Jacobs University Bremen Summer School

*Progress in Mathematics for Communication Systems*

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# MIMO Channel Measurements With A Hardware Demonstrator

Henning Paul

University of Bremen

Department of Communications Engineering

# Short Overview On The ANT

- Department of Communication Engineering (Arbeitsbereich Nachrichtentechnik, „ANT“) is part of the Institute of Telecommunications and High-Frequency Techniques (ITH)
- Head of Department: Prof. Dr.-Ing. K.-D. Kammeyer
- 1 Post-Doc, 8 Ph.D. students
- Main focus of research: Mobile Communications, Adaptive Systems, OFDM, CDMA, MIMO, Blind/Semi-blind Channel Estimation, Cross Layer Optimization, Speech Processing, Multiple Antenna System for ISM Band Transmission (MASI)

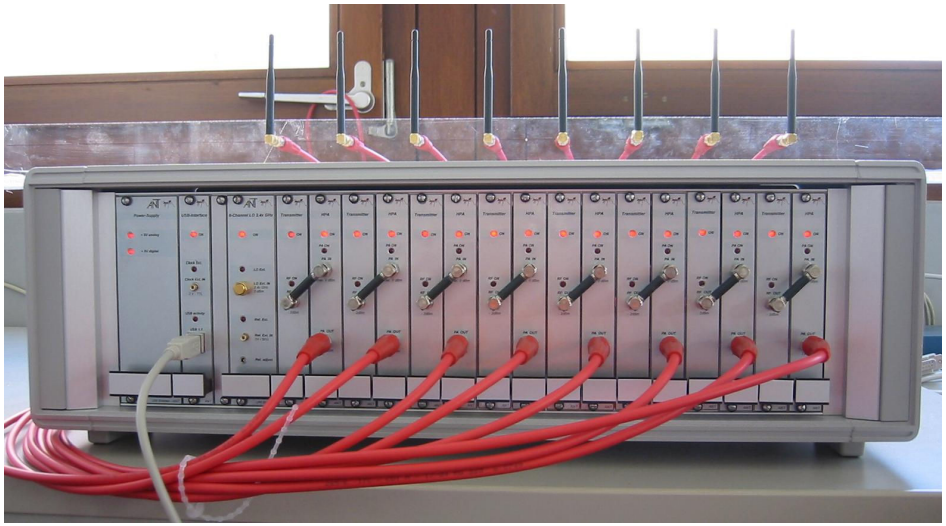
# Outline

- Motivation
- Properties of MASI
- Measurement Results

- Future Research Topic

# Motivation

- Simulations use ideal assumptions
- These assumptions can be verified by measurements employing the hardware demonstrator
- Usage of off-the-shelf components that are also being used in commercial products
- Thus, realistic transmission conditions can be achieved

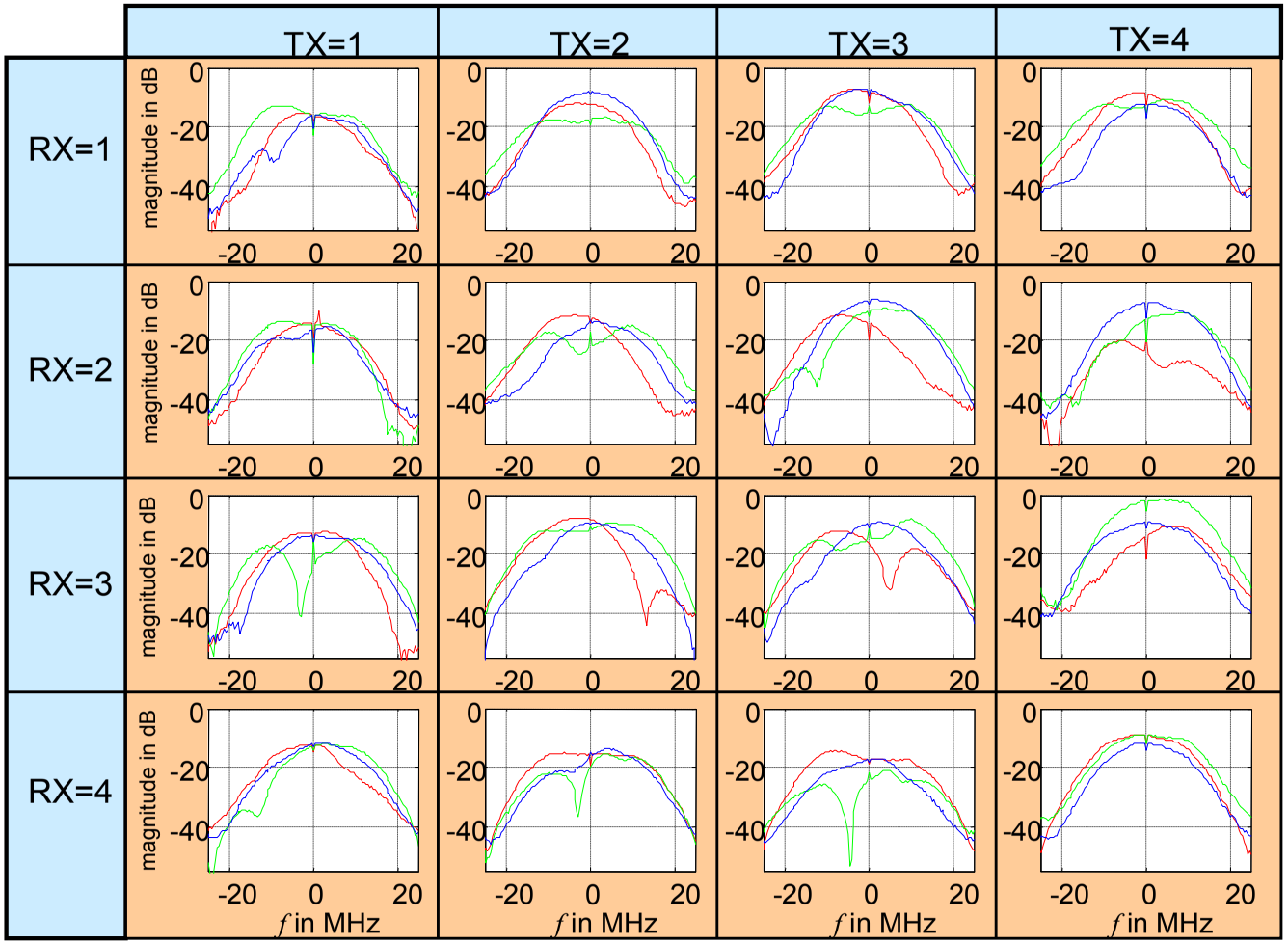


**M**ultiple **A**ntenna **S**ystem for **I**SM Band Transmission

# Properties of MASI

- 19“ rack mount technology, individually extensible (1 to 8 channels)
- Transmission band: 2.4GHz ISM band (10MHz channel grid / 8 frequencies possible)
- Transmit power: +20dBm (100mW) per channel
- Zero-IF modulator & demodulator circuits (Analog Devices AD8346/8347)
- Analog I/Q baseband bandwidth: 16MHz (due to hardware filters)
- 12 bit DAC (Analog Devices AD 9765), 12 bit ADC (AD 9432)
- Sampling frequency 10MHz, 40MHz, 50MHz, PLL clock and external
- Maximum sampling depth 524.288 (Tx) / 1.048.576 (Rx) I/Q samples
- Connection to PC (control and data transfer) via USB for offline signal processing using MATLAB

# Results of Frequency Response Measurements



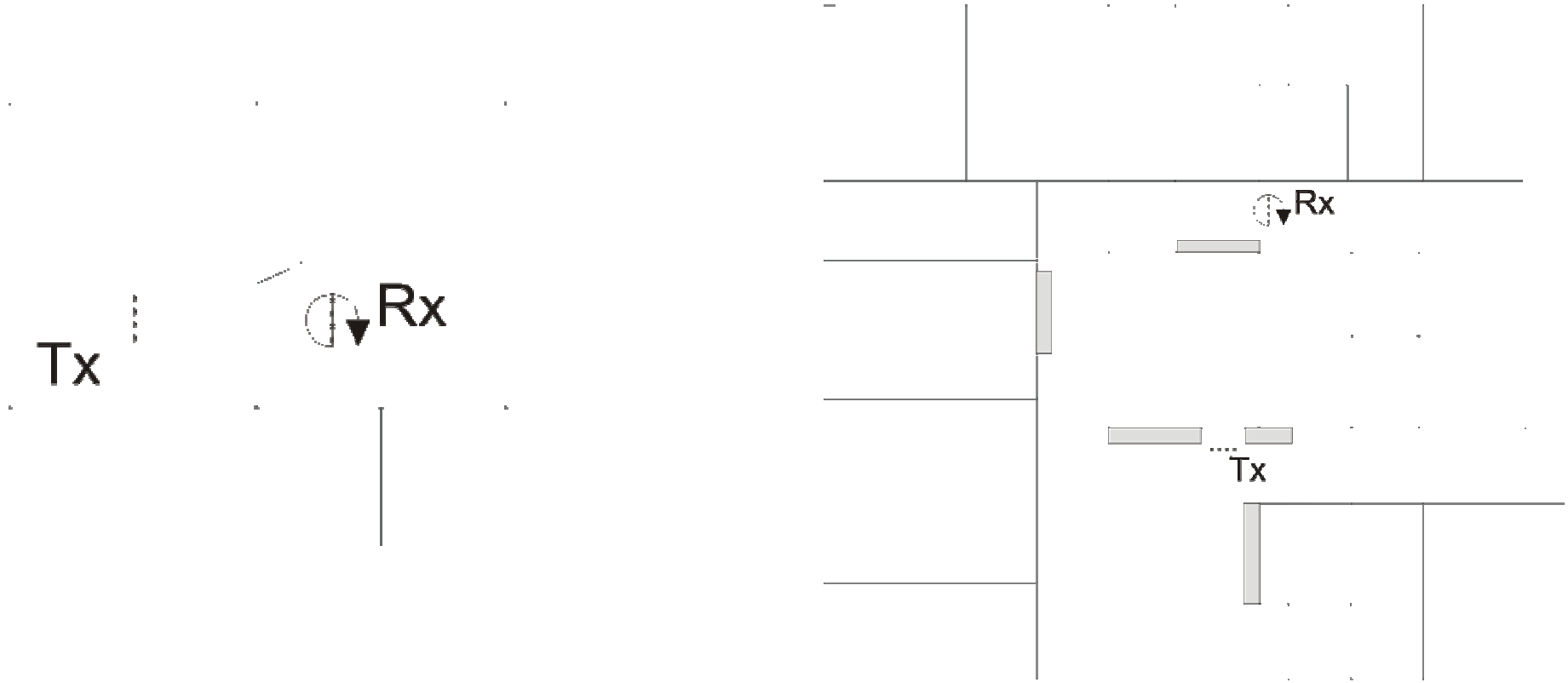

- Transmission of chirp signals over transmit antennas in multiplex

# Measurement Of MIMO Channel Matrices

- Transmission of Zadoff-Chu pilot sequences with $f_{samp}$ = 50MHz, $T_{symb}$ = $8/f_{samp}$, $f_{LO}$ = 2.44GHz in time multiplex over transmit antennas
- Receiver-side signal processing (Frame detection, carrier offset correction, symbol clock synchronization, downsampling)
- Calculation of 15 estimates of channel matrix $\mathrm{H}$ per frame

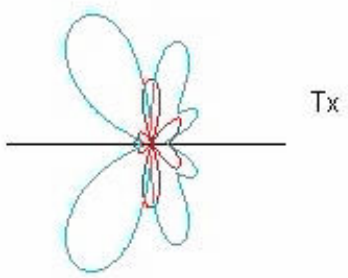
- Eigenvalue decomposition of receiver side channel correlation matrices $\mathrm{R_{HH,R}}=\mathrm{E}\{\mathrm{HH^H}\}$ and $\mathrm{R_{HH,T}}=\mathrm{E}\{\mathrm{H^HH}\}$ yield eigenvectors and eigenvalues
- describe spatial propagation characteristics
- can be presented as beam patterns

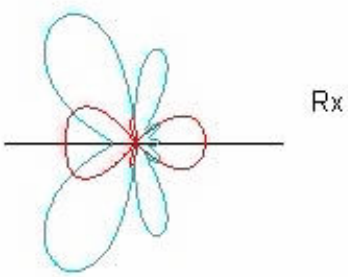
# Measurement Campaigns

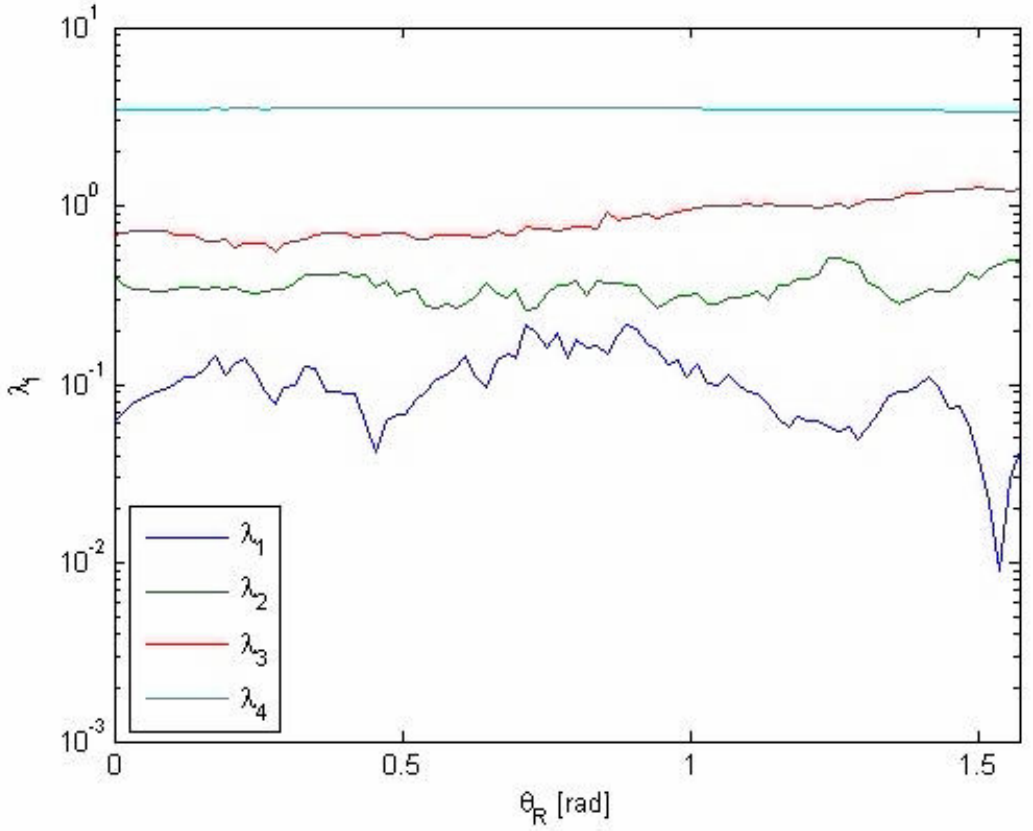



- Measurement of 4x4 ULA system, rotation of receive array in 1° steps between frames

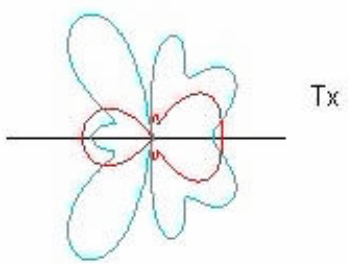
# Beam Patterns for Line-of-Sight Transmission

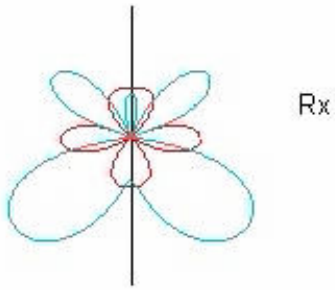


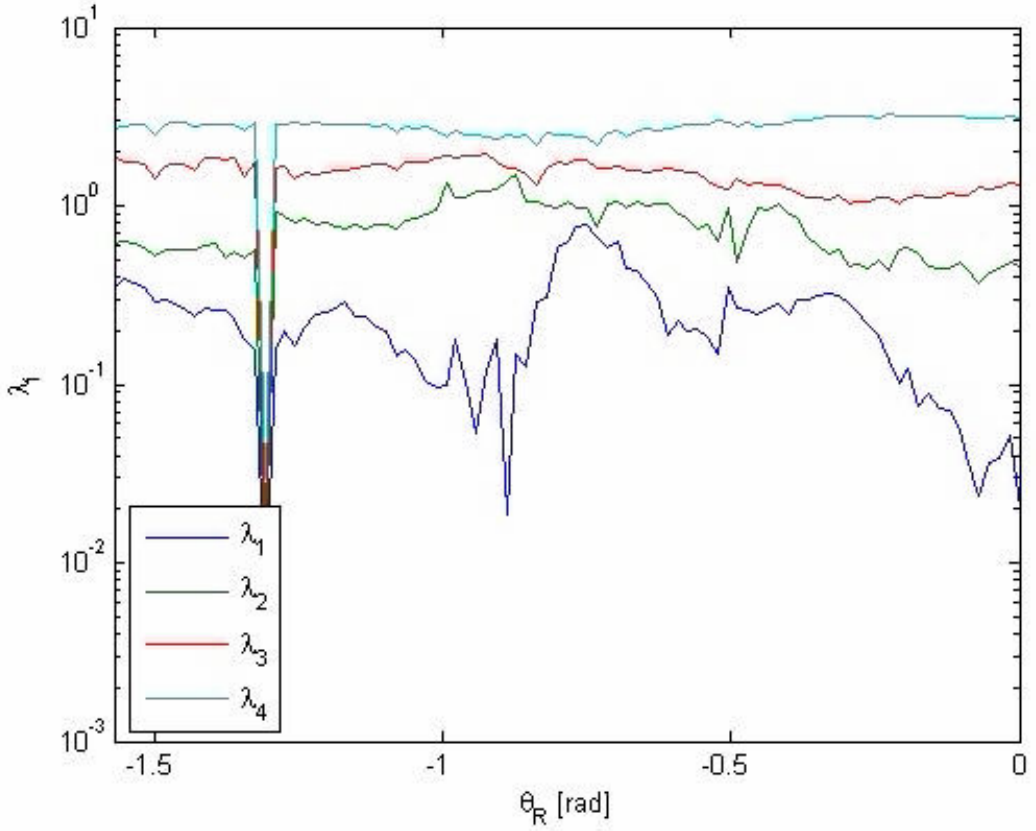



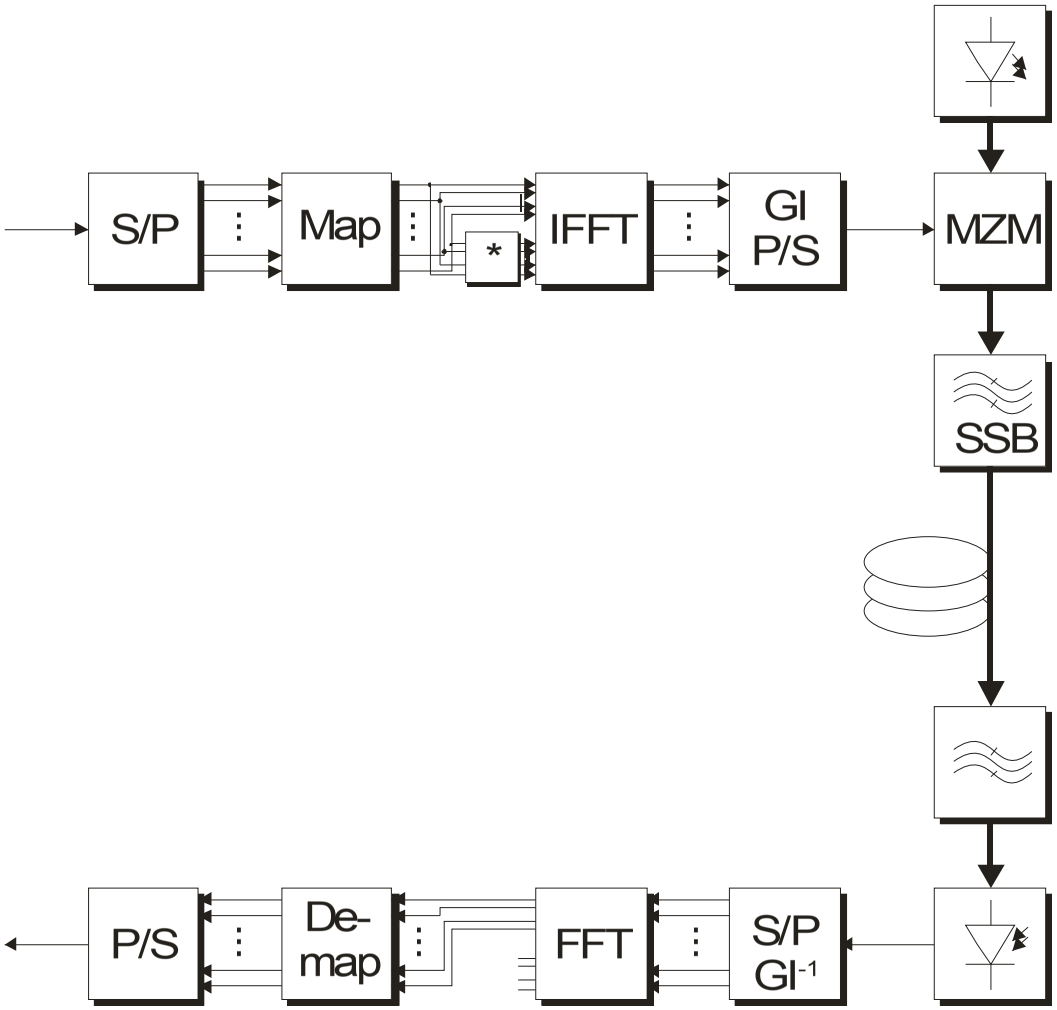
# Beam Patterns for Non-LoS Case



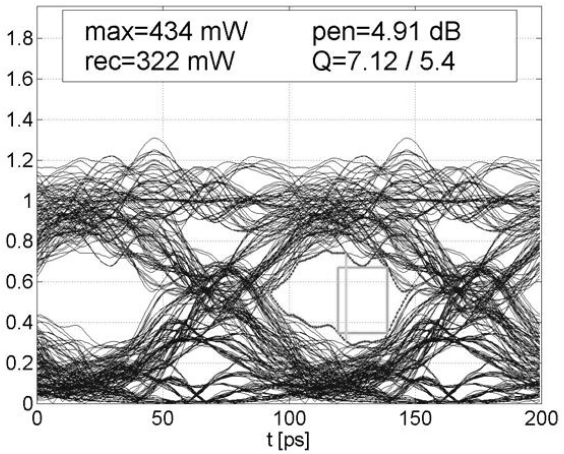



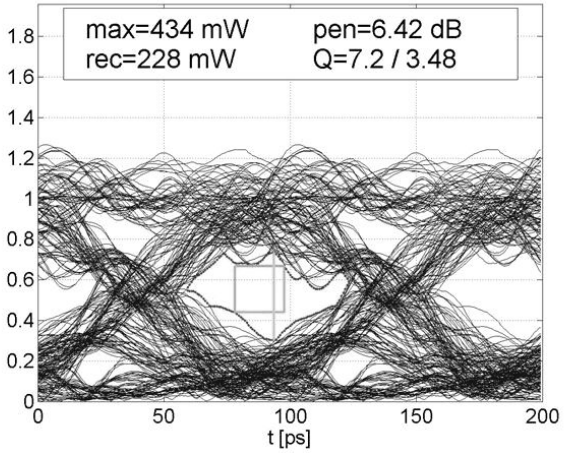
# Future Research Topic: OFDM for Optical Media

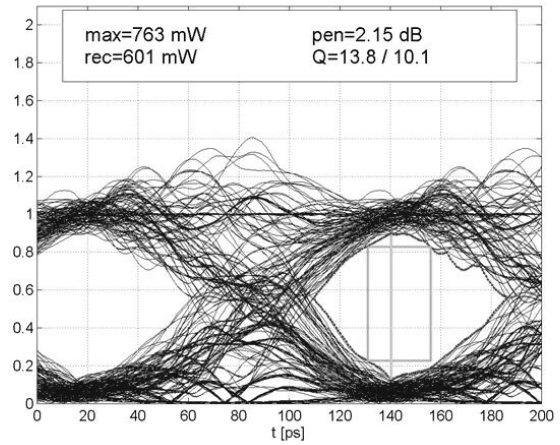


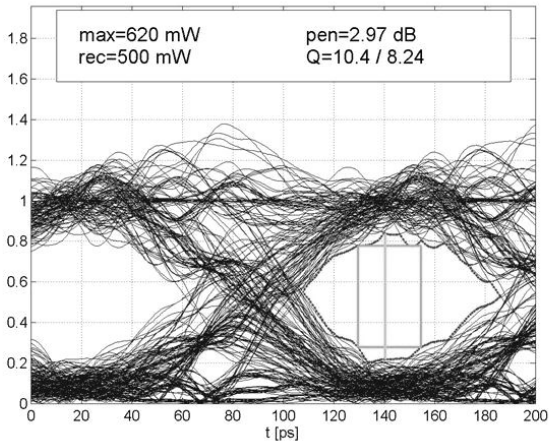

- OFDM allows parallel signal processing for equalization
- Problems: Nonlinearities
  - Nonlinearity of components such as Mach-Zehnder Modulator and photo diode
  - Power (envelope) detection („incoherent“) leads to nonlinear distortions
  - Nonlinearity of optical channel itself

# Optical Channel Models




- Optical channel models are supplied by our cooperation partner (University of Kiel)
- Nonlinear effects to be modelled: Kerr effect, Self Phase Modulation, Cross Phase Modulation, Four Wave Mixing, Stimulated Raman Scattering

Thank you for your attention!