes

➢ Model able to describe arbitrary other gain progressions

Optimal Parameters for Given Measurement

- RIS designed for far field beamforming
- Fraction of Fraunhofer dist. $k = 0.1$
- Near field exponent $p_{\text{near}} = 1.3$
- Fixed far field exponent $p_{\text{far}} = 2$



Path gain over RIS-RX distance

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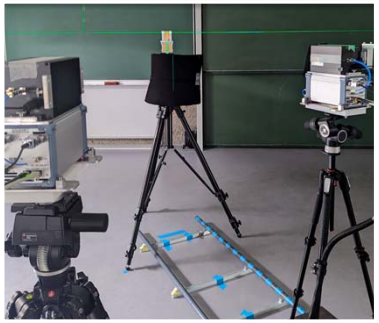

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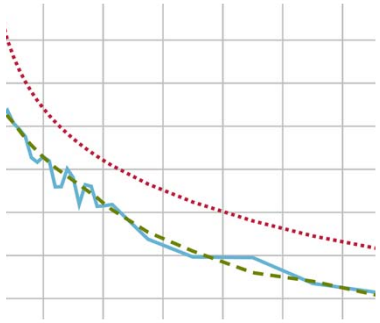

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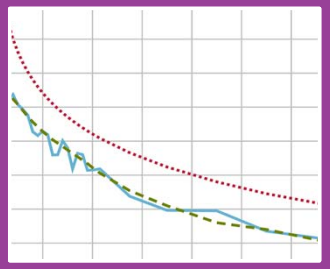
Conclusion

Measurements

- Radar equation suitable for path gain modeling of TX-RIS-RX links
- Fraunhofer distance too strict in this regard



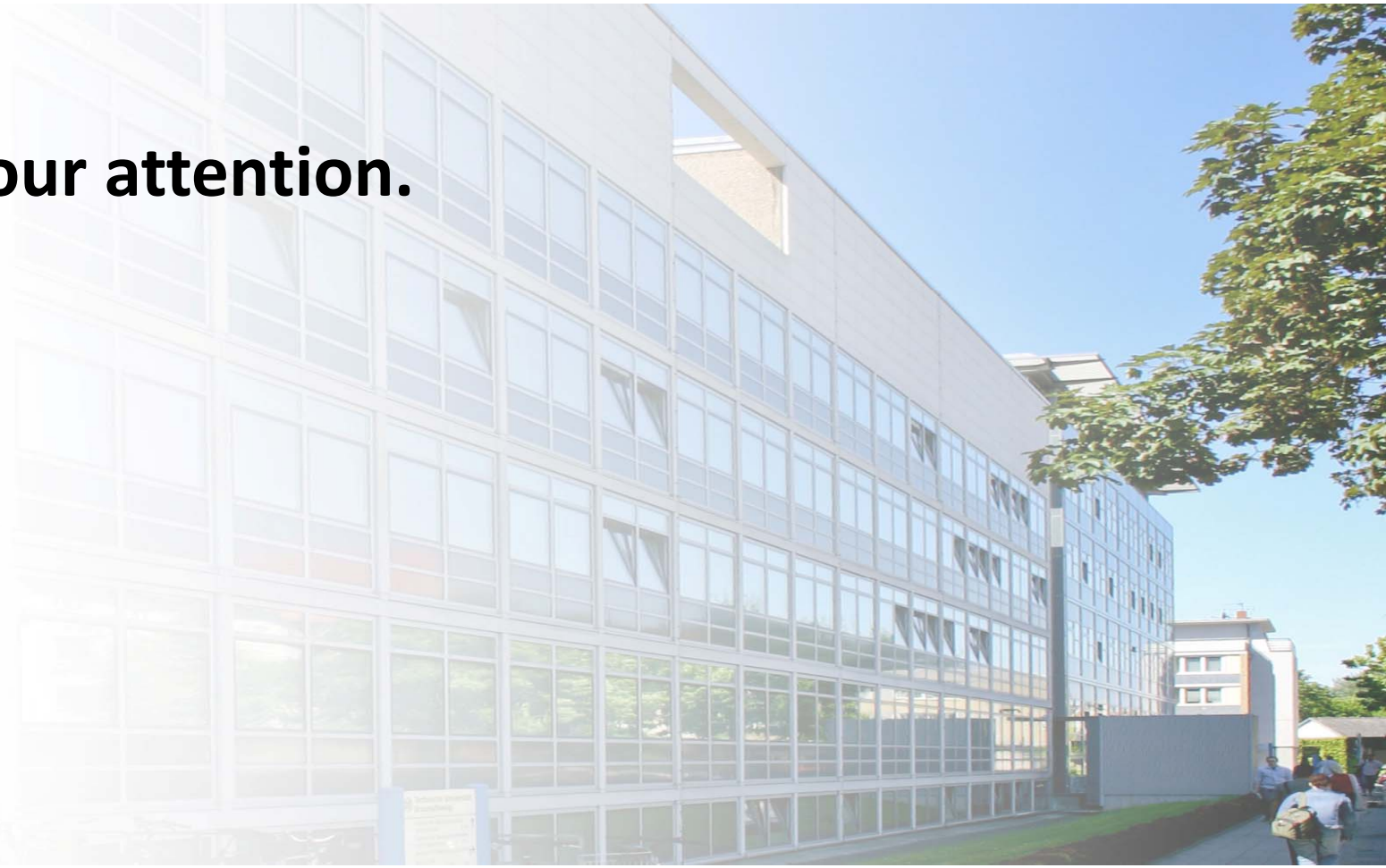
Models

- Adjustment of power loss exponents
- Radar cross section in design directions
- Illumination loss

Objective

A heuristic path loss model for RIS links

Thank you for your attention.



Prof. Dr.-Ing. Thomas Kürner

t.kuerner@tu-braunschweig.de