UWB & Multiple Antenna Systems ?

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- Feng Zheng
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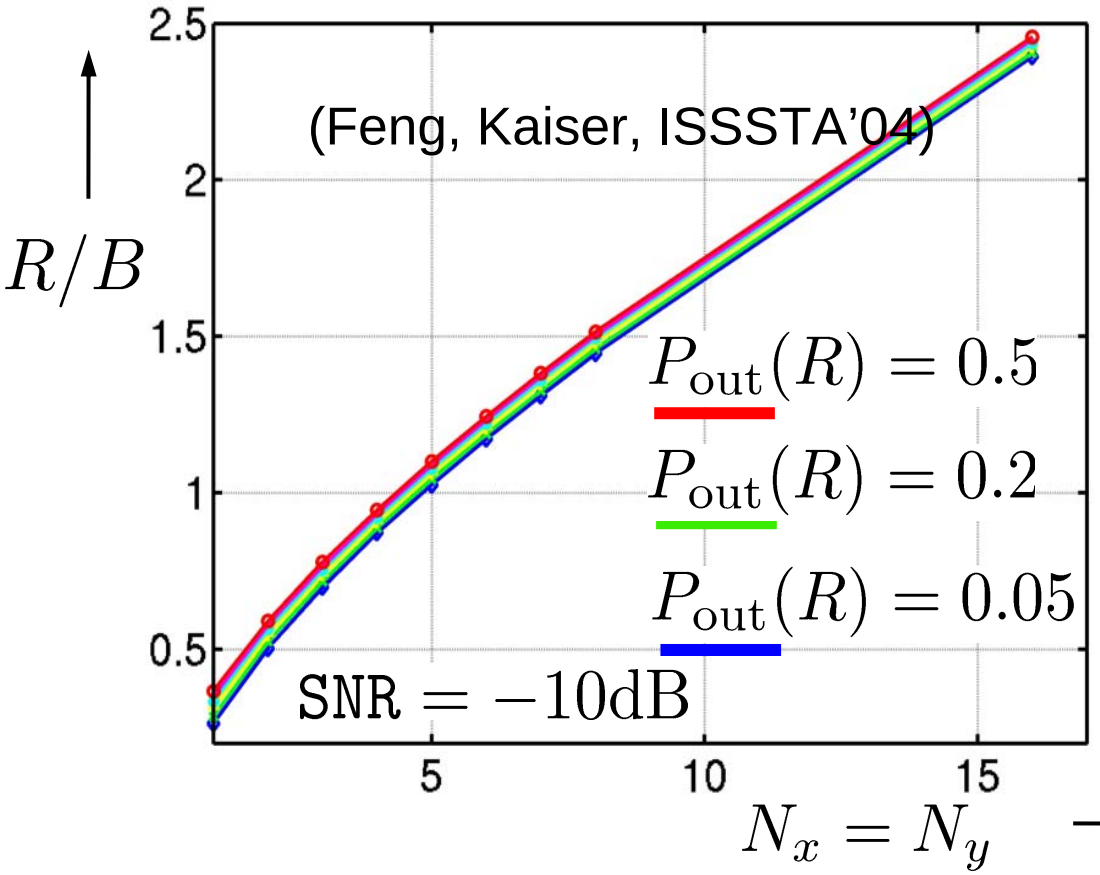
Outline

- UWB & MIMO Channel Capacity
- „Double-dB-Gain“ of UWB beamforming
- The „BeamLoc“-Algorithm - Localization in NLoS
- Spatial Multiplexing with „MISO“

UWB & MIMO Channel Capacity

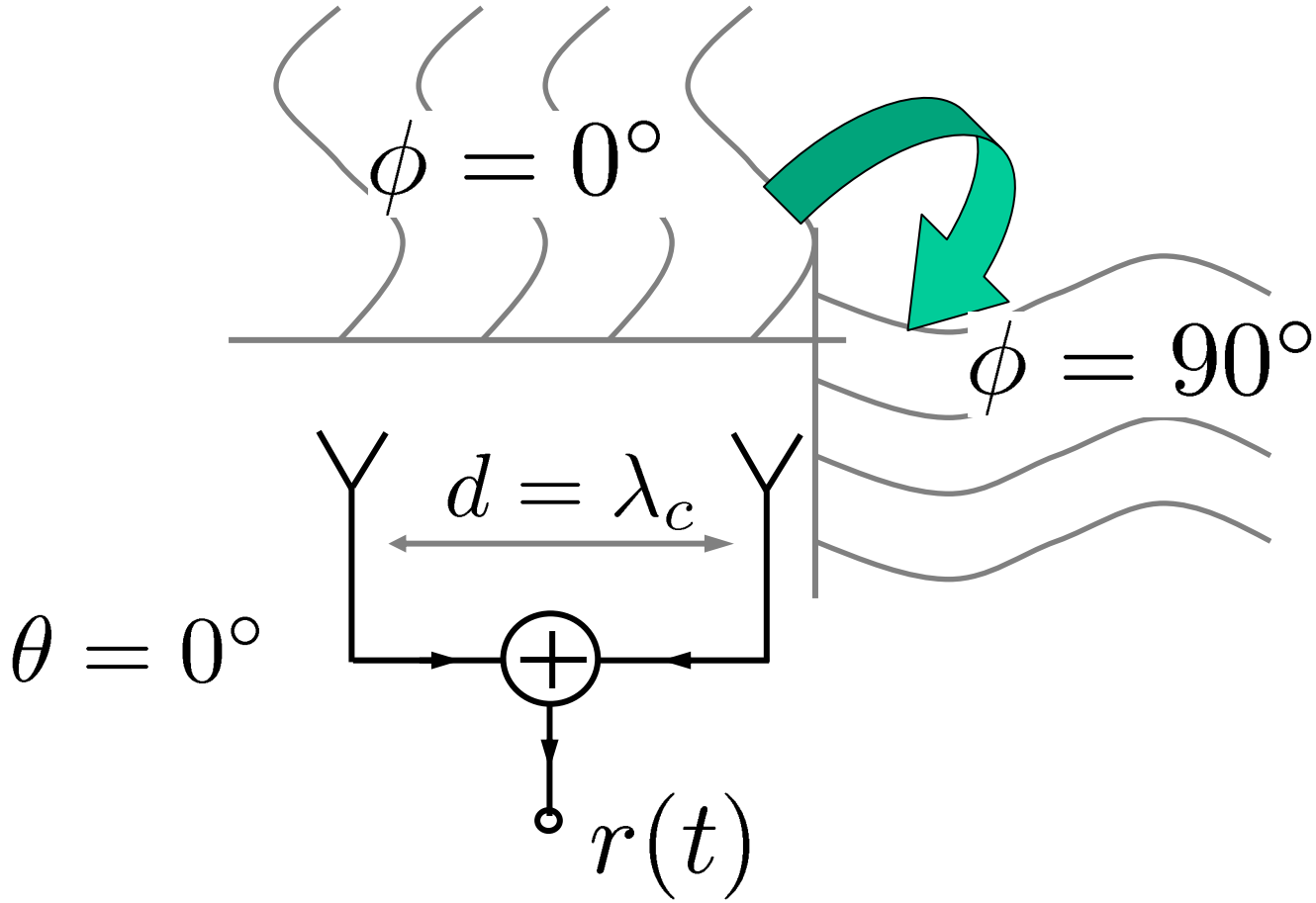


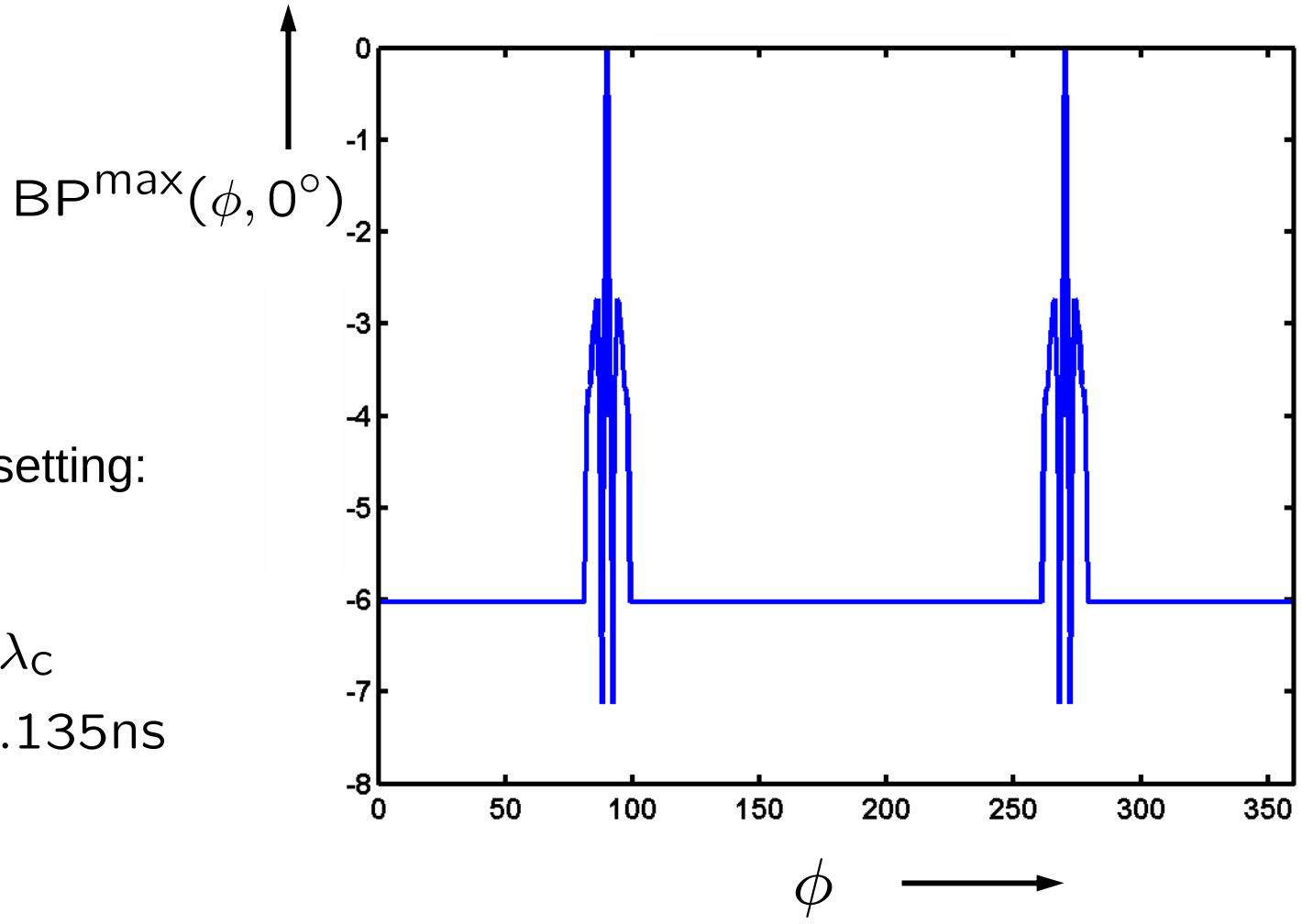
Limit for indoor communication is **UWB & MIMO**

$$C \cong \min(N_X, N_Y)\, B \log_2(1 + \text{SNR})$$

UWBMIMO

„Double-dB Gain“ of UWB Beamforming



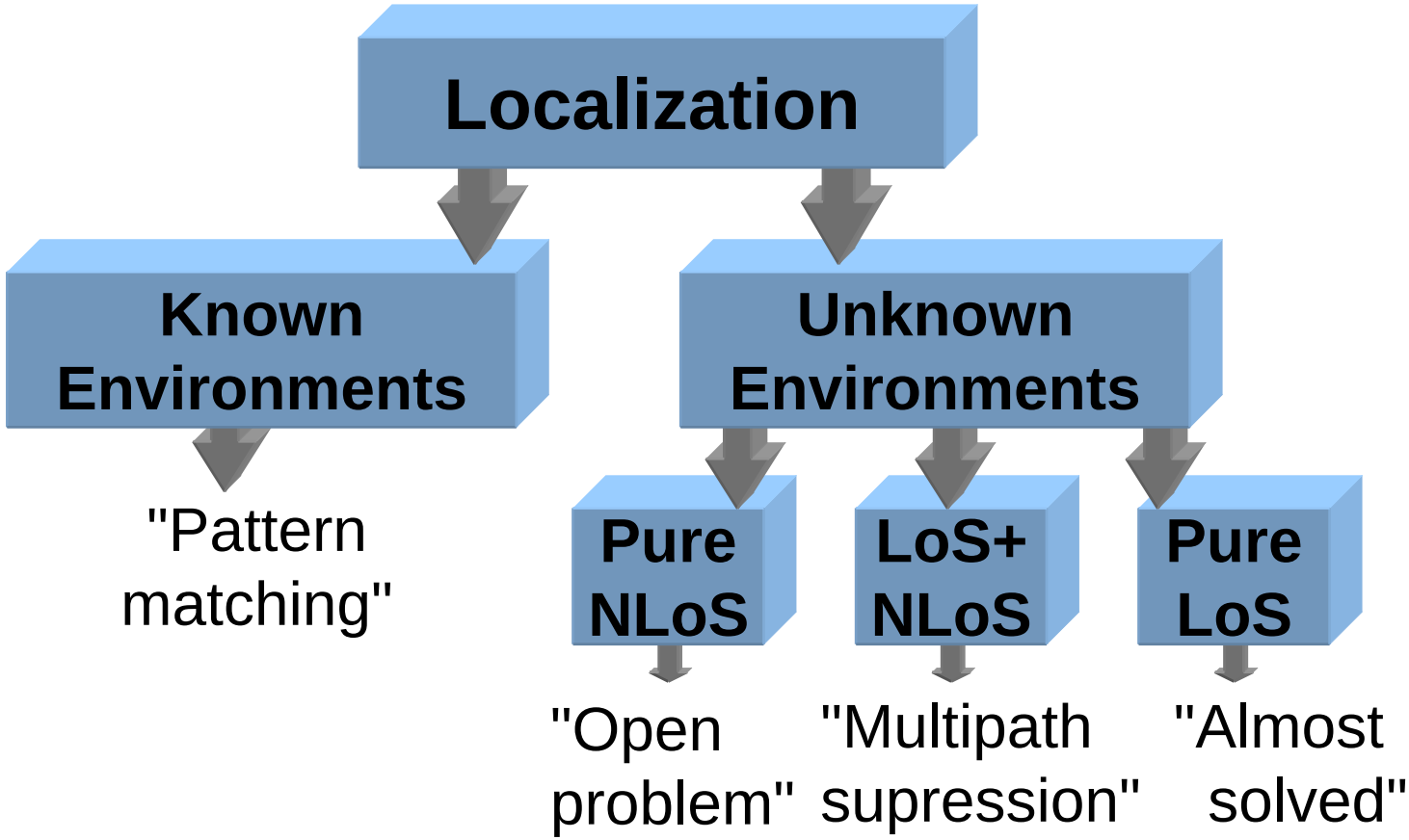


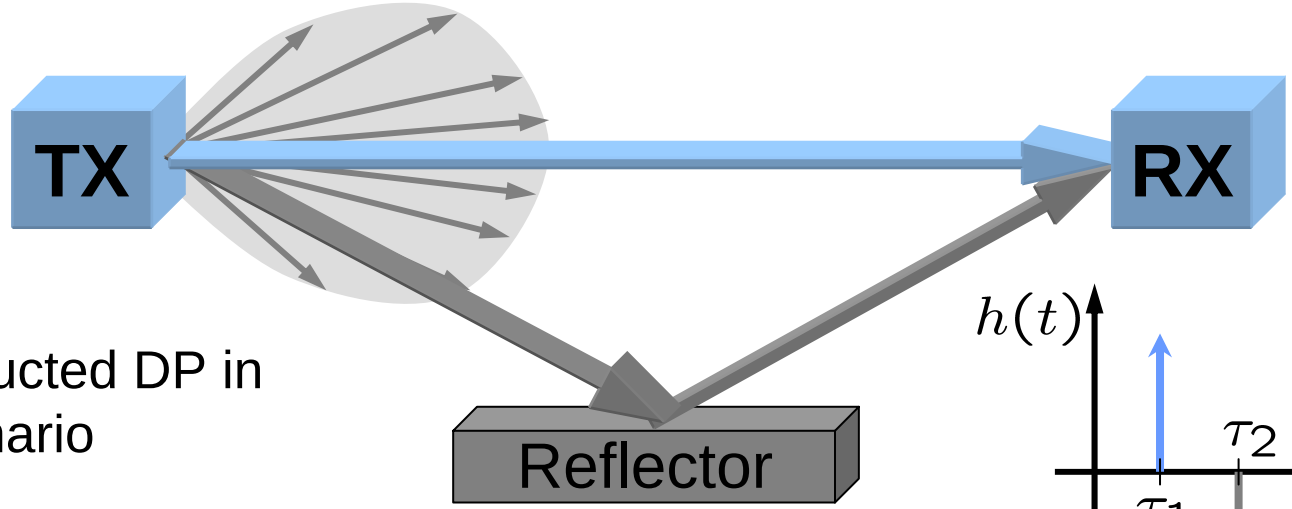
Parameter setting:

$$N = 2$$
$$d = 3\lambda_c$$
$$T_p = 0.135\text{ns}$$

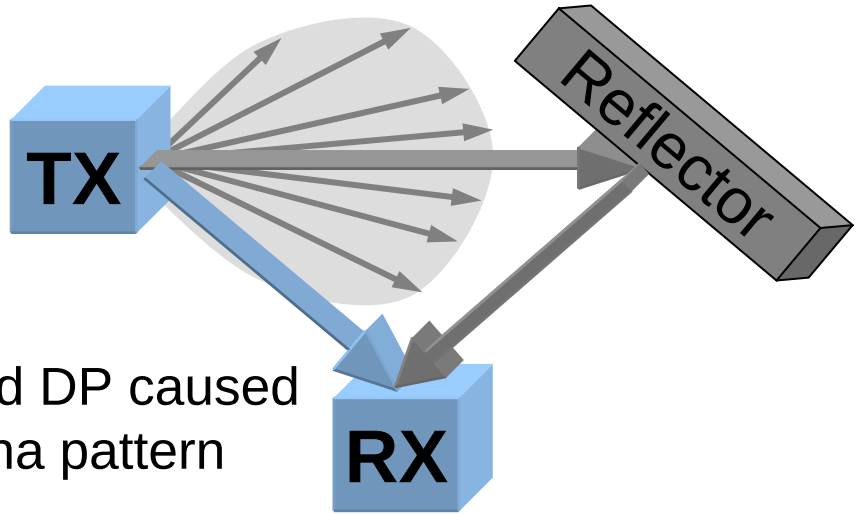
$$\mathrm{BP}^{\max}(\phi, \theta) = \max_t \left(\int_{t+T/2}^{t-T/2} |r(\tau, \phi, \theta)|^2 \mathrm{d}\tau \right)^{1/2}$$

The „BeamLoc“ Approach - Localization in NLoS Environments

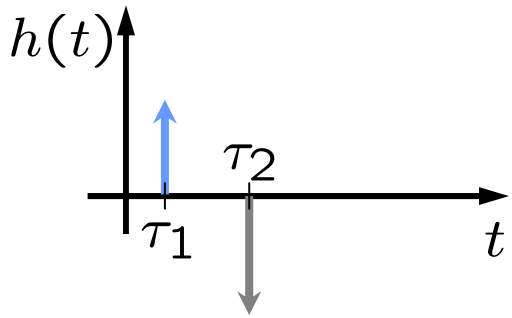




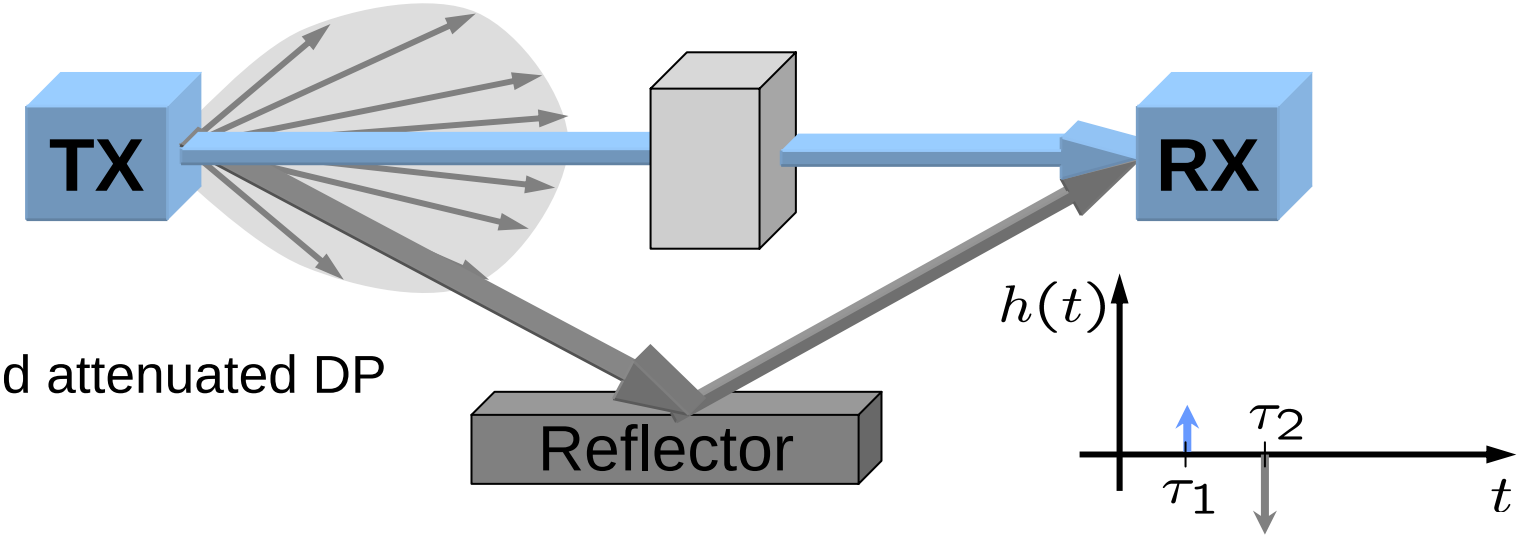
An unobstructed DP in a LoS Scenario



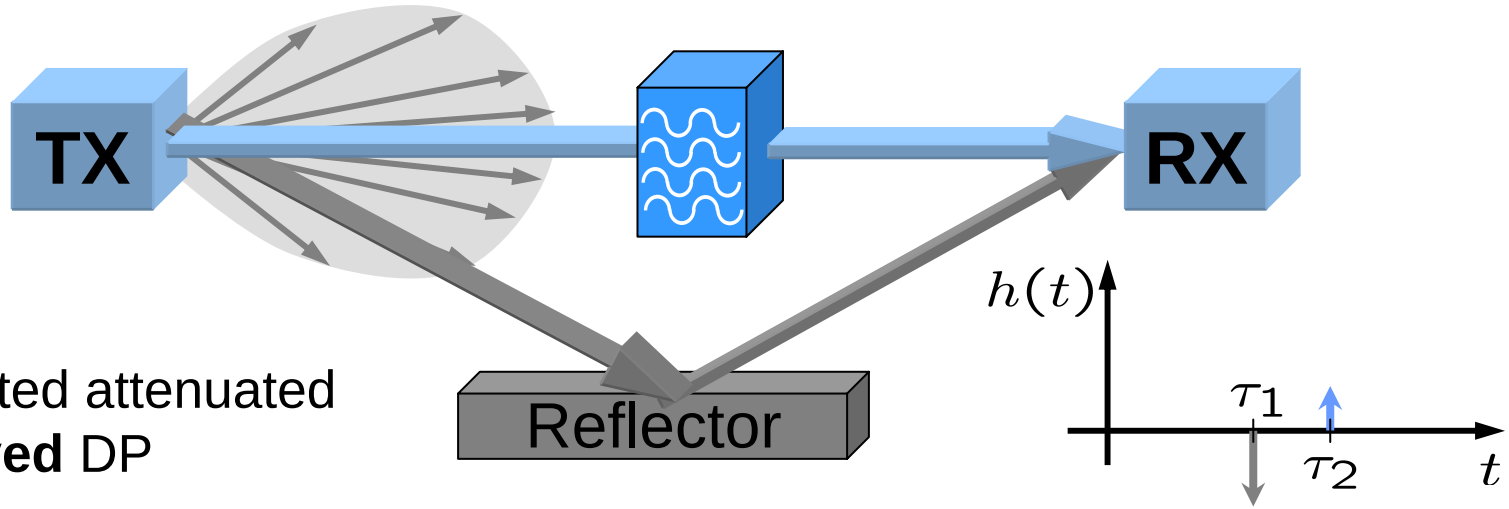
An attenuated DP caused by the antenna pattern



An obstructed attenuated DP



An obstructed attenuated **and delayed** DP

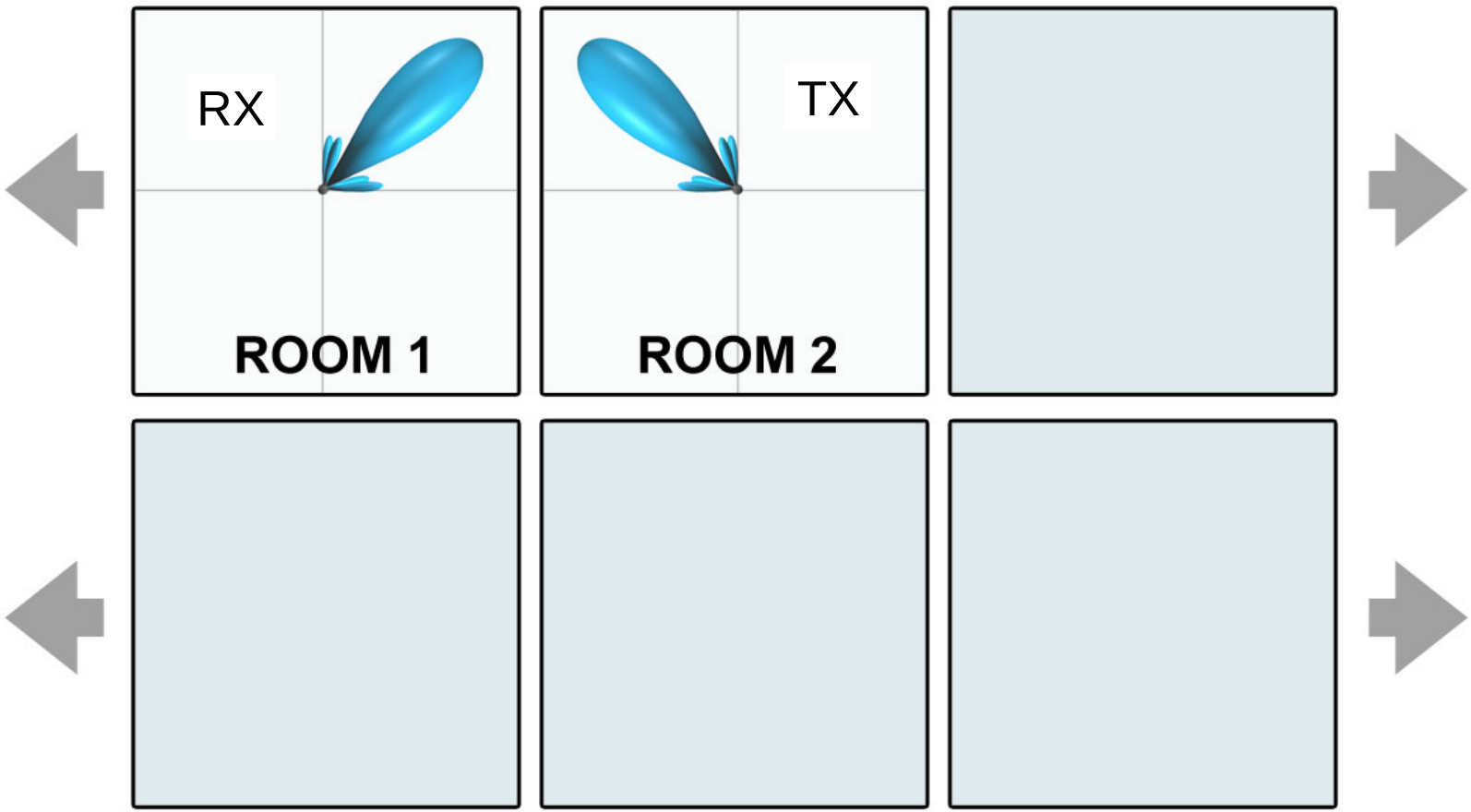


Challenge: Multipath Propagation

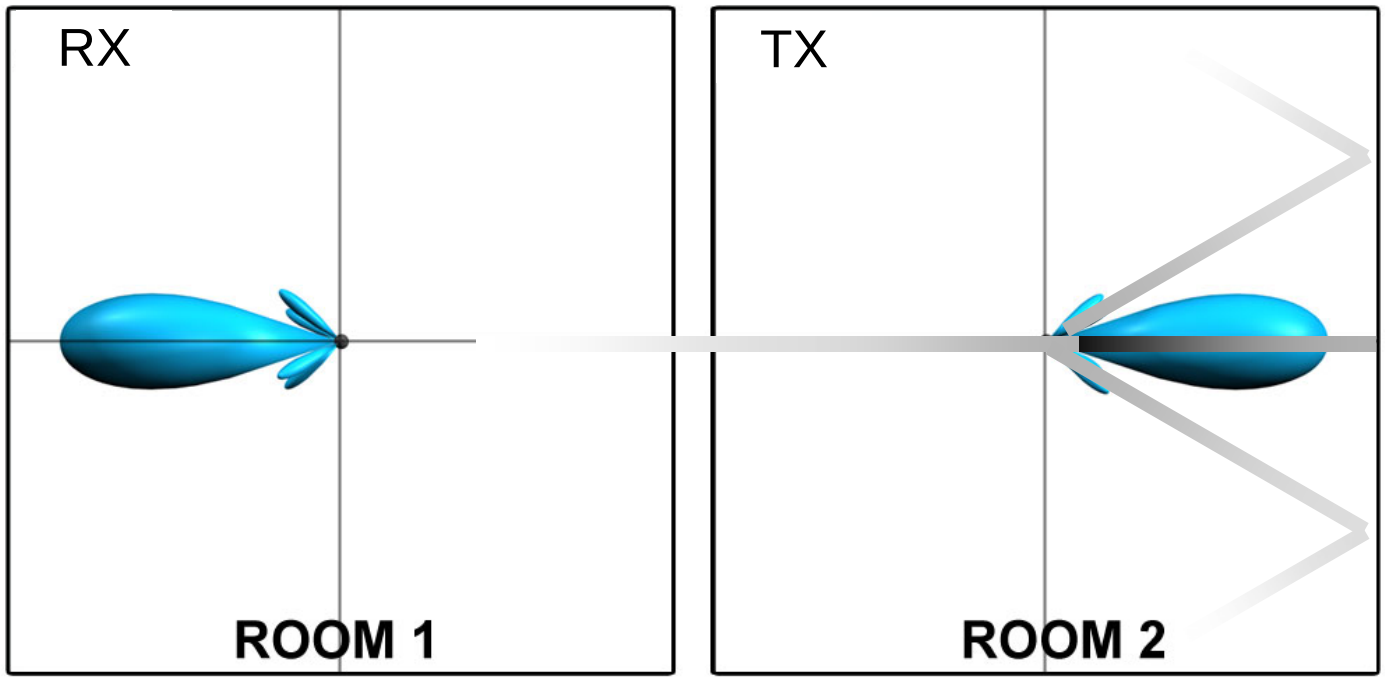
Mitigation by

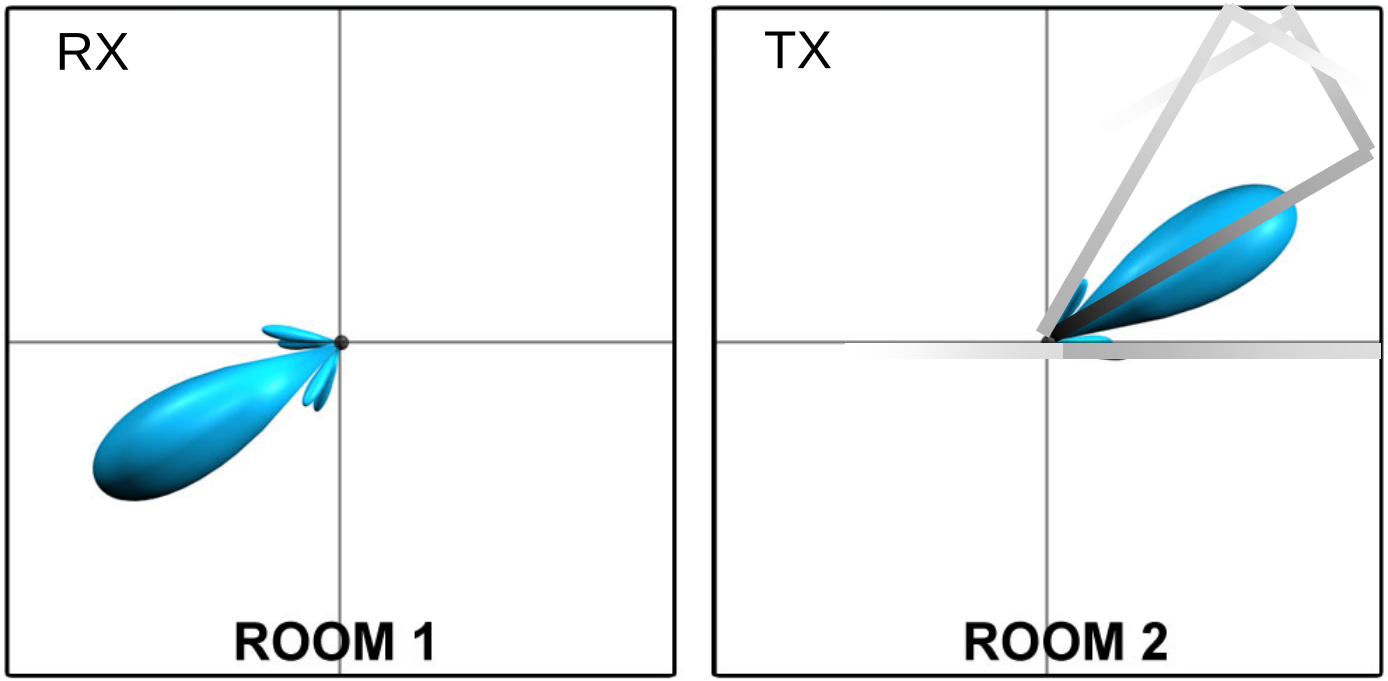
1. Direct path arrives first
2. Filter matched to the transmitted pulse shape
3. Polarization
4. Power level of direct path
5. **Beamforming by using multiple antennas**

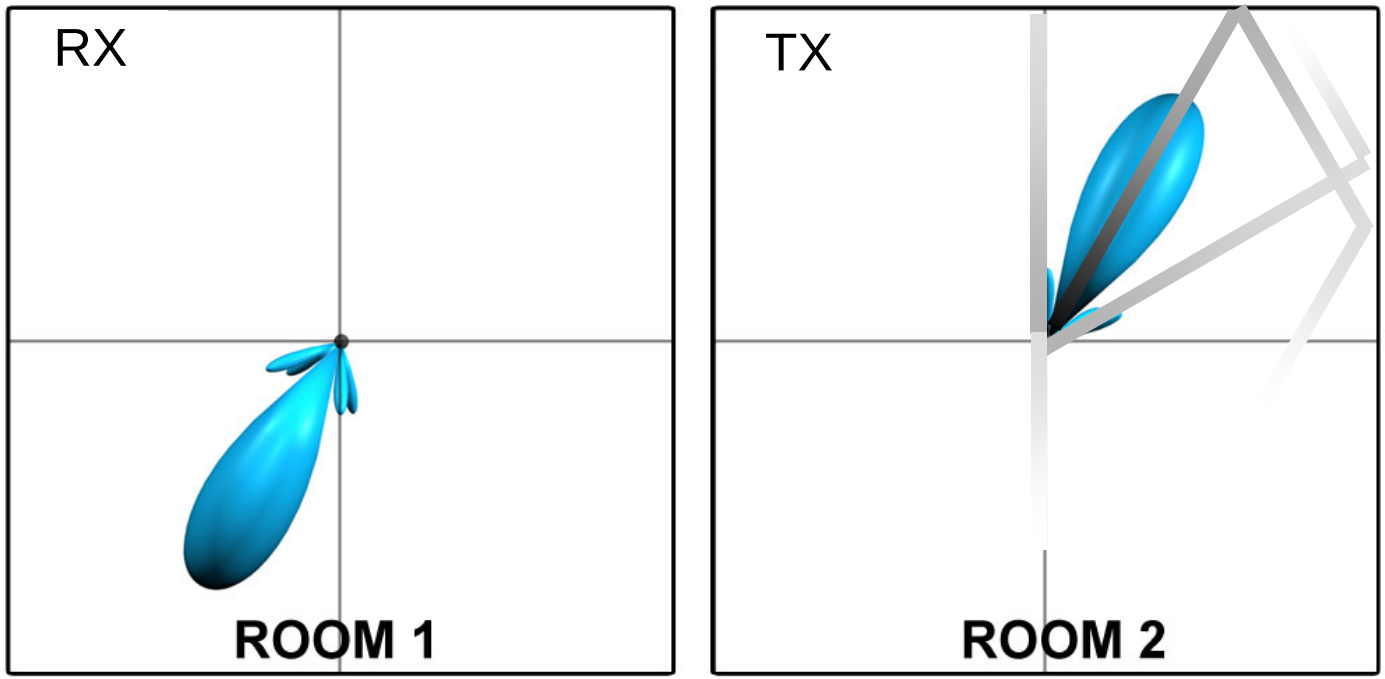
Indoor Positioning Network (IPN)

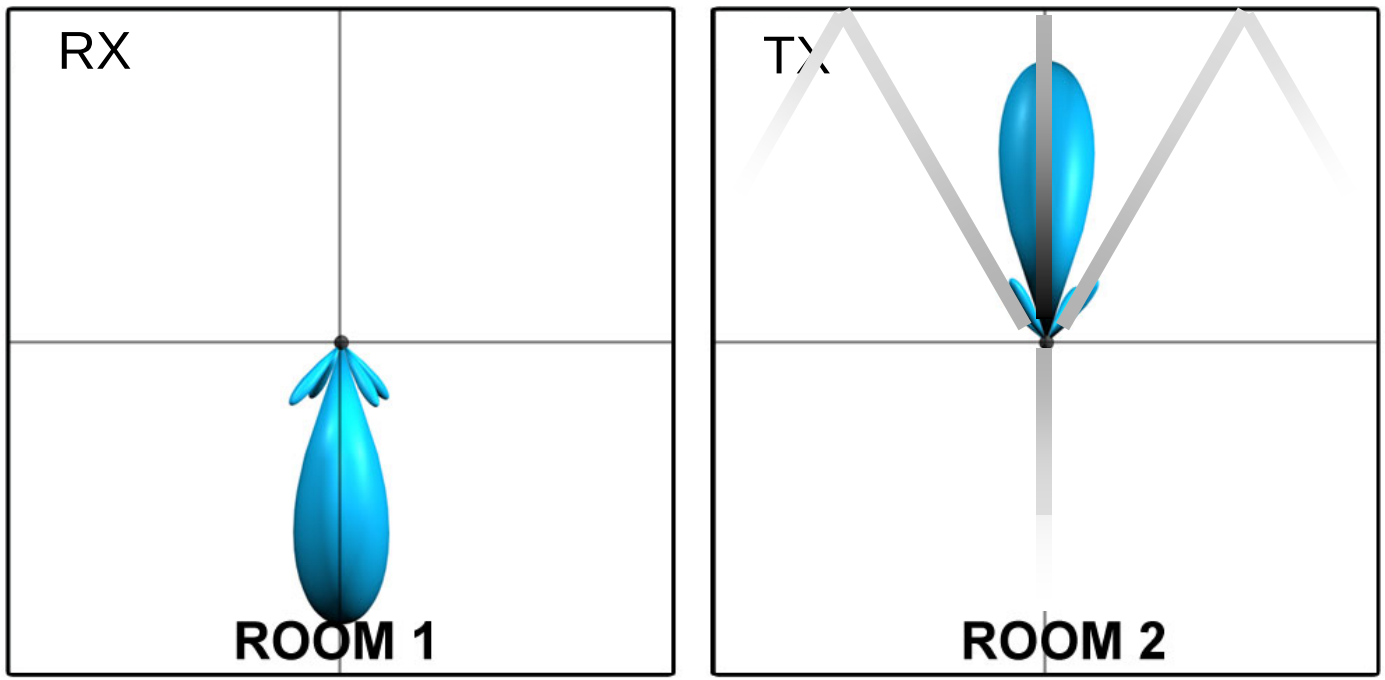


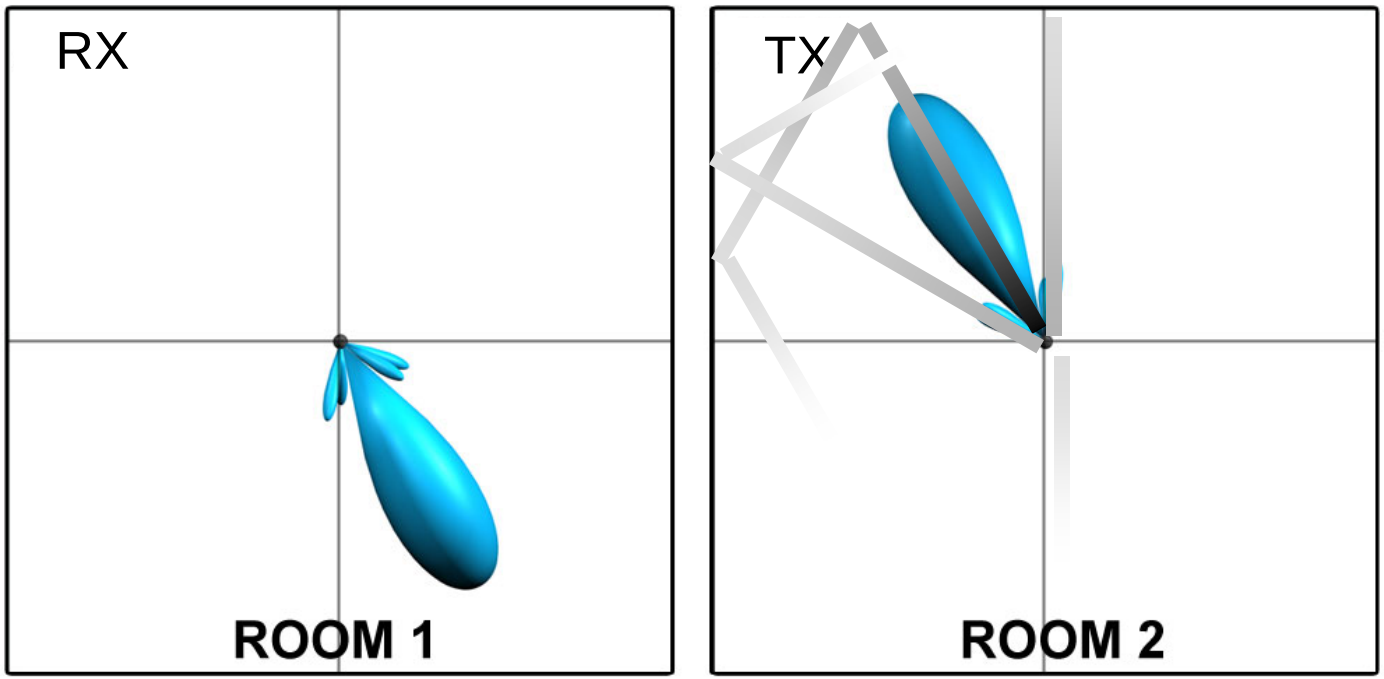
Concept illustration (with compass)

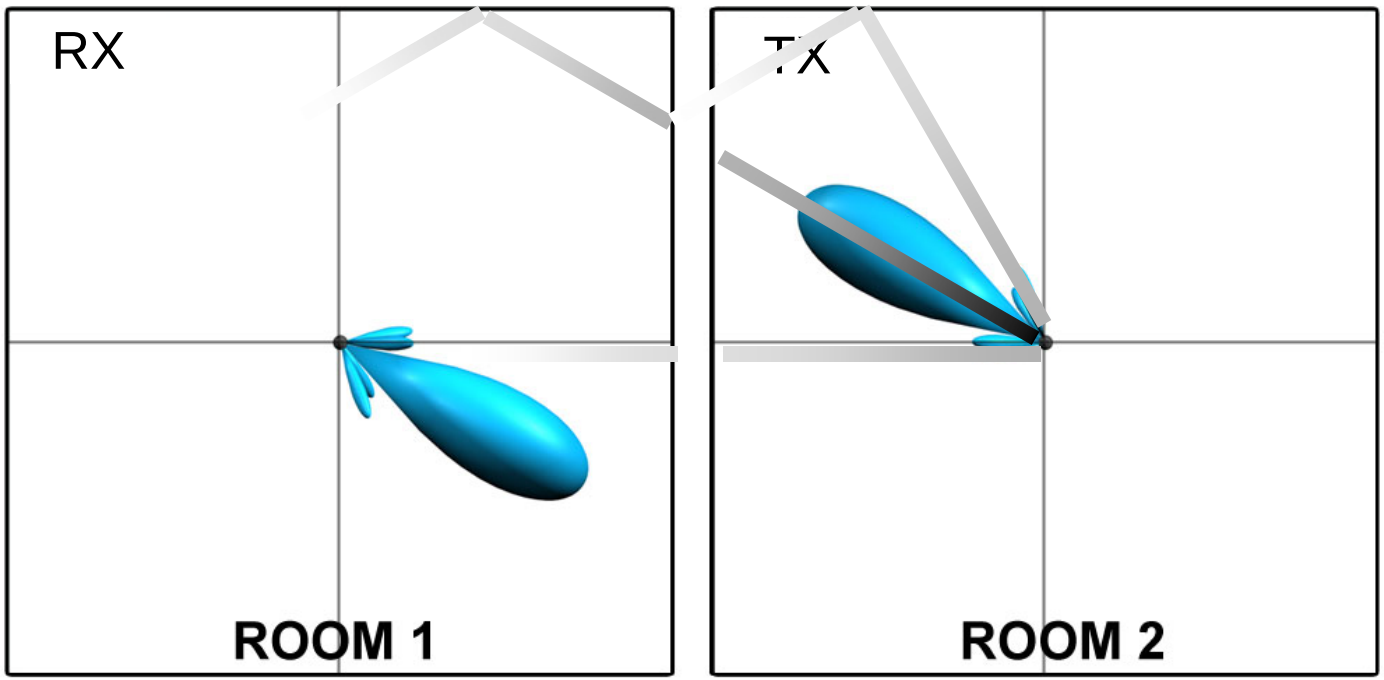



RX
ROOM 1
TX
ROOM 2

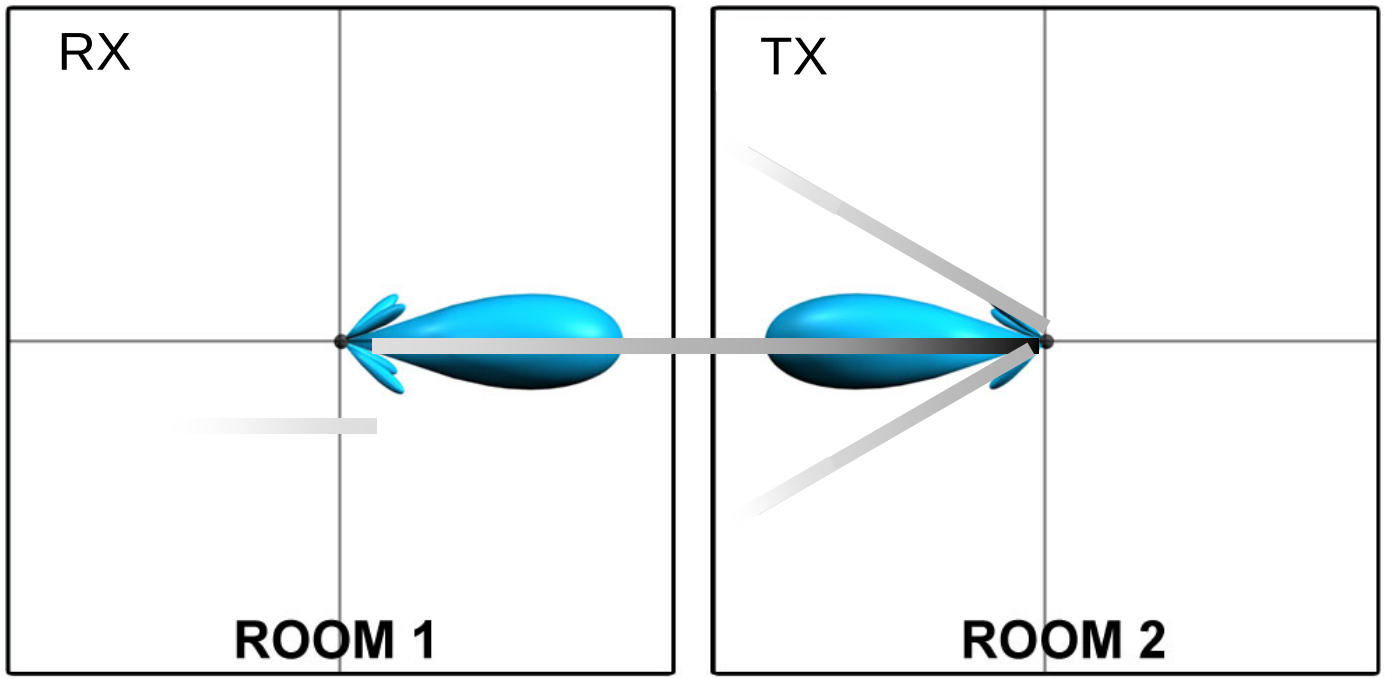

RX
ROOM 1
TX
ROOM 2

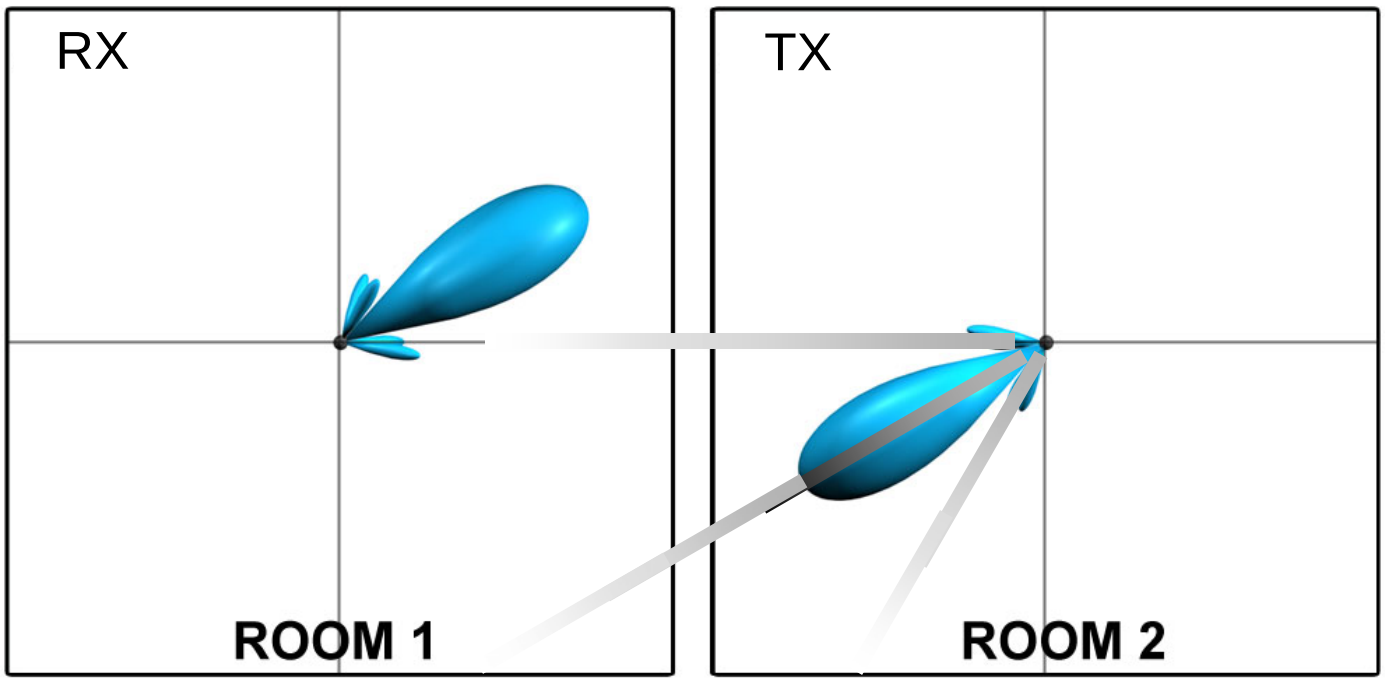

RX
ROOM 1
TX
ROOM 2

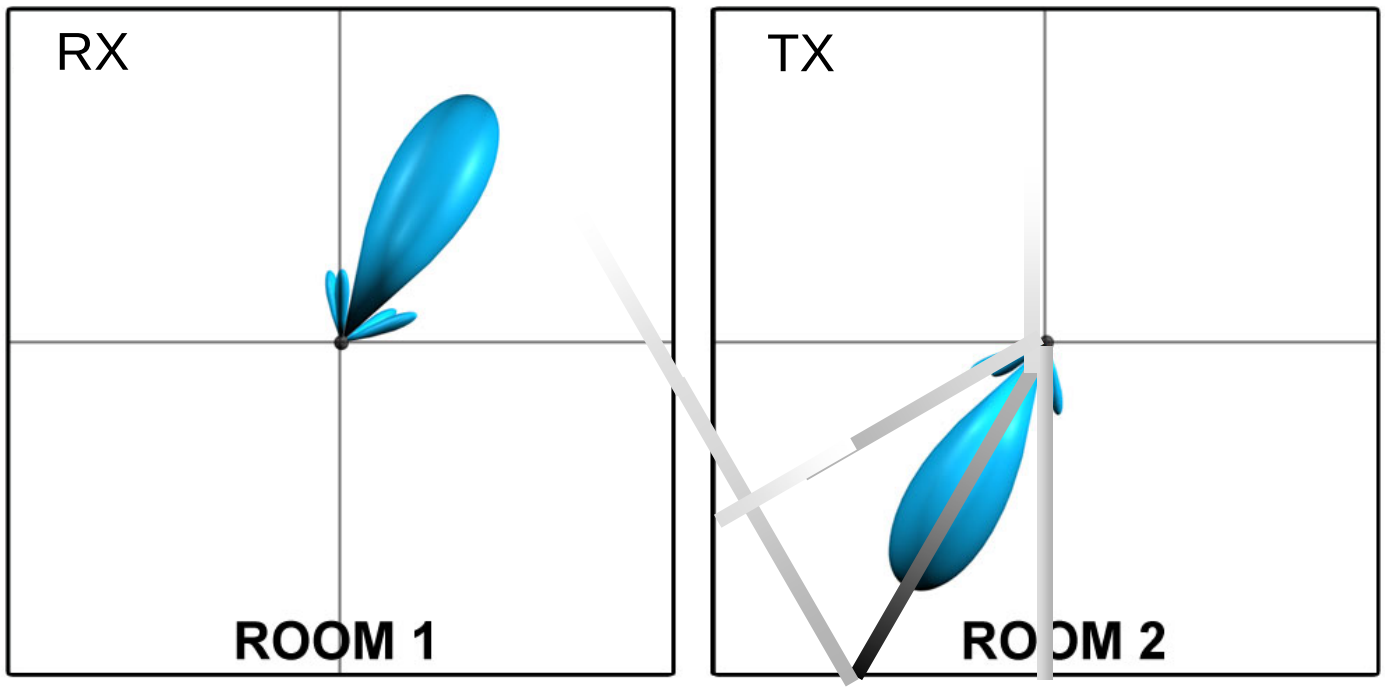

RX
ROOM 1
TX
ROOM 2

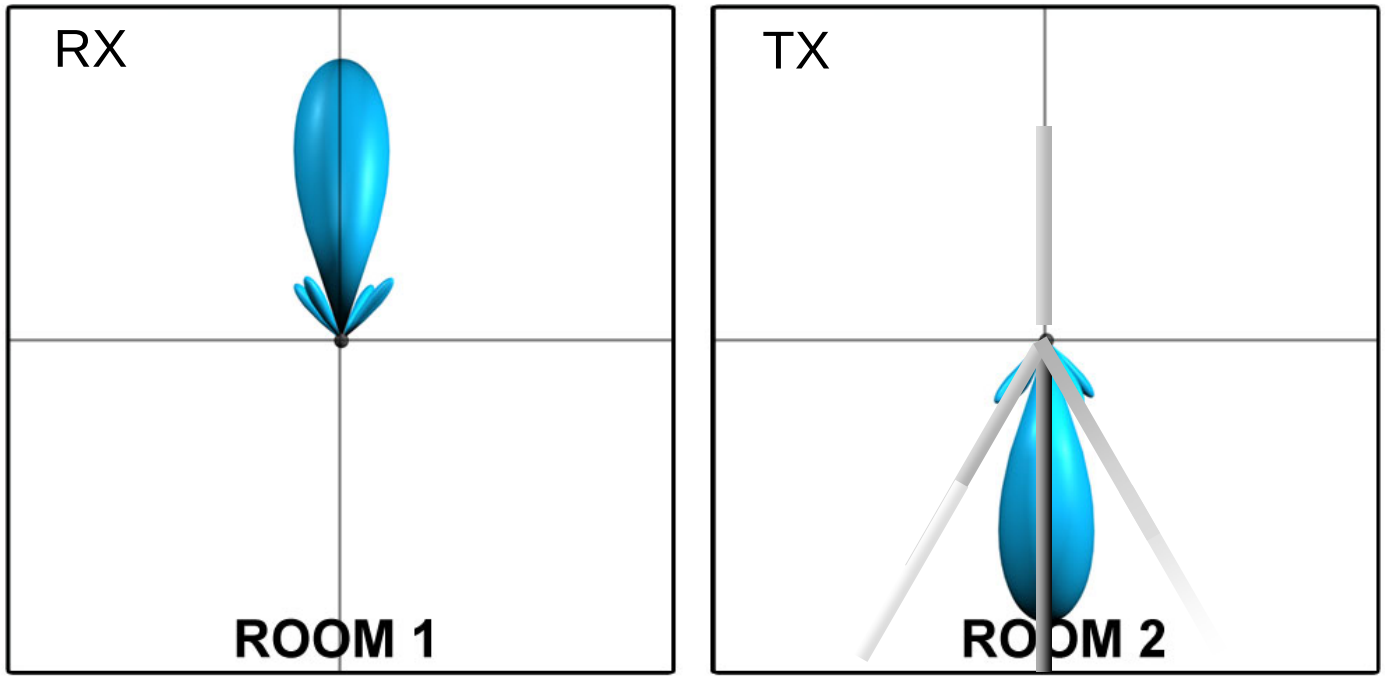

RX
TX
ROOM 1
ROOM 2

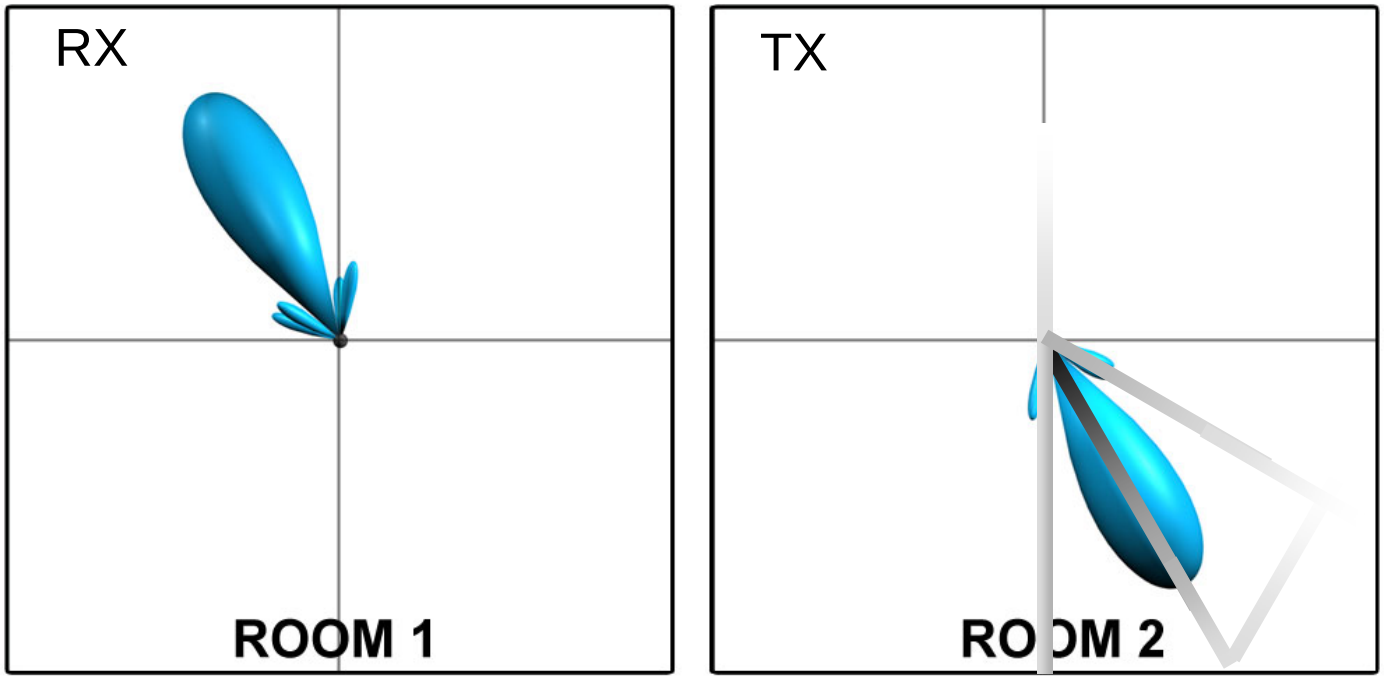
Locked mode (LM)

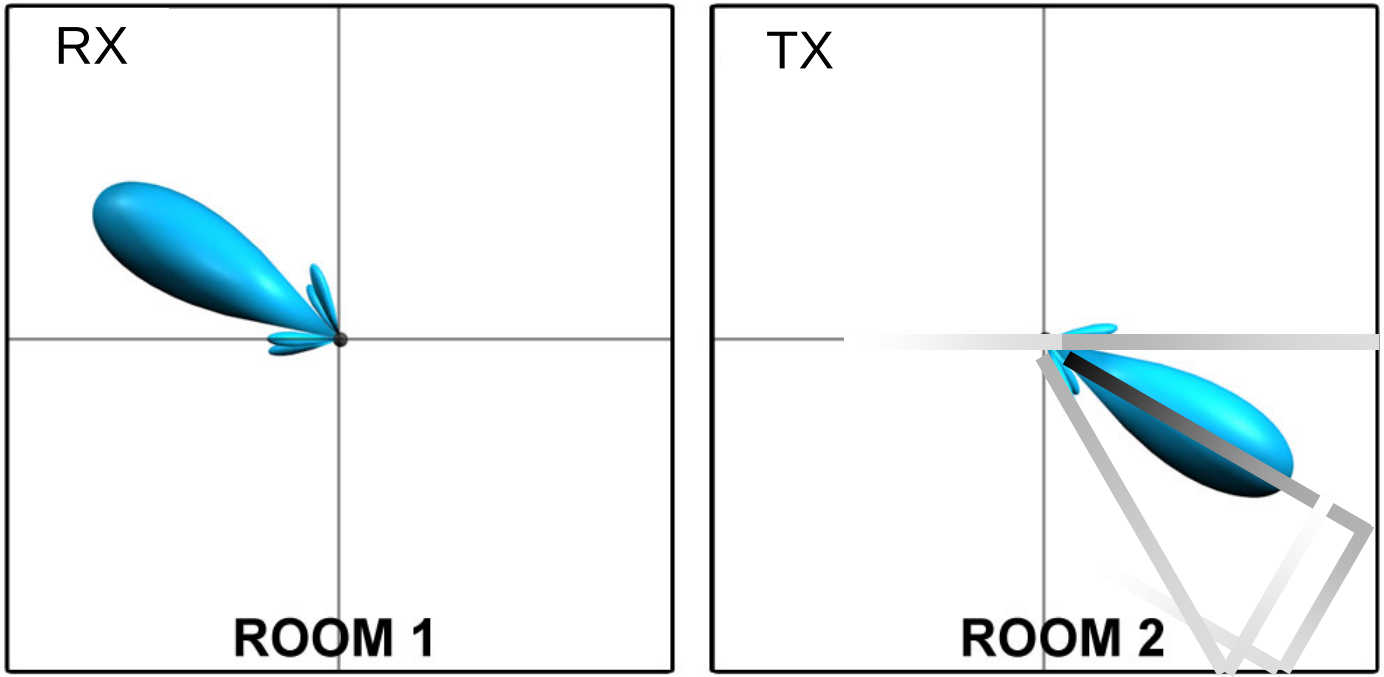


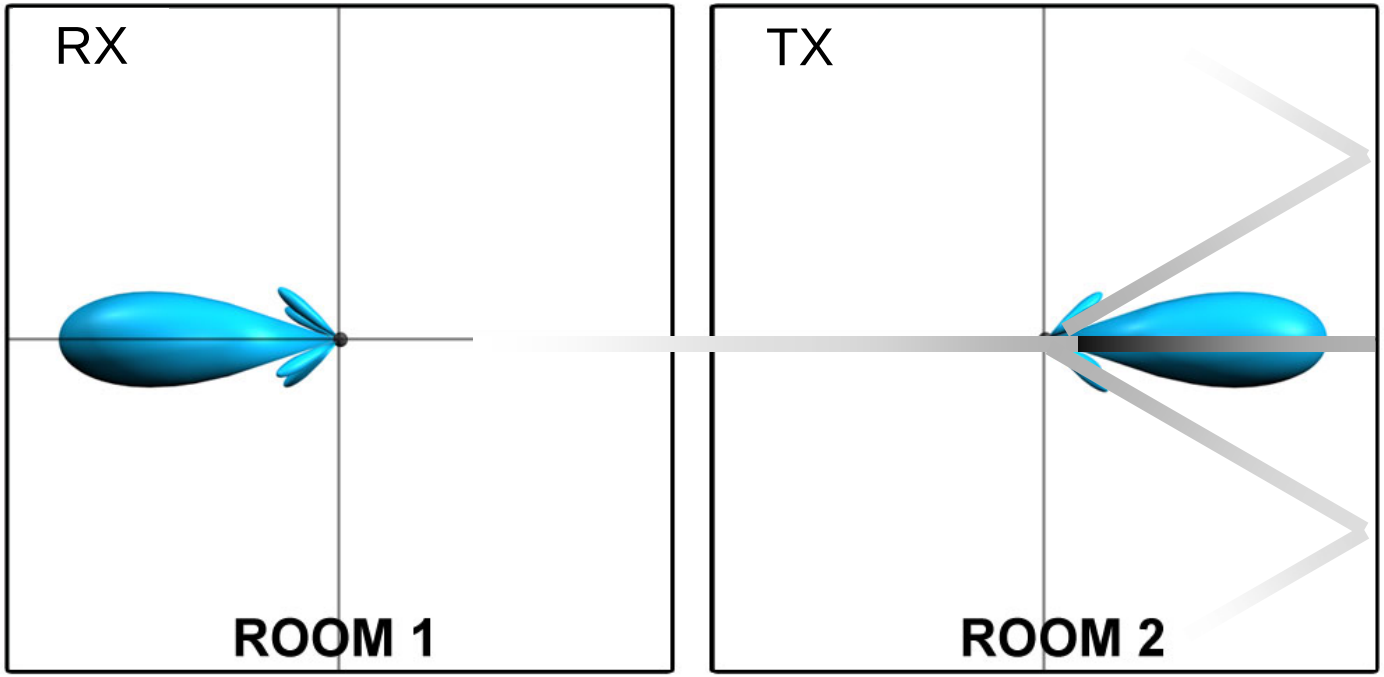

RX
TX
ROOM 1
ROOM 2


RX
TX
ROOM 1
ROOM 2

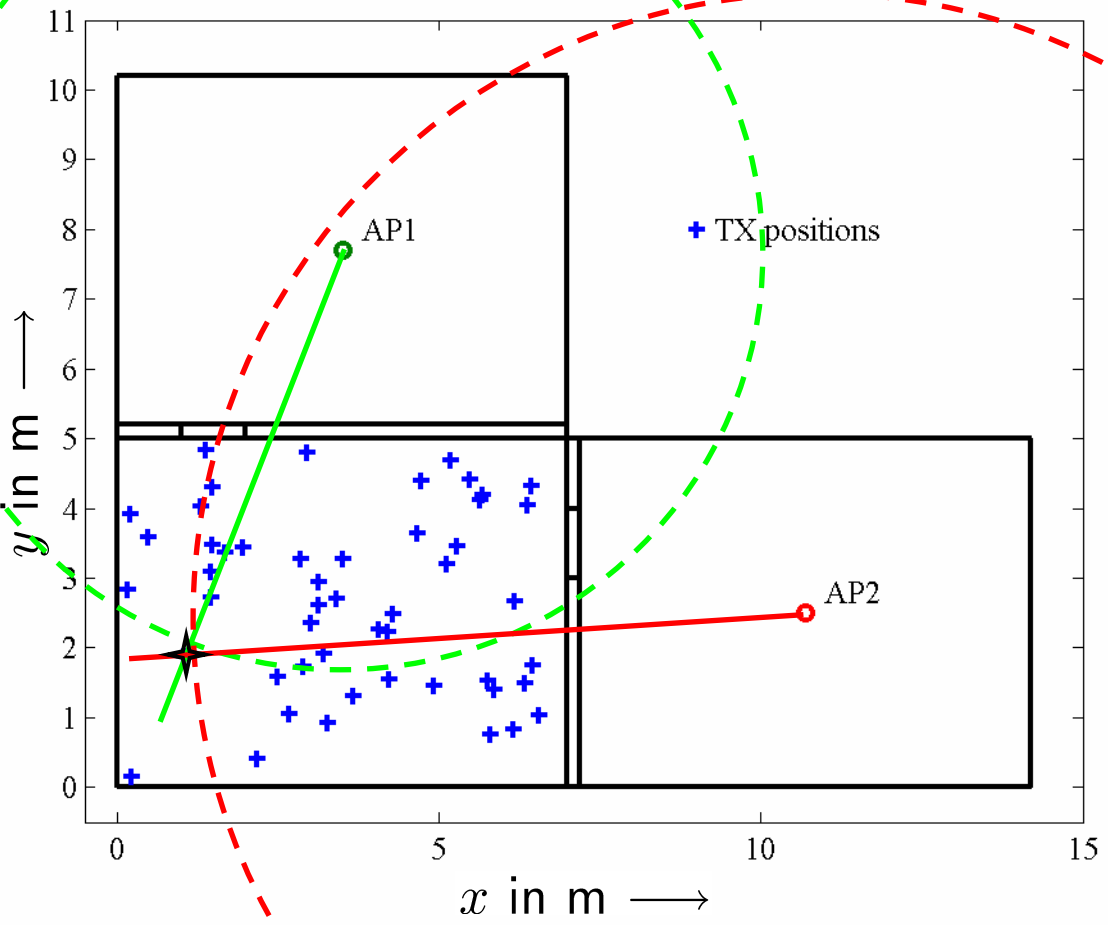

RX
ROOM 1
TX
ROOM 2


RX
ROOM 1
TX
ROOM 2


RX
ROOM 1
TX
ROOM 2


RX
TX
ROOM 1
ROOM 2

Simulation Setup



Default Settings:

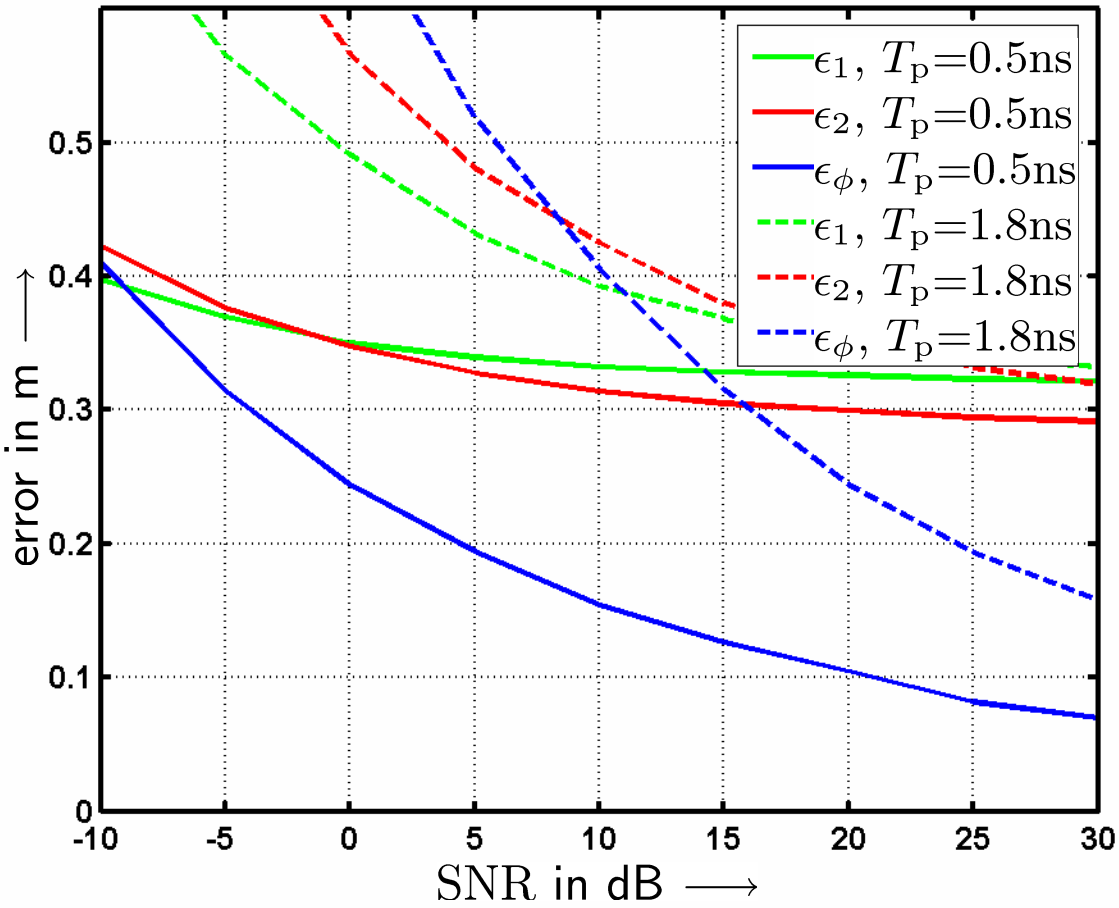
$N = N_{\mathrm{T}} = N_{\mathrm{R}} = 8$

$L = \lambda_c = 4.4\,\mathrm{cm}$

$T_{\mathrm{p}} = 0.5\,\mathrm{ns}$

$\Delta\theta = 1°$

Results


ϵ_1, T_p=0.5ns
ϵ_2, T_p=0.5ns
ϵ_ϕ, T_p=0.5ns
ϵ_1, T_p=1.8ns
ϵ_2, T_p=1.8ns
ϵ_ϕ, T_p=1.8ns
error in m ⟶
SNR in dB ⟶
0
0.1
0.2
0.3
0.4
0.5
-10
-5
0
5
10
15
20
25
30

Spatial Multiplexing with „MISO“

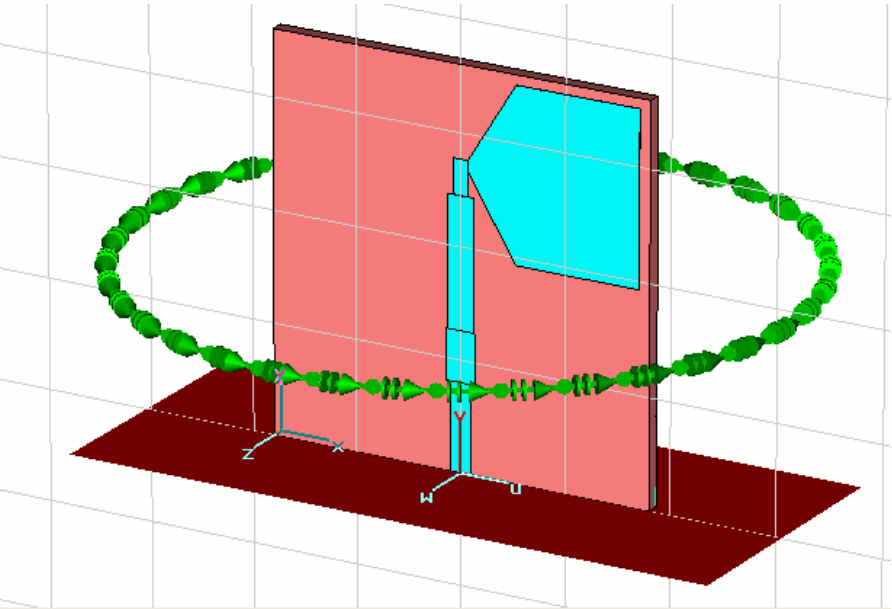
TX Antenna | **Multipath Channel** | **RX Antenna**

$$h_{\mathrm{T}}(t,\phi_T) \qquad h_{\mathrm{C}}(t,\phi_T,\phi_R) = \sum_{l=1}^{L} \alpha_l\, \delta(t-\tau_l)\, \delta(\phi_T-\phi_{T,l})\, \delta(\phi_R-\phi_{R,l}) \qquad h_{\mathrm{R}}(t,\phi_T)$$

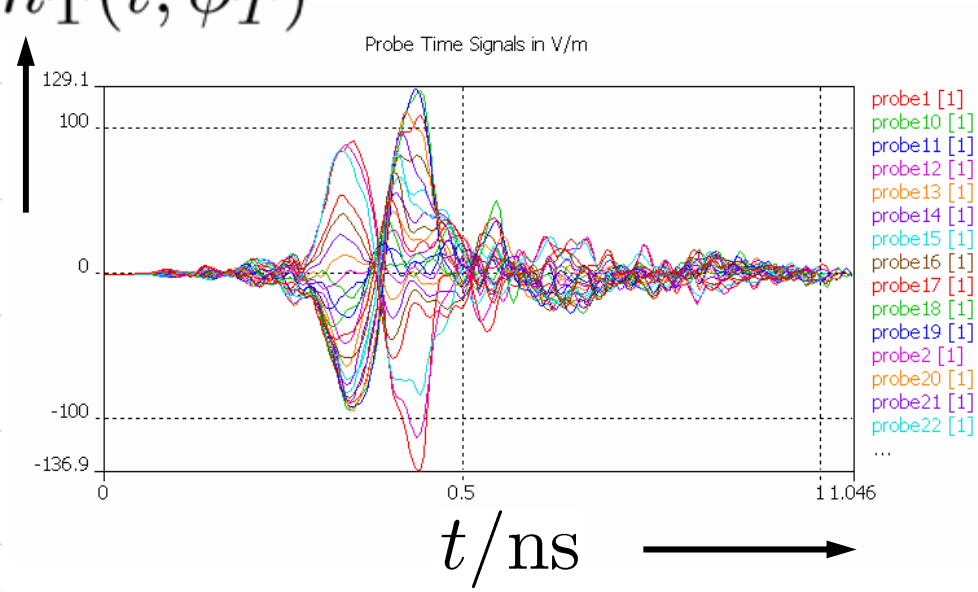
$$h(t) = \int_0^{2\pi}\int_0^{2\pi} h_{\mathrm{T}}(t,\phi_T) * h_{\mathrm{C}}(t,\phi_T,\phi_R) * h_{\mathrm{R}}(t,\phi_R)\, \mathrm{d}\phi_T\, \mathrm{d}\phi_R$$

$$= \sum_{l=1}^{L} \alpha_l\, \delta(t-\tau_l) * h_{\mathrm{T}}(t,\phi_{T,l}) * h_{\mathrm{R}}(t,\phi_{R,l})$$

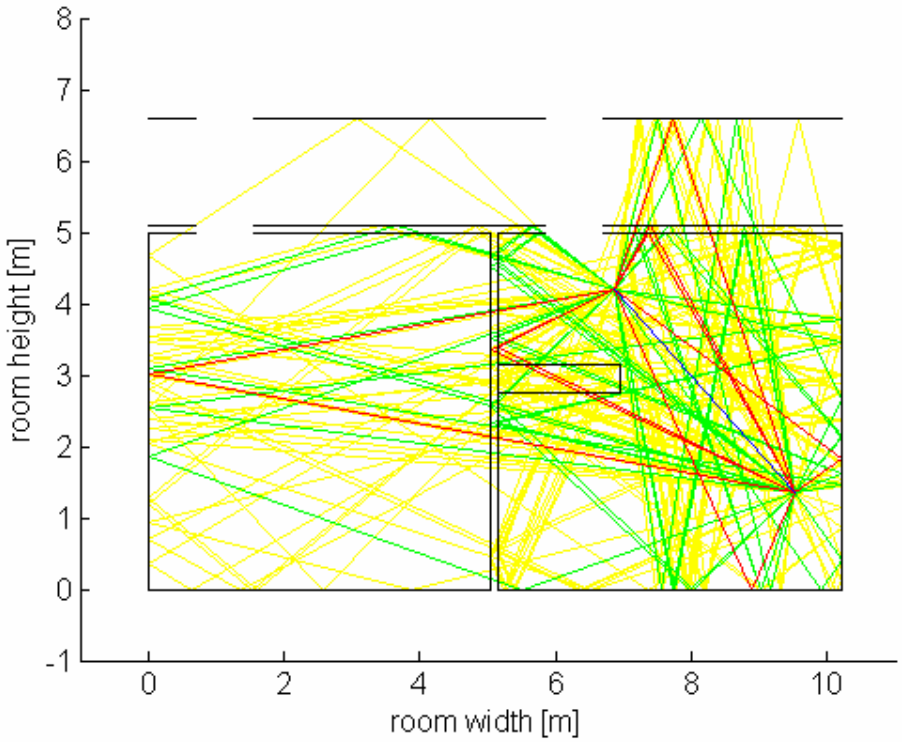
Bowtie Antenna Simulation

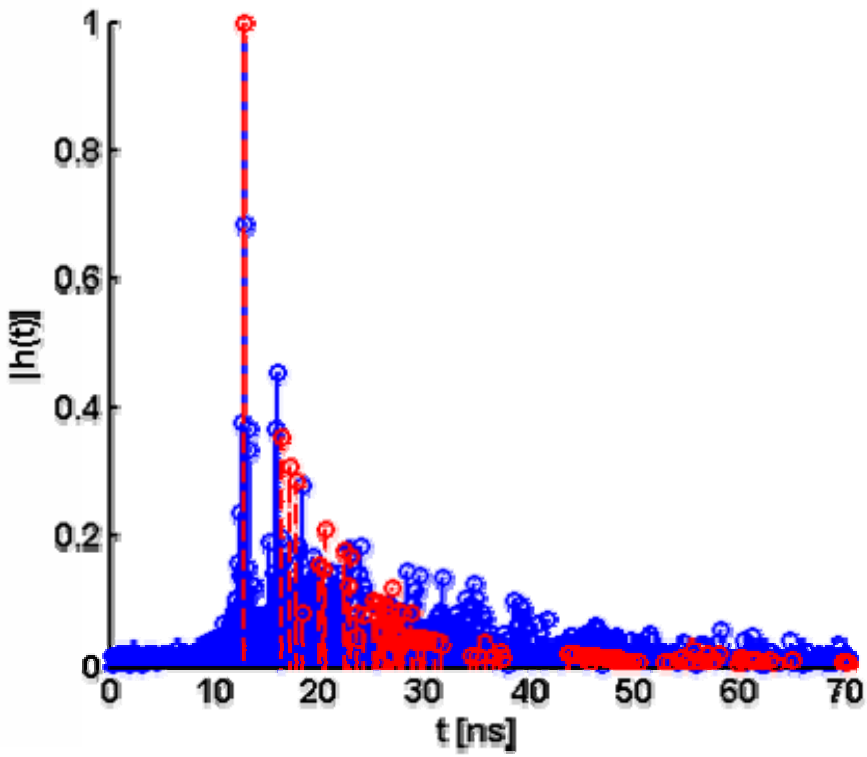


$h_T(t, \phi_T)$



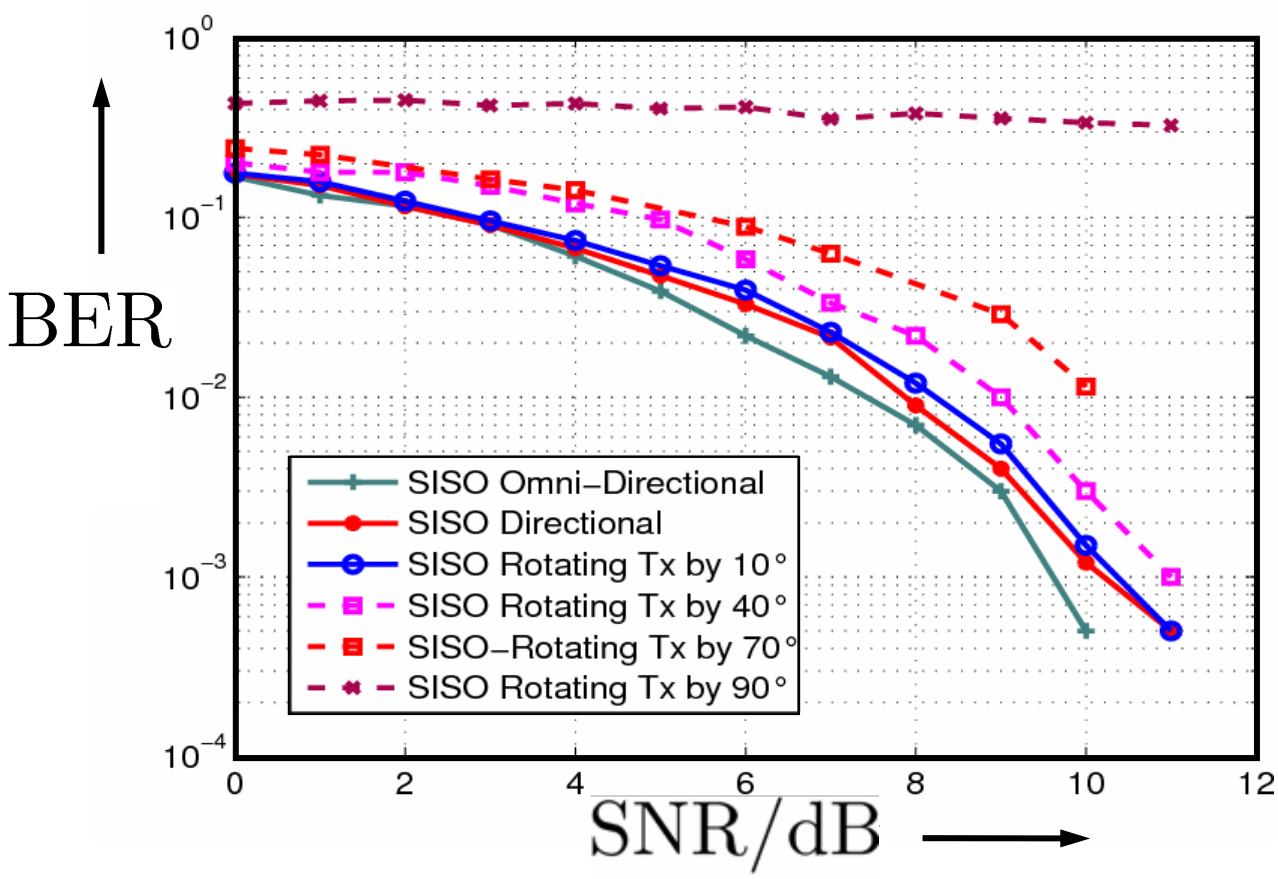
Ray Tracing vs. Measurements





Results

BER Performance for UWB (M)ISO Spatial Multiplexing with S-Rake Receiver



Conclusions

Google Hits for „MIMO UWB“

Oct 03	April 04	Aug 04	Jan 05	Feb 06	April 06
26	**41**	**61**	**118**	**234**	**576**

UWB & MAS offer:

- multiplexing gain
- diversity gain (?)
- coding/array gain
- localisation gain
- hardware gain (?)