DFG-Schwerpunktprogramm „TakeOFDM“

Adaptive Modulation and Multiuser Diversity in OFDM Transmission Systems

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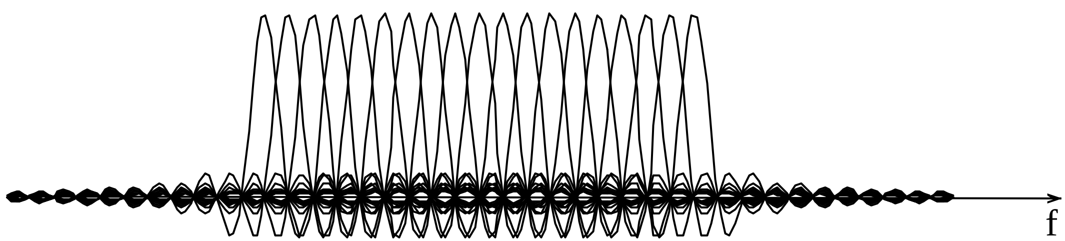
Outline

- Chosen system and channel parameters
- Multiuser situation in OFDM based systems
- Multiuser diversity and subcarrier selection in OFDM-FDMA
- Adaptive modulation in OFDM-TDMA
- Simulation results

Advantages of OFDM

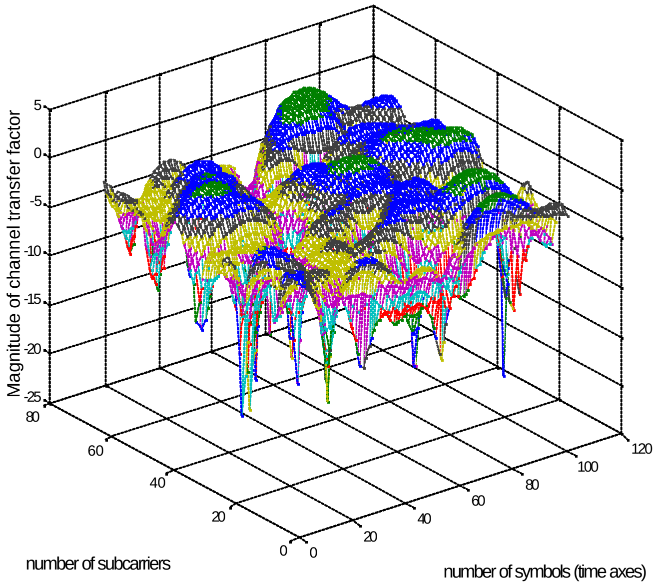
- Robust to multipath radio channel and efficient removal of ISI
- Maintaining orthogonality of subcarriers at the output of a radio channel
- Suitable for high and variable data rate transmission
- Flexible and adaptable to hostile radio channel conditions



WSSUS channel parameters

Maximum delay of the channel	3.2 $m s$
OFDM symbol duration	16 $m s$
Number of multipath	30

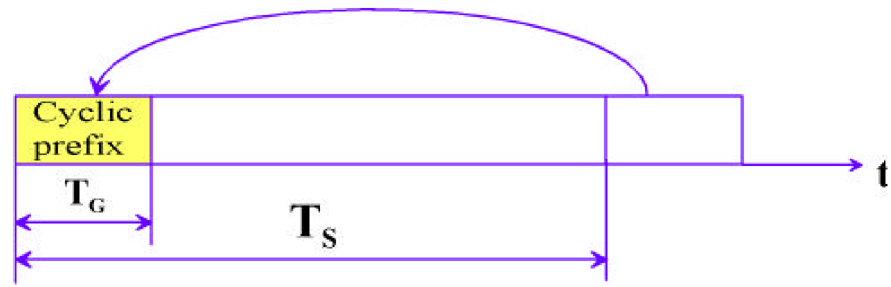
$$h_T(t,t) = \sum_{l=1}^{L} e^{-j(2pf_{D,l}t)-q_l} d(t - t_l)$$

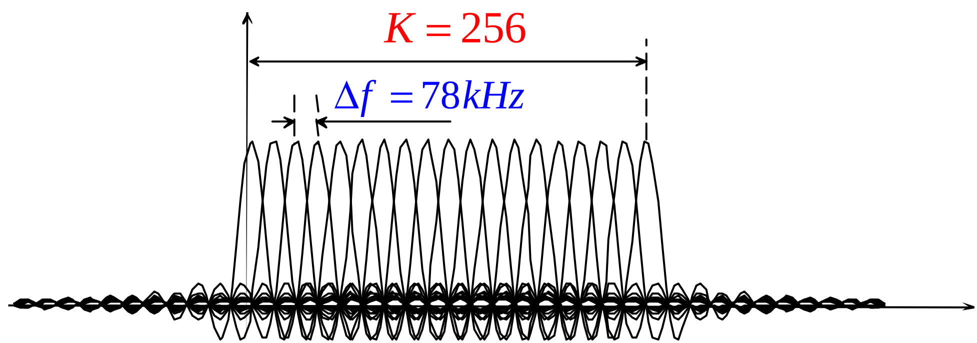


Time variant and frequency selective channel transfer function for a single user

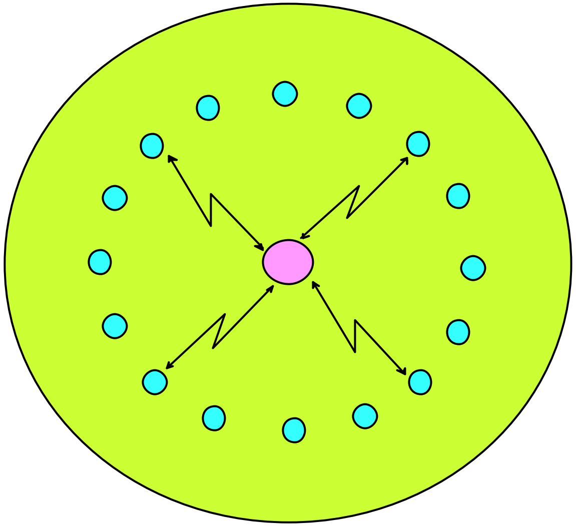
- **OFDM system parameters**

Carrier frequency	f_0=5 GHz
Bandwidth	B=20 MHz
Number of Subcarriers	K=256
Subcarrier distance Df	78125 Hz
Guard interval	T_G=3.2ms
OFDM symbol duration	T_s=16 ms
Total number of users	N_u=16
Convolutional Coder	R=1/2
Considered PHY modes	QPSK, 16QAM R=1/2





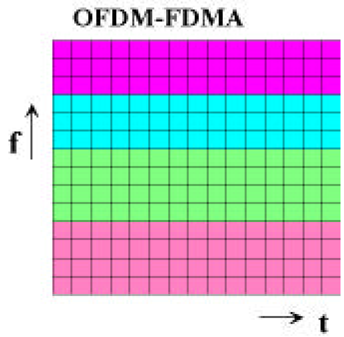
Assumptions on system configuration



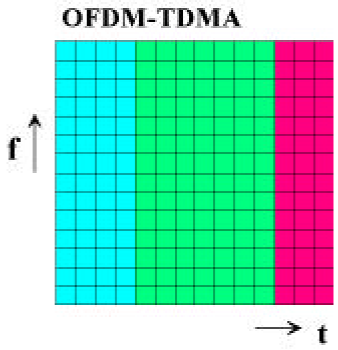
Single cell with 16 users at the same distance from BS

- Same data rate for all users
- Perfect channel knowledge at both receiver and transmitter
- No shadowing and path loss
- Downlink situation
- Time invariant channel, no Doppler
- Perfect syncronisation

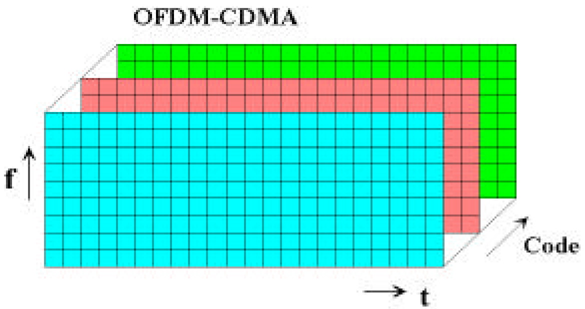
Multiuser situation



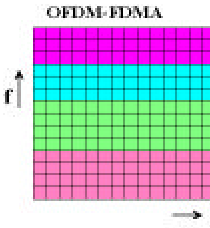
Subcarrier selection for each user



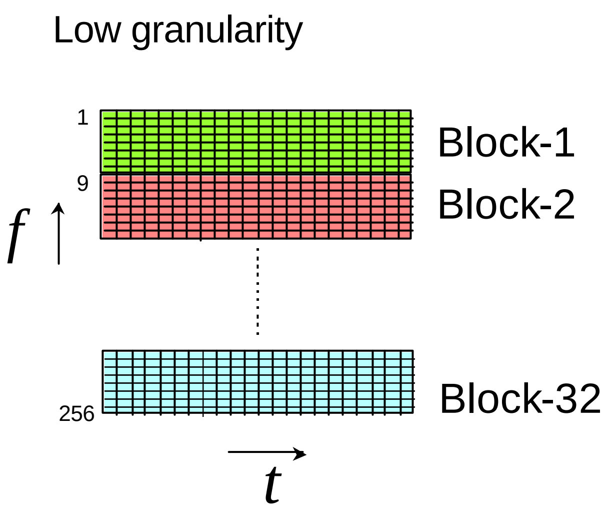
Time slot selection

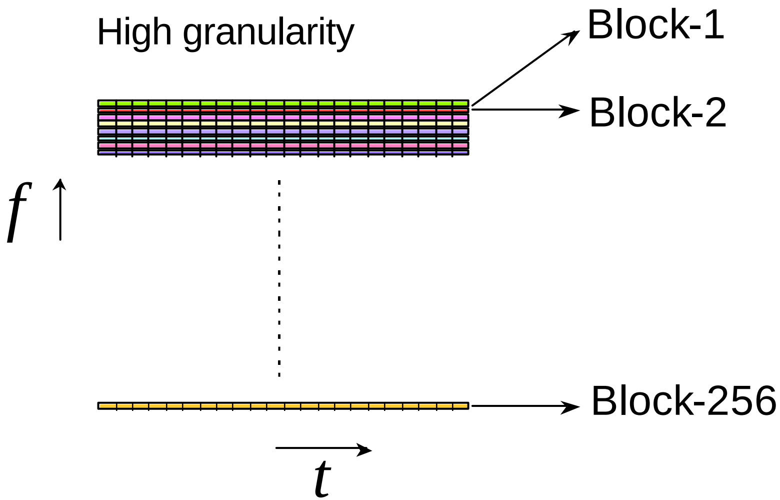


Spreading code selection



Selecting time frequency blocks



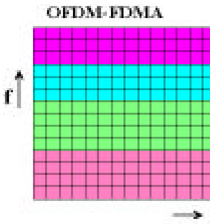


Time frequency block with 8 adjacent subcarriers

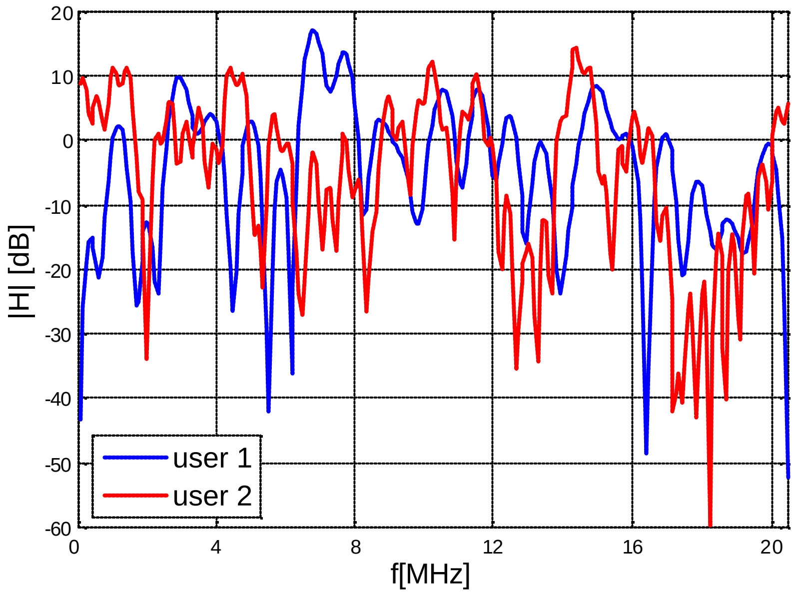
Subcarrier specific time frequency block

low signalling overhead, easy subcarrier selection process

high signalling overhead, high computational complexity for subcarrier selection



Multiuser diversity



Magnitude of channel transfer function
for a radio channel with multiptath

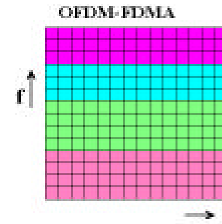
- Subcarriers fade differently from user to user

OBJECTIVES

- Benefit from multiuser diversity
- Select subcarriers with highest possible SNR
- Guarantee all users the same QoS

Selection scheme is most important !

OFDM-FDMA



- Subcarrier selection algorithm

selection criteria: maximize Z

$$Z = \sum_{i=1}^{N_u} \sum_{j=1}^{K} \left| H_{i,j} \right|^2 x_{i,j}$$

Selection parameter

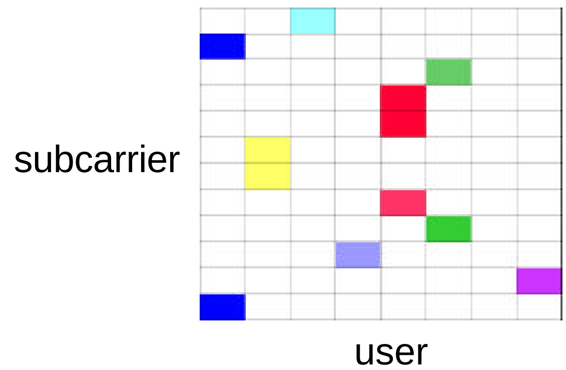
user

subcarrier

$$x_{i,j} = \begin{cases} 1 & \text{allocation} \\ 0 & \text{no allocation} \end{cases}$$

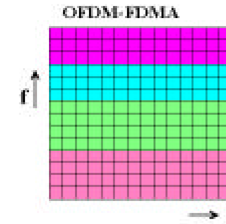
under following constraints

$$\sum_{i=1}^{N_u} x_{i,j} = 1$$



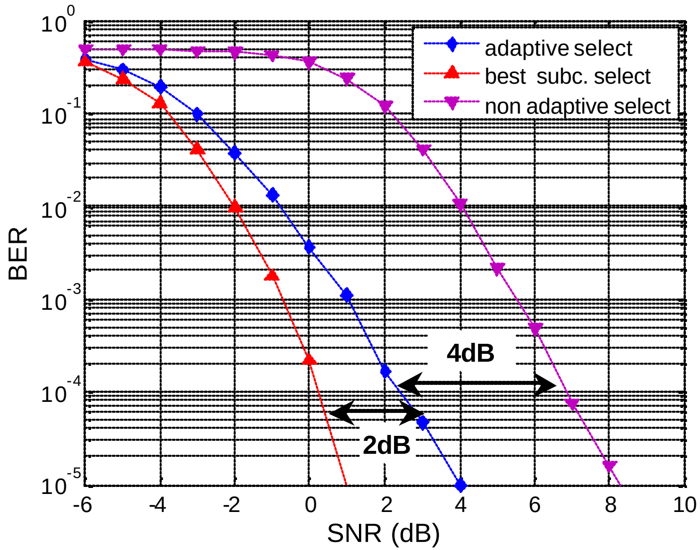
one subcarrier is selected at once, users do not share the same subcarriers

OFDM-FDMA Simulation results



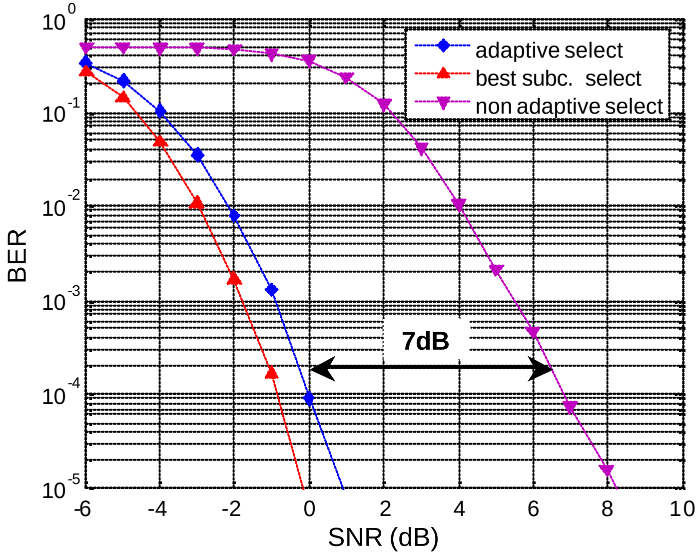
BER of a fully loaded (all users are active) OFDM-FDMA (QPSK, R=1/2)

low granularity



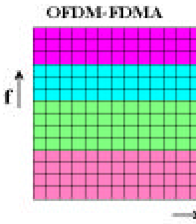
8 subcarriers per block, 16 users

high granularity



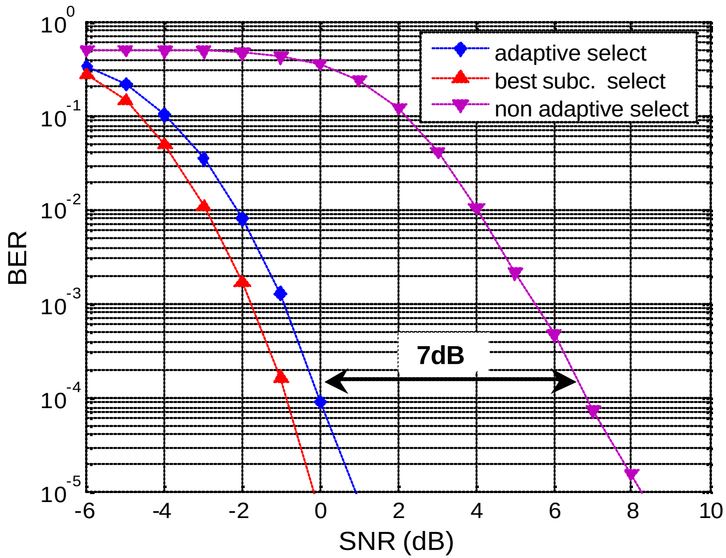
1 subcarrier per block, 16 users

OFDM-FDMA Simulation results



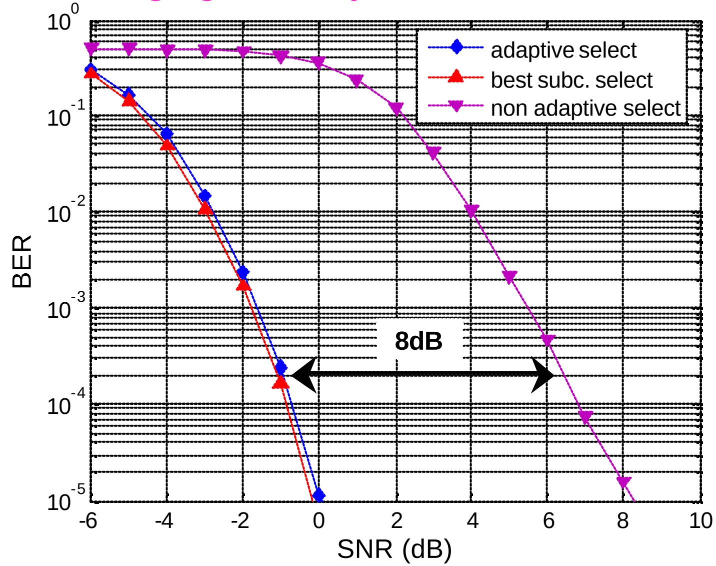
BER of OFDM-FDMA (QPSK, R=1/2)

high granularity



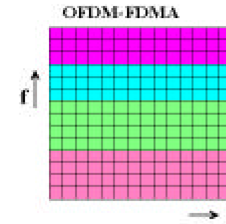
Fully loaded system

high granularity



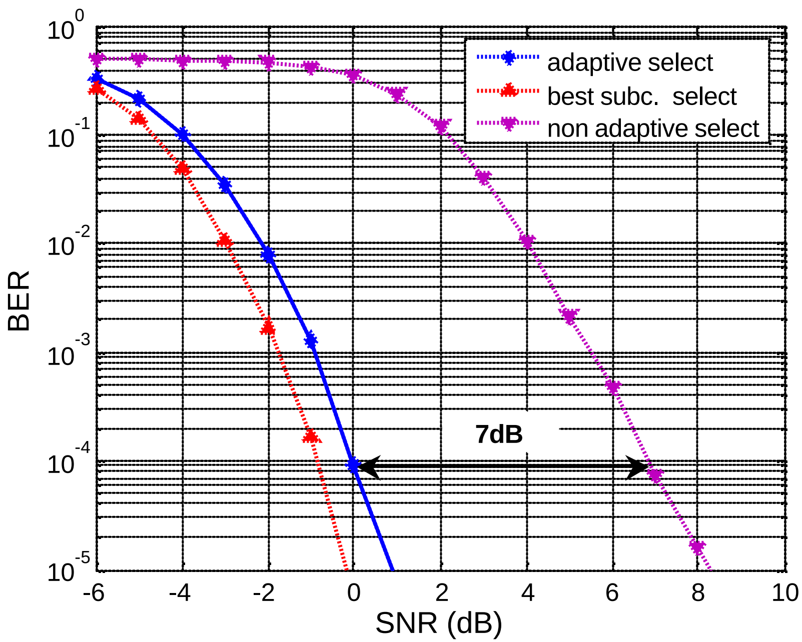
Half loaded system

OFDM-FDMA Simulation results



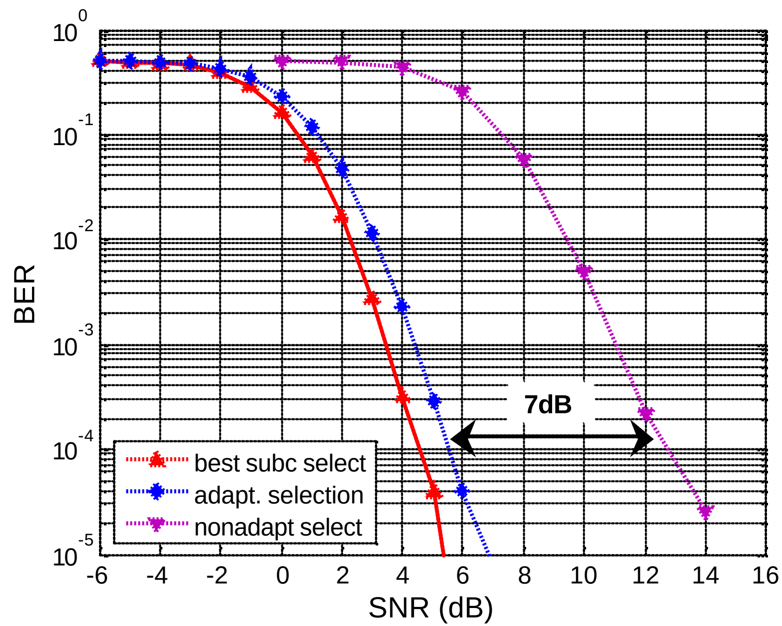
BER of a fully loaded OFDM-FDMA

high granularity



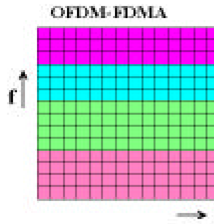
QPSK, R=1/2

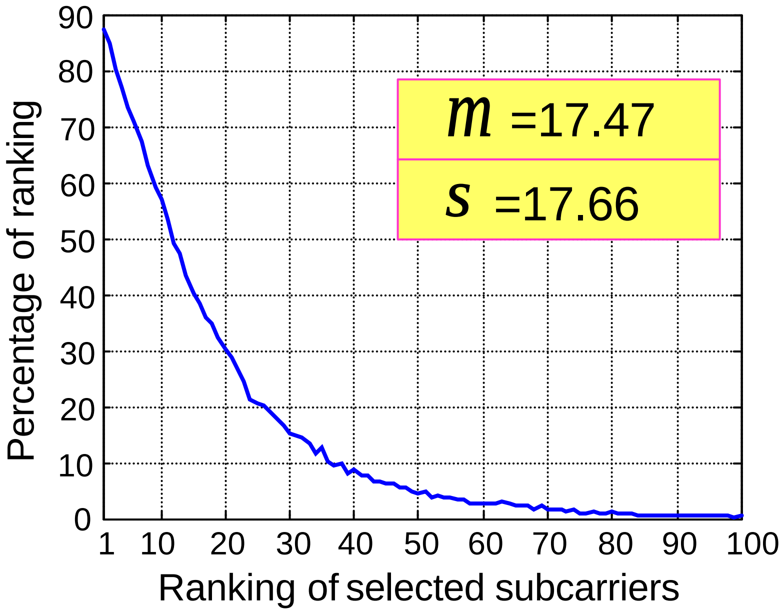
high granularity



16 QAM, R=1/2

OFDM-FDMA Simulation results

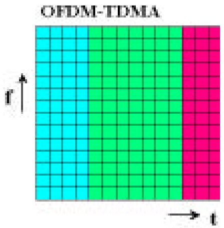


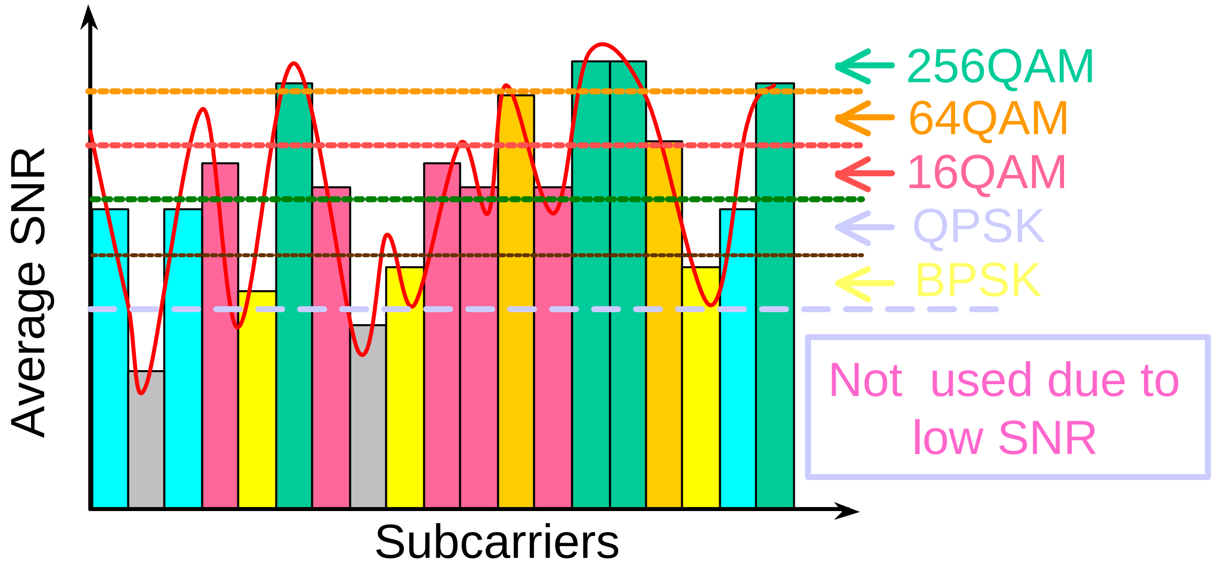


Percentage of the ranking of selected subcarriers for a fully loaded system

- In most cases the best subcarriers are selected
- 90% of selections include best subcarriers

Adaptive modulation





Algorithms: Chow, Cioffi and Bingham: capacity maximization

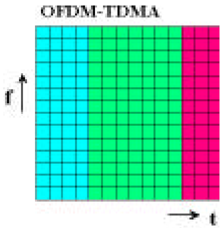
Fischer: Error probability minimization

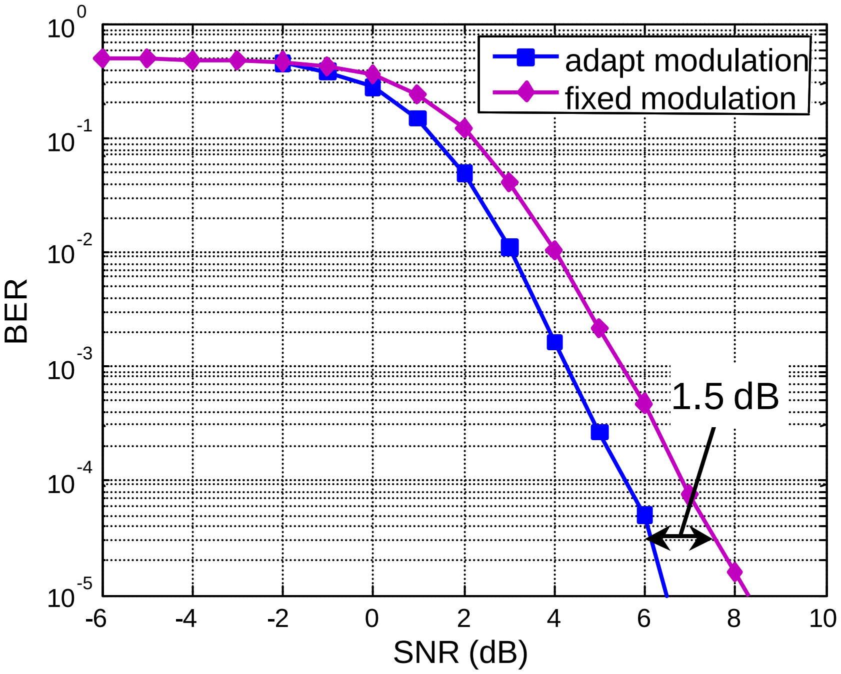
Grünheid: simple blockwise loading algorithm

Hughes-Hartogs: sets target rate R, intensive searching

OFDM-TDMA Simulation results

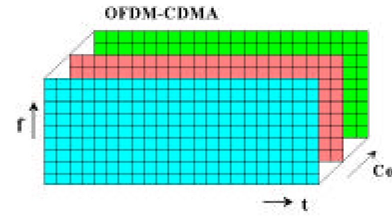
- Adaptive modulation (average 2 bits per subcarrier)





Bit loading by Fischer Algorithm

OFDM-TDMA with fixed and adaptive modulation (R=1/2)



❖ Single User Detection

Despread signals with corresponding spreading codes

Loss of orthogonality between spread codes due to multi access interference (MAI)

MMSE Equalization required

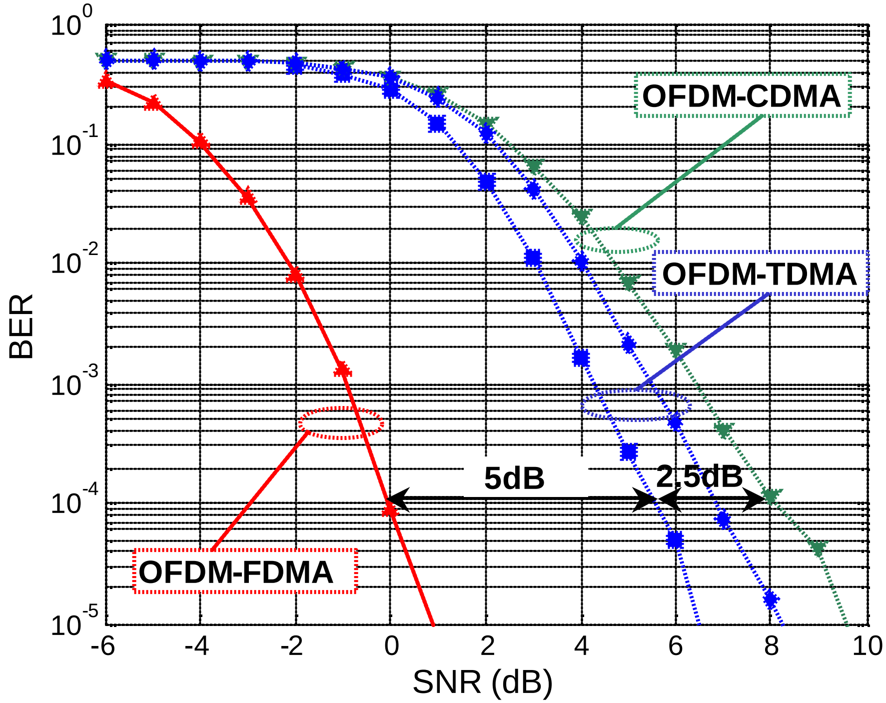
❖ Multi User Detection

Removal of MAI improved performance

High computational complexity

Simulation results

BER performance comparison between OFDM multiple access techniques (QPSK, R=1/2)



Conclusion

- OFDM-FDMA with adaptive subcarrier selection (multiuser diversity) outperforms both OFDM-TDMA with adaptive modulation and SUD OFDM-CDMA
- Subcarrier selection scheme plays a central role for OFDM-FDMA
- OFDM-TDMA achieves better performance with the introduction of adaptive modulation compared with the fixed modulated OFDM-TDMA

Thank you for the attention