Investigation of Performance Gain in 802.11n Systems due to Antenna Switching Using Simulated Radiation Patterns

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Outline

1. Introduction & motivation

2. Basics of MIMO channel-simulator

3. Investigation of simple antenna arrays

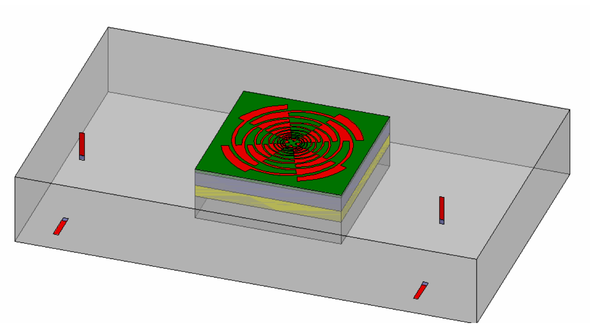
4. Conclusions

Introduction & motivation

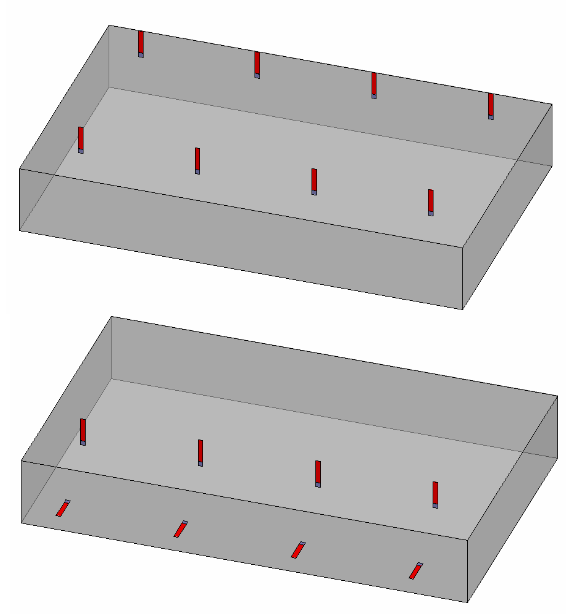
Motivation

- modern communication systems include multiple antennas, e.g. IEEE 802.11n
- investigation of performance gain due to antenna selection
- influence of real antennas on the system performance
- placing and design of antennas becomes more important

[Source: www.cisco.com]



antenna design



antenna placing

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Basics of MIMO channel simulator

HFT

Pattern
- Real Pattern

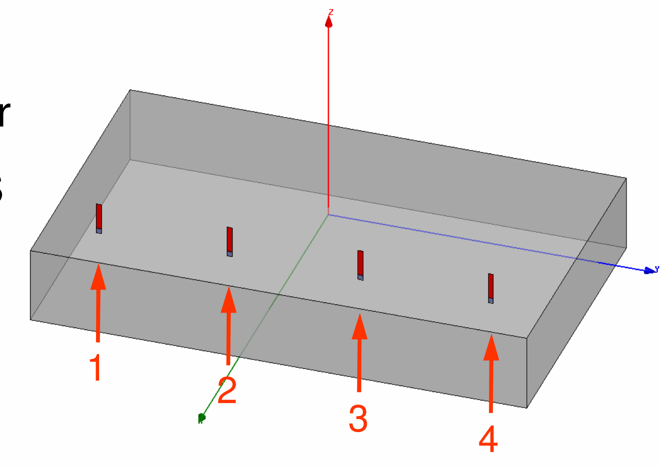
Channel modeling
- 3- dimensional
- Fix SNR per eigen-path
- Cluster & Taps
- 802.11 TGn

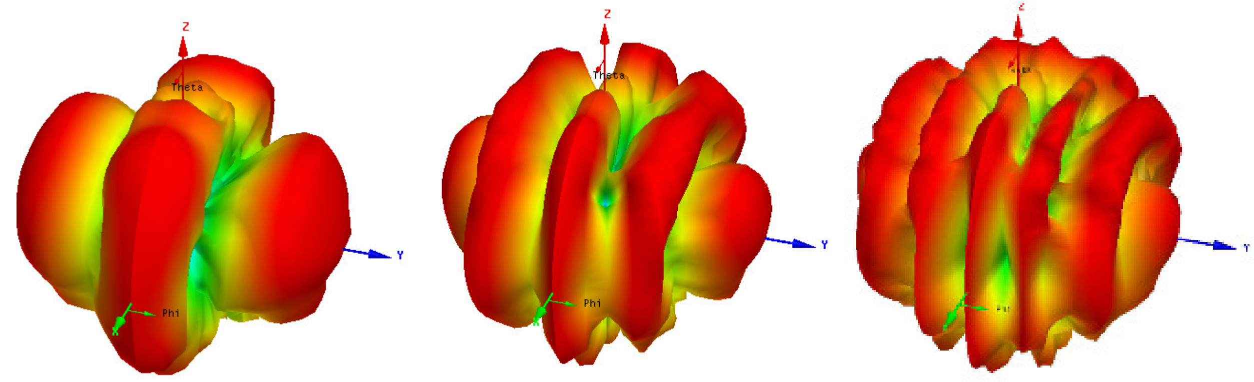
Effects
- No Doppler
- No interferers

Visualization
- CDF

Real Pattern

- commercial FEM-Solver
- pattern by Ansoft HFSS





Basics of MIMO channel simulator

Correlation Coefficient

- envelope correlation described by antenna correlation $\rho_e \approx \left|\rho_{ij}\right|^2 = \frac{\left|R_{ij}\right|^2}{\sigma_i^2 \cdot \sigma_j^2}$

$$R_{ij} = K \cdot \int_0^{2\pi}\int_0^{\pi} \left[C_{\vartheta_i}(\vartheta,\varphi) \cdot C_{\vartheta_j}^{*}(\vartheta,\varphi) + XPR \cdot C_{\varphi_i}(\vartheta,\varphi) \cdot C_{\varphi_j}^{*}(\vartheta,\varphi) \right] \cdot \ldots$$

$$\ldots p_{\vartheta,\varphi}(\vartheta,\varphi) \cdot e^{j\vec{k}\vec{r}_{ij}} \cdot \sin(\vartheta)\, d\vartheta\, d\varphi$$

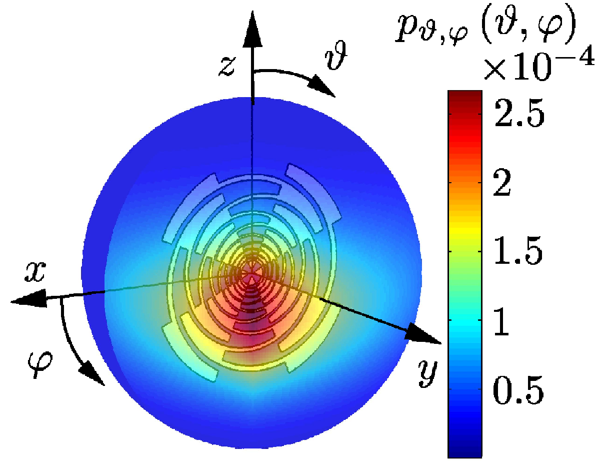
- cross polarization ratio $XPR = P_V / P_H$
- statistical channel modeling
- $C_{\vartheta,\varphi}(\vartheta,\varphi)$ radiation pattern of antenna

$$C(\vartheta,\varphi) = \frac{\left|E(\vartheta,\varphi)\right|}{\left|E_{\max}\right|}$$

- **Pattern diversity**
- **Polarization diversity**
- **Space diversity**

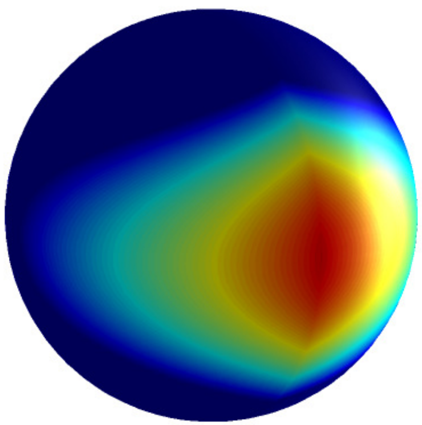
Basics of MIMO channel simulator

- **Stochastic model** for AoA environment, envelope fading
- Common channel parameters $m_\vartheta = 90°,\ m_\varphi = 60°,\ \sigma_\vartheta = 20°,\ \sigma_\varphi = 60°$
- $\vec{p}(\vartheta,\varphi) = p_\vartheta(\vartheta,\varphi) = p_\varphi(\vartheta,\varphi) = p_{\vartheta,\varphi}(\vartheta,\varphi)$ assumed
- Azimuth spectrum - Laplace $p_{\vartheta,\varphi}(\varphi)$
- Elevation spectrum - Gauß $p_{\vartheta,\varphi}(\vartheta)$

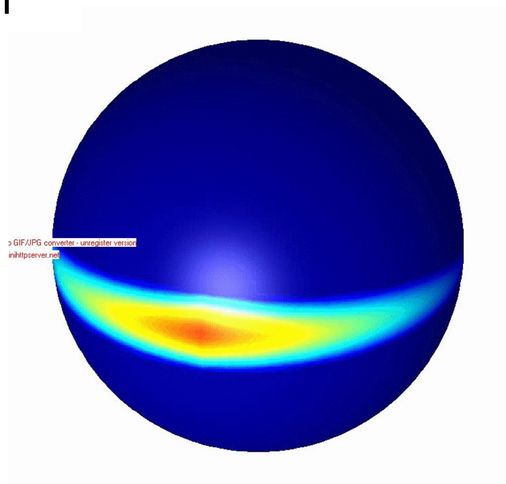


Channel Models IEEE 802.11n (e.g.)

- Channel model A
- 1 taps
- 1 clusters



- Channel model F
- 18 taps
- 6 clusters



Basics of MIMO channel simulator

MIMO: Channel Capacity

- no interferers, AWGN (σ_N^2)
- equally distributed transmit power P_T

Including signal correlation

$$C_{MIMO} = \log_2 \det\left(\bar{E} + \frac{P_T}{\sigma_N^2 M} \tilde{H}\tilde{H}^H \right)$$

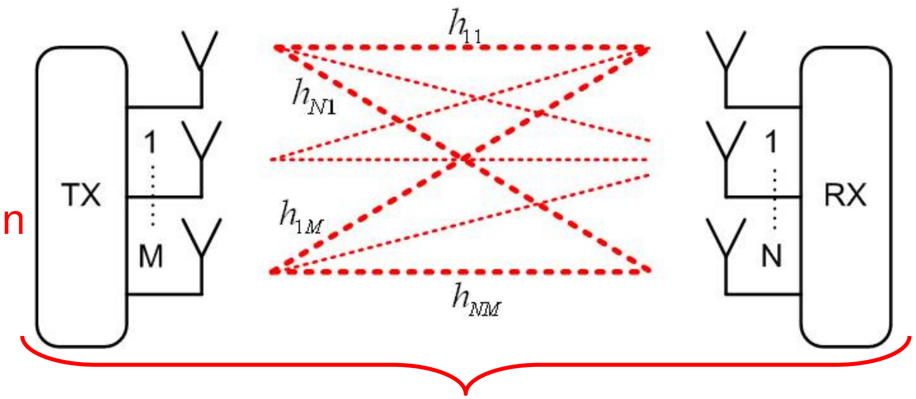
Eigenvalue problem

Subchannel capacity

$$C_i = \log_2\left(1 + \frac{P_T}{\sigma_N^2 M}\lambda_i\right)$$

$$C_{MIMO} = \sum_{i=1}^{\min\{M,N\}} C_i$$

Used MIMO Channel Modell



$$\tilde{H} = \begin{bmatrix} \tilde{h}_{11} & \tilde{h}_{12} & \cdots & \tilde{h}_{1N} \\ \tilde{h}_{21} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ \tilde{h}_{M1} & \cdots & \cdots & \tilde{h}_{MN} \end{bmatrix}$$

Mobile Channel

- narrow band
- **Stochastic model** for AoA environment, envelope fading
- channel coefficients uncorrelated
- including antenna correlation

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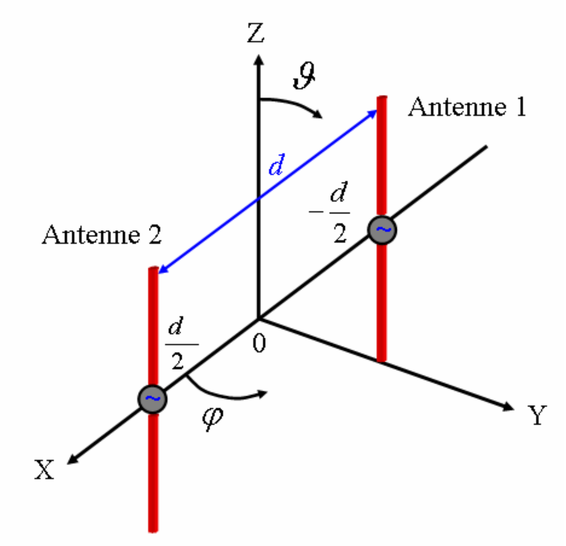
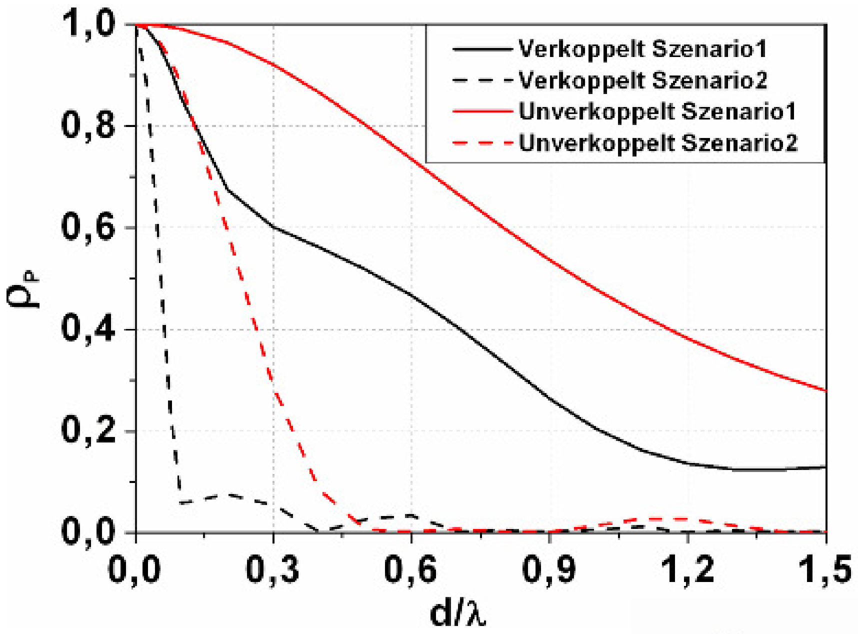
Investigation of simple antenna arrays

Dipole-Array



Power Correlation Coefficient

- **scenario 1:** weak scattering, $\sigma_\varphi = 10°$
- **scenario 2:** rich scattering, $\sigma_\varphi = 60°$



Topology

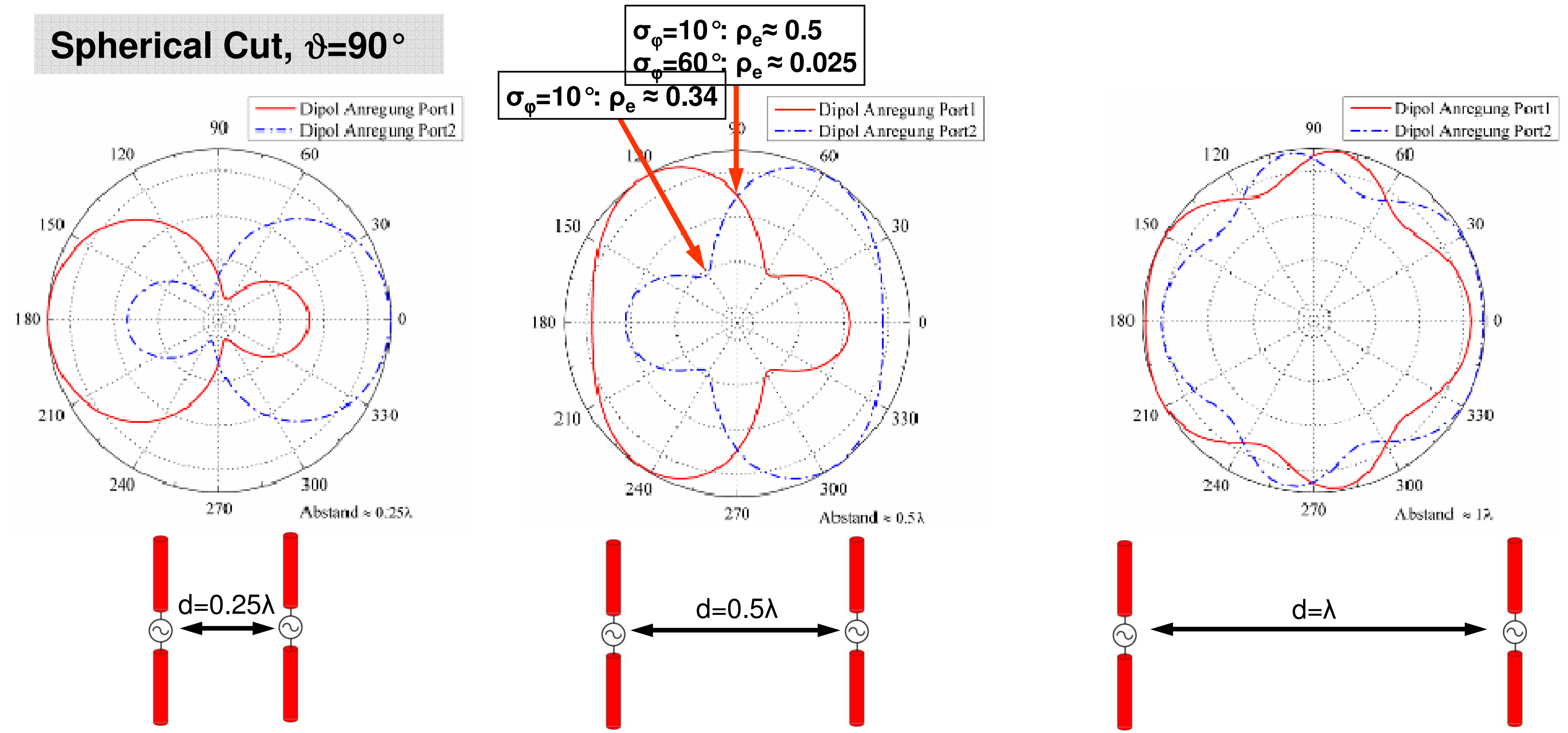
- optimal reference
- simulations in free space
- coupled and decoupled
- variation of inter element distance

Effects

- decorrelation by coupling
- decorrelation by scattering
- decorrelation by distance

Investigation of simple antenna arrays

Spherical Cut, ϑ=90°



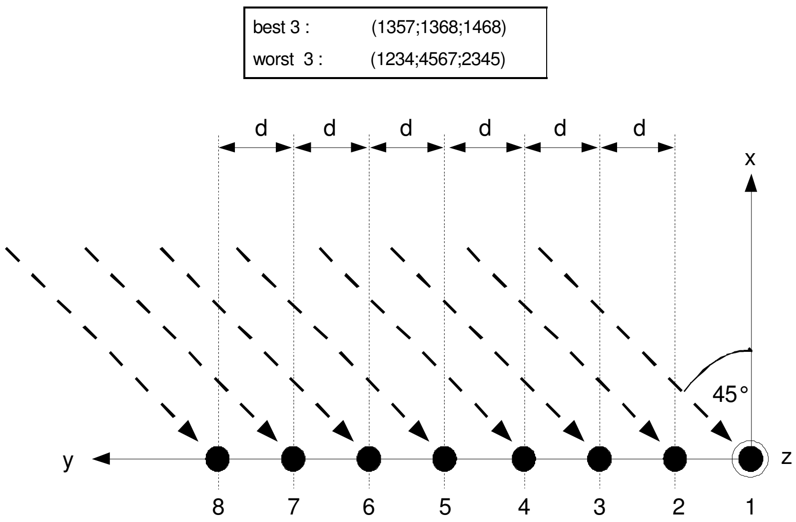
Effects

- radiation pattern changes due to mutual coupling
- resulting in a better decorrelation
- performance gain due to diverse patterns

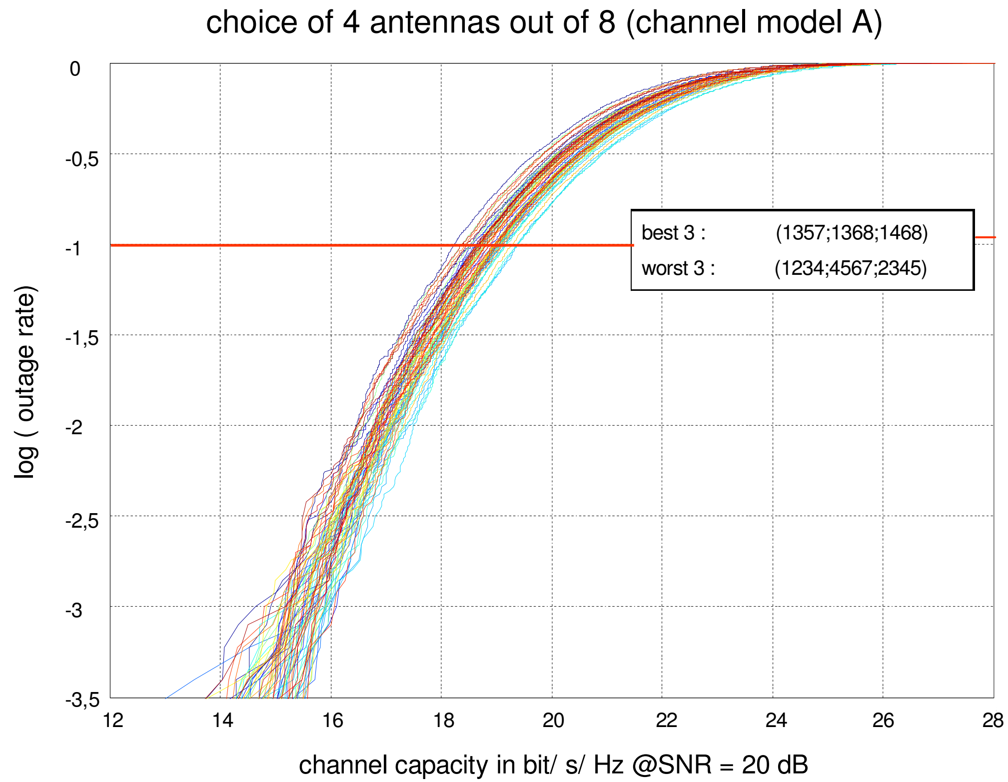
Investigation of simple antenna arrays

- real antenna pattern, element spacing d=λ/2 @ 5.6 GHz
- channel model A, one tap $m_{\vartheta} = 90° \; \sigma_{\vartheta} = 0° \; m_{\varphi} = 45° \; \sigma_{\varphi} = 40°$
- selection of 4 out of 8 antennas (in correspondence to 4 RF-chains)

Simulation Model



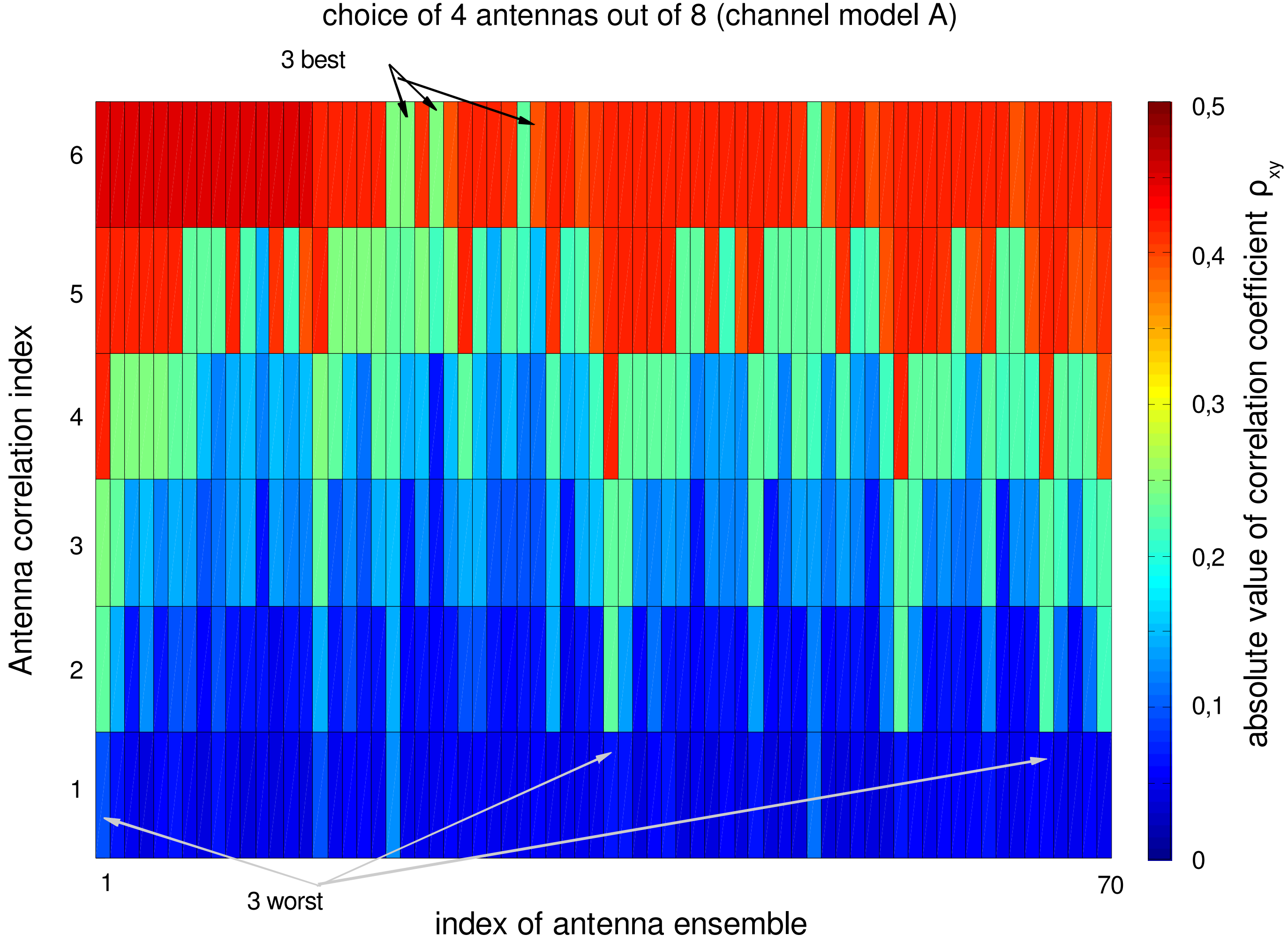
Outage Rate for Antenna Selection (4/8)



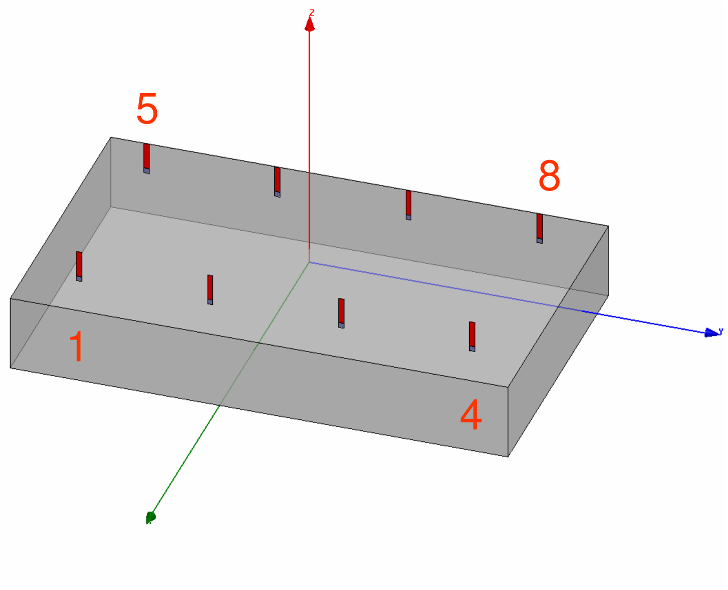
Investigation of simple antenna arrays

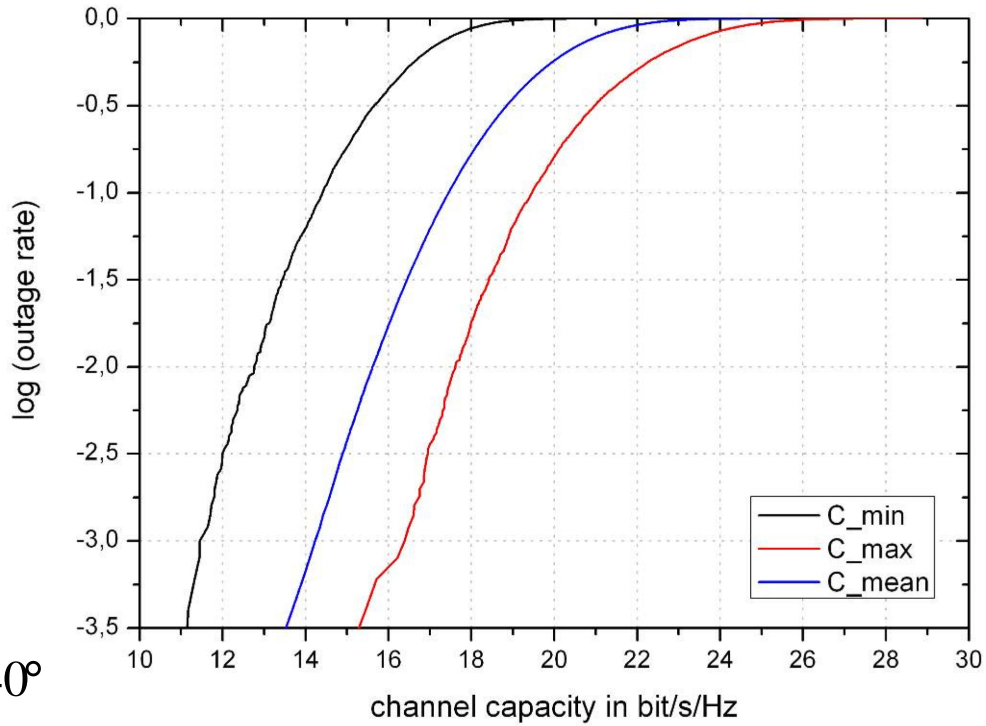
Analysis Method

- select antenna combination (abscissa)
- determine 6 correlation coefficients (left index)
- sort resulting 6 coefficients (right index)



Investigation of simple antenna arrays



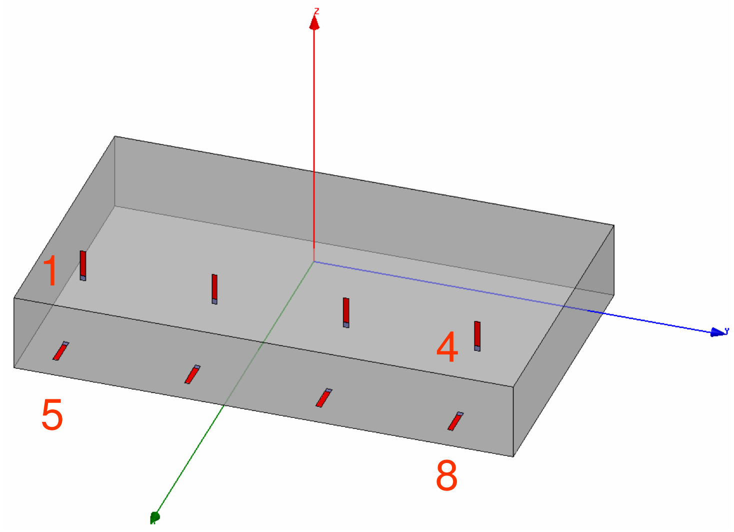


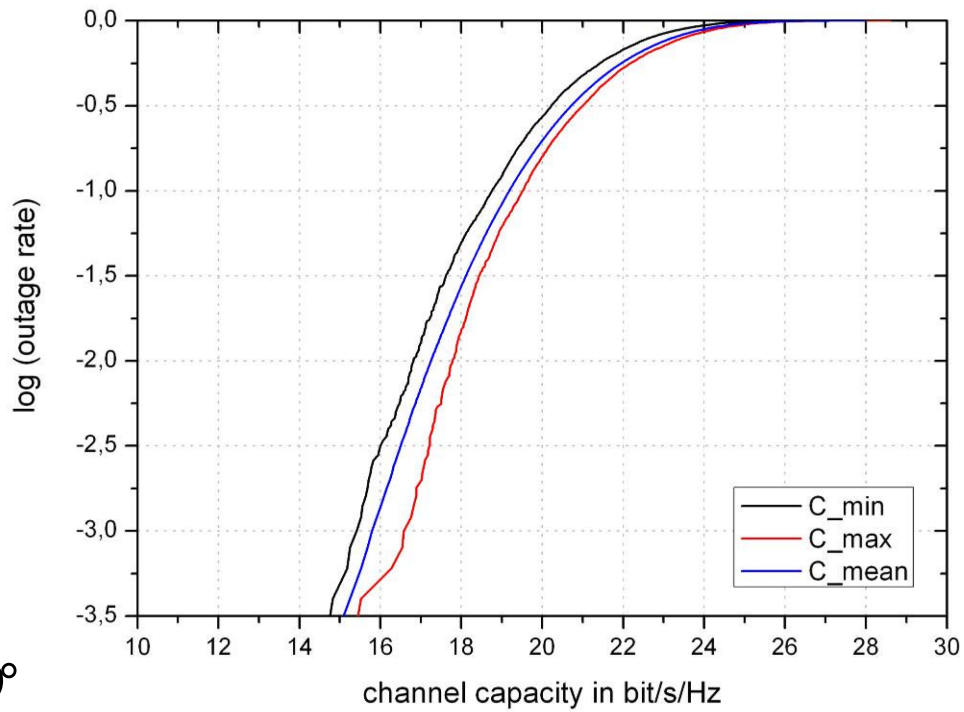
Simulation setup

- TX: 4 dipoles spaced λ/2 @ 5.6 GHz
- CM A: $m_\vartheta = 90° \ \sigma_\vartheta = 0° \ m_\varphi = 45° \ \sigma_\varphi = 40°$
- all RX antenna combinations
- SNR = 20dB
- Size of PEC Box (190mm x 115 mm x 30mm)

- C_min for antenna combination (3,4,7,8)
- C_max for antenna combination (1,3,6,8)

Investigation of simple antenna arrays





Simulation setup

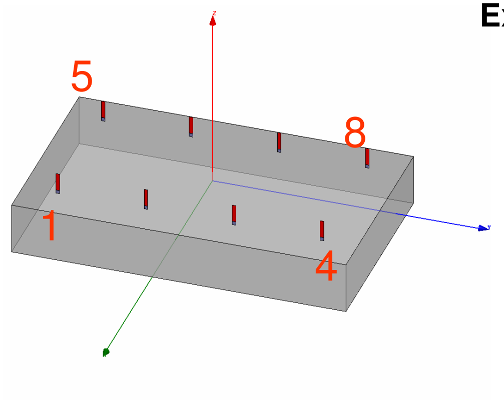
- TX: 4 dipoles spaced λ/2 @ 5.6 GHz
- CM A: $m_\vartheta = 90° \; \sigma_\vartheta = 0° \; m_\varphi = 45° \; \sigma_\varphi = 40°$
- all RX antenna combinations
- SNR = 20dB

- C_min for antenna combination (1,5,6,7)
- C_max for antenna combination (3,4,6,8)

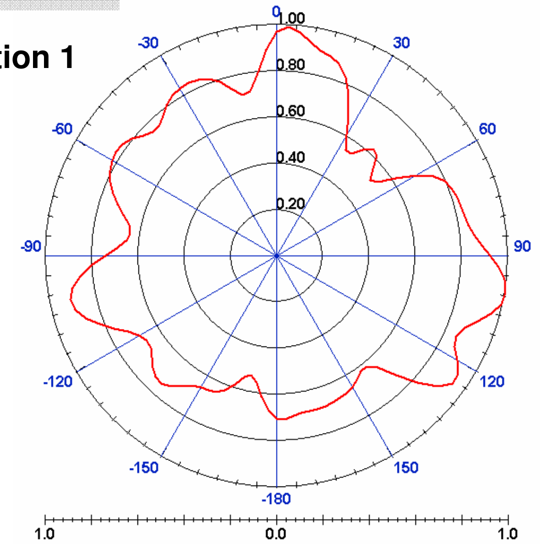
➢**polarization diversity increases C_min**

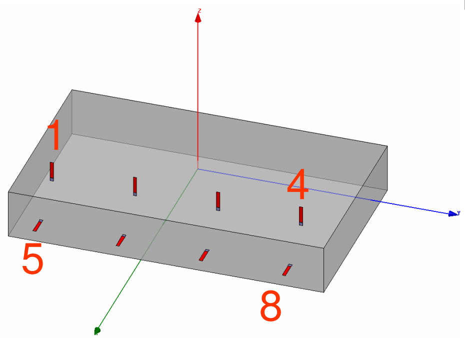
Investigation of simple antenna arrays

Spherical Cut, ϑ=90° of E-Field

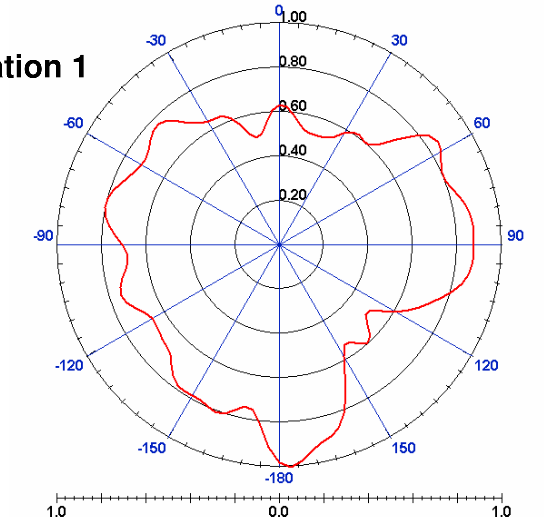


Excitation 1

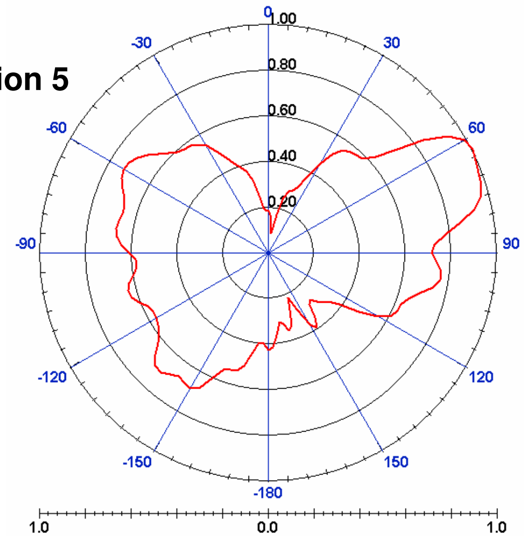




Excitation 1



Excitation 5



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Conclusions

- Higher accuracy due to 3D-modeling including real patterns of antennas
- Performance estimation for a given antenna setup and channel model (including switching)

Future Work

- Gain of antenna needs to be included for real system modeling (no fix SNR)
- Mean effective gain

$$MEG = \int_0^{2\pi}\int_0^{\pi}\left[\frac{1}{1+XPR}\cdot G_\vartheta(\vartheta,\varphi)+\frac{XPR}{1+XPR}\cdot G_\varphi(\vartheta,\varphi)\right]\cdot\ldots$$
$$\ldots p_{\vartheta,\varphi}(\vartheta,\varphi)\cdot\sin(\vartheta)\,d\vartheta\,d\varphi$$

$$XPR = P_V / P_H$$

- Goal: General antenna design criterions

Thanks for your attention