Technische Universität Braunschweig

TPG
THz Photonics Group

Grundlagen der Informationstechnik (Wireless)

Drahtlose Kommunikation / Funksysteme

Thomas Schneider

Inhalt

- Motivation und Einführung
- Die elektromagnetische Welle
- Der drahtlose Kanal
- Antennen
- Ausbreitung e/m Wellen
- Berechnung von Funkstrecken
- THz-Kommunikation
- **Funksysteme**
- Optische Kommunikation
- Silizium Photonik
- Plasmonik

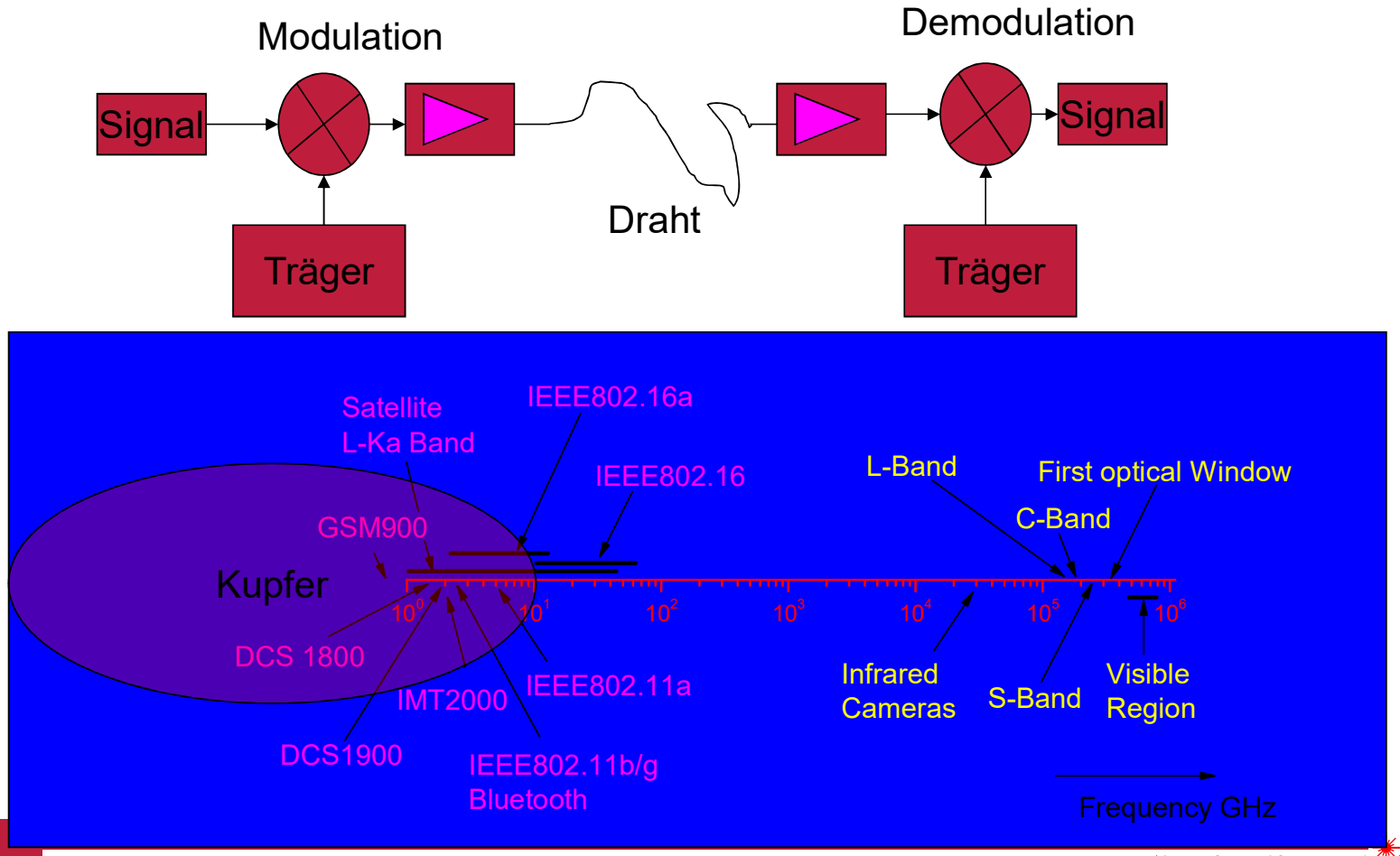
Inhalt

- **Beispiele**
- **Maximale Datenrate in begrenzter Bandbreite**
- **Beispiel LTE**

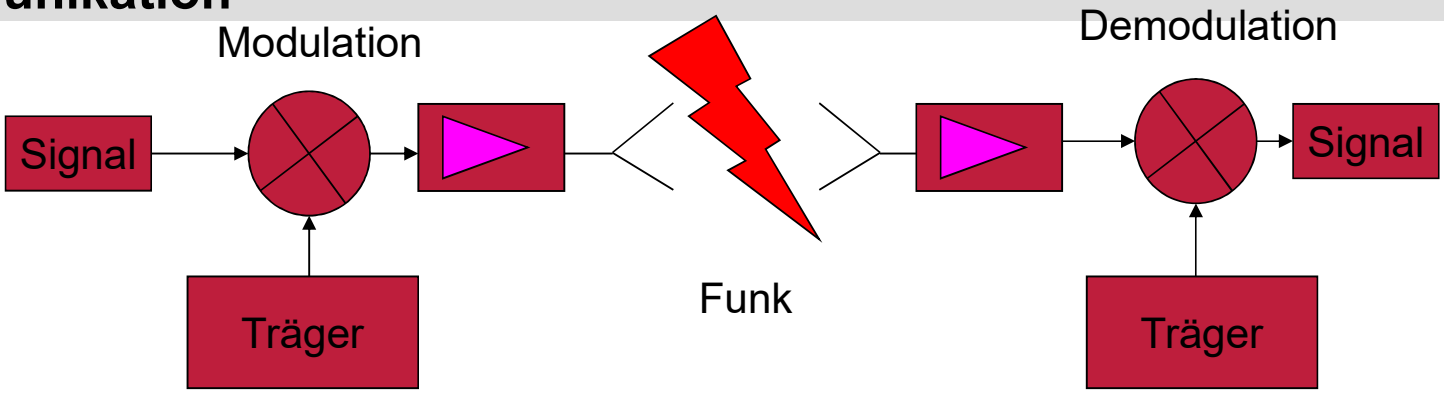
Inhalt

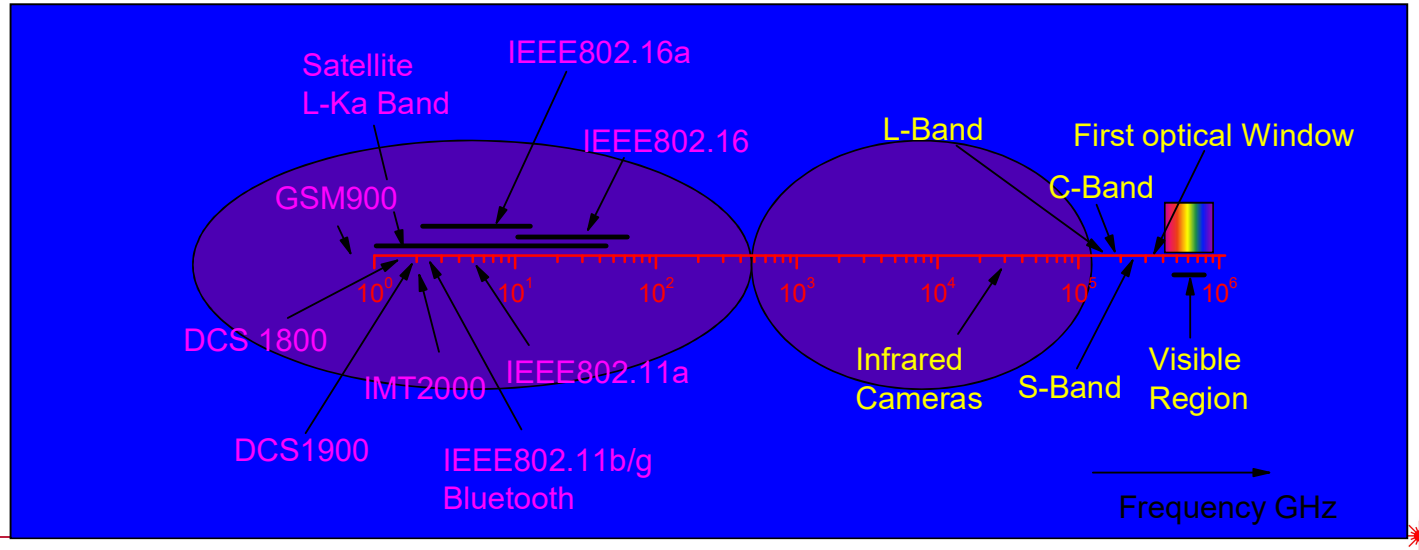
- **Beispiele**
- Maximale Datenrate in begrenzter Bandbreite
- Beispiel LTE

Drahtlose Kommunikation

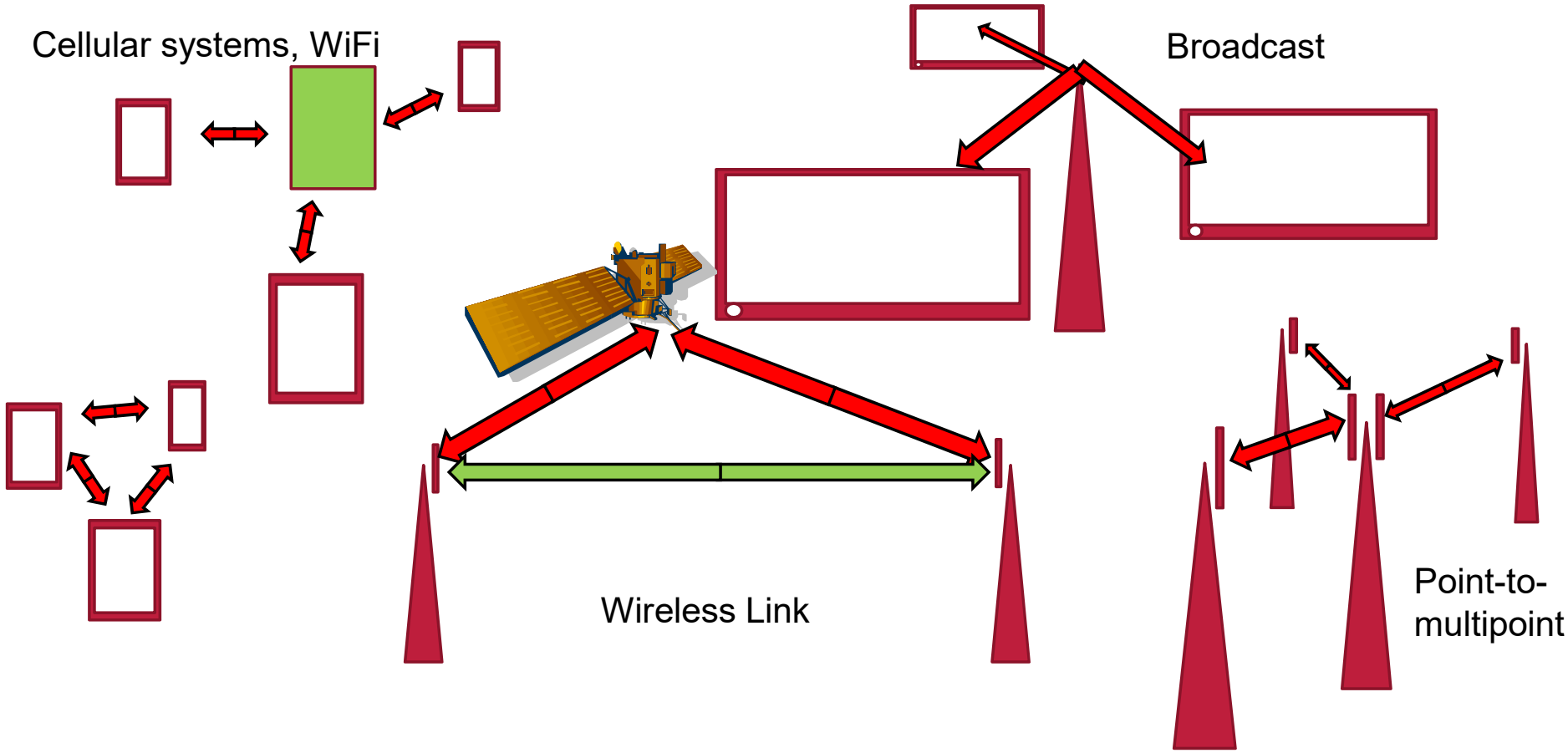


Drahtlose Kommunikation

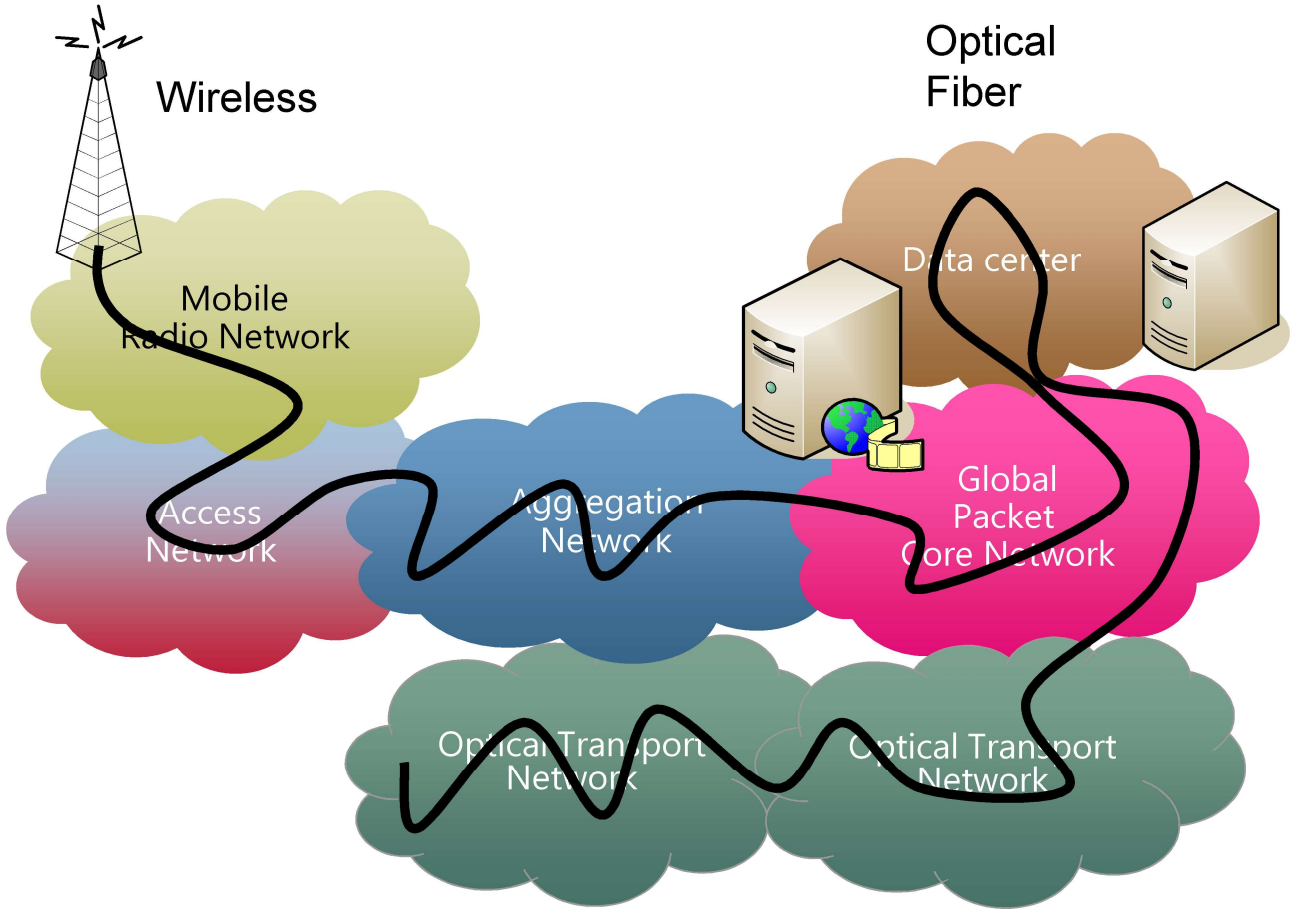




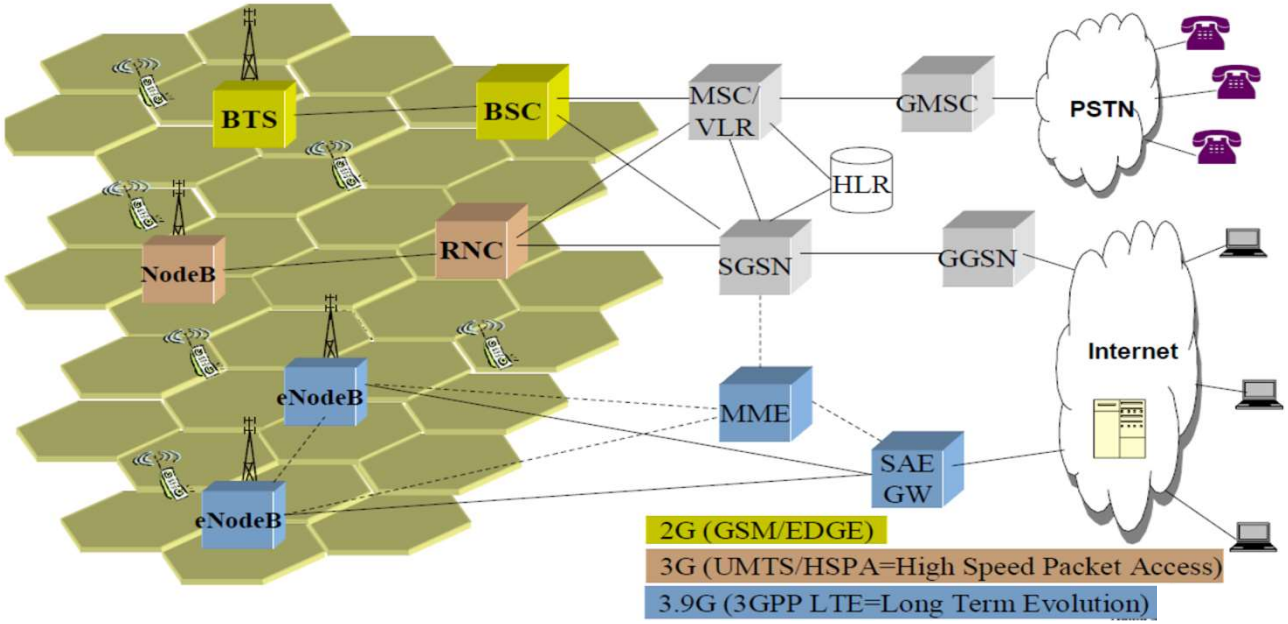
Drahtlose Kommunikation



Drahtlose Kommunikation



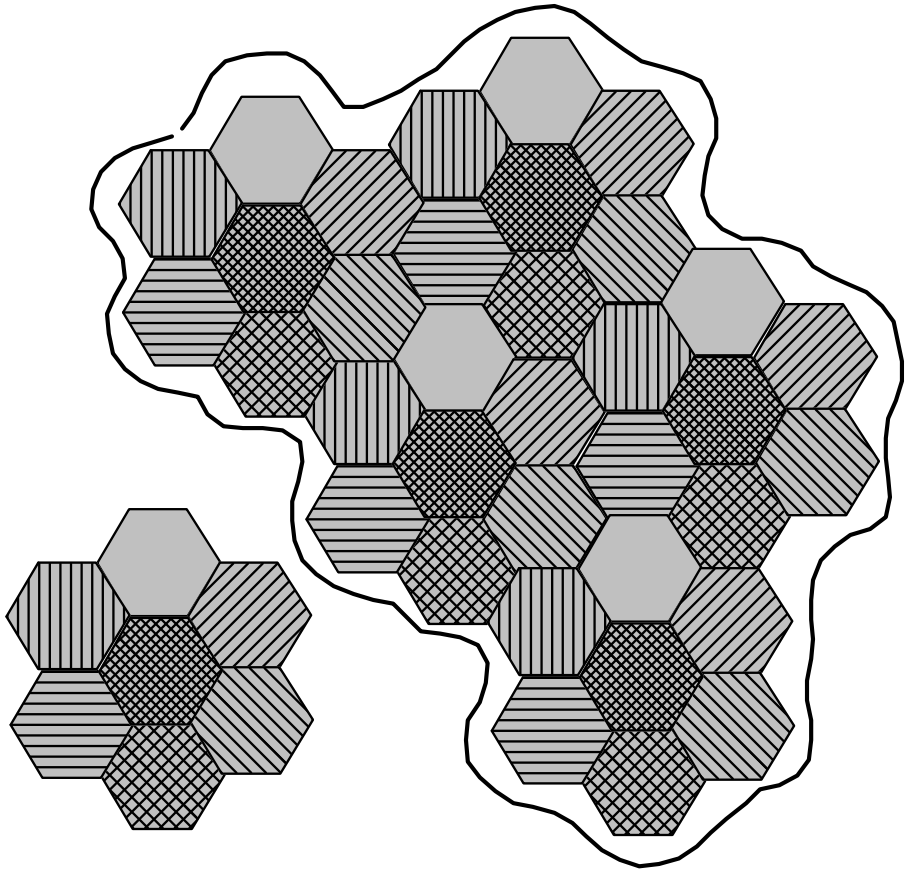
Drahtlose Kommunikation



Cellphones	3 Bill X 0.1W = 1MT/a CO_2
BTS, NodeB	4 Mill X 1000W = 30MT/a
RNC/BNC	10T X 1000W = <0.5MT/a
HLR/VLR	? X 10000W = 7MT/a

O. Blume et al., Energieeffizienz zukünftiger Mobiltechnologien ITG 7.2, Berlin 2009

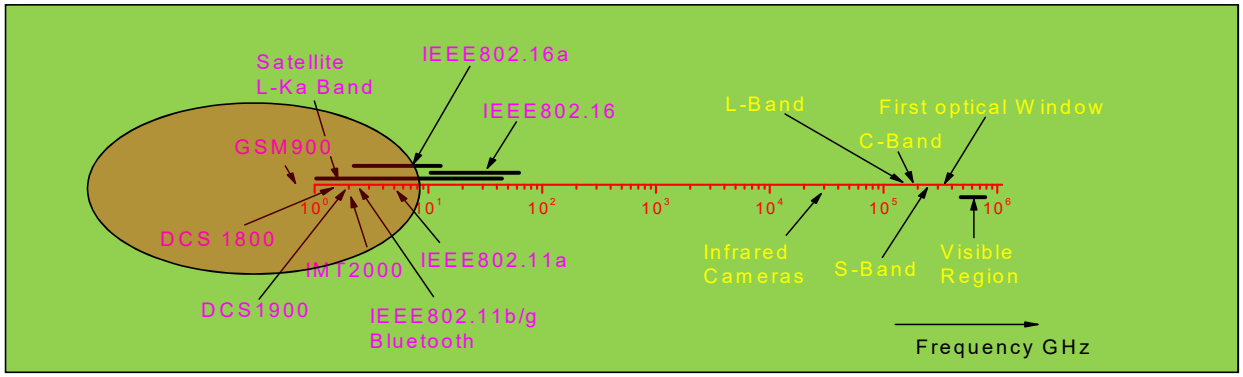
Drahtlose Kommunikation



Inhalt

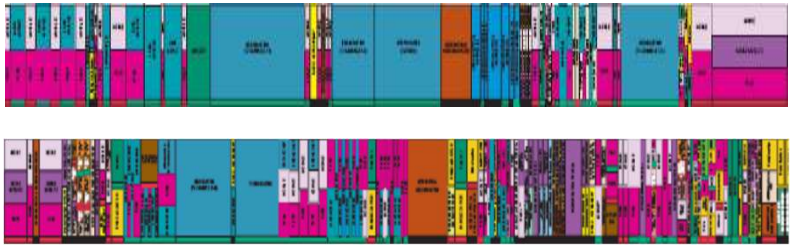
- Beispiele
- **Maximale Datenrate in begrenzter Bandbreite**
- Beispiel LTE

Drahtlose Kommunikation



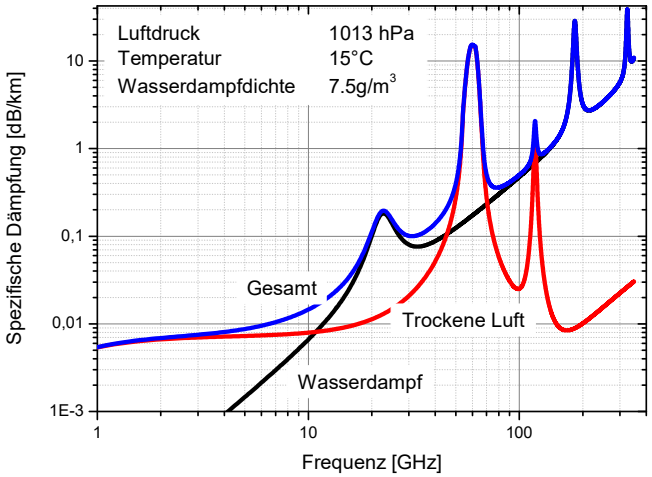
Why have almost all systems today carrier frequencies < 10 GHz ?

Drahtlose Kommunikation



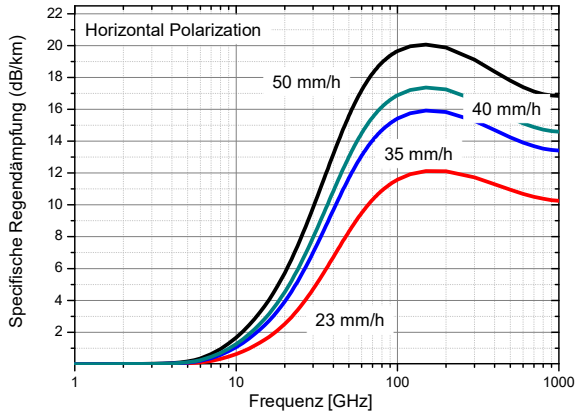
30 – 300 MHz

0.3 – 3 GHz

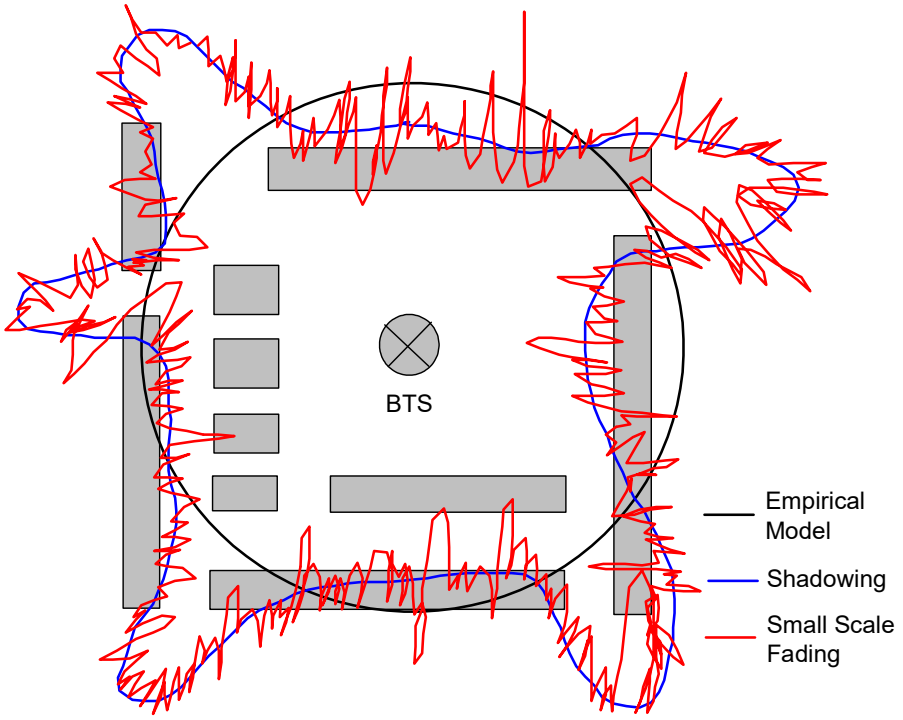


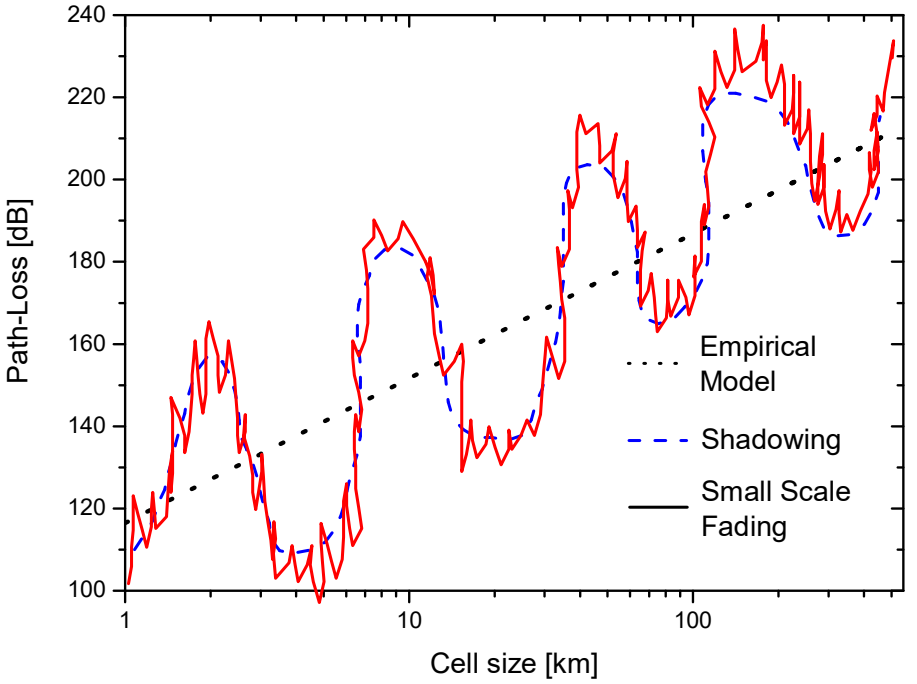
1. Almost no attenuation
2. Good scattering properties
3. Very good diffraction properties

One antenna site can cover a whole area.
no line-of-sight necessary

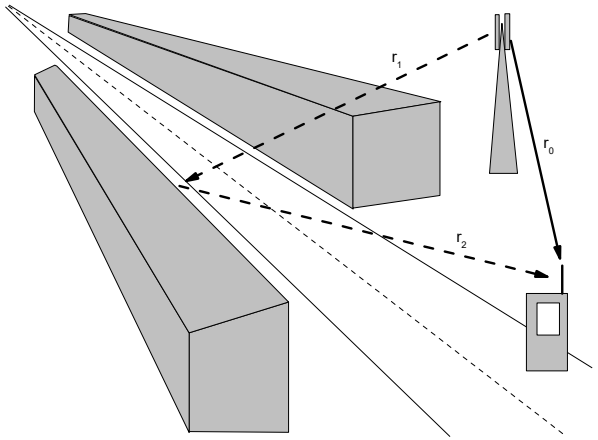


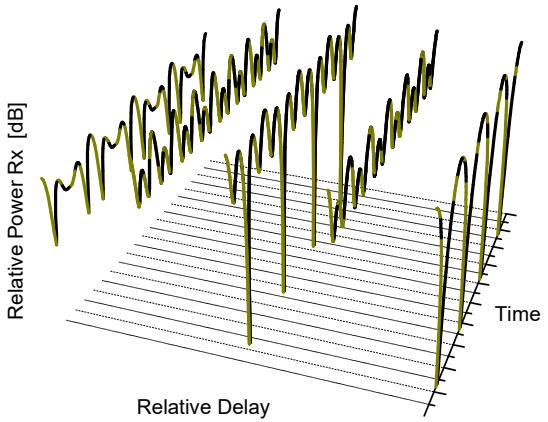
Problems 1: The Wireless Channel

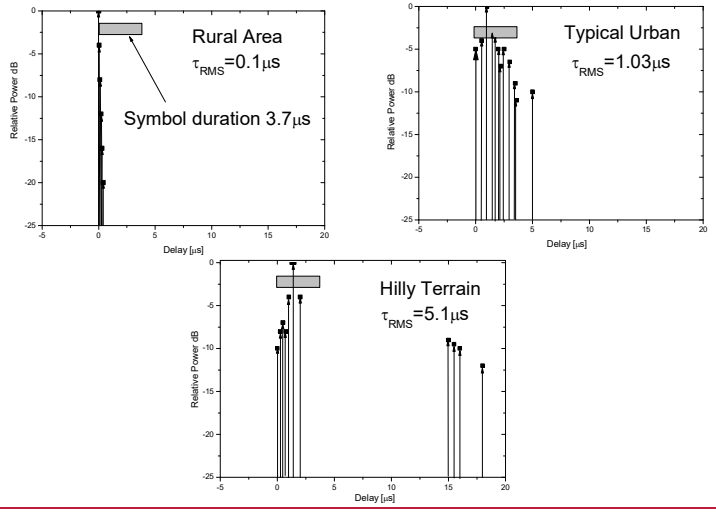


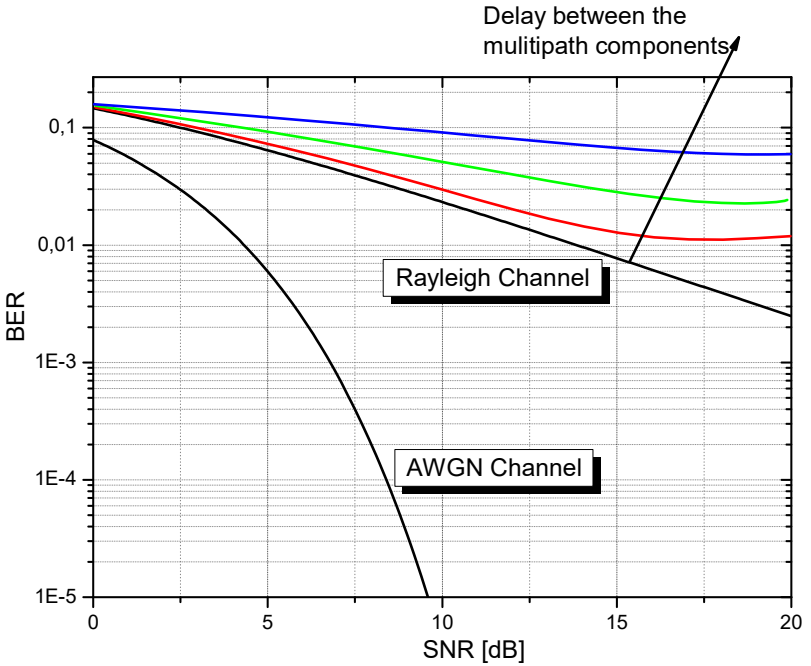


Drahtlose Kommunikation



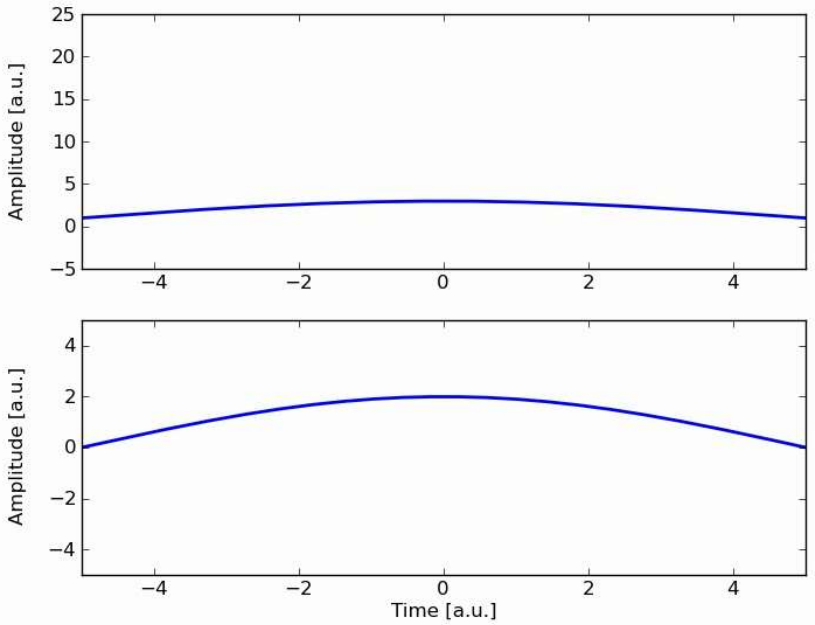






Problems 2: Limited Bandwidth

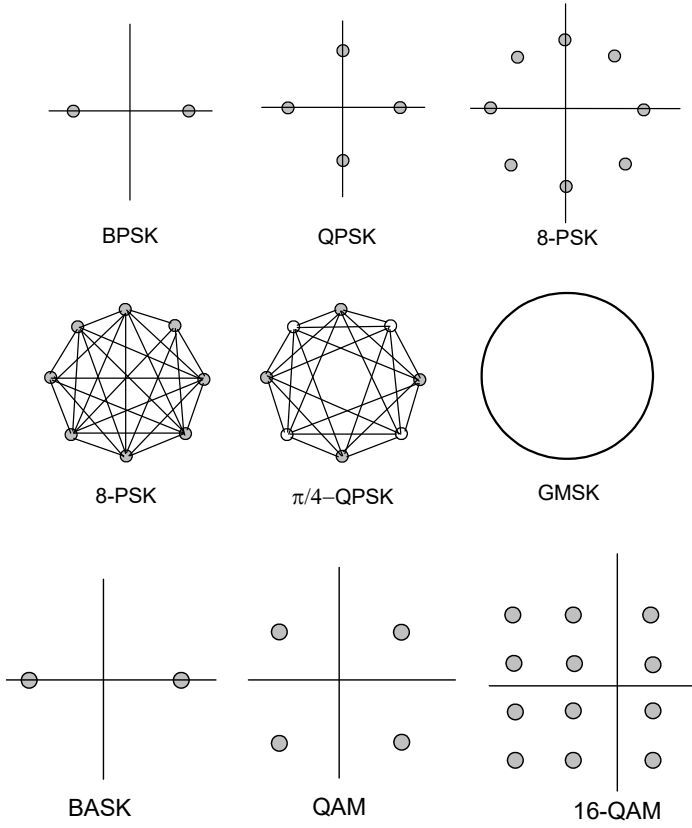
$$E(z,t) = \left|\hat{E}\right| \cos(k_0 z - \omega t + \varphi_0) e_i$$

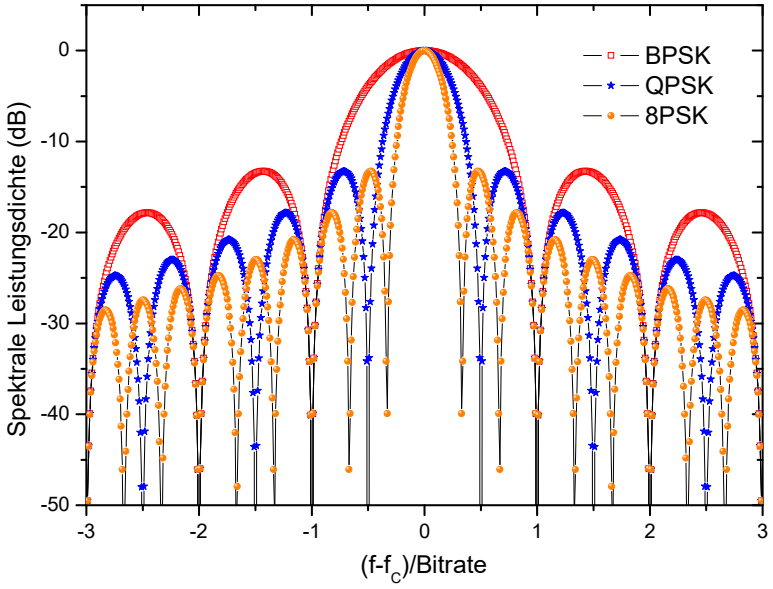


Solution today: spectral efficiency

1. Spectral efficient modulation
2. Spectral efficient coding
3. MIMO
4. Error correction
5. Small cells

Solution #1: spectral efficient modulation





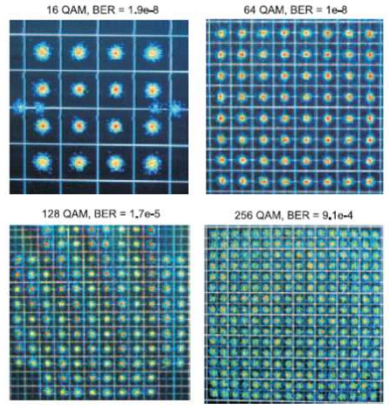
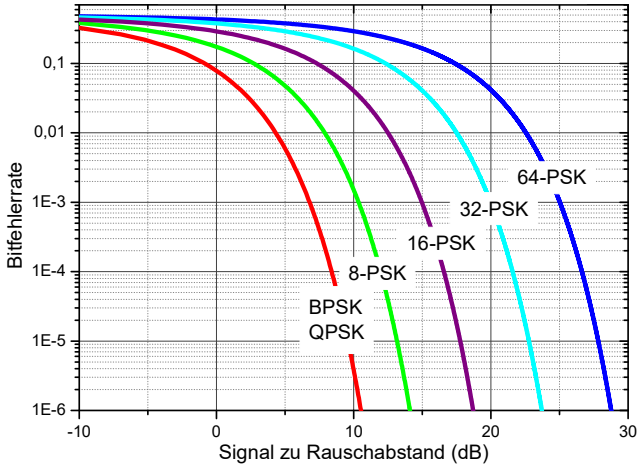
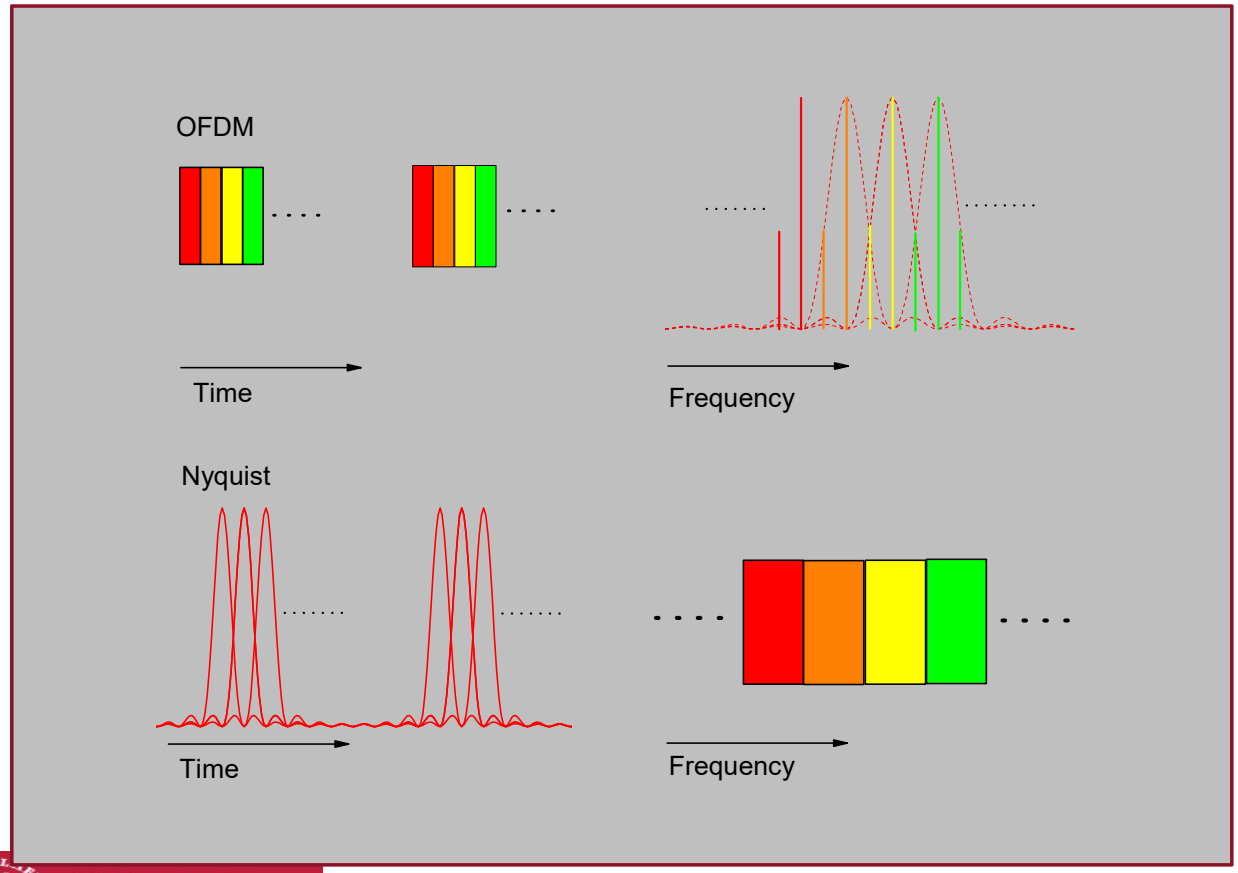
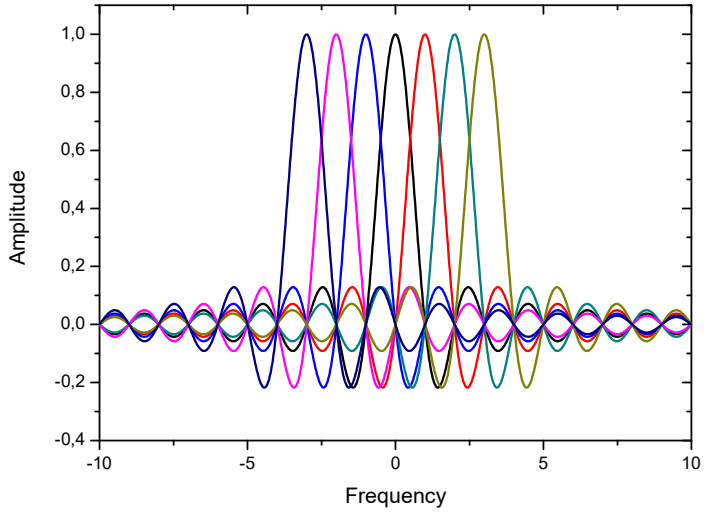


Figure 12. Constellation diagrams for 16- to 256-QAM transmission and corresponding uncorrected bit error rates.

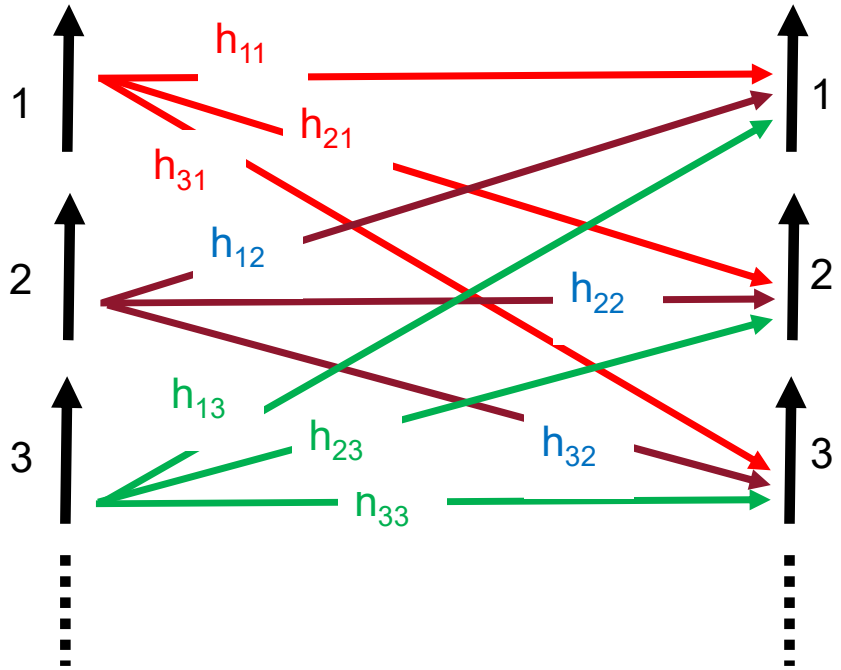


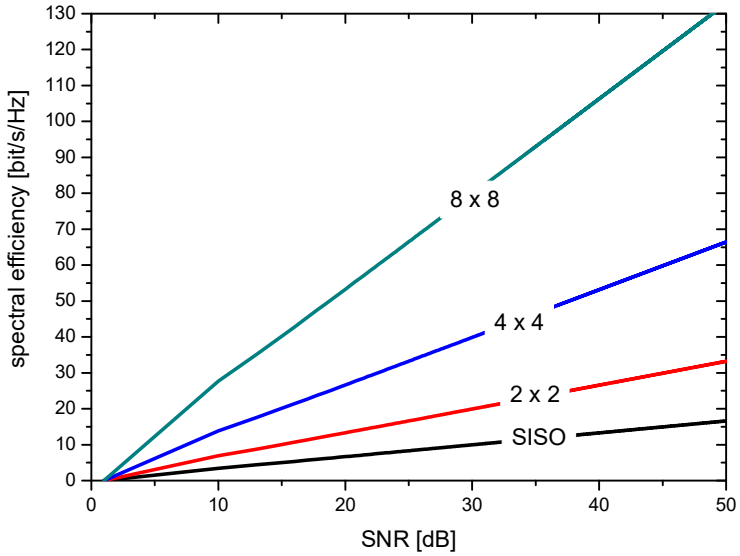
Solution #2: spectral efficient coding



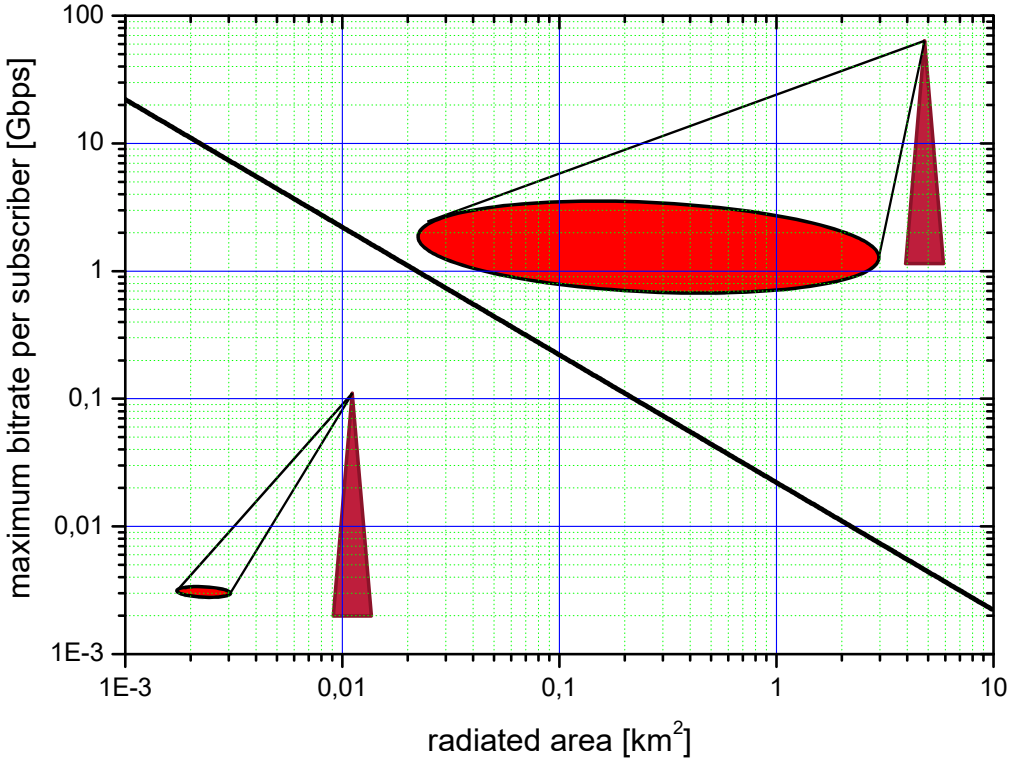


Solution #3: MIMO





Solution #5: small cells



$$C_T = \frac{B}{AN_A}\log_2\left(1+\frac{P_T}{kTB}A_eN_A\right)$$

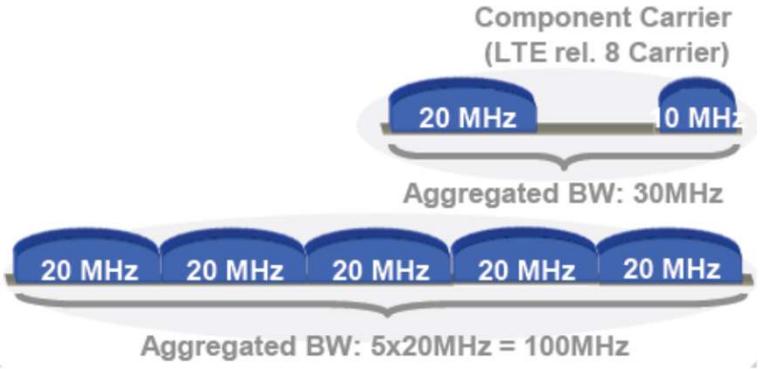
A	radiated area	
N_a	subscriber density	100 km^{-2}
P_T	transmitted power	10 W
k	Boltzmanns constant	1.38 x 10^{-23} Ws/K
T	temperature	23°C
B	bandwidth in the beam	100 MHz
A_e	effective antenna aperture	1.8 x 10^{-3} m^2 (2GHz)

Inhalt

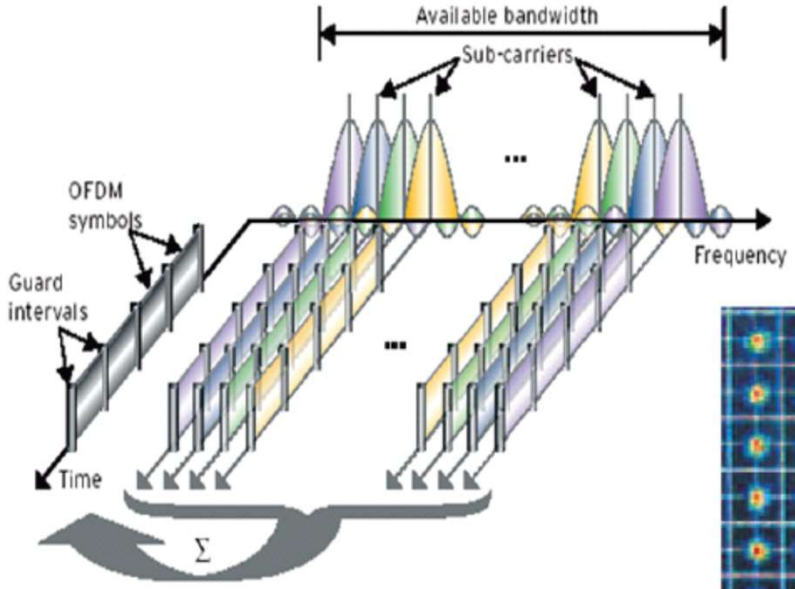
- Beispiele
- Maximale Datenrate in begrenzter Bandbreite
- **Beispiel LTE**

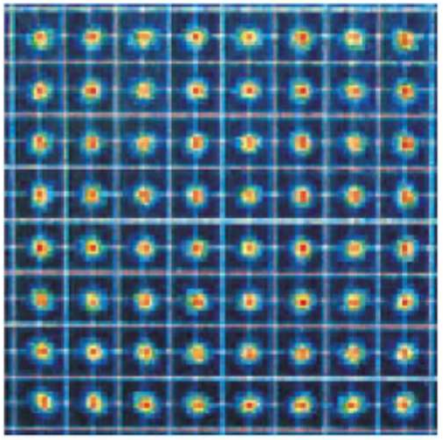
Example: LTE and LTE-A

- up to 100 MHz
- Flexible component carrier aggregation
  - different frequency bands
  - asymmetric in UL/DL



Bandwidth Extension



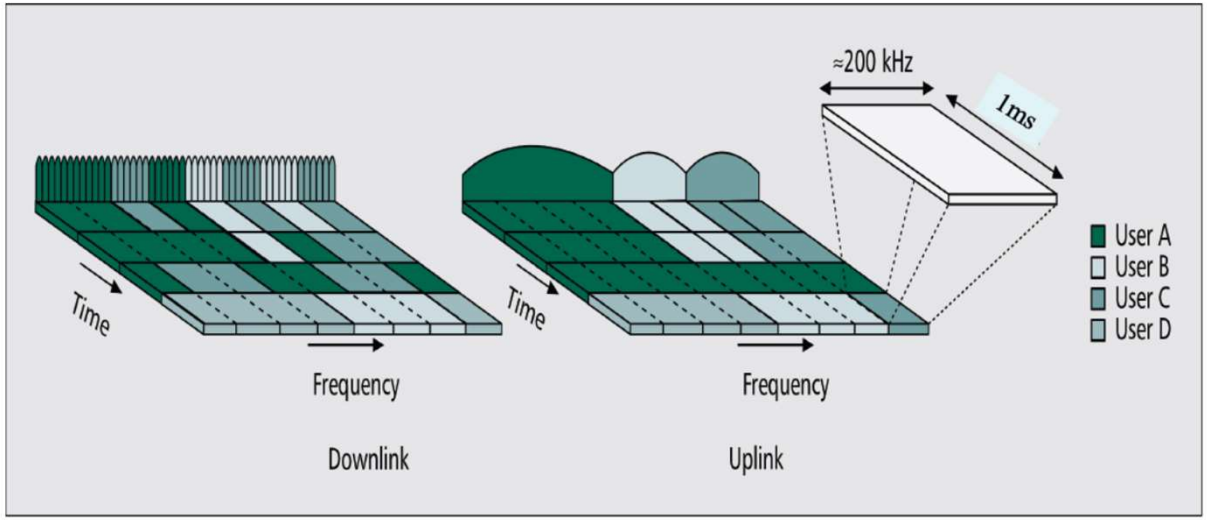


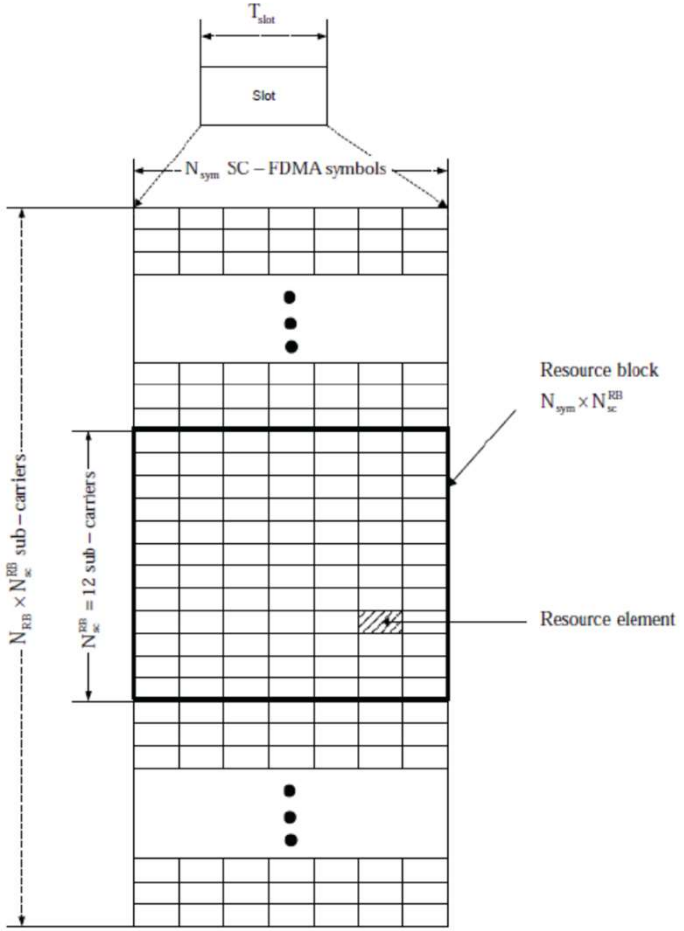
64 - QAM

With permission from T. Haustein & T. Magedanz Fraunhofer HHI & Focus

Drahtlose Kommunikation

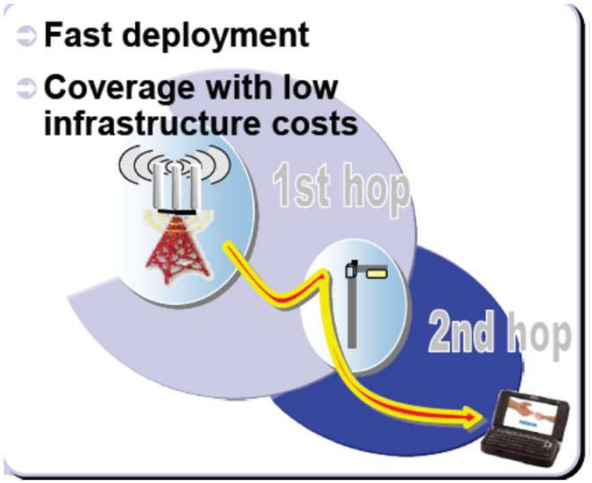
- LTE requires new transmission technologies in PHY
  - Downlink: MIMO-OFDM
  - Uplink: SC-FDMA



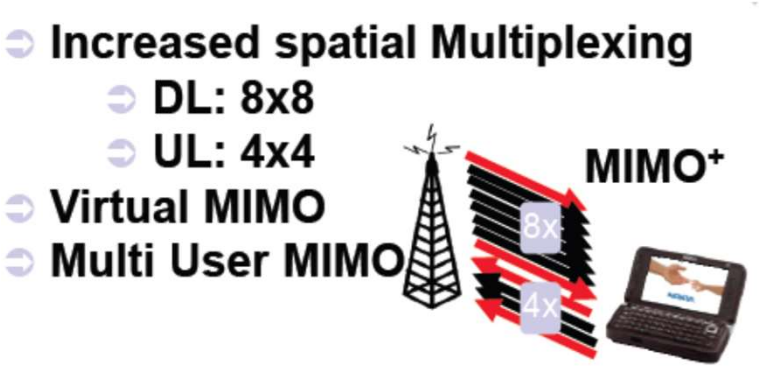


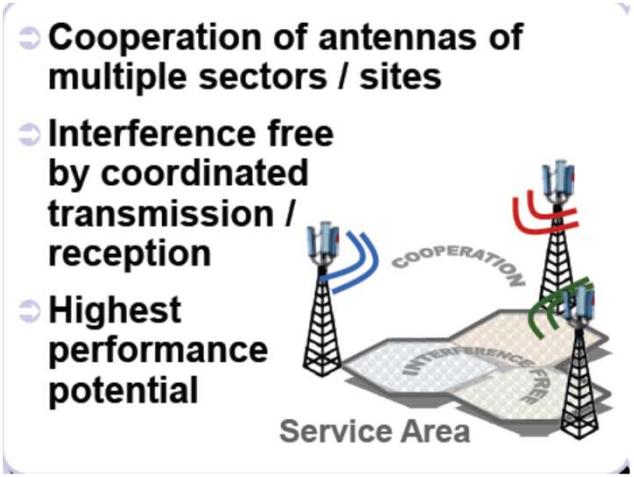
With permission from T. Haustein & T. Magedanz Fraunhofer HHI & Focus

Drahtlose Kommunikation



Multihop technology



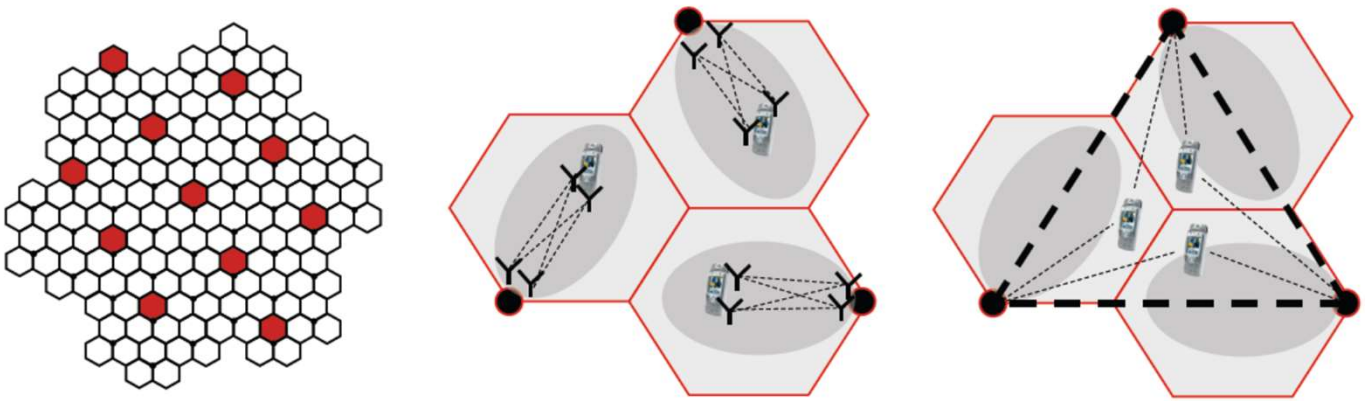


Cooperative antennas

With permission from T. Haustein & T. Magedanz Fraunhofer HHI & Focus

Interference Management – Change in Paradigm

1st/2nd generation	3rd generation	4th generation
• Interference **Avoidance** through high reuse factors	• Interference **Suppression** through classical MIMO	• Interference **Shaping** and **Exploitation** through **Distributed MIMO** and **Relaying**



With permission from T. Haustein & T. Magedanz Fraunhofer HHI & Focus

Solution today: spectral efficiency

0.3 – 3 GHz

1. Spectral efficient modulation
2. Spectral efficient coding
3. MIMO
4. Error correction
5. Smaller cells

All these solutions are ultimately limited by the restricted available bandwidth.

The higher the spectral efficiency, the higher the energy consumption!!

Example: LTE-A

1 Gbps @ 20 MHz bandwidth → 50 bit/s/Hz

1 Gbps @ 100 MHz bandwidth → 10 bit/s/Hz

10 Gbps @ 100 MHz → 100 bit/s/Hz

Drahtlose Kommunikation

- Traffic from wireless and mobile devices will exceed traffic from wired devices by 2016 [Cisco].
- Current systems: spectral efficiency is increased to keep pace with the incraesing data rates.
- Spectral efficient modulation and coding, MIMO and small cells are the solutions for today.
- However, todays systems < 10 GHz are ultimately limited by the small available bandwidth.
- In future new frequency ranges like mm- and THz-band must be exploited for ultrahigh bitrate data transmission.
- In these windows maximum data rates of 1 Tbps are possible.
- New developments in high frequency generation and first transmission testbeds show very promising results.