Wideband Characterization of UHF RFID Channels for Ranging and Positioning

Daniel Arnitz, Ulrich Muehlmann, and Klaus Witrisal

daniel.arnitz@tugraz.at, ulrich.muehlmann@nxp.com, witrisal@tugraz.at

Graz University of Technology / NXP Semiconductors, Austria

TU Graz
Graz University of Technology

NXP

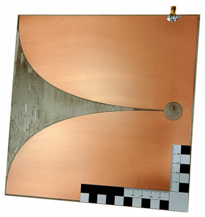
Abstract

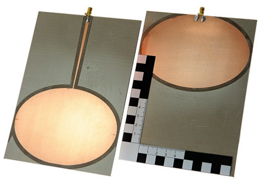
- **Positioning** is a much-desired feature in UHF RFID: Methods using **phase shifts between multiple carriers** have been proposed (fit into spectral masks)
- Unfortunately, the phase shifts are **heavily affected by multipath propagation**.
- As a consequence, **wideband properties** of UHF RFID channels are **imperative for positioning**, yet not well understood and rarely taken into account
- **This work presents the first (ultra)wideband channel characterization for typical UHF RFID setups (indoor, short-range, suitable TX antennas, ...)**

1. Measurement Setup

Measurement Description

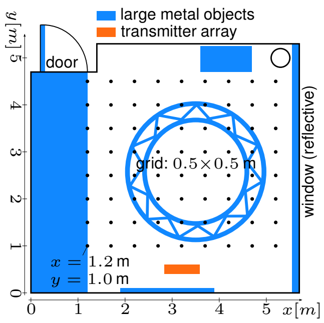
- $500..1500$ MHz using a Vector Network Analyzer
- TX antenna: custom 4×1 Vivaldi array (left photo; gain pattern resembling a typical UHF RFID reader antenna)
- RX antenna: custom omnidirectional UWB antenna (right photo; gain pattern resembling a typical UHF RFID tag antenna)





Measurement Environment: Semi-Industrial

- reinforced concrete floor, walls, and ceiling
- large window with highly reflective coating
- large metal objects (metal platings, large circular strut mounted on ceiling, large cabinet, ...)



2. Channel Model, Simulation Setup

Channel Model

- deterministic largescale: log-distance line-of-sight (LOS)
- deterministic smallscale: reflections using simple ray-tracing
- stochastic smallscale (scattering)

Simulation Setup

Simulation results have been created by [1] with some enhancements. Modeled are:

- RX-antenna and TX-array directivity (far field)
- reflections on walls, floor, and ceiling (simple ray-tracing)
- statistial model of scattering

Explicity NOT modeled are:

- exact room geometry and/or materials
- TX antenna array size / near-field effects

3. Measurement and Simulation Results

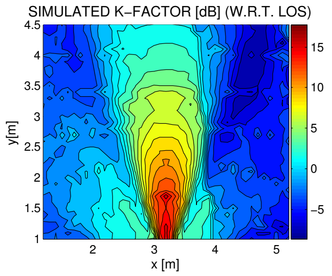
In a Nutshell...

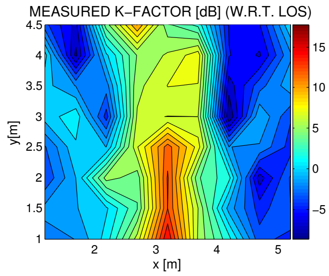
- surprisingly low K-factor: max. $10..15$ dB within main lobe
- coverage (tag powered) approx. $15\,\%$ of meas. area
- local influence of metal objects evident

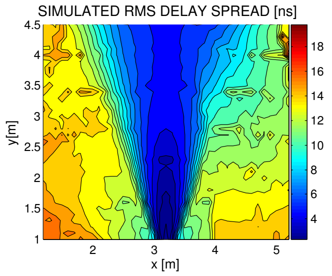
Simulation (left) vs. Measurement (right):

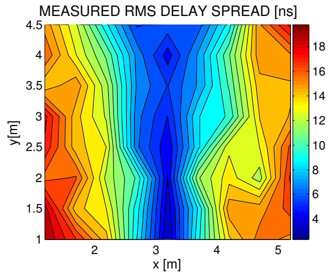
Differences mainly due to:

- point source vs. $60\times21\times21$ cm array (close to TX)
- local influence of complex metal objects (top and right side)



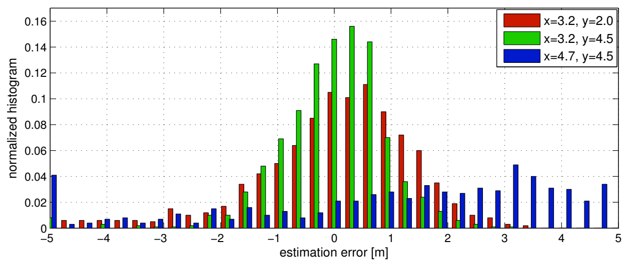






Example: Phase-Difference-Based Ranging TX→RX

- two carriers at $0.5..1.5$ GHz, offset $\Delta f = 1$ MHz
- dist. estimate TX→RX: $\hat{d} = \Delta\hat{\varphi}/(2\pi)\,\lambda = c\,\Delta\hat{\varphi}/(2\pi\,\Delta f)$



- ranging even in main lobe not a simple task (low K-factor)
- close to uniform phase outside main lobe ($\Rightarrow$ random $\hat{d}$)
- $90\,\%$ coh. BW: ≈ 50 MHz inside main lobe, ≈ 4 MHz outside

4. Conclusion

- **Multicarrier positioning methods without taking the wideband channel parameters into account will fail under realistic indoor conditions**
- **Simulations using the wideband UHF RFID simulator match the measurement results**
- **Future Work: Industrial environments / gates**

References

[1] D. Arnitz, U. Muehlmann, T. Gigl, and K. Witrisal. Wideband system-level simulator for passive UHF RFID. In *IEEE Intl. Conf. on RFID, RFID'09*, Orlando, Florida, April 2009.

The authors would like to express their gratitude to Grzegorz Adamiuk from University of Karlsruhe for the antenna designs. This work was supported by NXP Semiconductors, Gratkorn, Austria, and by the Austrian Research Promotion Agency (FFG) under grant 818072. The measurements were taken using remote control functions developed by Carlos Manuel Delgado Ramirez during his master's thesis at TU Graz.