Wireless propagation plan

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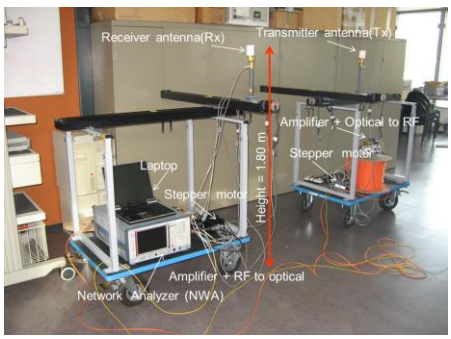
Motivation

- Wireless in factories can be challenging
  - metallic environment
  - dynamic environment
- Recent technologies bring about more challenges
  - e.g., MIMO, OFDM, and UWB
  - RSSI alone is no longer sufficient as a performance indicator
- Therefore: wireless propagation research to learn about the nature of the industrial channel

Measurement equipment

- Wireless channel sounder
  - scans channel in space, frequency, and time
  - all these dimensions affect performance of modern wireless technologies (MIMO/OFDM/UWB)!

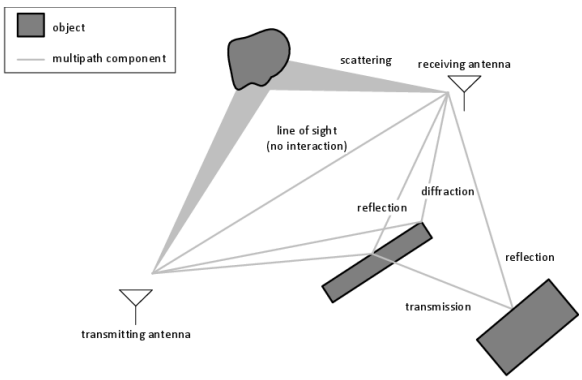


Measurement procedure

- First test measurements in industrial environment
  - container repair shop in port of Antwerp

Measurement procedure

- Extraction of *physical* channel parameters
- Physical model of the channel = multipath

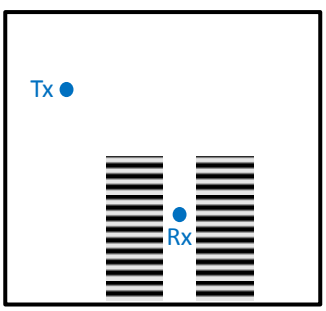


parameters:

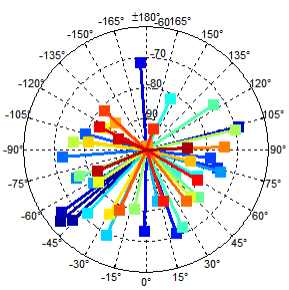
- time delay
- angle of departure
- angle of arrival
- power

Measurement procedure

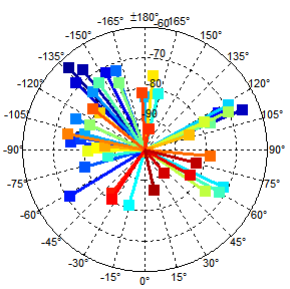
- Parameter extraction
  - with maximum likelihood algorithms
  - example



angular at Tx

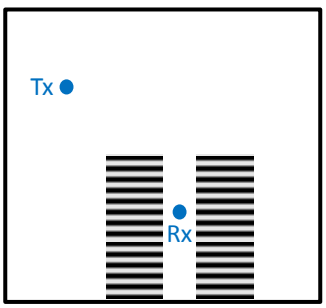


angular at Rx

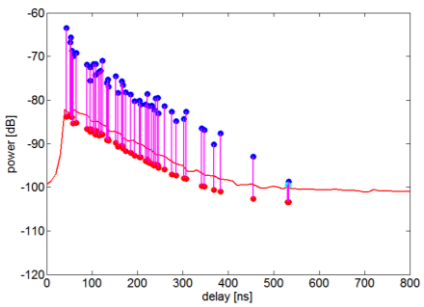


Measurement procedure

- Parameter extraction
  - with maximum likelihood algorithms
  - example



time-delay at Rx



Measurement procedure

- Industrial channel model
  - = statistics of physical channel parameters

MPC parameter	Intra-cluster distribution	Inter-cluster and intra-cluster parameters	Statistical modelling
$\Phi^A_{c,k}$ [rad]	von Mises	(inter) ϕ^A_c [rad]	*uniformly distributed*
		(intra) κ^A_c [-]	*lognormally distributed*
			$\mathrm{E}\left[\log\left(\kappa^A_c\right)\right] = 0.50$
			$\mathrm{Std}\left[\log\left(\kappa^A_c\right)\right] = 0.33$
$\Phi^D_{c,k}$ [rad]	von Mises	(inter) ϕ^D_c [rad]	*uniformly distributed*
		(intra) κ^D_c [-]	*lognormally distributed*
			$\mathrm{E}\left[\log\left(\kappa^D_c\right)\right] = 0.36$
			$\mathrm{Std}\left[\log\left(\kappa^D_c\right)\right] = 0.32$
$T_{c,k}$ [ns]	exponential	(inter) τ_c [ns]	*exponentially distributed*
			$\mathrm{E}\left[\tau_c - \tau_{c-1}\right] = 2.30$ ns (LOS)
			and 1.21 ns (NLOS)
		(intra) λ_c [ns]	*lognormally distributed*
			$\mathrm{E}\left[\log\left(\lambda_c\right)\right] = 0.03$
			$\mathrm{Std}\left[\log\left(\lambda_c\right)\right] = 0.35$
$P_{c,k}$ [-]	lognormal	(inter) p_c [dB]	$= -20.14 - 0.81 \cdot \tau_c$ [ns] $+ \epsilon_c$
			ϵ_c zero-mean normally distributed
			with standard deviation 4.72 dB
		(intra) σ_c [dB]	*lognormally distributed*
			$\mathrm{E}\left[\log\left(\sigma_c\right)\right] = 0.88$
			$\mathrm{Std}\left[\log\left(\sigma_c\right)\right] = 0.14$

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Applications

- Practical uses of channel models
  - link budget calculations (wireless range)
  - quantify MIMO benefits
    - diversity order (range increase)
    - multiplexing gain (bitrate increase)
  - simulation of RF exposure
    - comparison with measurements
  - channel playback/emulation in a testbed
    - e.g., for performance testing of a proprietary industrial MAC-protocol

Planning and final goal

- Measurement campaign
  - Labo Soete at Campus Zwijnaarde
  - SNCF in Lille
  - ...

- Goal: presentation of findings at final workshop