

Evaluation of MIMO concepts in HSDPA by system level simulations

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Contents

List of notations and abbreviations	V
Abstract	1
1. Introduction	3
1.1 Wireless multiuser communications context	3
1.2 Contributions and overview of the thesis	4
2. HSDPA system background	7
2.1 Fundamentals of the HSDPA system	7
2.1.1 Adaptive Modulation and Coding	8
2.1.2 Hybrid Automatic Repeat Request (HARQ)	10
2.1.3 Fast Cell Selection (FCS)	11
2.1.4 Fast Scheduling	12
2.2 Cellular system model	13
3. Space-Time channel model	15
3.1 3GPP Spatial Channel Model (SCM)	19
4. MIMO link level processing for HSDPA	21
4.1 Signal processing for MIMO HSDPA	21
4.1.1 No channel knowledge at the Tx side	21
4.1.2 Long-term / partial channel knowledge at Tx	23
4.1.3 Full channel knowledge	24
4.2 Long-term Eigenbeamforming and ST-MMSE equalization	24
4.2.1 System model - link level	25
4.2.2 Transmit processing	27

4.2.3	Receive processing	28
4.3	Link to system level interface	32
4.3.1	SINR after ST-MMSE equalization and mapping to throughput	32
4.3.2	Validation of the link to system level interface	34
4.3.3	SINR computation at system level	36
5.	Single antenna scheduling	45
5.1	Feedback report	45
5.2	Link adaptation	48
5.3	Scheduling	48
5.3.1	Scheduling objectives	48
5.3.2	Scheduling strategies for single antenna systems	50
5.3.3	Concluding remarks for SISO scheduling	57
6.	Scheduling for MIMO-HSDPA	59
6.1	Feedback report	61
6.1.1	Feedback computation	61
6.1.2	Link adaptation mismatch	64
6.1.3	Scheduling-aware feedback measurement	65
6.2	Beamforming for multi user scheduling	70
6.2.1	Eigenbeamforming	70
6.2.2	Fixed Grid of Beams	72
6.3	Scheduling algorithm and strategies	73
6.3.1	Maximum throughput scheduling	76
6.3.2	Proportional fair scheduling	76
6.4	Simulation results	78
6.4.1	System setup	79
6.4.2	Simulation results for single user scheduling	80
6.4.3	Simulation results for multi user maximum throughput scheduling	90
6.4.4	Simulation results for multi user proportional fair scheduling	101
7.	Conclusions	105
	Appendix	107
A1	Antenna system gain for an ULA	107
A2	Additional results for the histograms of the selected CQI	110
	Bibliography	111

General notations

$E\{\cdot\}$	expectation operation
$()^T$	transpose of a matrix or a vector
$()^*$	complex conjugate
$()^H$	hermitian of a matrix or a vector
$\delta(\cdot)$	Dirac impulse
x	a scalar symbol
$\mathbf{x}$	a vector symbol
$\mathbf{X}$	a matrix symbol
$\mathbf{x}_n$	n^{th} column vector of matrix $\mathbf{X}$
$\mathbf{X}_{(a,b)}$	the element of the matrix $\mathbf{X}$ on the position (a, b)
$\mathbf{0}_{M \times N}$	matrix of zeros of size $M \times N$
$\mathbf{I}_N$	identity matrix of size N
$\mathbf{e}_n$	unity vector with all elements equal with 0 except the position n equal with 1
$\lfloor \frac{n}{N} \rfloor$	largest integer smaller than $\frac{n}{N}$
$\lceil \frac{n}{N} \rceil$	remainder of the integer division of n to N
$ A $	cardinality of the set A
$\ \mathbf{x}\ _2$	L2 norm of the vector $\mathbf{x}$
$\overline{T}$	mean value of a variable T
$\Pr\{x\}$	probability of an event x

Symbols (in the order of use)

<u>Symbol</u>	<u>Meaning of symbol</u>	<u>page of first use</u>
t_{TTI}	transmission time interval duration	12
v	speed of the mobile device	12
c	speed of light	12
Λ	number of macro propagation paths	15
$h(t, \tau)$	time variant channel impulse response	15
t	continuous time	15
τ	propagation delay	15
α_l	amplitude of macropath l	15
ϕ_l	phase rotation of macropath l	15
$h_{ij}(t, \tau)$	channel impulse response between TX antenna j and RX antenna i	16
$\mathbf{H}(t, \tau)$	MIMO channel impulse response	16
M_T	number of transmit antennas	16
M_R	number of receive antennas	16
$\mathbf{a}(\theta)$	steering vector	17
K_l	number of micropath to model a macropath	18
$\theta_{l,k_l,\text{AOD}}$	angle of departure of micropath k_l belonging to macropath l	18
$\theta_{l,k_l,\text{AOA}}$	angle of arrival of micropath k_l belonging to macropath l	18
β_{l,k_l}	amplitude of micropath k_l belonging to macropath l	18
ϕ_{l,k_l}	phase shift of micropath k_l belonging to macropath l	18
ζ	combined scrambling and spreading code	21
N	number of spatial multiplexed data streams	25
s_n	data stream n	25
$\mathbf{V}$	linear prefiltering (beamforming) matrix	25

$\tilde{\mathbf{H}}[k]$	discrete time equivalent channel	25
L	CIR length expressed in chips	26
$\mathbf{x}$	spreaded signal, input to the equivalent channel	26
$\mathbf{y}$	received signal, output of the equivalent channel	26
$\mathbf{\Gamma}$	matrix formulation of the equivalent MIMO frequency selective channel	26
$\mathbf{R}_{\text{Tx}}$	spatial channel covariance matrix from the transmitter side	27
p_{pw}	threshold fraction for selecting significant beamforming vectors	27
E	equalizer span	28
$\mathbf{y}_E$	received signals throughout one equalizer span	28
$\mathbf{x}_E$	transmitted signals throughout one equalizer span and CIR length	28
$\mathbf{\Gamma}_E$	channel throughout one equalizer span and CIR length	28
$\tilde{\mathbf{y}}_E$	noise prewhitened and matched filtered received signal	28
$\mathbf{R}_{\mathbf{x}_1\mathbf{x}_2}$	crosscovariance matrix of vectors $\mathbf{x}_1$ and $\mathbf{x}_2$	28
$\mathbf{W}_d$	equalizer matrix for delay d	29
$\hat{\mathbf{x}}$	equalized output	29
$\overline{\mathbf{W}}_d$	equalizer matrix averaged over the spreading and scrambling codes	30
$\mathbb{E}_s\{\cdot\}$	expectation operation over the set of spreading and scrambling sequences.	30
$\hat{\hat{\mathbf{x}}}$	equalized result for the average equalizer	30
$\mathbf{W}$	equalizer matrix including noise prewhitening and match filtering	32
$SINR_n$	signal to noise and interference ratio of the data stream n	33
P	number of interferes at the user of interest	38
$\mathbf{\Gamma}_E^p$	channel from the interfering BS p to the user of interest	38
$B + 1$	number of BSs, $b = 0$ index of the central BS	39
$U_b + 1$	number of MSs in the cell b	39
ψ_{ub}^p	scrambling code from the pool Ψ_{ub} of codes assigned to user u served BS b	39
φ_{ub}^p	spreading code from the pool Φ_{ub} of codes assigned to user u served by BS b	39
$\mathbf{W}_0$	equalizer matrix of user of interest, user 0	41
$\mathcal{G}$	spreading factor	42
P_{INTERF}	interference power of type INTERF at the user of interest	42
$\overline{T}_q^s$	average scheduled throughput of user q	50
$\overline{T}_q$	statistical average throughput of user q	50
Q	number of active HSDPA users in cell	50
$T_q^i[k]$	throughput achievable by user q at scheduling moment k	51
$1/t_c$	forgetting factor in the exponential decaying filter model	52
W_{Doppler}	Doppler bandwidth of the channel	52
G	MUDiv gain	50
$\mathcal{U}_1$	set of users simultaneously scheduled, in feedback measurement analysis	62
$(\cdot)^f$	variable computed for feedback measurment	63
$\mathcal{U}_2$	set of users simultaneously scheduled, after feedback when $\mathcal{U}_1$ was scheduled	63
M	number of spatially multiplexed users (SDMA)	70
N_m	number of data streams spatially multiplexed to user m (SDM)	70
$\mathbf{v}_{n,q}$	beamforming vector n of user q	70
$\mathbf{R}_q$	spatial transmit covariance matrix of user q	71
$p_{n,m}$	transmitted power of stream n of user m	71
$\mathbf{R}_t$	sum spatial transmit covariance matrix	71
ρ	orthogonality threshold between two beamforming vectors	74

orthogonality threshold to detect if two beamforming vectors interfere	74
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List of abbreviations (in alphabetical order)

<i>Abbrev.</i>	<i>Meaning of the abbreviation</i>	<i>page of first use</i>
HSDPA	High Speed Downlink Packet Access	1
MIMO	Multiple Input Multiple Output	1
3GPP	3rd Generation Partnership Project	4
AMC	Adaptive Modulation and Coding	8
BER	Bit Error Ratio	33
BLER	Block Error Ratio	8
CDMA	Code Division Multiple Access	8
CIR	Channel Impulse Response	15
CSI	Channel State Information	3
DCH	Dedicated CHannel	7
DPS	Doppler Power Spectrum	16
FCS	Fast Cell Selection	11
FDD	Frequency Division Duplex	3
FER	Frame Error Rate	33
FGOB	Fixed Grid Of Beams	73
GI	Genie Interference	66
GW	Genie equalizer	66
HARQ	Hybrid Automatic Repeat Request	8
HS-DPCCH	High Speed Dedicated Physical Control CHannel	7
HS-DSCH	High Speed Downlink Shared CHannel	7
HS-SCCH	High Speed Shared Control CHannel	8
IR	Incremental Redundancy	8
ITU	International Telecommunication Union	19
MAC	Medium Access Control	7
MCS	Modulation and Coding Scheme	4
MISO	Multiple Input Single Output	3
ML	Maximum Likelihood	22
MMSE	Minimum Mean Squared Error	22
MRC	Maximum Ratio Combining	22
MUDiv	Multi User Diversity	12
MT	Maximum Throughput	12
Node B	Term used in UMTS for base station	7
OFDM	Orthogonal Frequency Division Multiplexing	3
PARC	Per Antenna Rate Control	24
PAS	Power Angular Spectrum	16
PDS	Power Delay Spectrum	16
PSRC	Per Stream Rate Control	24
PF	Proportional Fair	12
QAM	Quadrature Amplitude Modulation	8
QoS	Quality of Service	8
RR	Round Robin	12

RRC	Root Raised Cosine	35
RX	Receiver	8
SaW	Stop and Wait	8
SC	Soft-Combining	8
SCM	Spatial Channel Model	19
SDM	Spatial Division Multiplexing	39
SDMA	Spatial Division Multiple Access	39
SIC	Successive Interference Cancellation	22
SIMO	Single Input Multiple Output	3
SINR	Signal to Noise and Interference Ratio	9
SISO	Single Input Single Output	16
SR	Selective Repeat	10
SSDT	Site Selection Diversity Transmission	12
ST-MMSE	Space Time Minimum Mean Squared Error	5
STTD	Space Time Transmit Diversity	23
TDMA	Time Division Multiple Access	7
TPC	Transmit Power Control	7
TTI	Transmission Time Interval	5
TX	Transmitter	10
UE	User Equipment	7
UMTS	Universal Mobile Telecommunication System	4
US	Uncorrelated Scattering	15
UTRAN	UMTS Terrestrial Radio Access Network	45
VBLAST	Vertical Bell Labs Layered Space-Time	22
WCDMA	Wideband Code Division Multiple Access	7
WSS	Wide Sense Stationary	15
ZF	Zero Forcing	22