



# **Overview of Multiple-Input Multiple-Output (MIMO) Techniques for HSDPA**

**RAN WG2 Meeting**

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## Multiple antenna advantages

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- ◆ **Motivation:**
  - If multiple antennas are used at both the transmitter and receiver, capacity gains and/or power savings are enormous.
- ◆ **Examples [notation: (# tx antennas, # rx antennas)]**
  - At 18dB SNR and 10% outage,  
(1,1) capacity is 3bps/Hz, (4,4) capacity is 17bps/Hz
  - At 10% outage and 3bps/Hz,  
(1,1) system requires 18dB SNR,  
(4,4) system requires less than 3dB SNR.



## MIMO in HSDPA

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- ◆ **Multiple antenna techniques (called multiple-input, multiple-output, or MIMO) have been proposed for providing high speed downlink packet access (HSDPA) on the downlink shared channel (DSCH).**



## MIMO advantages

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- ◆ **Lower SNR for a given data rate**
  - Increases cell region
- ◆ **Smaller constellation sizes (even for high bit rates)**
  - Lower peak-to-average ratio at transmitter
  - Reduced sensitivity to channel estimation errors etc.
- ◆ **Higher peak data rates**
  - Up to 21.6 Mbps with (4,4)



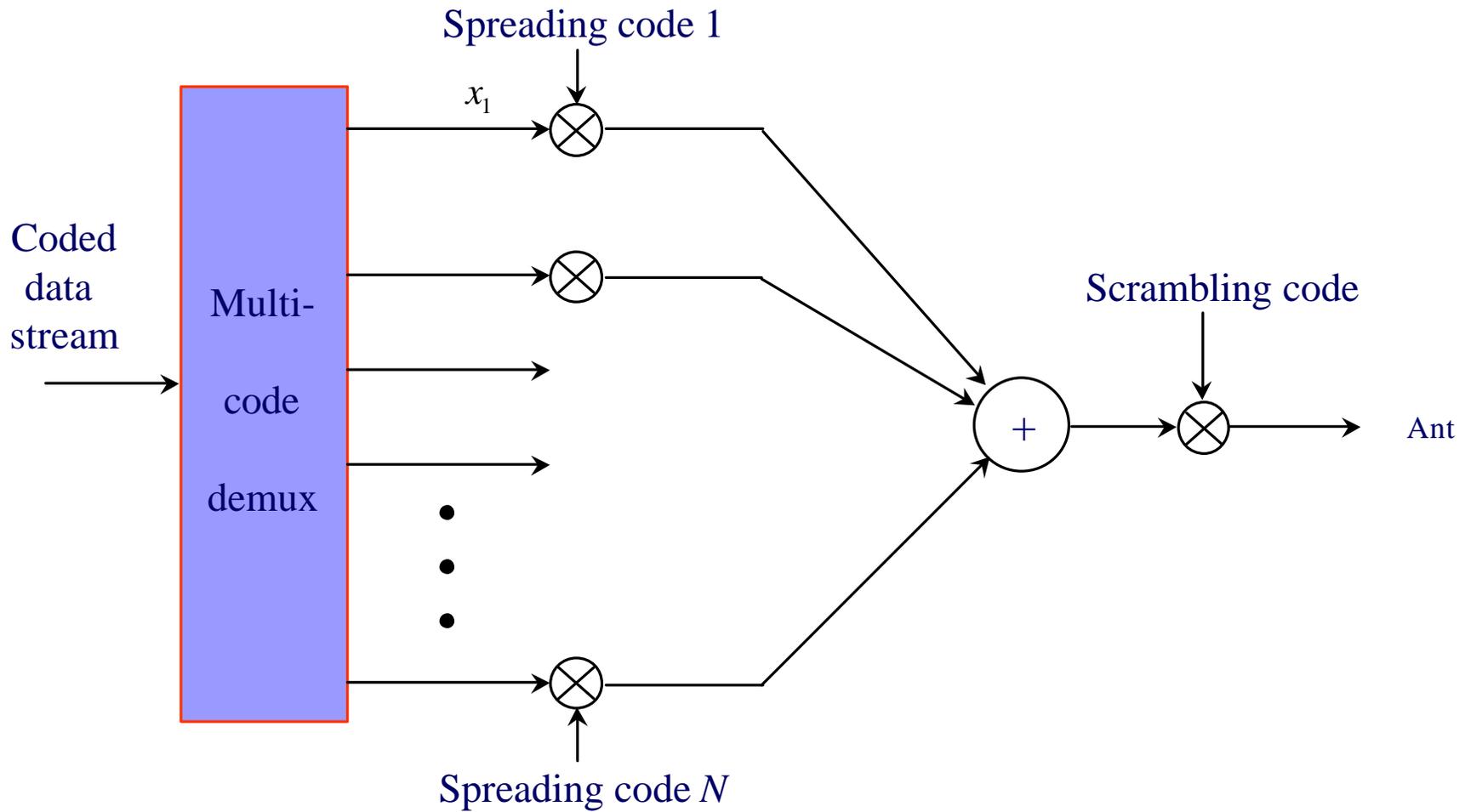
## Outline

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- ◆ **Introduction to MIMO**
- ◆ **Transmission architecture**
- ◆ **Receiver architecture**
- ◆ **Performance results**

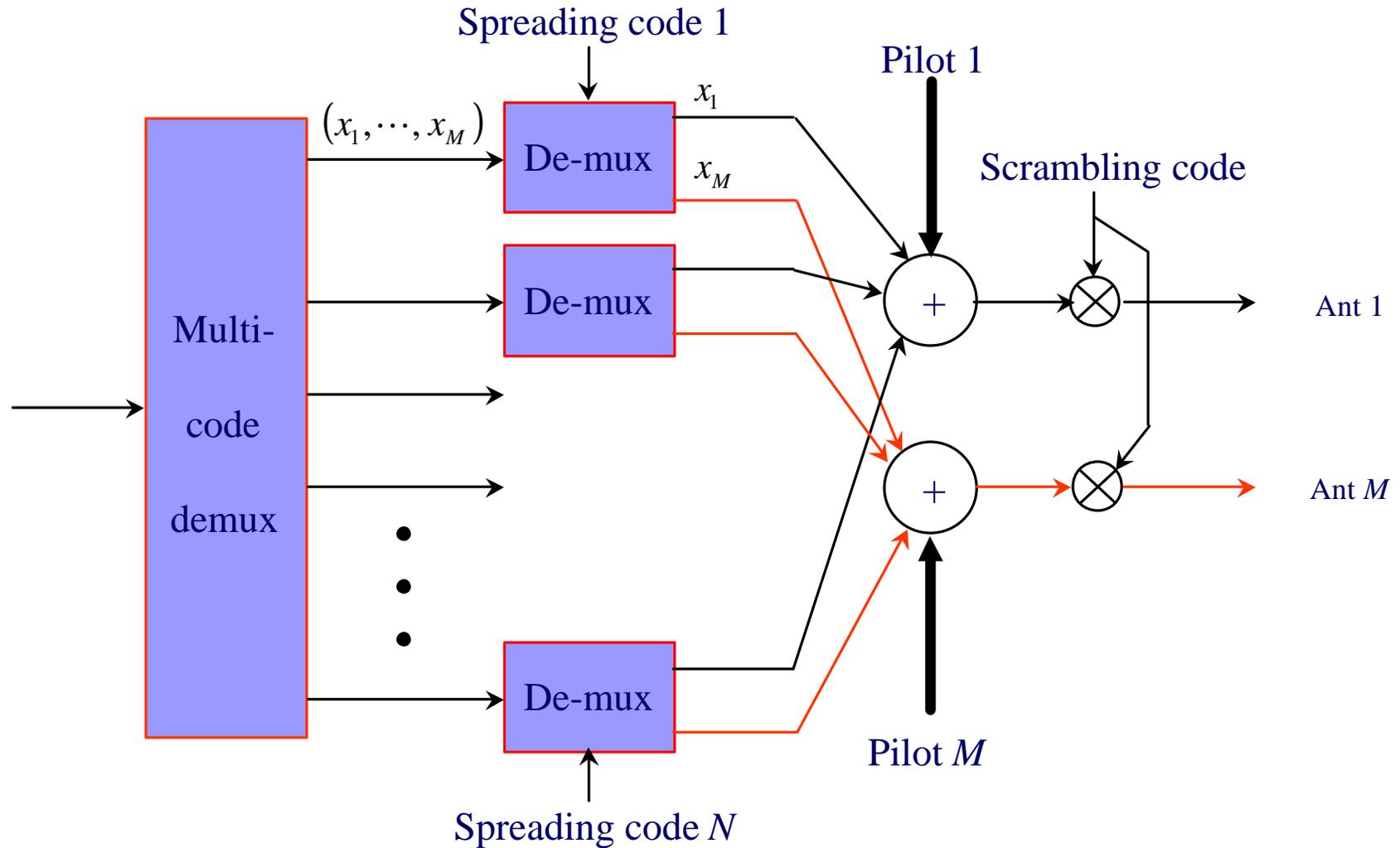


# Conventional transmission





# MIMO transmission with $M$ Tx antennas





## Representative transmission architectures

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# TX ants	TX technique	code rate	modulation	rate per substream	# sub- streams	total rate
1	Conv.	3/4	64QAM	540kbps	20	10.8Mbps
2	MIMO	3/4	8PSK	270kbps	40	10.8Mbps
2	MIMO	3/4	16QAM	360kbps	40	14.4Mbps
4	MIMO	~1/2	QPSK	135kbps	80	10.8Mbps
4	MIMO	3/4	QPSK	180kbps	80	14.4Mbps
4	MIMO	3/4	8PSK	270kbps	80	21.6Mbps

All options use  $N = 20$  spreading codes.



## Base station transmitter impact

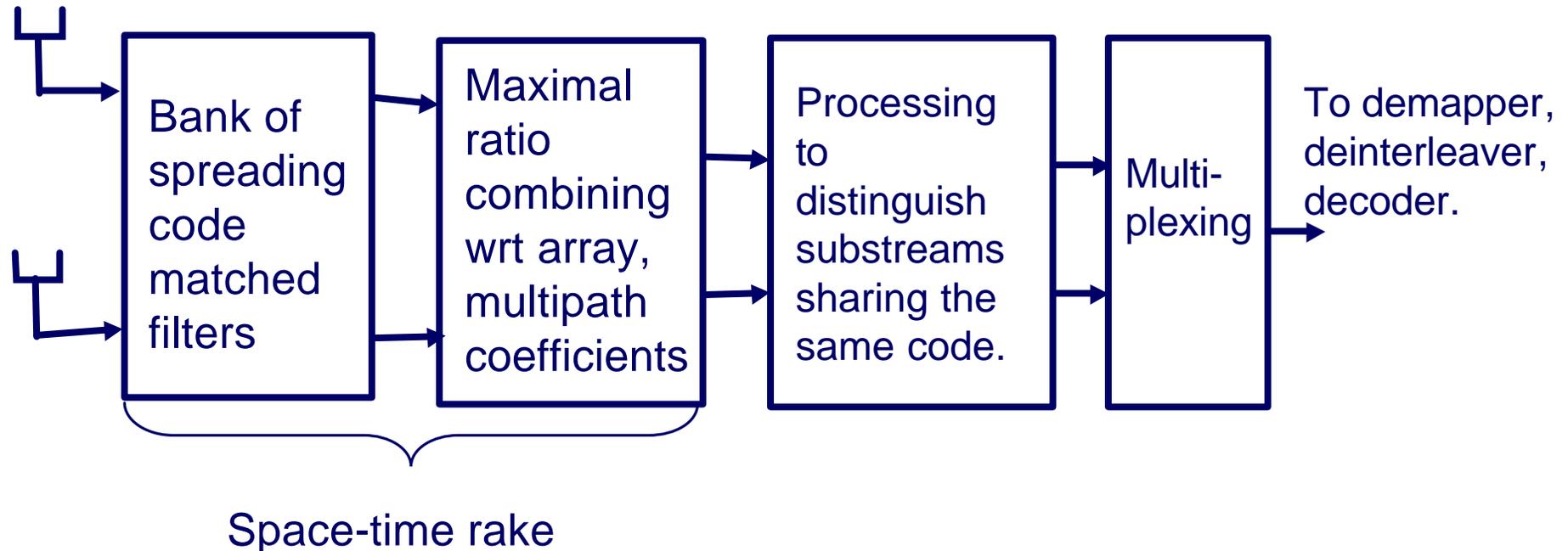
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- ◆ **Baseband impact**
  - additional demultiplexing
  - pilot sequences for each antenna
  - no additional channel codes required
  - code orthogonality is maintained
- ◆ **RF impact: multiple power amplifiers**
- ◆ **Antenna impact: multiple antennas require 2-10 (30 - 150cm @ 2GHz carrier) wavelength spacing for uncorrelated fading.**



## MIMO receiver architecture

- ◆ Multiple antennas and extra processing required for spatially resolving MIMO signals.





## UE receiver impact

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- ◆ **Antenna impact: multiple antennas require  $1/2$  wavelength spacing (about 7.5 cm for 2GHz carrier) for uncorrelated channels.**
- ◆ **RF impact:**
  - RF/IF chain for each receive antenna
  - reduced complexity using homodyne chips
- ◆ **Baseband impact:**
  - additional channel estimators
  - space-time processor for detection
  - faster Turbo decoder (dominates baseband complexity)



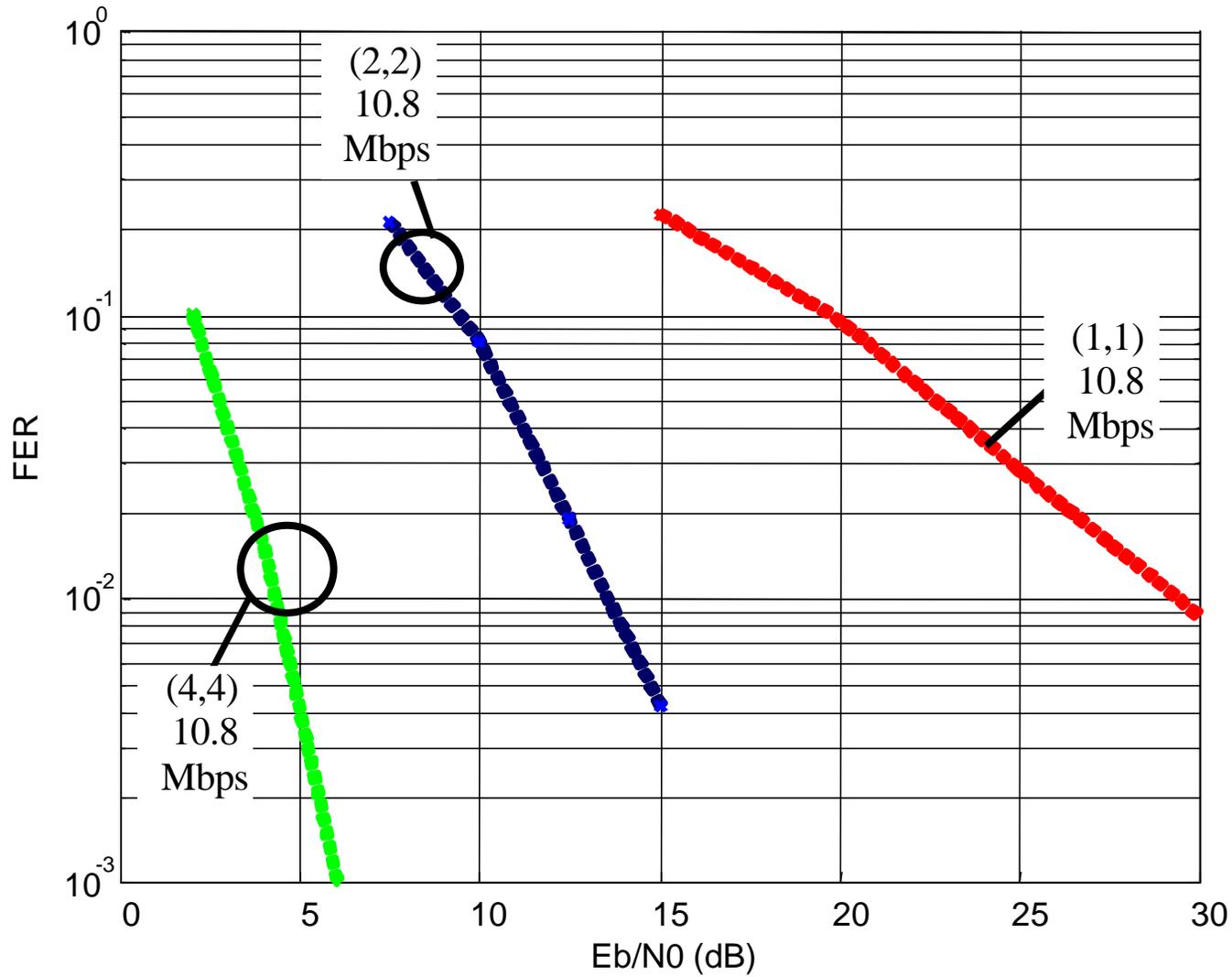
## Initial simulation assumptions

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- ◆ **Turbo coding**
- ◆ **Flat Rayleigh fading channel, 3km/hr  
(later: 30km/hr)**
- ◆ **Uncorrelated fading between antenna pairs  
(later: correlated fading for indoor or urban channels)**
- ◆ **Known channels  
(later: channel estimated from pilot signals)**

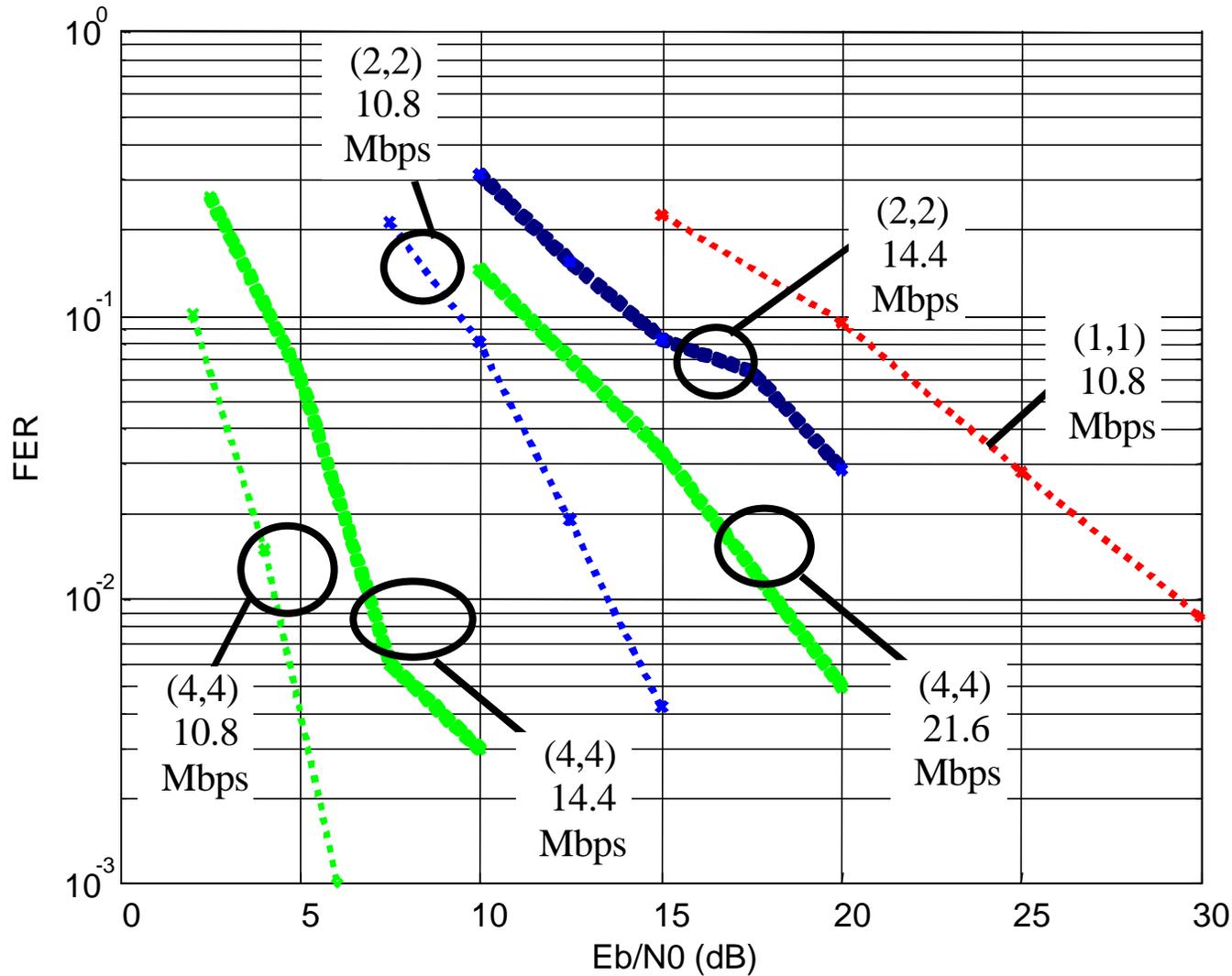


# FER @ 10.8 Mbps, known channels, 3km/hr





# FER @ higher data rates, known channels, 3km/hr





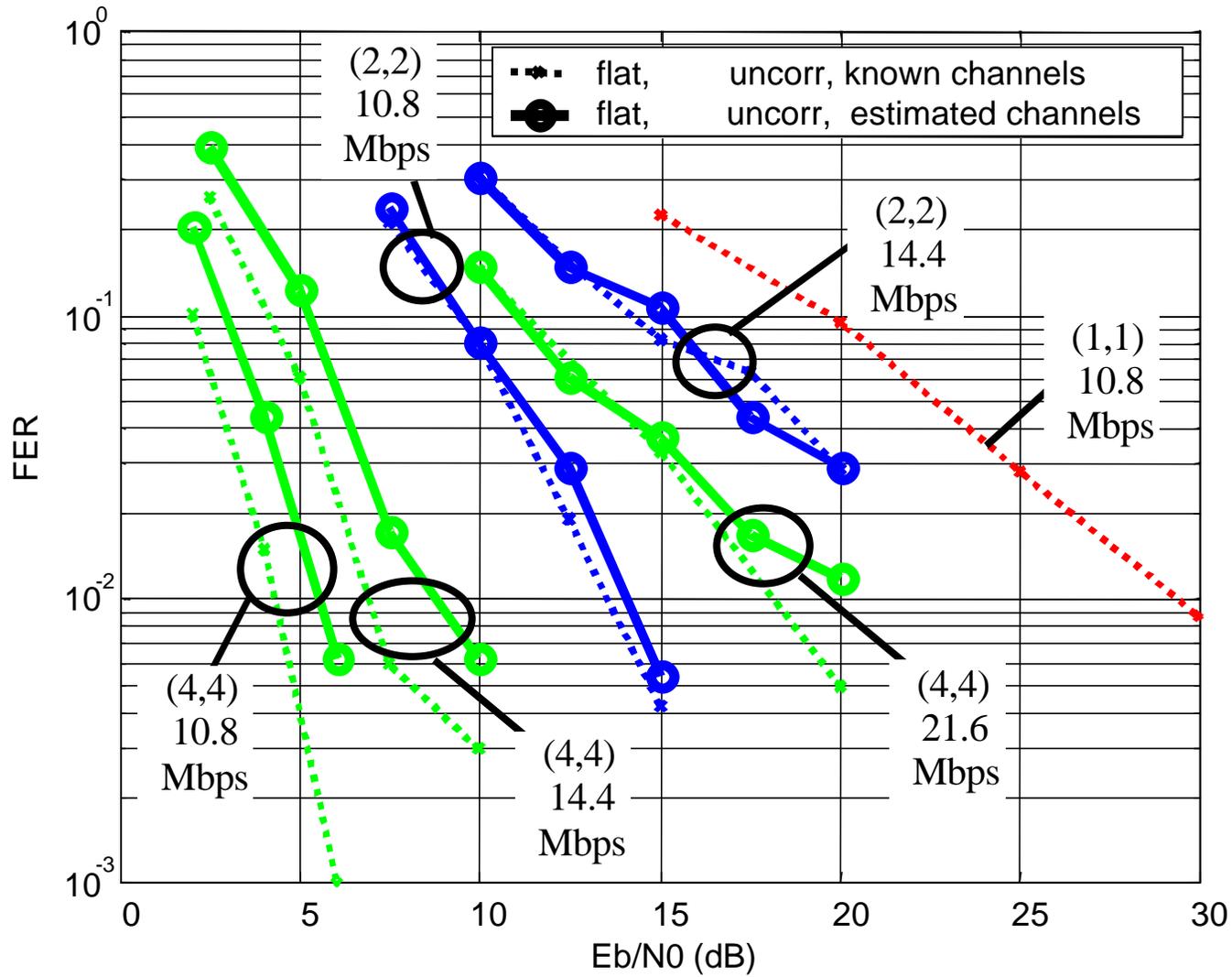
## Channel estimation

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- ◆ Data sequences are length 32.
- ◆ Pilot sequences for each antenna are length 256.
  - Derived from a length 32 code which is orthogonal to the data sequences to maintain overall code orthogonality.
- ◆ Pilot power is 10% of total transmit power and power is distributed evenly among the  $M$  antennas.
- ◆ Channel estimation based on pilot sequence correlation.



# FER with channel estimation, 3km/hr

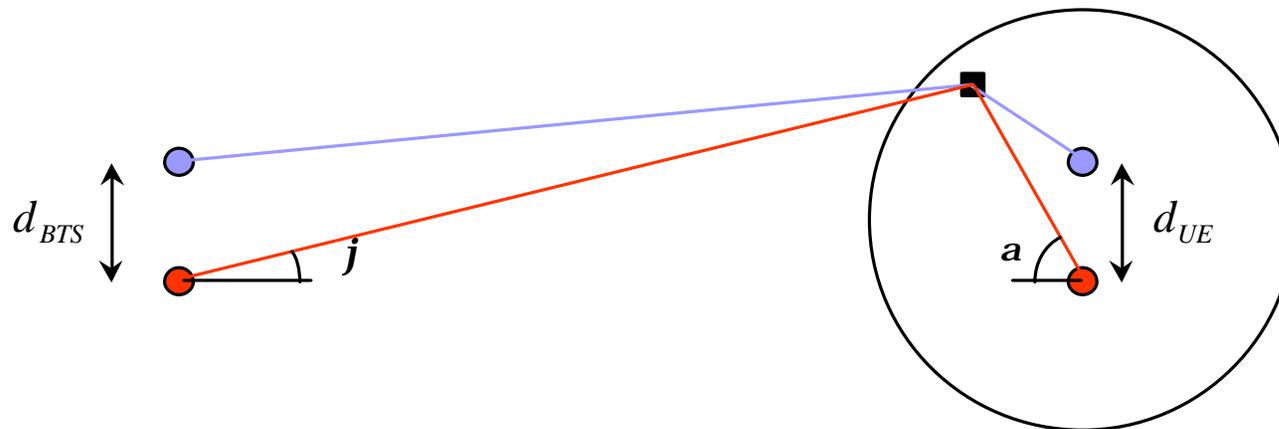






## Correlated channel model

- ◆ Derived from ring of scatterers surrounding terminal [Siemens].
  - Uniform distribution of scatterers:  $\mathbf{j} \in [\mathbf{j}_{\min}, \mathbf{j}_{\max}]$ ,  $\mathbf{a} \in [0, 2\mathbf{p}]$



- ◆ Correlation among receive antennas is independent of transmitter and correlation among transmit antennas is independent of receiver.

$$E[h_{m_1 \rho_1} h_{m_2 \rho_2}^*] = E\left\{\exp\left(j2\mathbf{p} \frac{d(m_1, m_2) \sin \mathbf{j}}{\mathbf{l}}\right)\right\} E\left\{\exp\left(j2\mathbf{p} \frac{d(\rho_1, \rho_2) \sin \mathbf{a}}{\mathbf{l}}\right)\right\}$$



## Correlated channel parameters

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	Urban	Indoor
$d_{BTS}$	$10l$	$2l$
$d_{UE}$	$0.5l$	$0.5l$
$j_{\min}$	7.5 deg	-70 deg
$j_{\max}$	52.5 deg	70 deg
$a_{\min}$	0 deg	0 deg
$a_{\max}$	360 deg	360 deg



## Example: (2,2) channels

$$\mathbf{h} = \begin{pmatrix} h_{11} \\ h_{21} \\ h_{12} \\ h_{22} \end{pmatrix}, \quad h_{ij} \text{ channel from Tx antenna } i \text{ to Rx antenna } j$$

Urban channel

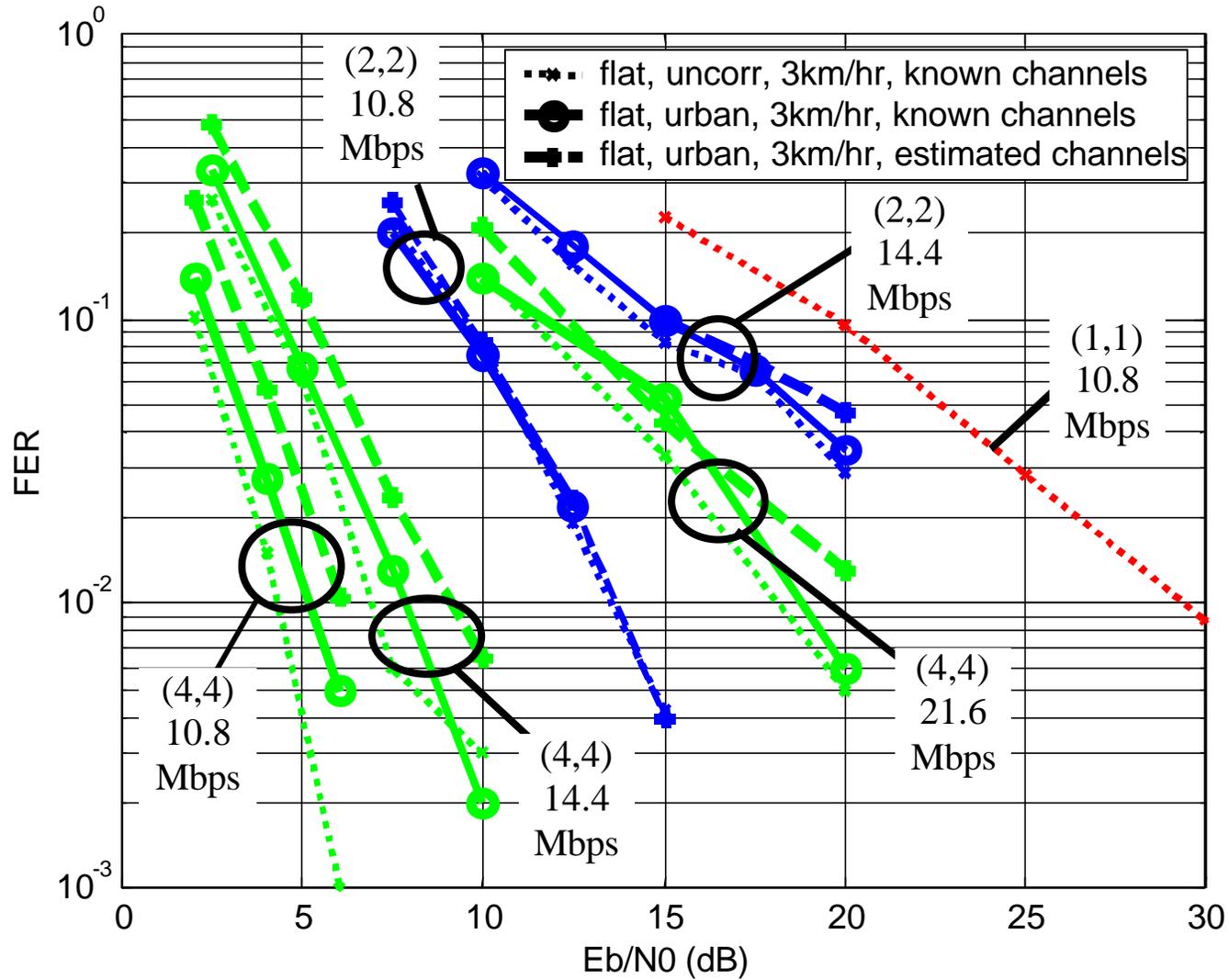
$$\mathbf{R} \stackrel{\Delta}{=} E[\mathbf{h}\mathbf{h}^H] = \begin{bmatrix} 1 & 0.05e^{-j2.3} & 0.30e^{-j3.1} & 0.01e^{j0.9} \\ 0.05e^{j2.3} & 1 & 0.01e^{-j0.9} & 0.30e^{-j3.1} \\ 0.30e^{j3.1} & 0.01e^{j0.9} & 1 & 0.05e^{-j2.3} \\ 0.01e^{-j0.9} & 0.30e^{j3.1} & 0.05e^{j2.3} & 1 \end{bmatrix}$$

Indoor channel

$$\mathbf{R} \stackrel{\Delta}{=} E[\mathbf{h}\mathbf{h}^H] = \begin{bmatrix} 1 & -0.07 & -0.30 & 0.02 \\ -0.07 & 1 & 0.02 & -0.30 \\ -0.30 & 0.02 & 1 & -0.07 \\ 0.02 & -0.30 & -0.07 & 1 \end{bmatrix}$$

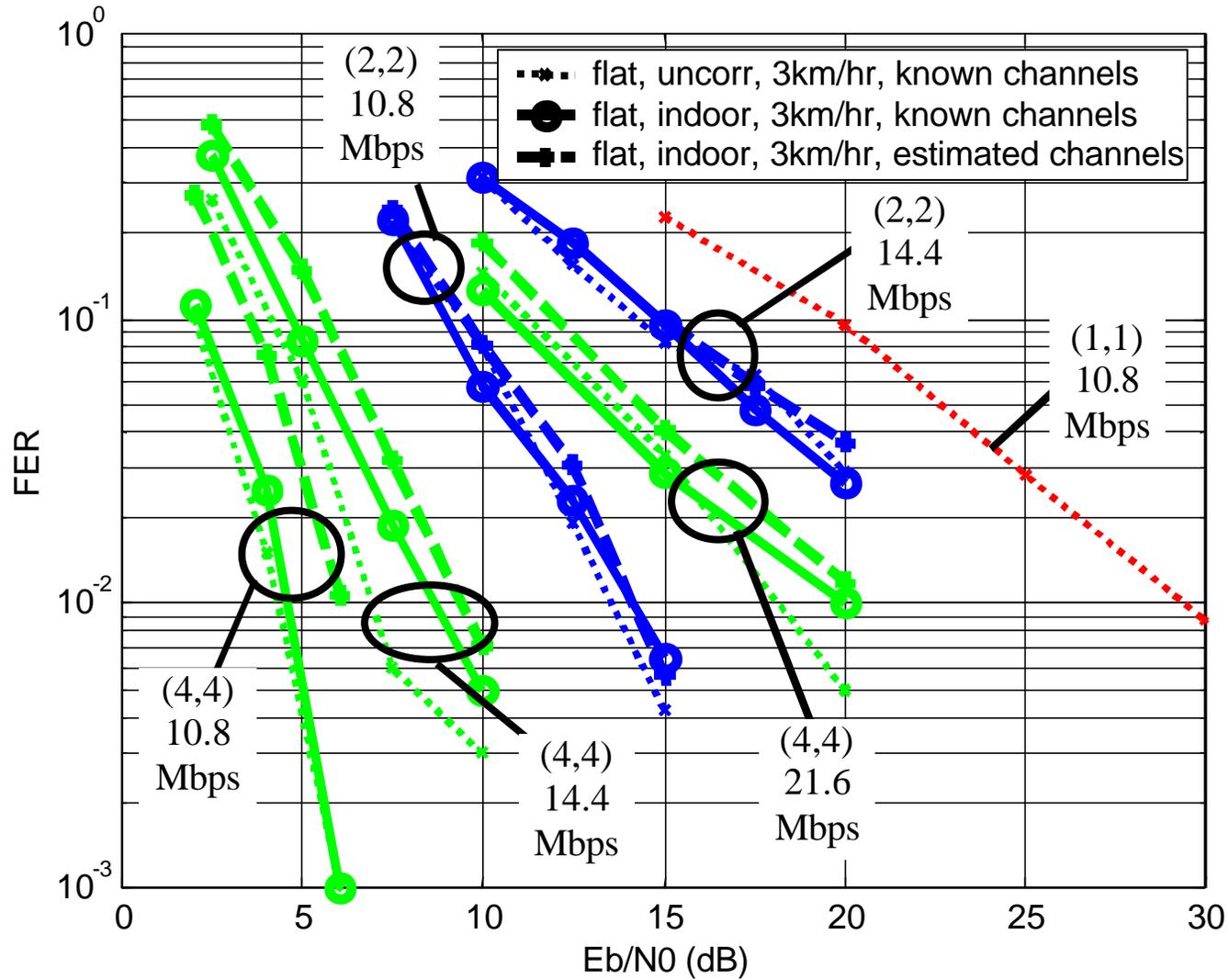


# Urban channel, 3km/hr





# Indoor channel, 3km/hr





## Conclusions

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- ◆ If multiple antennas are used at both the transmitter and receiver, capacity grows *linearly* with number of antennas.
- ◆ Lower required  $E_b/N_0$  for a fixed data rate
- ◆ Smaller signal constellations can be used
- ◆ Higher peak data rates