

COURSE OUTLINE

Radio Propagation Overview and Antenna

- Fundamentals
- Propagation in dispersive multipath channels
- Basic antenna characteristics (time, frequency and angular spread)
- Vertical, horizontal and circular polarization of electromagnetic wave
- Basic antenna structures (isotropic and dipole), their characteristics and parameters
- Sector antenna pattern, influence of down-tilting
- Line-of-sight and non-line-of-sight propagation

Spatial Diversity Methods

- Three domains for providing diversity (time, frequency and space)
- Diversity combining schemes: MRC for receive diversity, Alamouti for transmit diversity and selection combining for both
- Combination of spatial diversity (RAKE receiver and cyclic delay diversity)
- Use of space time coding (STBC, STTC)

Beamforming

- Fundamentals of creating adaptive antenna patterns
- Transmit and receive beamforming (DoD and DoA)
- Physical vs. mathematical beamforming
- Switched multibeam vs. adaptive antenna array
- Optimal usage of beamforming (desired signal enforcement, interference suppression or cancellation)
- Combination of beamforming with spatial diversity or spatial multiplexing
- Practical examples of range increase

Spatial Multiplexing

- Basic idea of creating independent spatial channels
- General mathematical model for spatially multiplexed channels
- Encoder and decoder for Horizontal Layered Space (H-BLAST)
- Encoder and decoder for Vertical Layered Space (V-BLAST)
- Encoder and decoder for Diagonal Layered Space (D-BLAST)
- Spatial multiplexing with feedback (closed loop)
- Water-filling concept in closed loop MIMO
- Zero-forcing receiver and singular value decomposition (SVD)

MIMO in Multiple-user Scenario

- Extension of spatial multiplexing concept to multiple-user scenarios

- Classification of multiple-user scenarios for MIMO usage
- 3-dimensional scheduling in LTE system
- Coordinated MIMO transmission from more than one base station

Combination of MIMO with OFDMA and SC-FDMA

- OFDMA and SC-FDMA as the key transmission techniques in the LTE specs
- MIMO-related synchronization and channel estimation aspects
- Combination of STBC and OFDMA
- Combination of SM/BF and OFDMA
- Possible allocations of transmit diversity and spatial multiplexing
- Receive beamforming with SC-FDMA

E-UTRA Release 8 MIMO Processing

- Downlink and uplink scenarios for Rel. 8 MIMO
- Pilot patterns for 1, 2 and 4 antenna ports at the eNB
- Signal processing chain for MIMO including eNB transmitter and UE receiver
- MIMO mapping including transport blocks, codewords and layers
- MIMO operation for SFBC, spatial multiplexing and beamforming
- MIMO modes and feedback (PMI, RI)

E-UTRA Release 10 and Beyond MIMO Enhancements

- 8x8 spatial multiplexing in downlink and new reference signals
- 4x4 spatial multiplexing in uplink
- SU-MIMO for PUSCH and transmit diversity for PUCCH
- Coordinated multipoint transmission in downlink
- Coordinated multipoint reception in uplink

LTE MIMO in Network Deployment

- Antenna system elements and site configurations
- Practical realization of MIMO configurations
- MIMO impact on coverage, capacity, reliability and interference
- Influence on link budgets and capacity budgets
- Typical design trade-offs in application of MIMO

Numerical Experiments (tool-based)

- MIMO processing at eNB transmitter (including SISO, TX Diversity, Spatial Multiplexing)
- MIMO related reference signals
- Channel correlation influence on spatial stream separation

Note: the course content is subject to minor changes and adaptations to the customer needs.