TECHNISCHE UNIVERSITÄT MÜNCHEN
Lehrstuhl für Netzwerktheorie und Signalverarbeitung

Evaluation of MIMO concepts in HSDPA by system level simulations

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Contents

General notations

$\mathsf{E}\{\cdot\}$	expectation operation
$()^{\mathsf{T}}$	transpose of a matrix or a vector
$()^{*}$	complex conjugate
$()^{\mathsf{H}}$	hermitian of a matrix or a vector
$\delta(\cdot)$	Dirac impulse
x	a scalar symbol
$\boldsymbol{x}$	a vector symbol
$\boldsymbol{X}$	a matrix symbol
$\boldsymbol{x}_n$	n^{th} column vector of matrix X
$\boldsymbol{X}_{(a,b)}$	the element of the matrix $\boldsymbol{X}$ on the position (a, b)
$\mathbf{0}_{M\times N}$	matrix of zeros of size $M \times N$
$\boldsymbol{I}_N$	identity matrix of size N
$\boldsymbol{e}_n$	unity vector with all elements equal with 0 except the position n equal with 1
$\left\lfloor \frac{n}{N} \right\rfloor$	largest integer smaller than $\frac{n}{N}$
$\left\lfloor \frac{n}{N} \right\rceil$	remainder of the integer division of n to N
$\lvert A\rvert$	cardinality of the set A
$\lVert\boldsymbol{x}\rVert_2$	L2 norm of the vector $\boldsymbol{x}$
$\overline{T}$	mean value of a variable T
$\mathsf{Pr}\{x\}$	probability of an event x

Symbols (in the order of use)

Symbol	*Meaning of symbol*	*page of first use*
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
$\boldsymbol{H}(t,\tau)$	MIMO channel impulse response	16
M_{T}	number of transmit antennas	16
M_{R}	number of receive antennas	16
$\boldsymbol{a}(\theta)$	steering vector	17
K_l	number of micropath to model a macropath	18
$\theta_{l,k_l,\mathsf{AOD}}$	angle of departure of micropath k_l belonging to macropath l	18
$\theta_{l,k_l,\mathsf{AOA}}$	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
$\boldsymbol{V}$	linear prefiltering (beamforming) matrix	25

$\tilde{\boldsymbol{H}}[k]$	discrete time equivalent channel	25
L	CIR length expressed in chips	26
$\boldsymbol{x}$	spreaded signal, input to the equivalent channel	26
$\boldsymbol{y}$	received signal, output of the equivalent channel	26
$\boldsymbol{\Gamma}$	matrix formulation of the equivalent MIMO frequency selective channel	26
$\boldsymbol{R}_{\mathsf{Tx}}$	spatial channel covariance matrix from the transmitter side	27
p_{pw}	threshold fraction for selecting significant beamforming vectors	27
E	equalizer span	28
$\boldsymbol{y}_{\mathsf{E}}$	received signals throughout one equalizer span	28
$\boldsymbol{x}_{\mathsf{E}}$	transmitted signals throughout one equalizer span and CIR length	28
$\boldsymbol{\Gamma}_{\mathsf{E}}$	channel throughout one equalizer span and CIR length	28
$\tilde{\boldsymbol{y}}_{\mathsf{E}}$	noise prewhitened and matched filtered received signal	28
$\boldsymbol{R}_{\boldsymbol{x}_1\boldsymbol{x}_2}$	crosscovariance matrix of vectors $\boldsymbol{x}_1$ and $\boldsymbol{x}_2$	28
$\boldsymbol{W}_d$	equalizer matrix for delay d	29
$\hat{\boldsymbol{x}}$	equalized output	29
$\overline{\mathbf{W}}_d$	equalizer matrix averaged over the spreading and scrambling codes	30
$\mathsf{E}_s\{\cdot\}$	expectation operation over the set of spreading and scrambling sequences.	30
$\hat{\bar{\mathbf{x}}}$	equalized result for the average equalizer	30
$\boldsymbol{W}$	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
$\boldsymbol{\Gamma}_E^p$	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
$\boldsymbol{W}_0$	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
$\overline{T_q^{\mathsf{s}}}$	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
$T_q^{\mathsf{i}}[k]$	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
$(\,)^{\mathsf{f}}$	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
$\boldsymbol{v}_{n,q}$	beamforming vector n of user q	70
$\boldsymbol{R}_q$	spatial transmit covariance matrix of user q	71
$p_{n,m}$	transmitted power of stream n of user m	71
$\boldsymbol{R}_{\mathsf{t}}$	sum spatial transmit covariance matrix	71
ρ	orthogonality threshold between two beamforming vectors	74

η	orthogonality threshold to detect if two beamforming vectors interfere	74

List of abbreviations (in alphabetical order)

Abbrev.	*Meaning of the abbreviation*	*page of first use*
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	Moldulation 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 Sevice	8
RR	Round Robin	12