Measurements of MIMO HSDPA and WiMAX Transmissions

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Outline

- **MIMO Testbed**
- WiMAX Measurements
  - signal generation and reception
  - IEEE 802.16-2004 (Section 8.3) with OFDM physical layer
  - feedback realization
  - achievable and measured throughput
- HSDPA Measurements
  - signal generation and reception
  - feedback realization
  - achievable and measured throughput
- Conclusion

MIMO Testbed [T1,T2]

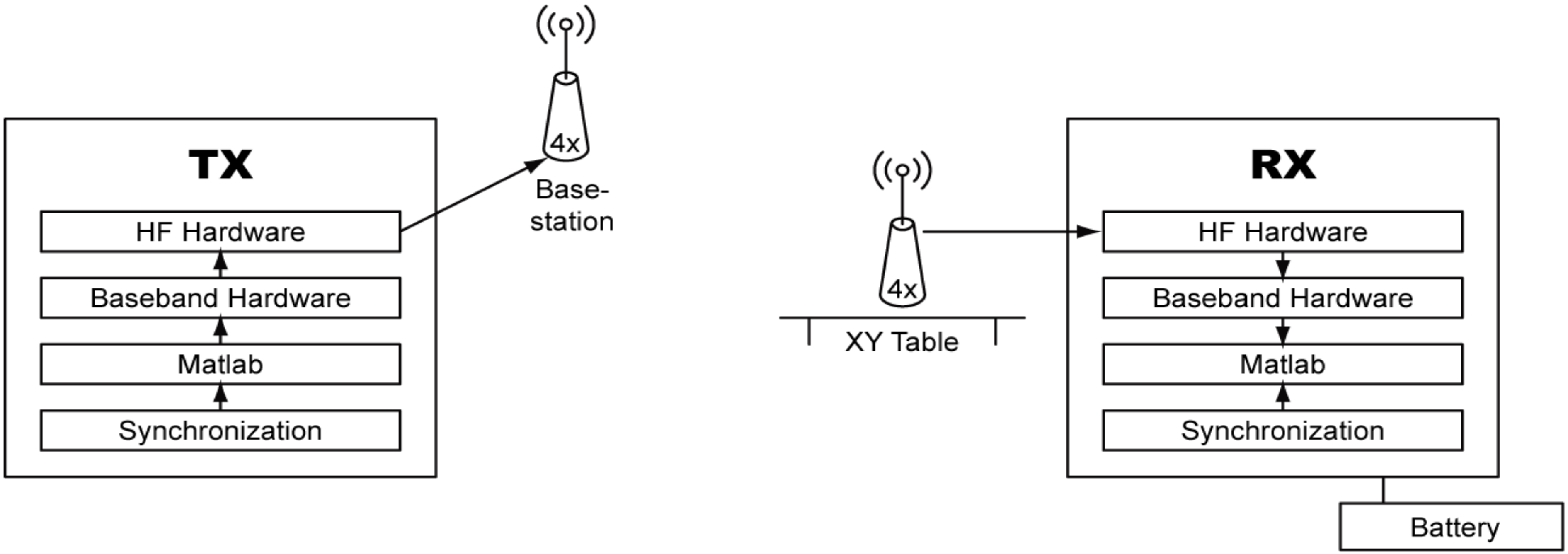
Evaluating MIMO radio communication

- theoretically
- by pure simulation
- by channel sounding
- utilizing a testbed
- utilizing a prototype
- using the final product

↓ **degree of realism**

effort

MIMO Testbed [T1,T2]

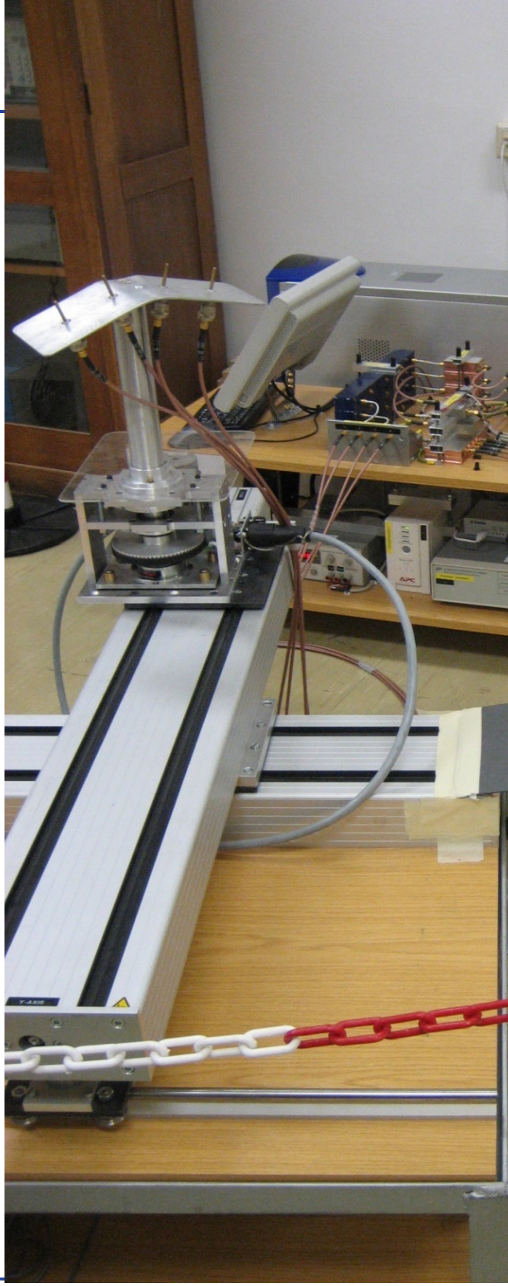


Data is created and evaluated in Matlab ...

Number of Antennas:	**4x4**
Bandwidth:	**5 MHz**
Center Frequency:	**2.5 GHz**

MIMO Testbed [T1,T2]

- **MIMO WiMAX 802.16-2004**
  OFDM physical layer
  - including channel coding and decoding
  - SISO and MIMO
- **MIMO HSDPA (TxAA, DTxAA)**
  CDMA physical layer
  - including channel coding and decoding
  - SISO and MIMO



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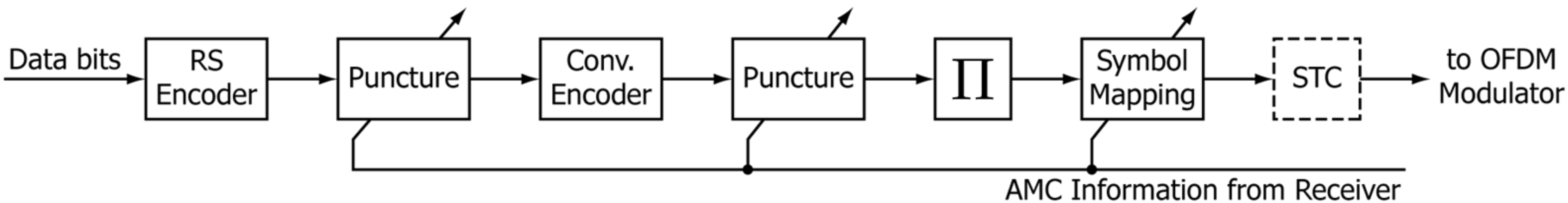
Adaptive Modulation and Coding (AMC)

- Encoding
  - concatenated Reed-Solomon / convolutional code
  - puncturing depending on AMC information
  - optional block/convolutional turbo coding
  - Alternatively: LDPC coding
- Adaptive symbol mapping
- Optional Alamouti space-time coding

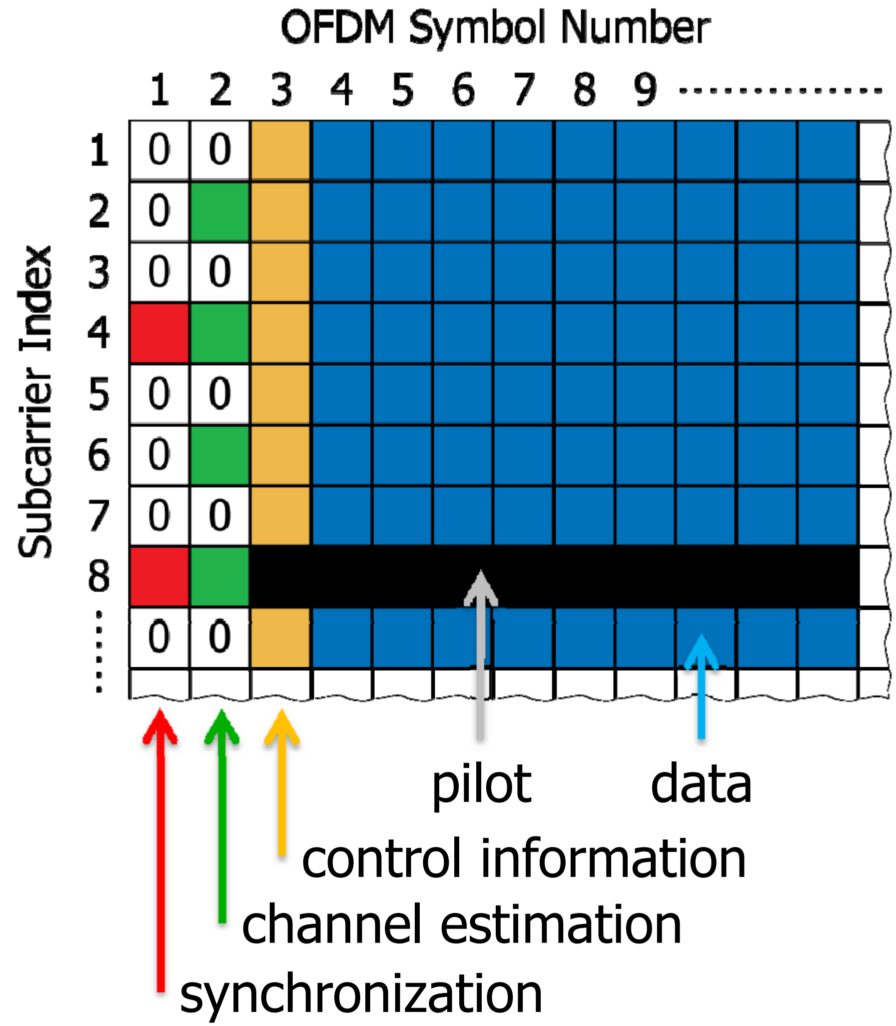


Coding and Modulation

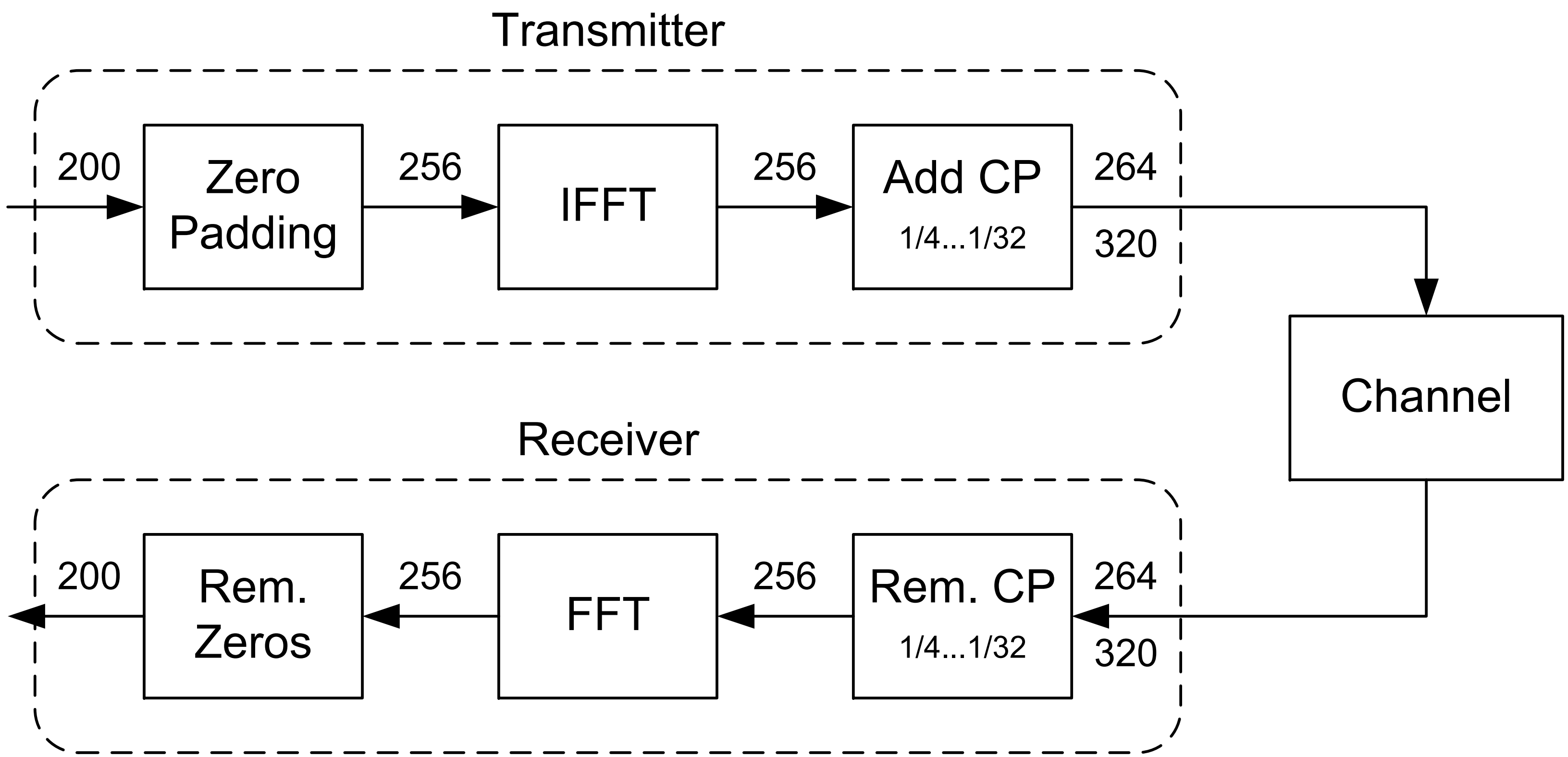
AMC value	Modulation	RS Code Rate	CC Rate	Overall Code Rate
1	2-PAM	1	1/2	1/2
2	4-QAM	3/4	2/3	1/2
3	4-QAM	9/10	5/6	3/4
4	16-QAM	3/4	2/3	1/2
5	16-QAM	9/10	5/6	3/4
6	64-QAM	8/9	3/4	2/3
7	64-QAM	9/10	5/6	3/4

OFDM Frame Structure

- 3 OFDM symbols preamble
  1. Synchronization
  2. Channel estimation
  3. Control information
- Subcarrier distribution
  - 192 data subcarriers
  - 8 pilot subcarriers
  - 1 zero DC subcarrier
  - 55 guard band subcarriers
  - $\rightarrow$ 256 total



OFDM Modulation and Demodulation

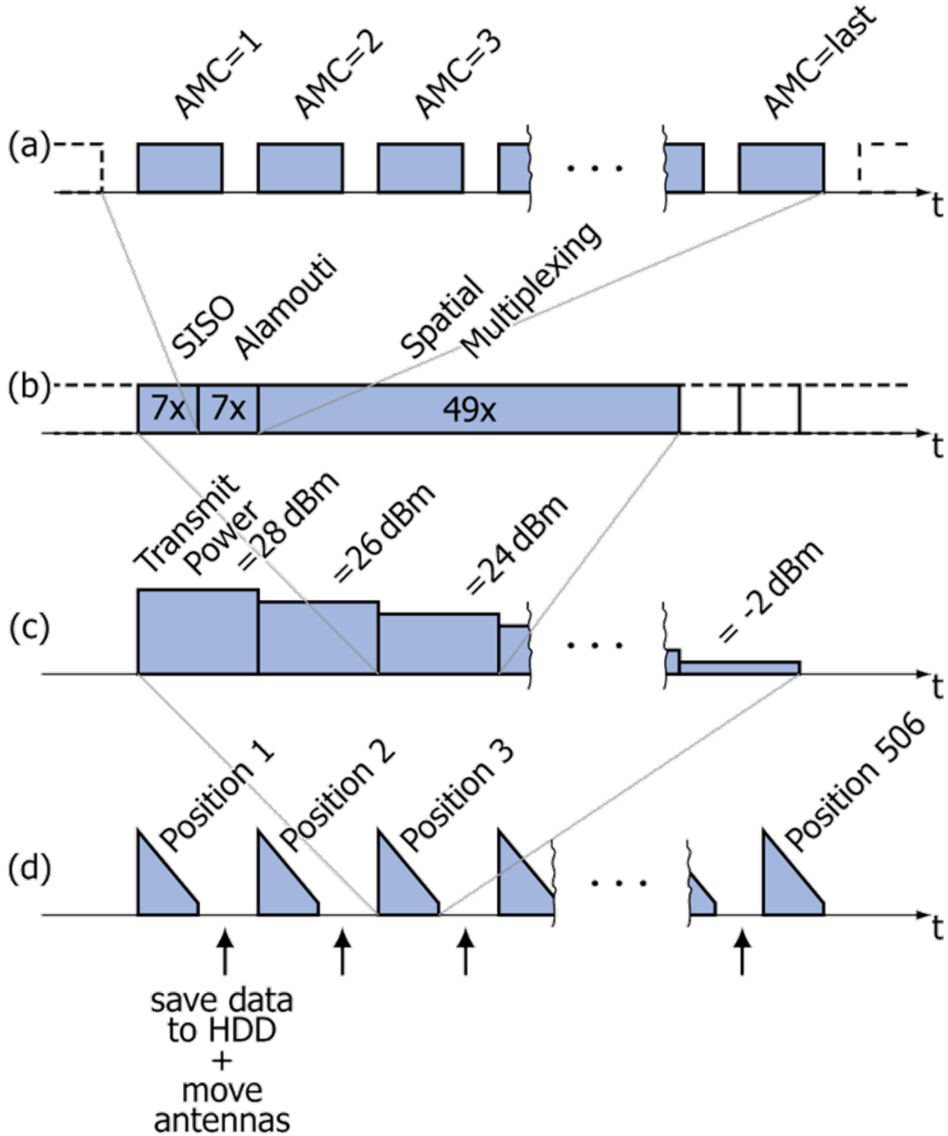


Measurement Setup [W2]

- 3 scenarios
  1. NLOS, outdoor-to-indoor
  2. NLOS, outdoor-to-outdoor
  3. LOS, outdoor-to-indoor
- Parameters
  - 5 MHz channel bandwidth
  - Cyclic prefix 1/4
  - 192 carrier OFDM

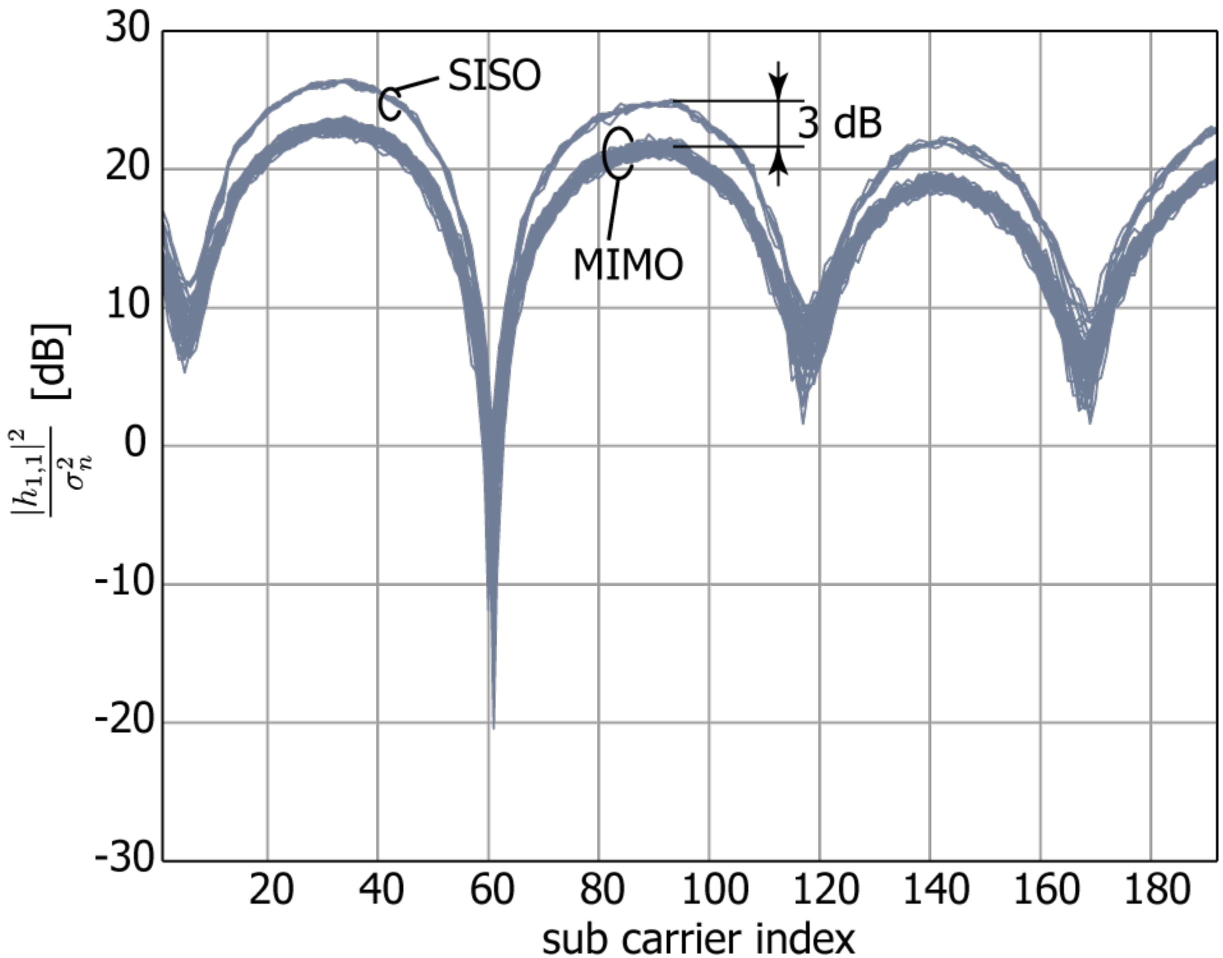
Distance: 50-100m

Block Transmission [W2]



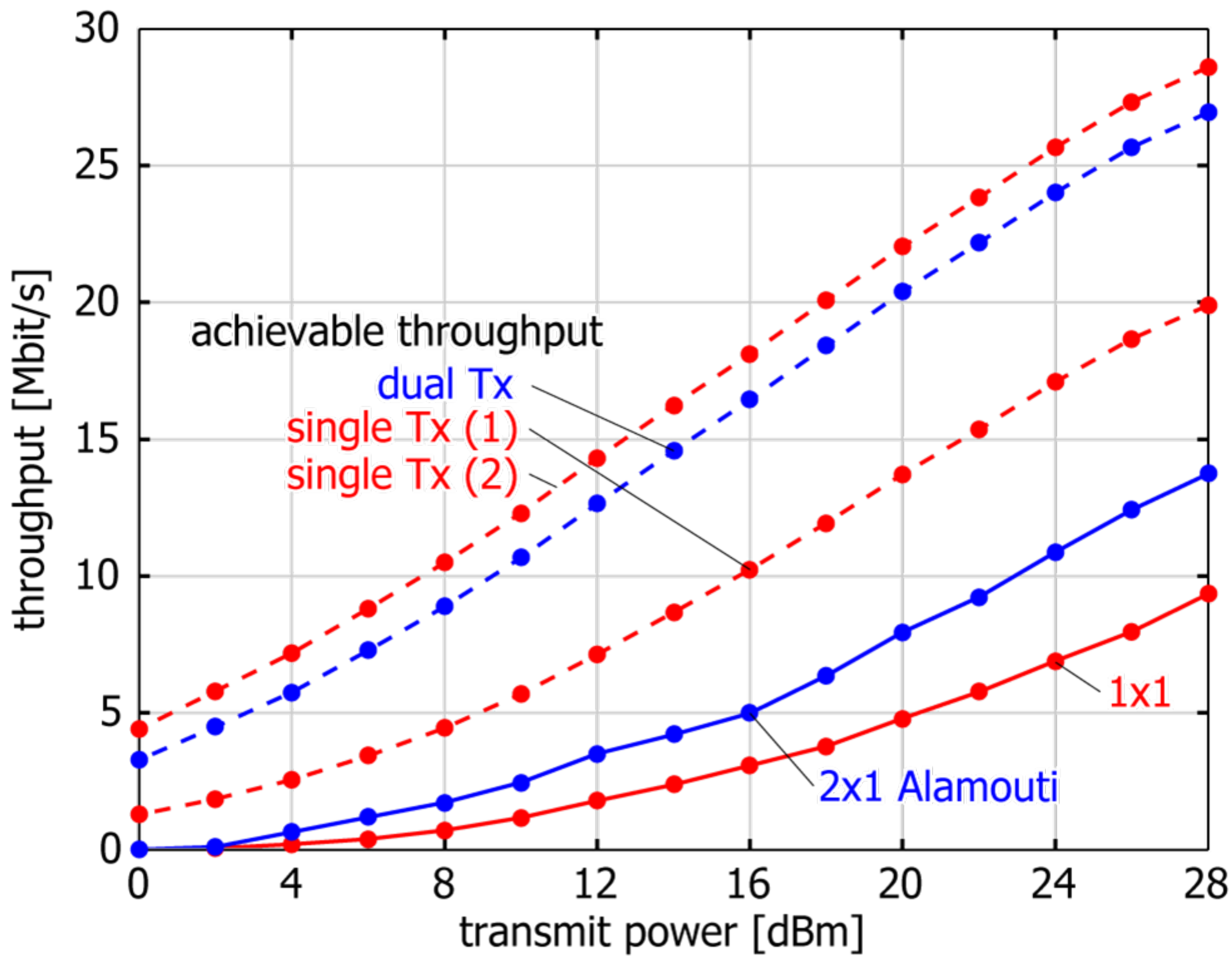
1. SIMO, 7 AMC schemes, 3 bit feedback
2. MIMO with Alamouti, 7 AMC schemes, 3 bit feedback
3. MIMO with spatial multiplexing, **same** coding scheme on both antennas, 3 bit feedback
4. MIMO with spatial multiplexing, **individual** coding schemes on both antennas, 6 bit feedback

Measured Channel Coefficients [W2]

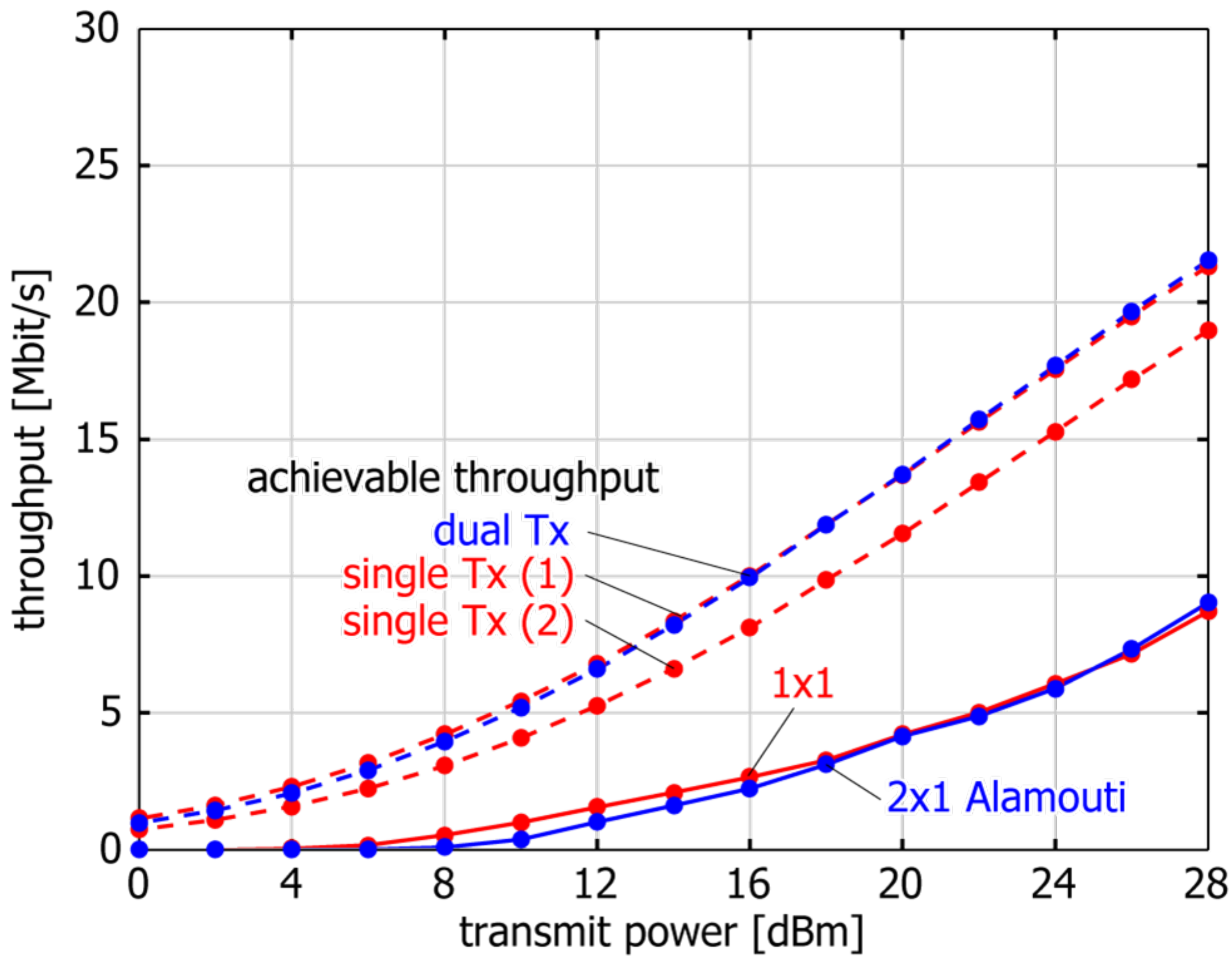


Duration of measurements: ~200ms

One Receive Antenna: NLOS outdoor-to-outdoor [W2]



One Receive Antenna: NLOS outdoor-to-indoor [W2]



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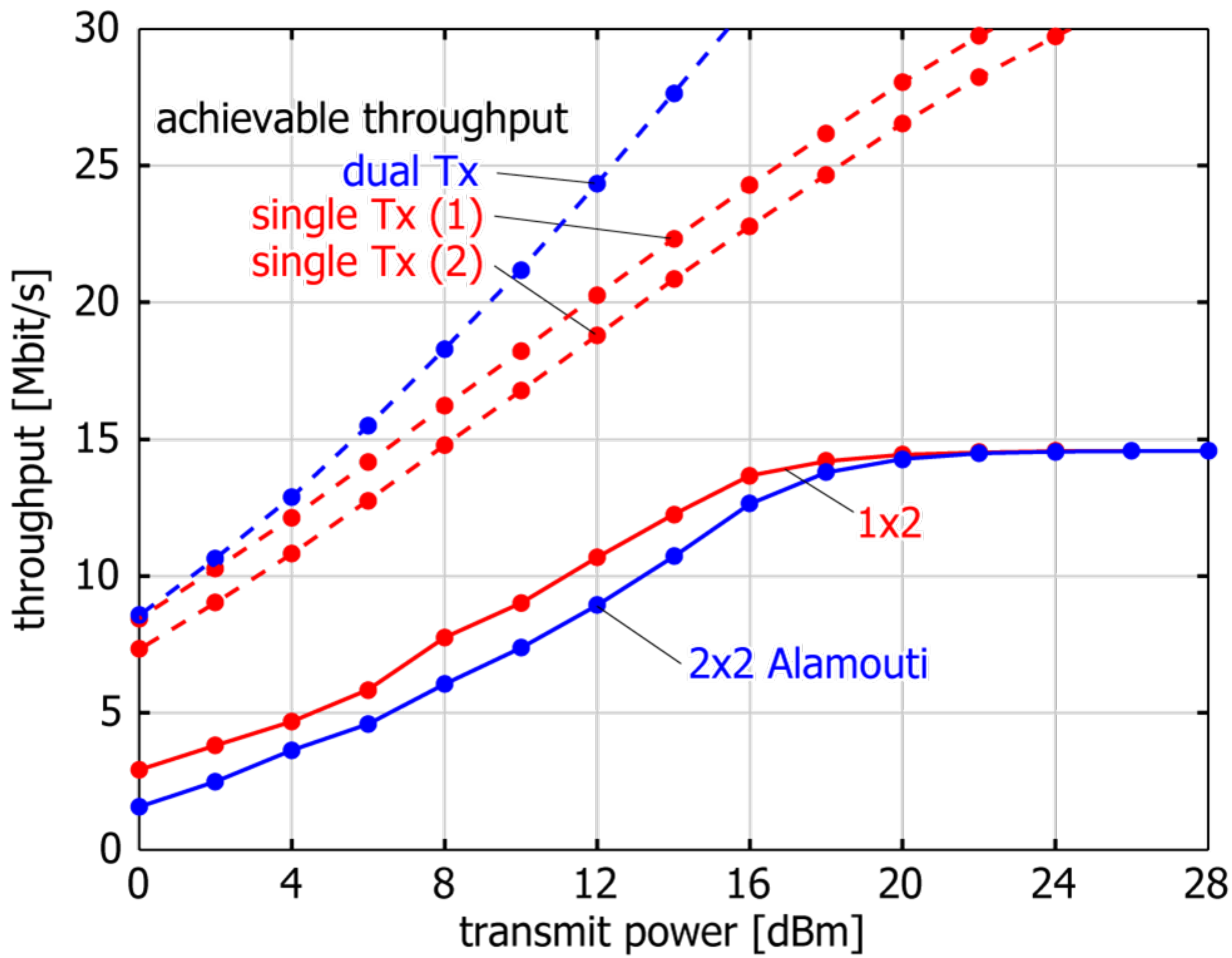
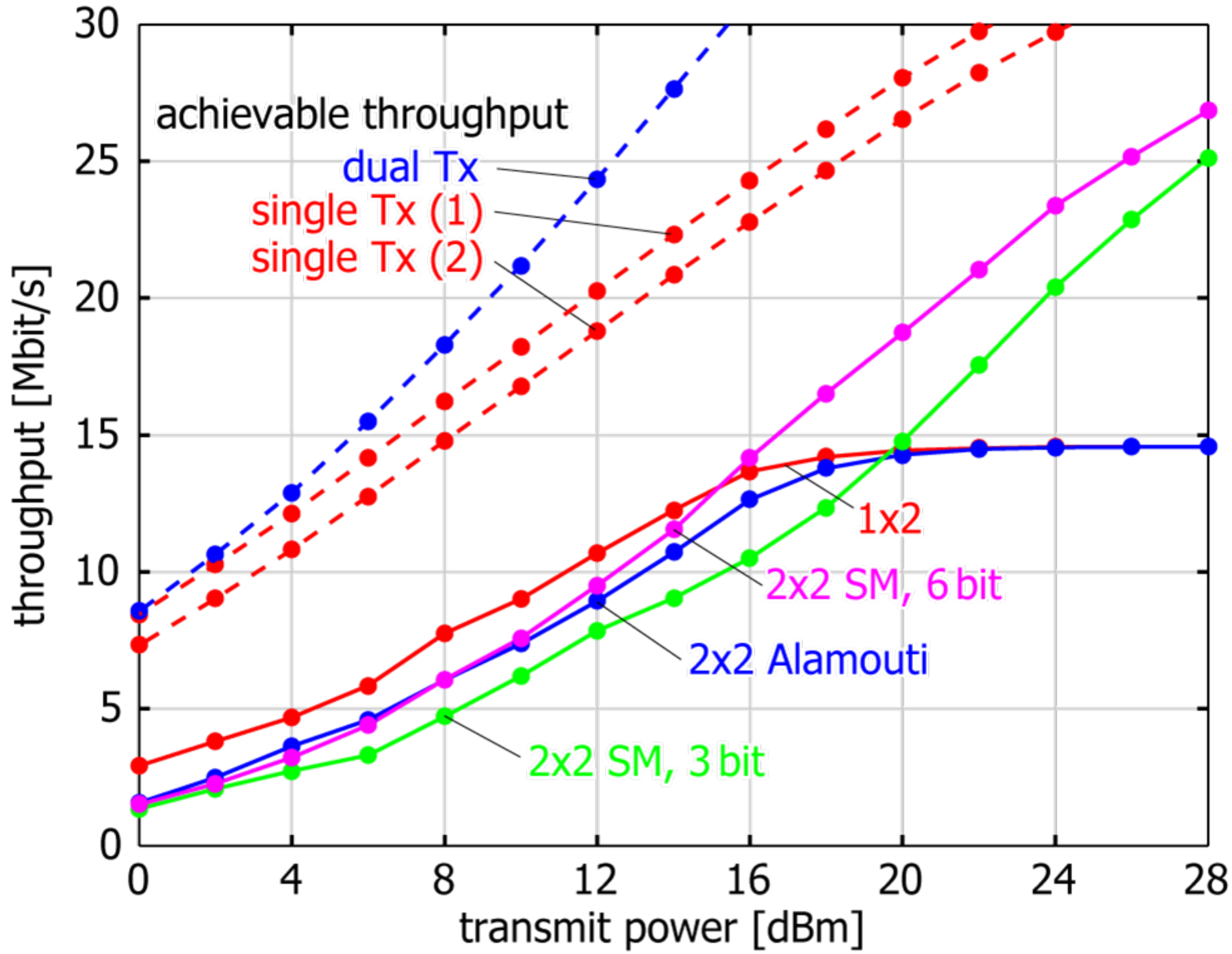
One Receive Antenna: Conclusions [W2]

- The measured scenarios behave asymmetric with respect to the transmit antenna
- If channel is known at the transmitter, antenna selection can improve the performance
- Alamouti looses (slightly) compared to single antenna transmission
  - more sensitive channel estimation errors
  - 3dB less power for training
  - Asymmetric scenario
- Huge gap of >10 dB between measured and achievable throughput!

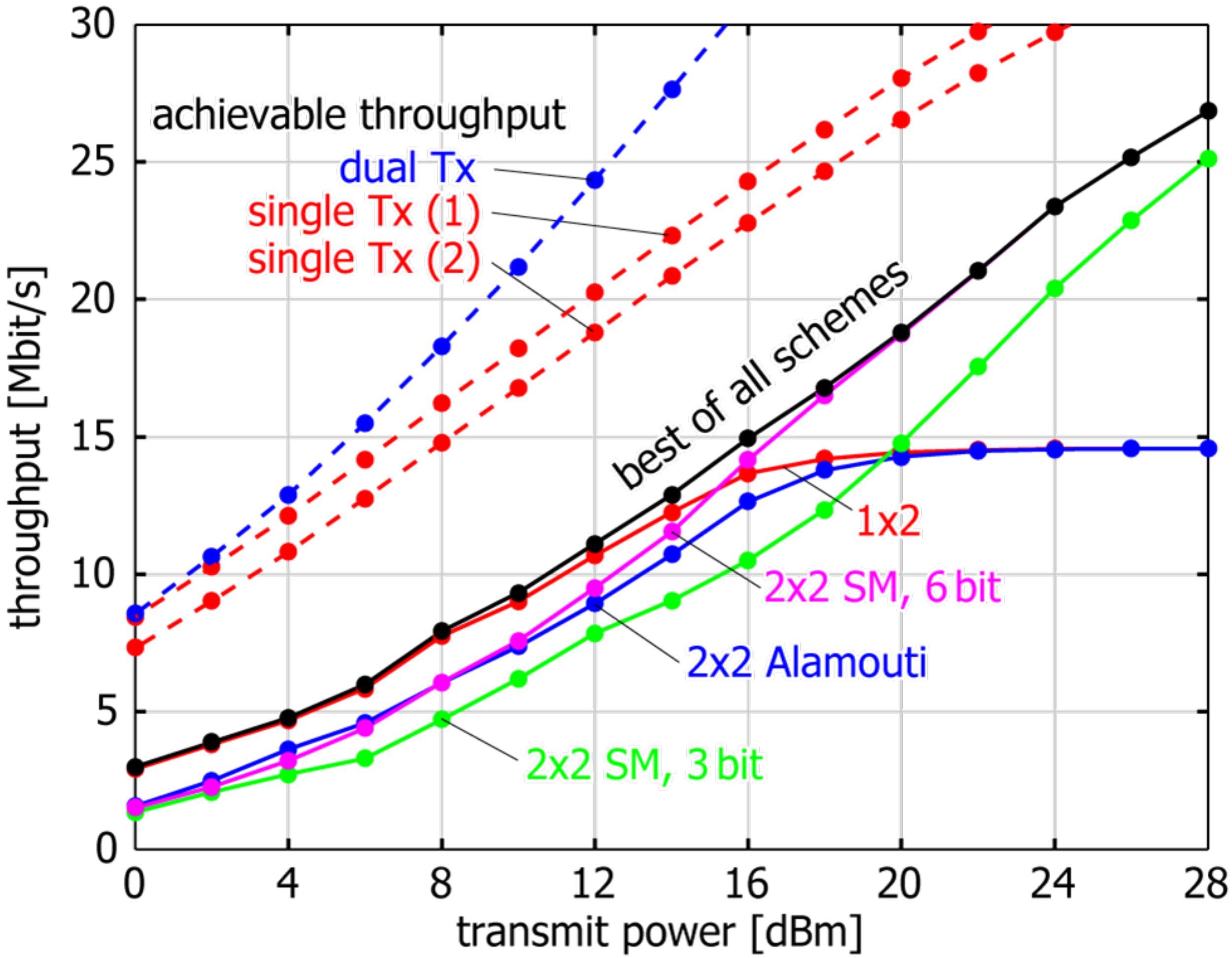
Two Receive Antennas MRC: LOS outdoor-to-indoor [W2]



Two Receive Antennas: LOS outdoor-to-indoor [W2]



Two Receive Antennas: LOS outdoor-to-indoor [W2]

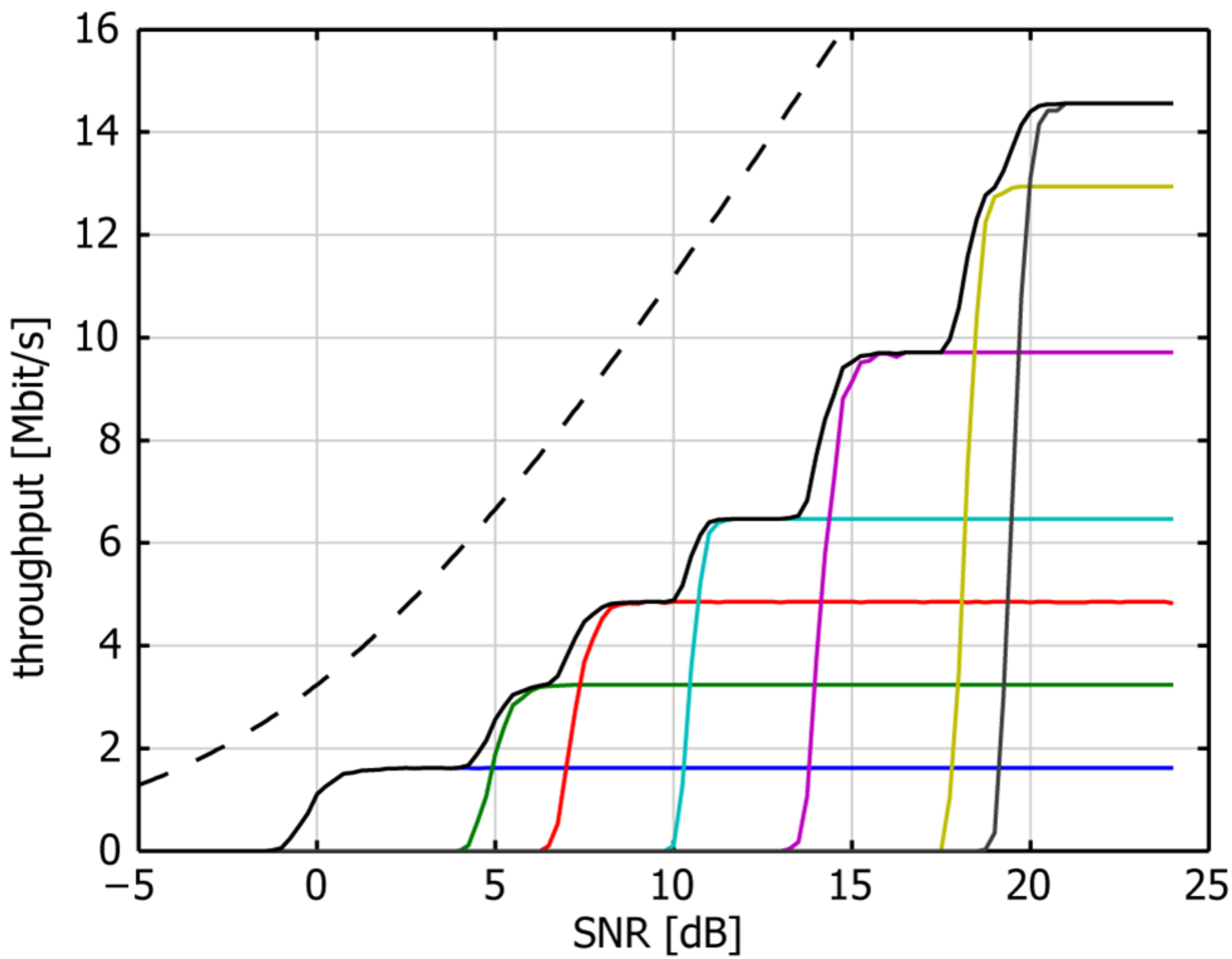


Two Receive Antennas: Conclusions [W2]

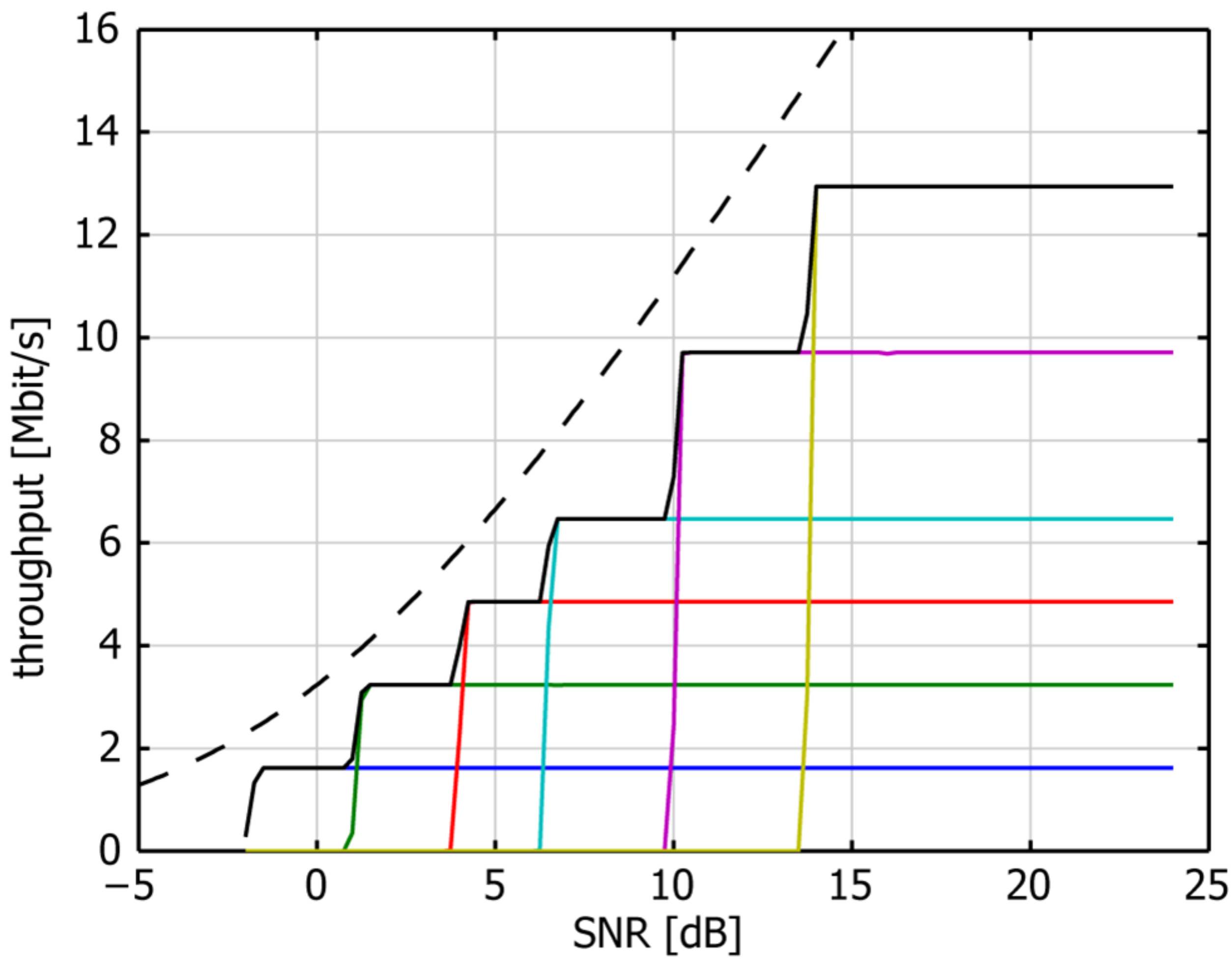
- Spatial multiplexing with 6 bit feedback outperforms spatial multiplexing with 3 bit feedback
  - The 6 bit feedback allows to exploit the asymmetric channels
- Alamouti is better than spatial multiplexing with 3 bit feedback due to transmit diversity
- Again, a huge gap of >10 dB between measured and achievable throughput is observed!

- Enhancements
  - Better channel coding
    - e.g. Low Density Parity Check (LDPC) codes
  - Enhanced channel estimation techniques
    - e.g. LMMSE channel estimation to exploit correlation between subcarriers

AWGN Performance of the Reed Solomon-Conv.Coder



AWGN Performance of LDPC codes



SNR Gain of Improved Channel Estimators over the LS Estimator [W1]

Scenario 1	LMMSE	genie-driven
1x1 SISO	0.6 dB	1.2 dB
2x1 Alamouti	1.8 dB	2.9 dB
1x2 SIMO	0.5 dB	1.2 dB
2x2 Alamouti	1.9 dB	3.2 dB
2x2 Spatial Multiplexing (3 bit)	1.4 dB	2.4 dB
2x2 Spatial Multiplexing (6 bit)	1.1 dB	2.2 dB

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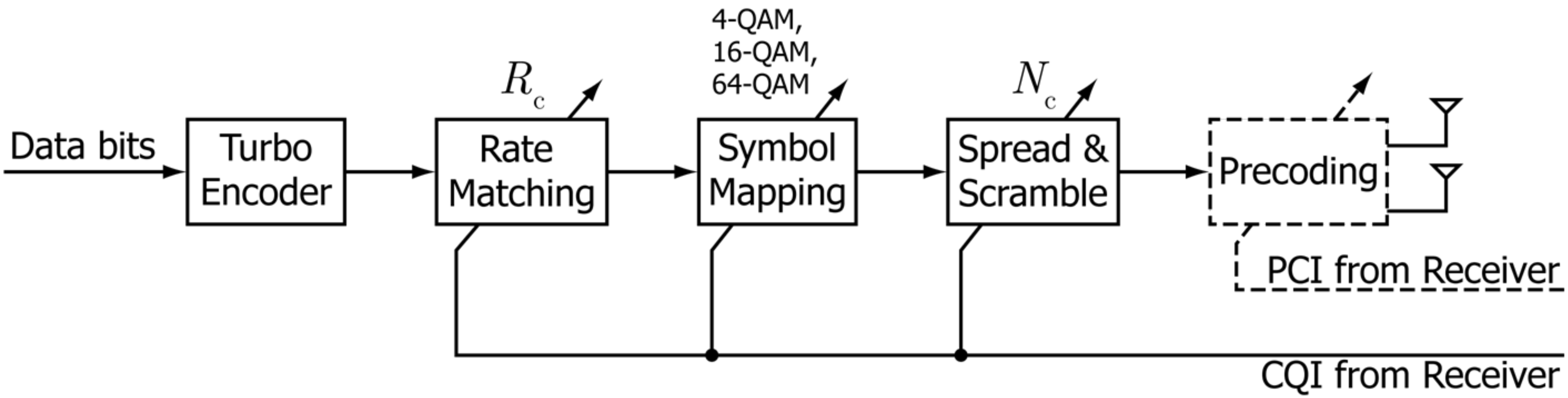
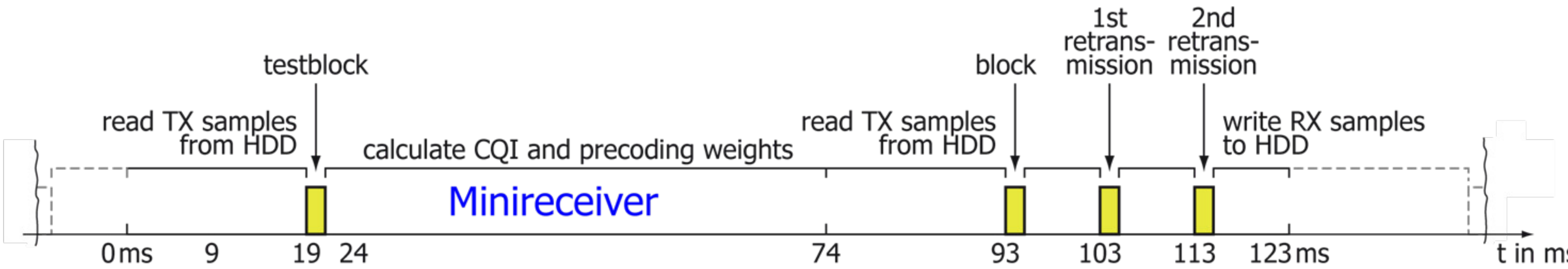
HSDPA Overview



- Channel adaptation is performed by means of
  - a Channel Quality Indicator (CQI) and
  - a Precoding Control Indicator (PCI) when two transmit antennas are available

Transmission Timing [H4]



- Large number of possible transmit blocks require channel evaluation at the receiver
- Minireceiver estimates channel and noise and calculates the CQI and PCI

SINR Estimation in Minireceiver [H5]

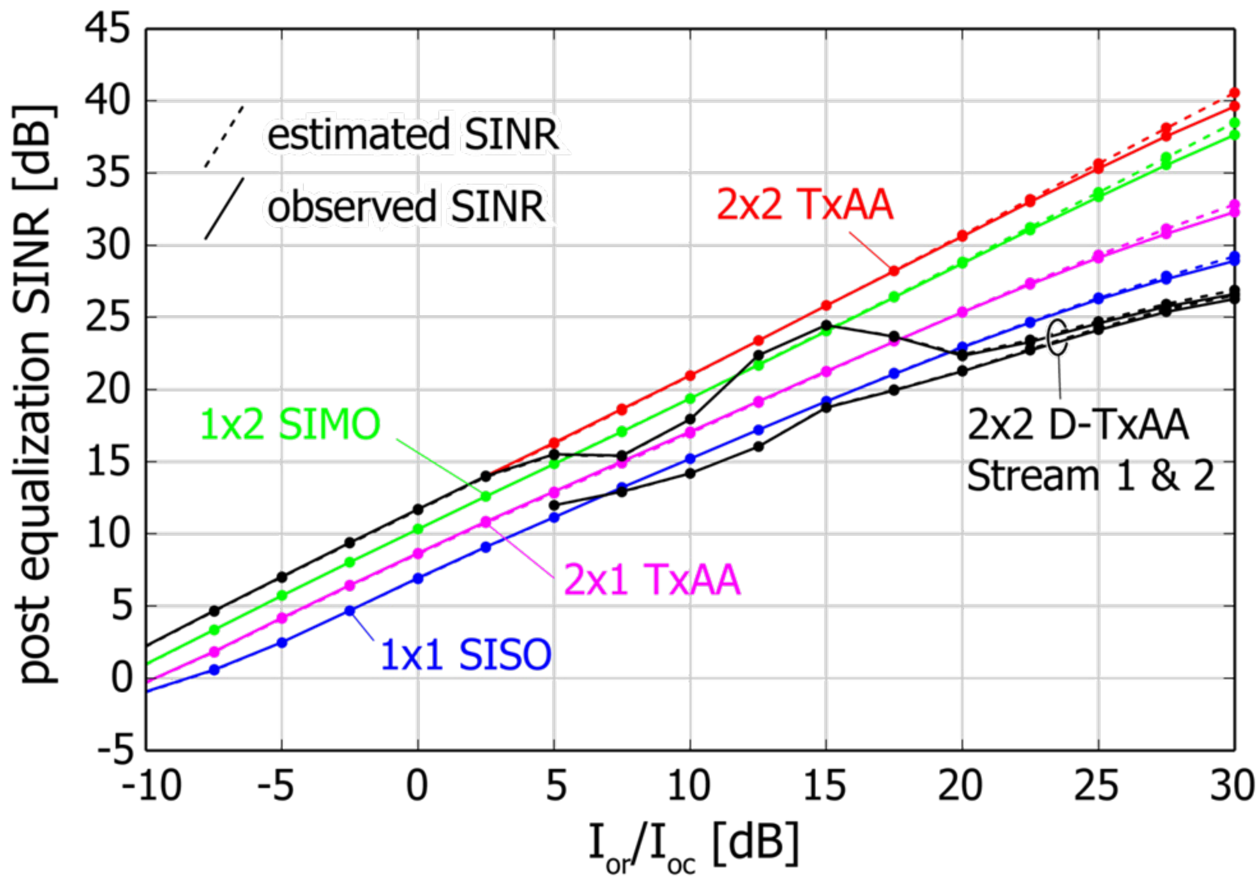
$$\text{SINR}_{\text{est}} = \frac{P_s}{\sigma^2_{n'} + P_{\text{ISI}} + P_{\text{INT}}}$$

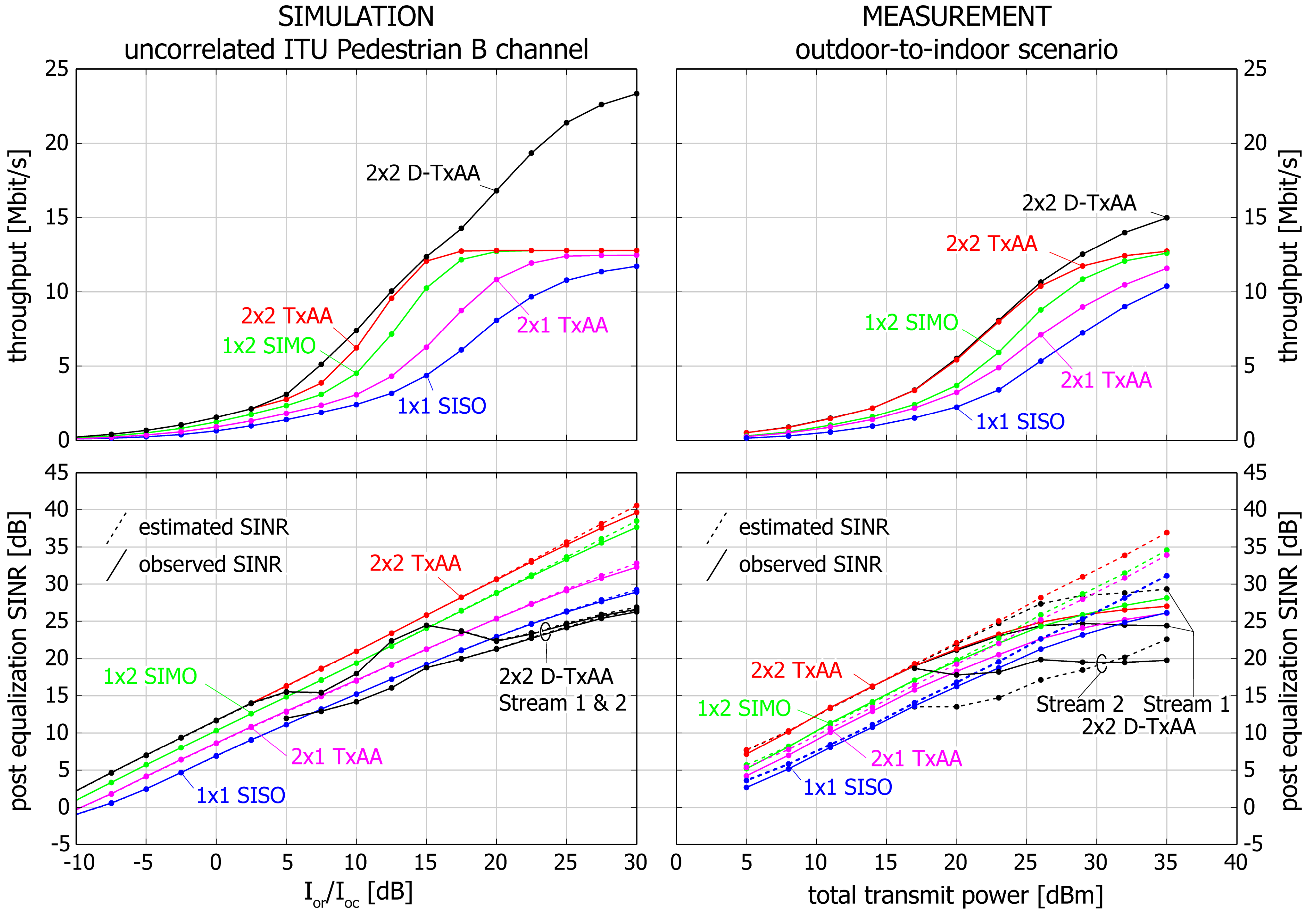
The post equalization SINR is given by

- the signal power P_s
- the noise at the output of the equalizer $\sigma^2_{n'}$
- the remaining inter-symbol interference P_{ISI}
- the interference caused by spatially multiplexed streams sharing the same scrambling and spreading codes P_{INT}

SINR is calculated for all possible precoding vectors and mapped to the supported CQI values. The precoding vector maximizing the transport block size is selected.

Verification of the SINR Estimation in the Simulation [H5]





SIMULATION
uncorrelated ITU Pedestrian B channel
MEASUREMENT
outdoor-to-indoor scenario
throughput [Mbit/s]
post equalization SINR [dB]
2x2 D-TxAA
2x2 TxAA
1x2 SIMO
2x1 TxAA
1x1 SISO
estimated SINR
observed SINR
2x2 D-TxAA
Stream 1 & 2
Stream 2
Stream 1
2x2 D-TxAA
I_or/I_oc [dB]
total transmit power [dBm]

Conclusion

- WiMAX suffers from inferior channel coding
  - 5dB can be gained in SNR by using an out-of-the-box LDPC code
  - Before deploying MIMO in WiMAX systems one should consider using advanced channel coding schemes
- Channel estimation is a key issue for MIMO WiMAX
  - Enhanced channel estimators can easily gain ~2 dB in the case of 2x2 Alamouti transmission
- SINR metrics used in HSDPA system simulations do not consider a saturation at high SINR. Refined SINR metrics are required to increase the accuracy of system simulations.

Thank you for your attention.

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[W2] Christian Mehlführer, Sebastian Caban, Markus Rupp, "**Experimental Evaluation of Adaptive Modulation and Coding in MIMO WiMAX with Limited Feedback**," in *EURASIP JASP Special Issue on MIMO Transmission with Limited Feedback,* Vol. 2008, Article ID 837102 (2008), http://publik.tuwien.ac.at/files/pub-et_13762.pdf