Comparisons and Discussion

Juha Ylitalo

Contents

Channel capacity (Shannon)

- Represents the maximum error-free bit rate
- Capacity depends on the specific channel realization, noise, and transmitted signal power.

- Single-input single-output (SISO) channel

$$y(t) = \alpha \cdot x(t) + n(t)$$

$$C = \log_2\left(1 + \frac{P}{\sigma_n^2}|\alpha|^2\right)$$

- Multi-input multi-output (MIMO) channel

$$\mathbf{y}(t) = \mathbf{H}\mathbf{x}(t) + \mathbf{n}(t)$$

$$C = \log_2\left[\det\left(\mathbf{I} + \frac{1}{\sigma_n^2}\mathbf{HQH}^H\right)\right]$$

Q is the covariance matrix of the transmitted vector

MIMO versus Rx/Tx Diversity (theoretical)

Spectral efficiency of one channel, no diversity:

$$C=\log_2(1+SNR)\ [b/s/Hz]$$

MIMO with N Tx and M Rx antennas, unknown channel:

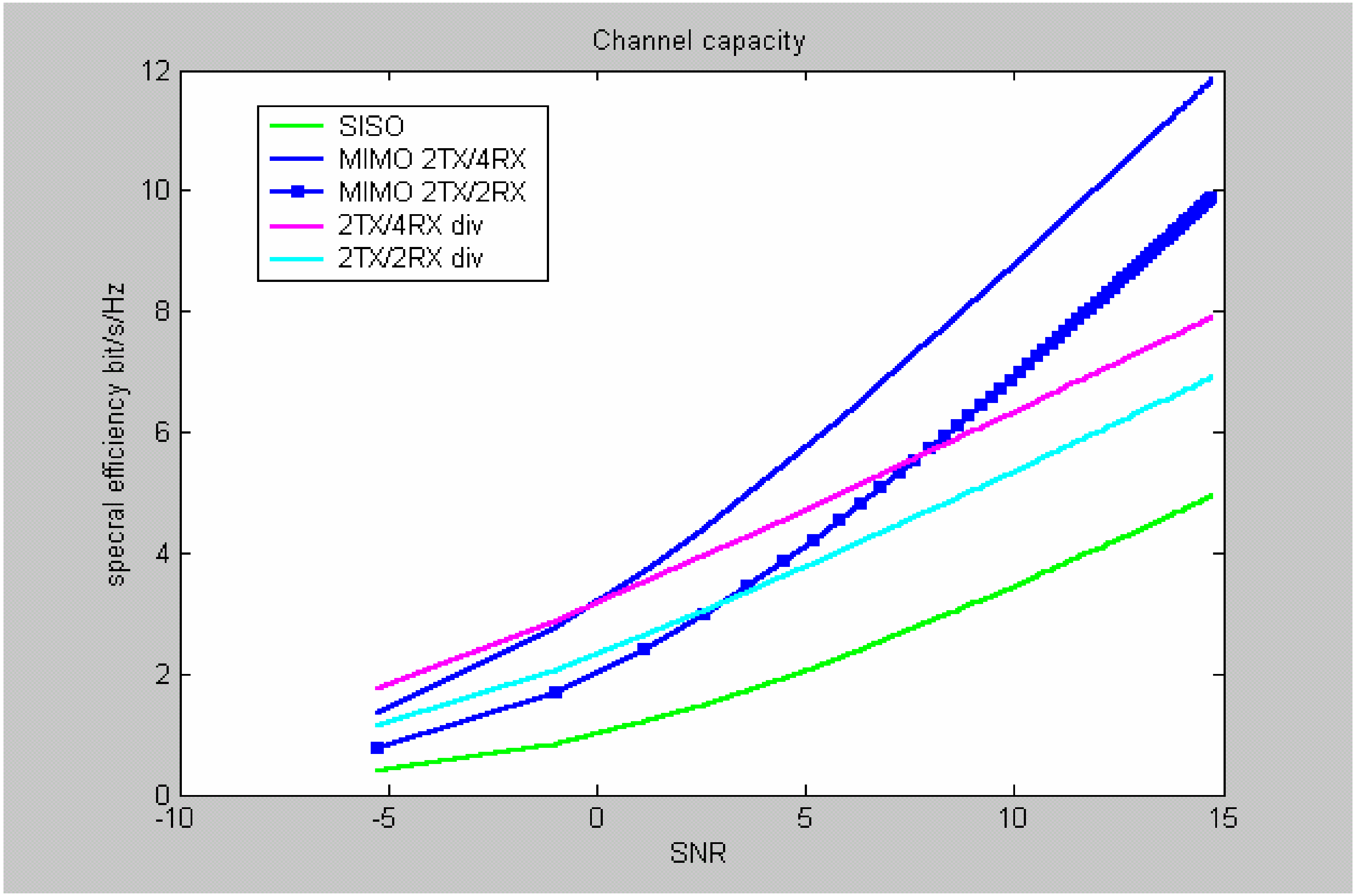
$$C=N\log_2(1+SNR*M/N)\ [b/s/Hz]$$

$$M=N \Rightarrow C= N\log_2(1+SNR)\ [b/s/Hz]$$

Rx & Tx diversity: N Tx and M Rx antennas, known channel:

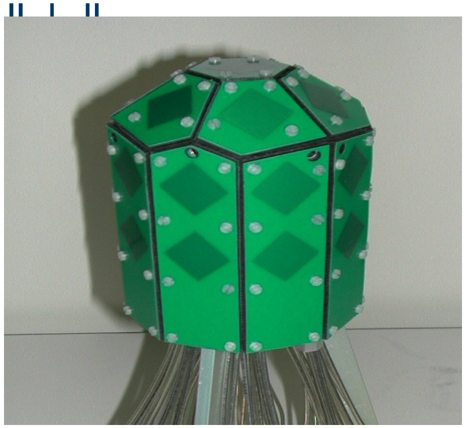
$$C=\log_2(1+SNR*M*N)\ [b/s/Hz]$$

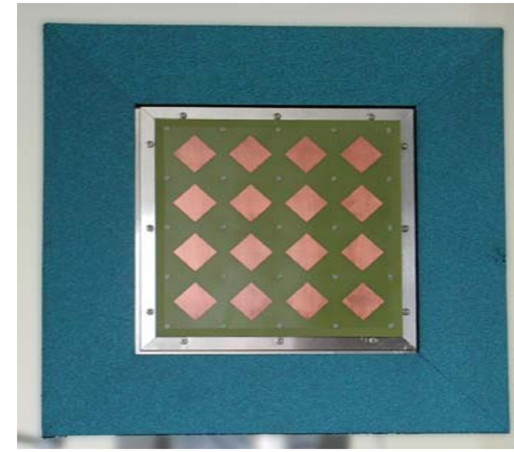
MIMO vs. diversity approaches

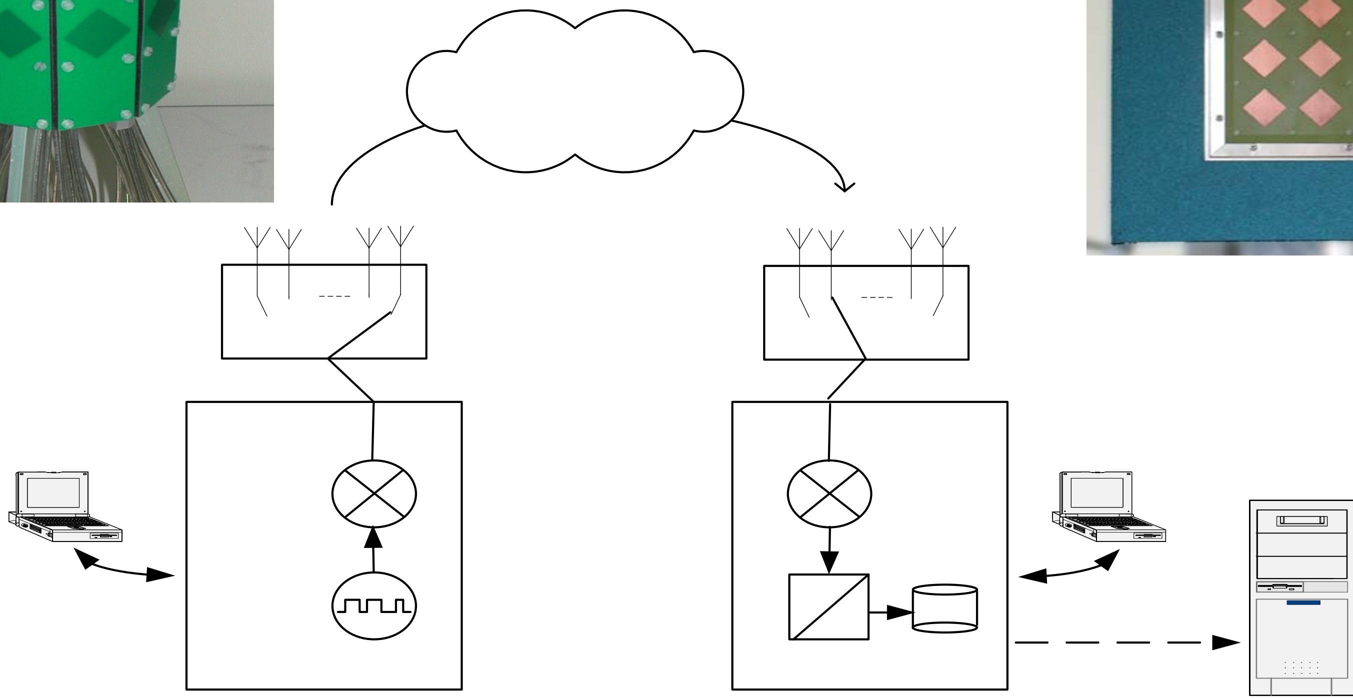


True MIMO has a theoretical potential at high SNRs, while conventional Rx schemes are more attractive at low SNRs

MIMO channel example: PropSound* measurement







Channel

*Trade mark of Elektrobit Ltd.

Table 1. Measurement parameters.

Carrier frequency	5.25 GHz
Chip frequency	100 MHz
Radio environment	LOS / NLOS
No. Tx antennas	9 dual-polarised
No. Rx antennas	16 dual-polarised
Code length	2.55 μs

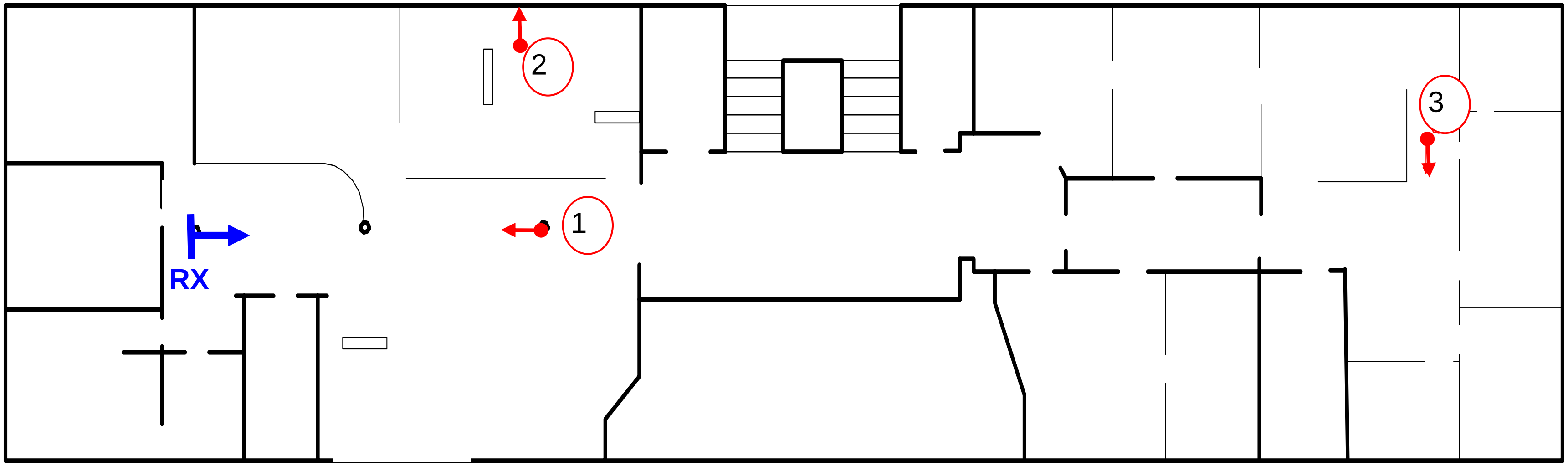


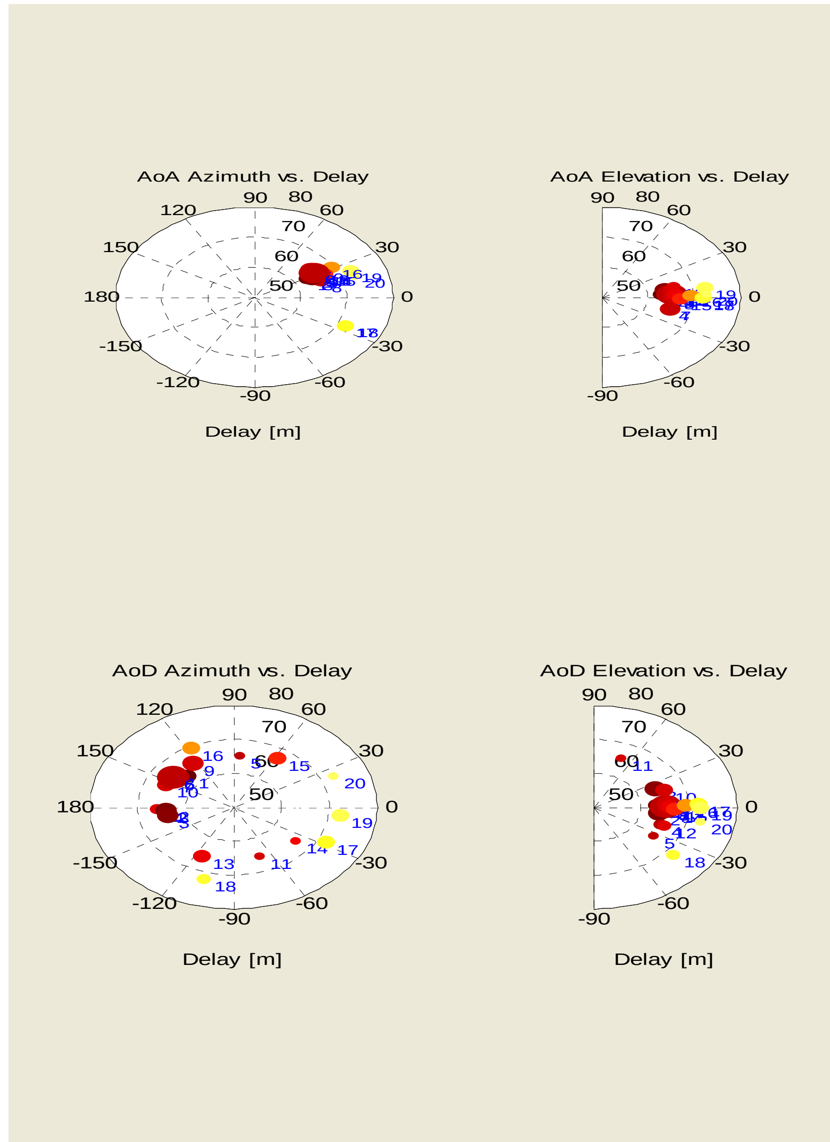
Figure 4. Floor plan of the measurement environment.

Indoor measurement: AoA, AoD

- Position 2: NLOS, SNR ~45 dB

Receiver
(AoA)

Transmitter
(AoD)

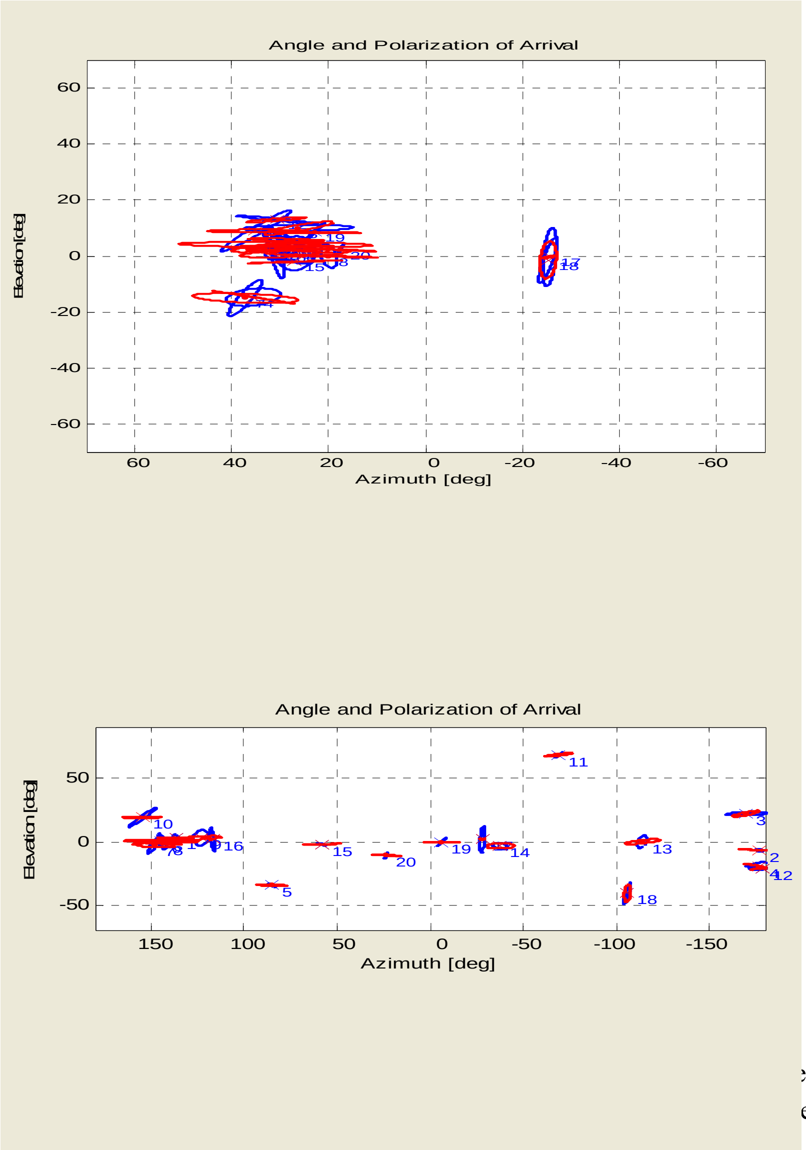


Indoor measurement: polarisation

- Position 2: NLOS, SNR ~45 dB

Receiver polarisation (AoA)

Transmitter polarisation (AoD)

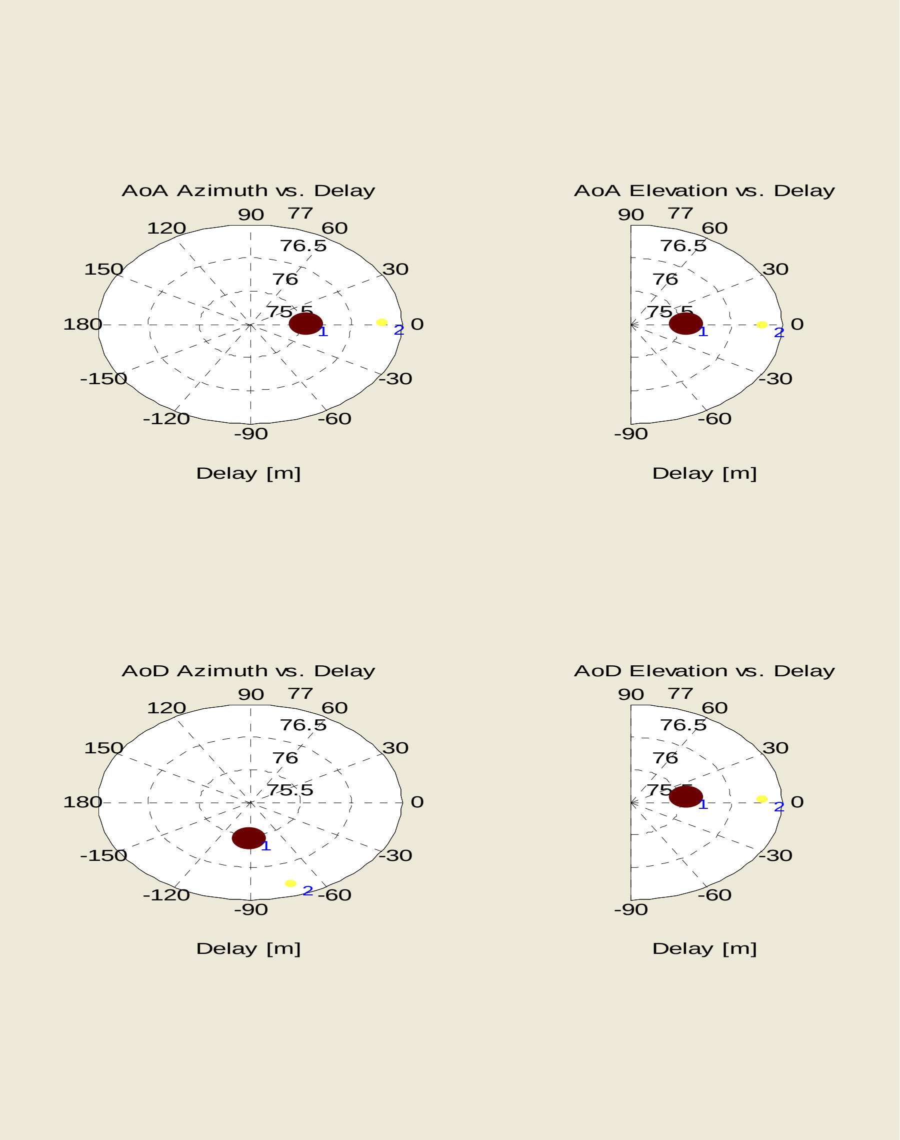


Indoor measurement with PropSound

- Position 3 :NLOS, SNR ~14 dB

Receiver
(AoA)

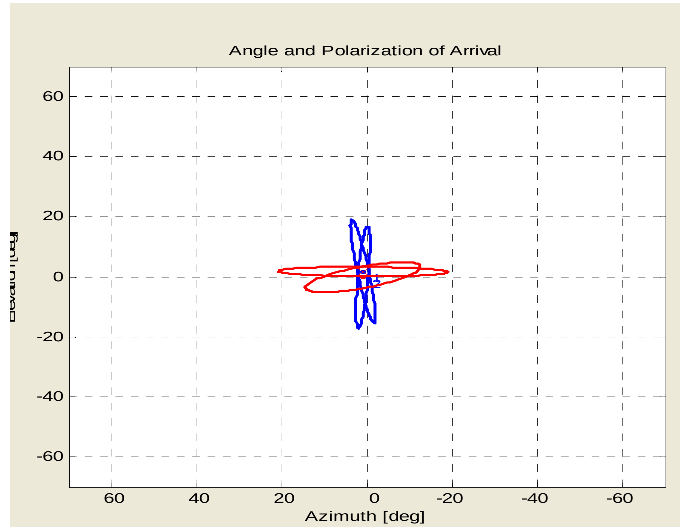
Transmitter
(AoD)



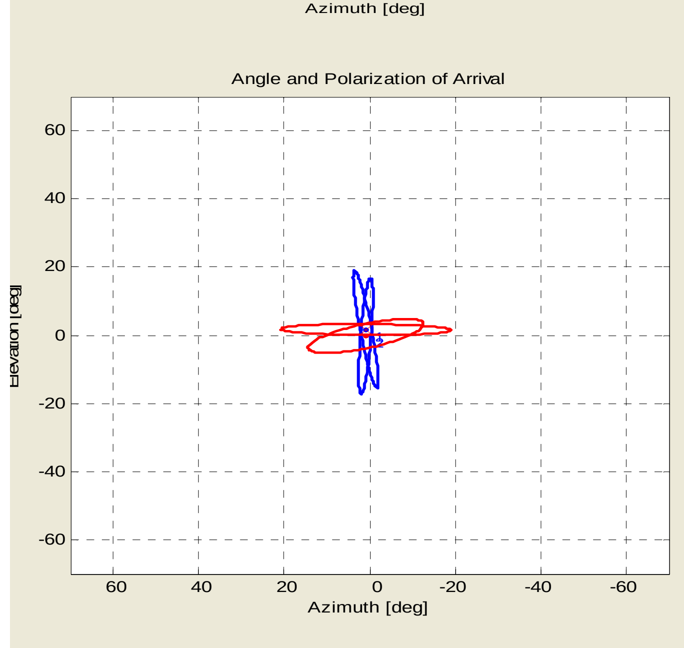
Indoor measurement: polarisation

- Position 3: NLOS, SNR ~14 dB

Receiver polarisation (AoA)



Transmitter polarisation (AoD)



Uplink MIMO in 3GPP WCDMA

- High Speed Uplink Packet Access
  - > **specification in 3GPP ongoing**
  - > **no reference channel in UL for the channel state measurement**
  - ⇒ **this makes optimal link adaptation difficult**

  - > **no feedback channel specified (so far)**
  - > **feedback rate is limited by high DL traffic requirements**
  - > **pilot power is limited (no common pilot channel)**
  - > **code limitation is not a key issue**
  - > **multiple antennas are already at the Node B (diversity)**

Diversity MIMO

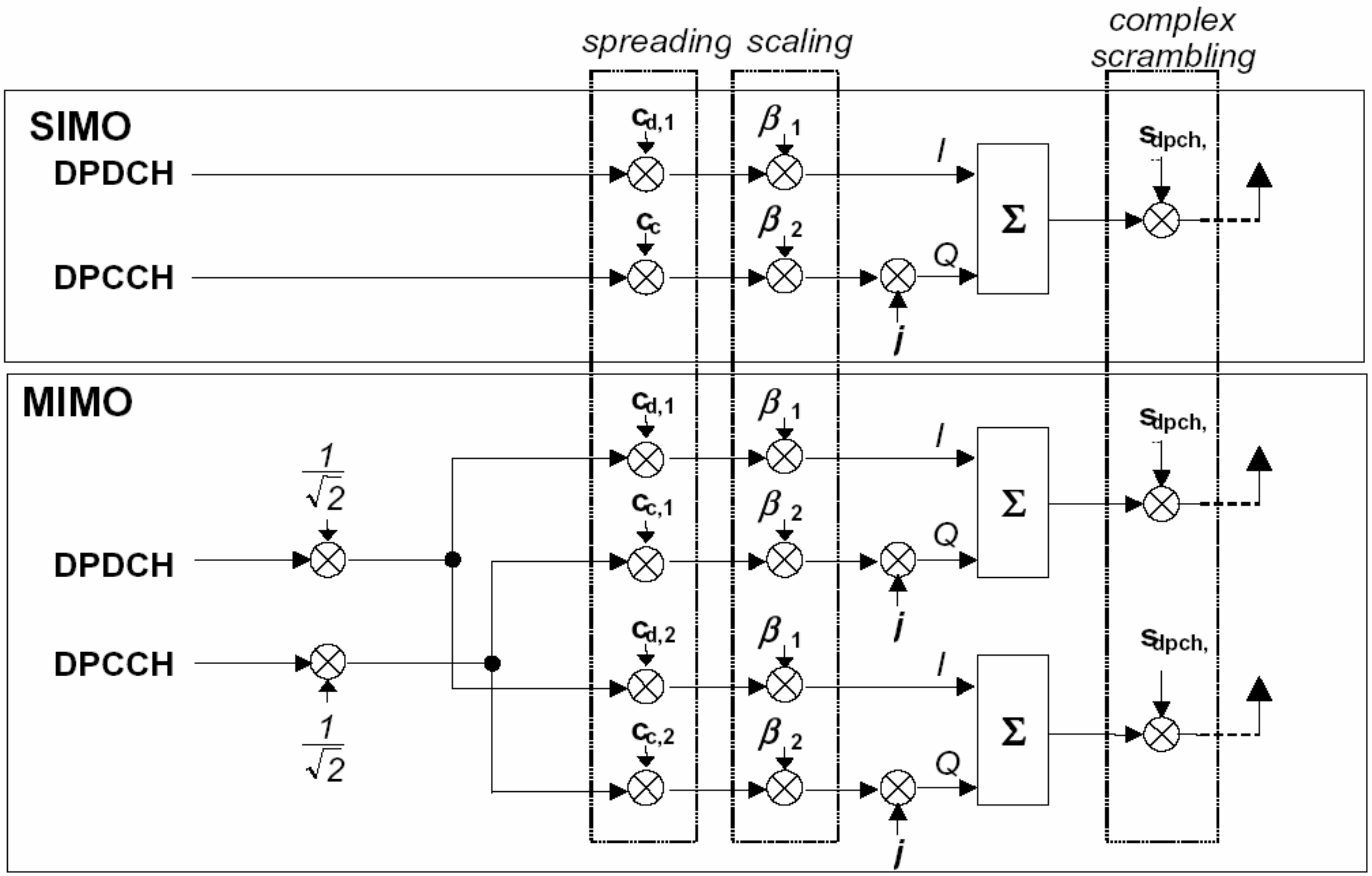


Fig. 1. System model for SIMO and diversity MIMO.

Link Simulation Details

Tx-scheme: 1/2 antenna transmission

Receiver: Rake (with 1/2/4 Rx antennas)

Interference: AWGN

Service: CS 64 kbps data (10% BLER target), 10 ms interleaving (SF=16)

Power Ctrl: **ON** (both inner and outer loops)
PC signaling errors (DL): 4%

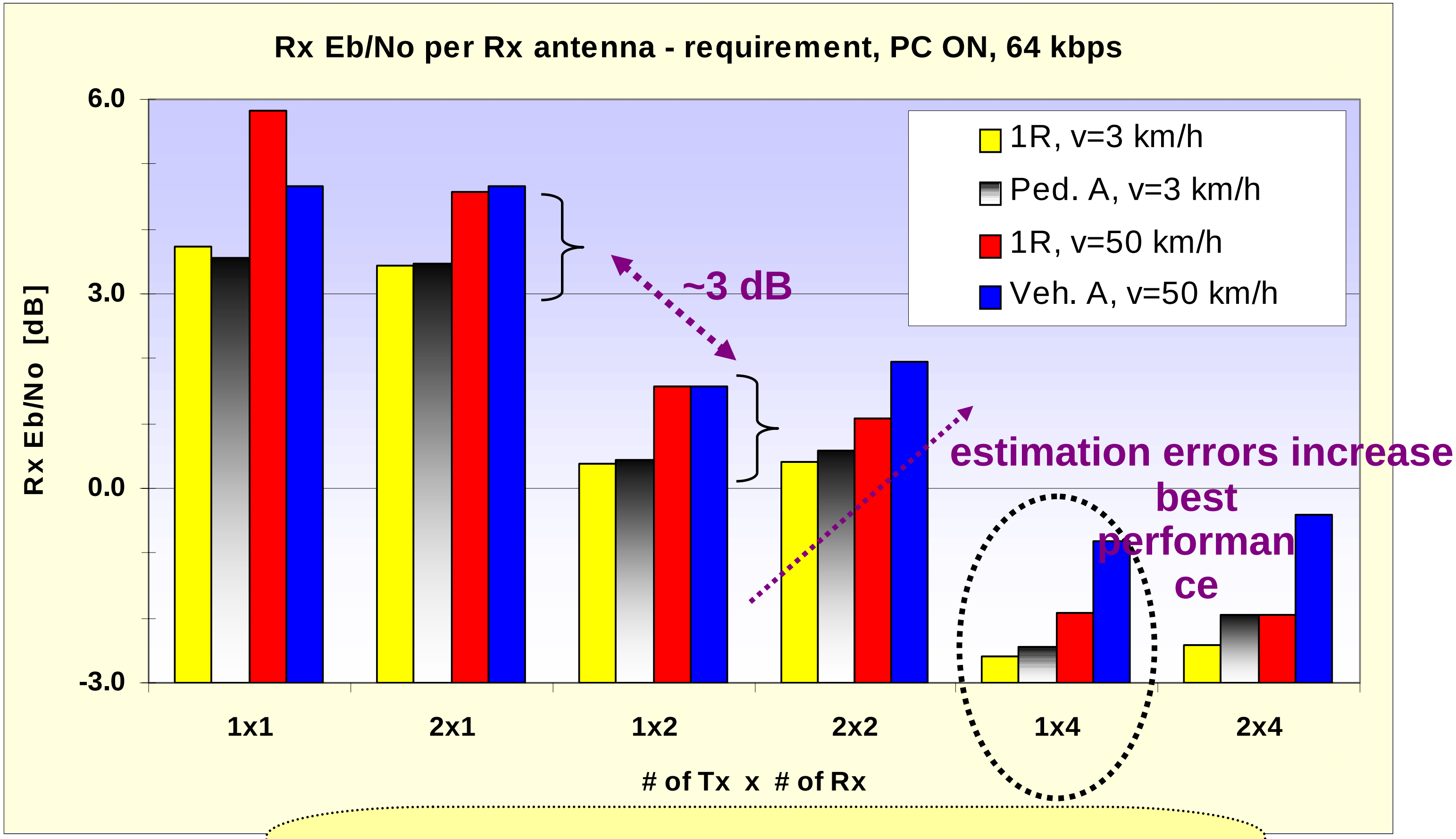
Ch. Est.: perfect timing, amplitude and phase

estimated from DPCCH

SIR Est.: estimated from DPCCH

Smpl rate: 1/chip

Simulated Rx Eb/No Performance



max. # of Rake fingers is limited in Veh. A channel:

- **4/6 strongest paths: 1x1 (4), 2x1 (8), 1x2 (8), 2x2 (16)**
- **2/6 strongest paths : 1x4 (8), 2x4 (16)**

Information MIMO

- In the proposed information MIMO approach
  - data are multiplexed into two or more independent streams that are transmitted from separate antennas by employing **different scrambling codes**.
  - All streams contain DPDCHs and DPCCHs so that in base station they can be interpreted as signals from different independent users.
  - The effective number of intracell users – when compared against system where all users apply single transmit antenna - can be two-fold in case of two mobile transmit antennas.

Simulation Setup

Carrier Frequency	1940 Mhz
Chip rate	3.840 Mchips
Sampling rate	1 sample/chip
Power control	ON, both inner and outer loops
BLER target (QoS)	10%
Rake finger allocation	Known delays
Maximum number of allocated Rake fingers	5 / receive antenna
Channel estimation	Estimated (DPCCH)
Signal-to-interference estimation	Estimated (DPCCH)

TABLE I

SIMULATION PARAMETERS.

Simulation Setup

Data rate DTCH/DCCH	64 / 2.4 kbps	960 / 0 kbps
Rate matching (DTCH)	16% repetition	0.5% puncturing
Channel coding	Turbo 1/3	Turbo 1/3
Interleaving period	10 ms	10ms
Number of dedicated physical data channels	1	3
Spreading factor on DPCCH/DPDCH	256 / 16	256 / 4
Dedicated control bits in slot: pilot / PC / TFCI	6 / 2 / 2	6 / 2 / 2
Power ratio of DPCCH/DPDCH	-5.46 dB	-9.54 dB

TABLE II

SERVICE RELATED PARAMETERS FOR 64 AND 960 KBPS CIRCUIT SWITCHED DATA.

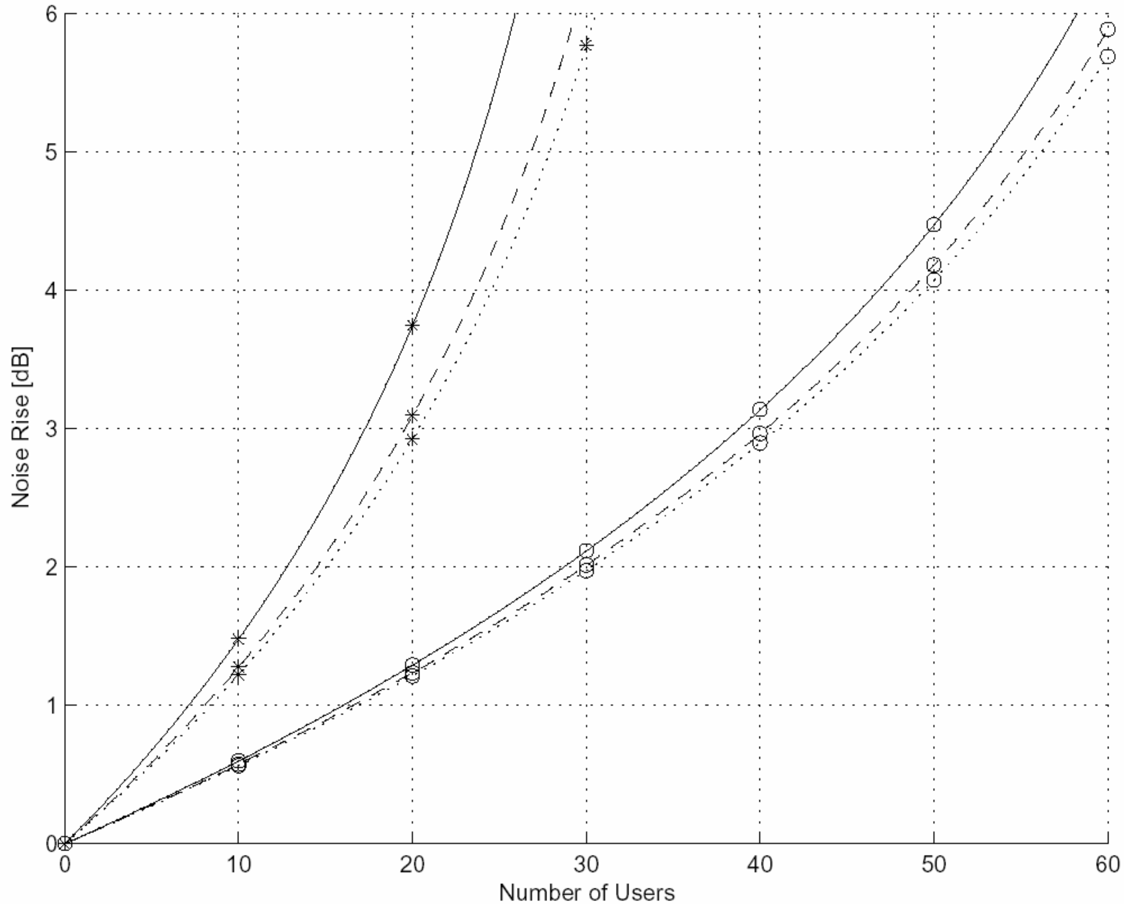
Performance Measures

- When studying the uplink performance of different transmission schemes on the system level, an important performance measure is the noise rise μ which is defined as a ratio of the total received wideband power to the thermal noise power. In terms of load η, noise rise is of the form

$$\mu = \frac{1}{1-\eta}$$

- Interference margin defines the maximum allowed noise rise and typically values 1.0-3.0 dB are used for coverage-limited cases with 20-50% load, and in capacity limited case, higher interference margins up to 6 dB can be used.

Simulation Results, Diversity MIMO



ν = other cell to own cell interference ratio

Fig. 2. Noise rise as a function of 64 kbps users in flat Rayleigh fading environment. The number of transmit antennas is 1 (solid curves), 2 (dashed curves) and 4 (dotted curves) while the number of receive antennas is 2 (-*-) and 4 (-o-). Initial interference ratio ν is 0.55.

Simulation Results, Diversity MIMO

- The results in Figure 2 show that gain from additional receive antennas is large while gain from transmit diversity is small.
- It is emphasized that transmit diversity gain vanishes in isolated cell, where $\nu=0$. This is due the fact that improved uplink performance of a user within the cell is by power control converted to the decrease in applied transmission power, while the intracell load in the base station receiver remains unchanged.
- However, improved uplink performance will provide coverage gain and reduction in intercell interference (if $\nu \neq 0$) that is favorable from network point of view.

Simulation Results, Information MIMO

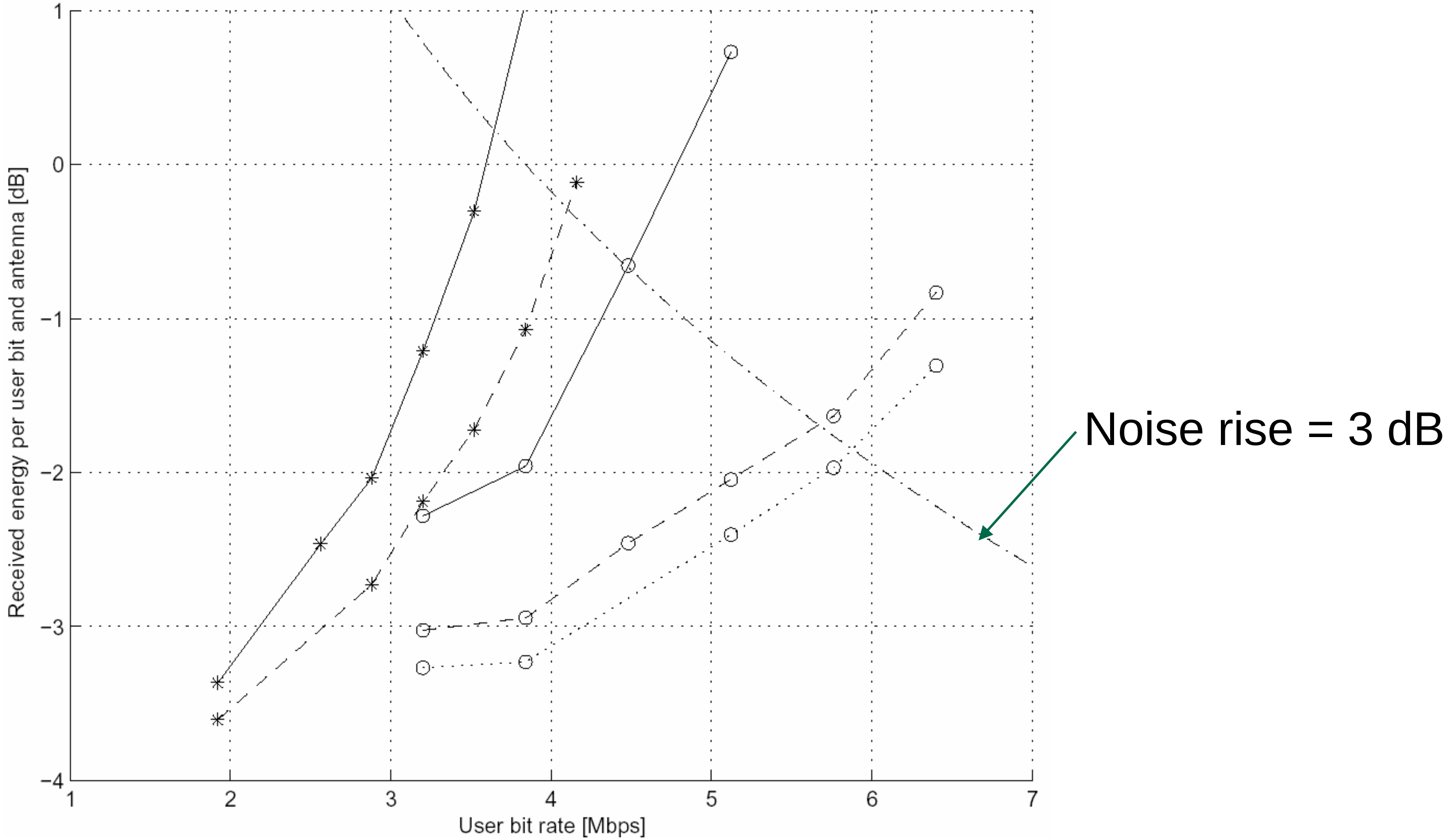


Fig. 4. Received energy per user bit and antenna for SIMO and MIMO systems with 4 receive antennas as a function of user bit rate in isolated cell assuming Pedestrian B channel and 3 km/h mobile speed. The number of transmit antennas is 1 (-*-) and 2 (-o-), and the employed receivers are Rake (solid curve), conventional PIC (dashed curve) and coded PIC (dotted curve).

Simulation Results, Information MIMO

- According to Figure 4 information MIMO is a better solution than SIMO or diversity MIMO if data services with bit rates higher than 2 Mbps are provided.
- Bit rates higher than 2 Mbps for SIMO and bit rates higher than 4 Mbps for MIMO are obtained by using code puncturing.
- Results show that user bit rates up to round 6 Mbps can be achieved with coded PIC and 50% system load. Even higher data rates would be possible by allowing a higher load for single user.

Conclusions

- Performance increase from additional base station antennas reflects straightforwardly to the coverage and capacity results but transmit diversity gain from additional antennas in the mobile end is relatively small.
- If user bit rates higher than 2 Mbps are employed, then gain from the information MIMO (spatial multiplexing) is large.
- In multiuser case throughput up to 10 Mbps can be achieved assuming four receive antennas, coded PIC and 75% system load. The result indicates a spectral efficiency of almost 2 bits/s/Hz that is achieved by well-known receiver methods without any changes in the present UTRA FDD standard.

References

- E. Tiirola and J. Ylitalo, Comparison of MIMO and SIMO Performance in UMTS Uplink, Vehicular Technology Conference, VTC 2003-Fall, 6-9 Oct. 2003
- J. Hämäläinen, K. Pajukoski, E. Tiirola, R. Wichman and J. Ylitalo, "MIMO Performance in UTRA FDD Uplink", Proceedings of ISSSTA , August 20004.