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Purpose	For discussion and approval by TGm
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References

[1] Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000, “Recommendation ITU-R M.1225,” 1997

[2] 3GPP2 C.R1002-0 1.0, “CDMA2000 Evaluation Methodology”, January 2005.

[3] Recommendation ITU-R M.1225, “Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000”, 1997.

[4] 3GPP-3GPP2 Spatial Channel Ad-hoc Group, “Spatial Channel Model Text Description,” V7.0, August 19, 2003

[5] RUNCOM, “Coverage capacity simulations for OFDMA PHY in ITU-T channel models, “ IEEE C802.16d-03/78r1, November, 2003

[6] RUNCOM, “Coverage simulation for OFDMA PHY mode,” IEEE C8021.6e-03/22r1 Sony, Intel, “TGn Sync TGn Proposal MAC Simulation Methodology”, IEEE 802.11-04/895r2, November 2004.

[7] Sony, Intel, “TGn Sync TGn Proposal MAC Simulation Methodology”, IEEE 802.11-04/895r2, November 2004.

[8] ST Micro-Electronics “Time Correlated Packet Errors in MAC Simulations”, IEEE Contribution, 802.11-04-0064-00-000n, Jan. 2004.

[9] Atheros, Mitsubishi, ST Micro-Electronics and Marvell Semiconductors, “Unified Black Box PHY Abstraction Methodology”, IEEE Contribution 802.11-04/0218r1, March 2004.

[10]3GPP TR 25.892 V2.0.0 “Feasibility Study for OFDM for UTRAN enhancement,”

[11]WG5 Evaluation Ad-hoc Group, “1x EV-DV Evaluation Methodology – Addendum (V6),” July 25, 2001

[12]Ericsson, “System level evaluation of OFDM- further considerations”, TSG-RAN WG1 #35, R1-03-1303, November, 2003

[13]Nortel, “Effective SIR Computation for OFDM System-Level Simulations,” TSG-RAN WG1 #35, R03-1370, November 2003.

[14]Nortel “OFDM Exponential Effective SIR Mapping Validation, EESM Simulation Results for System-Level Performance Evaluations,” 3GPP TSG-RAN1 Ad Hoc, R1-04-0089, January, 2004.

[15]K. Brueninghaus et. al. “Link performance models for system level simulations of broadband radio access,” IEEE PIMRC, 2005.

[16]L. Wan, S. Tsai, M. Almgren, “A fading insensitive performance metric for a unified link quality model,” WCNC, 2006.

[17]DoCoMo, Ericsson, Fujitsu, Mitsubishi Electric, NEC, Panasonic, Sharp, Toshiba Corporation, R1-060987, “Link adaptation schemes for single antenna transmissions in the DL, 3GPP-LTE WG1 meeting #44-bis, Athens, March 2006.

[18]P. Barford and M Crovella, "Generating Representative Web Workloads for Network and Server Performance Evaluation" In Proc. ACM SIGMETRICS International Conference on Measurement and Modeling of Computer Systems, pp. 151-160, July 1998.

[19]S. Deng. “Empirical Model of WWW Document Arrivals at Access Link.” In Proceedings of the 1996 IEEE International Conference on Communication, June 1996

[20]R. Fielding, J. Gettys, J. C. Mogul, H. Frystik, L. Masinter, P. Leach, and T. Berbers-Lee, "Hypertext Transfer Protocol - HTTP/1.1", RFC 2616, HTTP Working Group, June 1999. ftp://ftp.Ietf.org/rfc2616.txt.

[21]B. Krishnamurthy and M. Arlitt, "PRO-COW: Protocol Compliance on the Web", Technical Report 990803-05-TM, AT&T Labs, August 1999, http://www.research.att.com/~bala/papers/procow-1.ps.gz. 29 30 31 32 33 34 35 36 37

[22]B. Krishnamurthy, C. E. Wills, "Analyzing Factors That Influence End-to-End Web Performance", http://www9.org/w9cdrom/371/371.html

[23]H. K. Choi, J. O. Limb, "A Behavioral Model of Web Traffic", Proceedings of the seventh International Conference on Network Protocols, 1999 (ICNP '99), pages 327-334.

[24]F. D. Smith, F. H. Campos, K. Jeffay, D. Ott, "What TCP/IP Protocol Headers Can Tell Us About the Web", Proc. 2001 ACM SIGMETRICS International Conference on Measurement and Modeling of Computer Systems, pp. 245-256, Cambridge, MA June 2001.

[25]J. Cao, William S. Cleveland, Dong Lin, Don X. Sun., "On the Non-stationarity of Internet Traffic", Proc. ACM SIGMETRICS 2001, pp. 102-112, 2001.

[26]K. C. Claffy, "Internet measurement and data analysis: passive and active measurement", http://www.caida.org/outreach/papers/Nae/4hansen.html.

[27]3GPP TR 25.896 “3GPP TSG RAN Feasibility Study for Enhanced Uplink for UTRA FDD (Release 6)”, 2004-03

[28]RFC 3267 - Real-Time Transport Protocol (RTP) Payload Format and File Storage Format for the Adaptive Multi-Rate (AMR) and Adaptive Multi-Rate Wideband (AMR-WB) Audio Codecs

[29]3GPP2/TSG-C.R1002, “1xEV-DV Evaluation Methodology (V14)”, June 2003

[30]IEEE P 802.20™ PD-09 Version 1.0, “802.20 Evaluation Criteria – version 1.0,” September 23, 2005

[31]WINNER Project, IST-2003-507581 WINNER D1.3 version 1.0, “Final usage scenarios.”

[32] 3GPP TSG-RAN1#48 R1-070674, LTE physical layer framework for performance verification, Orange, China Mobile, KPN, NTT DoCoMo, Sprint, T-Mobile, Vodafone, Telecom Italia, February 2007.

1 Channel Models

The ITU channel model with correlation factor shall be used as the baseline channel model for link-level and system-level simulations. The SCM channel model described in this section may be used to generate the correlation coefficients and to perform certain system-level simulations. The same channel models shall be used for the downlink and uplink simulations.

ITU Channel Model

A channel model corresponds to a specific number of paths, path delay and power profile (ITU multi-path models), and Doppler frequencies for the paths. The tapped-delay line model defined by the ITU that is used to model fast-fading is characterized by the number of taps (or the number of paths), time delay relative to first tap, average power relative to the strongest tap, and Doppler spectrum of each tap.

The tapped delay line model can be represented in the time-domain as

$$h(t) = \sum_{l=1}^{n} p_l h_l(t)\, \delta(t - \tau_l) \qquad (1.1\text{-}1)$$

Where p_l and τ_l are amplitude and delay of path l, and $h_l(t)$ represents the time varying channel coefficient. All simulations assume that $h_l(t)$ is a temporally correlated random variable with classical (Jakes) Doppler spectrum

$$S(f) = \begin{cases} \dfrac{1}{f_d}\dfrac{1}{\sqrt{1-\left(f/f_d\right)^2}} & |f| \le f_d \\ 0 & \text{otherwise} \end{cases} \qquad (1.1\text{-}2)$$

Where f_d is the appropriate Doppler rate for the subscriber speed and the carrier frequency.

Channel Model	Multi-path Model	# of Paths	Speed (km/h)	Fading	Assignment Probability
Model A	Pedestrian A	4	3	Jakes	0.30
Model B	Pedestrian B	6	10	Jakes	0.30
Model C	Vehicular A	6	30	Jakes	0.20
Model D	Vehicular B	6	120	Jakes	0.10
Model E	Single Path	1	0, f_D=1.5 Hz	Rician Factor K = 10 dB	0.10

Table 1-1 Channel Models

The channel models are randomly assigned to the various users according to the probabilities of Table 1-1 at the beginning of each drop and are not changed for the duration of that drop. The assignment probabilities given in Table 1-1 are interpreted as the percentage of users with that channel model in each sector.

Each multipath model (Pedestrian A/B, Vehicular A/B) is characterized in terms of the total number of paths, together with actual power-delay profile of the multipath channel. For each multipath model, the power on all paths shall be normalized so that the total power adds up to one.

Model	# Paths	1	2	3	4	5	6
Ped-A	4	0	-9.7	-19.2	-22.8		
Ped-B	6	0	-0.9	-4.9	-8.0	-7.8	-23.9
Veh-A	6	0	-1.0	-9.0	-10.0	-15.0	-20.0
Veh-B	6	0	-2.5	-12.8	-10.0	-25.2	-16.0

Table 1-2 Relative Power of each Multipath Model (in dB)

Model	# Paths	1	2	3	4	5	6
Ped-A	4	0	110	190	410		
Ped B	6	0	200	800	1200	2300	3700
Veh-A	6	0	310	710	1090	1730	2510
Veh-B	6	0	300	8900	12900	17100	20000

Table 1-3 Delay of each Multipath Model (in ns)

The channel between the serving sector(s) and the subscriber is modeled using the multipath profiles defined above. The channel between any interfering sector and the subscriber is modeled as a one-path Rayleigh fading channel, where the Doppler of the fading process is randomly chosen based on the velocities and its corresponding probabilities specified in Table 1-1.

The tapped-delay line parameters of these channel models are further summarized in and Table 1-5. Note that the power values in the tables need to be normalized so that they sum to unit power (0 dB).

Tap	Channel Ped-A $_{rms}$ $45ns$		Channel Ped-B $_{rms}$ $750ns$		Doppler v $3_{km}/h$ and 10 km/h
	Delay (ns)	Power (dB)	Delay (ns)	Power (dB)	Jakes
1	0	0	0	0	Jakes
2	110	-9.7	200	-0.9	Jakes
3	190	-19.2	800	-4.9	Jakes
4	410	-22.8	1200	-8.0	Jakes

5	-	-	2300	-7.8	Jakes
6	-	-	3700	-23.9	Jakes

Table 1-4: Outdoor to indoor and pedestrian test environment channel impulse response

Tap	Channel Veh-A $(\ _{rms} \quad 370ns)$		Channel Veh-B $(\ _{rms} \quad 4000ns)$		Doppler $v \quad 30, 120 \; km/h$
	Delay (ns)	Power (dB)	Delay (ns)	Power (dB)	Jakes
1	0	0	0	0	Jakes
2	310	-1.0	300	-2.5	Jakes
3	710	-9.0	8900	-12.8	Jakes
4	1090	-10.0	12900	-10.0	Jakes
5	1730	-15.0	17100	-25.2	Jakes
6	2510	-20.0	20000	-16.0	Jakes

Table 1-5: Vehicular test environment channel impulse response

ITU Model with Correlation Factor

This MIMO channel model is a stochastic channel model for MIMO systems that extends the SISO channel model to the MIMO case by utilizing transmit and receive spatial correlation matrices. Let M and N be the number of TX and RX antennas, respectively, and let $\mathbf{R}_{TX}$, of dimensions MxM, and $\mathbf{R}_{RX}$, of dimensions NxN, be the correlation matrices at the transmit and receive side, respectively. If **H** denotes the NXM discrete-time MIMO channel impulse response matrix between the transmitter and the receiver with entries $H_{n,m}$ expressing the channel impulse response between transmit antenna m, m=1..M, and receive antenna n, n=1..N, then the elements $[R_{\mathrm{Tx}}]_{i,j}$, i,j=1..M, of the MxM spatial correlation matrix $\mathbf{R}_{TX}$ are defined according to

$$[R_{\mathrm{Tx}}]_{i,j} \quad \left\langle H_{l,i}, H_{l,j} \right\rangle \tag{1.1-3}$$

where $\left\langle H_{l,i}, H_{l,j} \right\rangle$ calculates the correlation coefficient between $H_{l,i}$ and $H_{l,j}$ and is independent of l, l=1..N, i.e., of the receive antennas at the MS. The elements of the NxN correlation matrix $\mathbf{R}_{Rx}$ are defined similarly.

Since the correlation coefficients between any two channel impulse responses connecting two different sets of antennas can be expressed as the product of the correlation coefficients at the transmit and the receive antennas (see [21] for a detailed proof), the spatial correlation matrix of the MIMO channel matrix **H** can be expressed as the Kronecker product of the spatial correlation matrices at the transmit and receive side:

$$\mathbf{R}_{\mathrm{MIMO}} \quad \mathbf{R}_{\mathrm{Tx}} \quad \mathbf{R}_{\mathbf{Rx}} \quad \mathbf{C}^{*\mathrm{T}}_{\mathrm{Tx}}\mathbf{C}_{\mathrm{Tx}} \quad \mathbf{C}^{*\mathrm{T}}_{\mathrm{Rx}}\mathbf{C}_{\mathrm{Rx}} \qquad 1.1\text{-}4)$$

where $\mathbf{C}_{\mathrm{Tx}}$ and $\mathbf{C}_{\mathrm{Rx}}$ represent the Cholesky decomposition of $\mathbf{R}_{\mathrm{Tx}}$ and $\mathbf{R}_{\mathrm{Rx}}$, respectively.

This property of the MIMO channel matrix **H** means that the effects of multipath propagation and mobility can be modeled by generating MxN uncorrelated channel impulse responses, each according to the ITU SISO power delay profile (PDP) and the desired model for including the impact of mobility, e.g., use of the Doppler spectrum, and then for each multipath component w, w=1..W, determine the MIMO channel matrix according to

$$\mathbf{H}_w = \mathbf{C}^{*\mathrm{T}}_{\mathrm{Rx}}\mathbf{H}_{\mathrm{un},w}\mathbf{C}^{*}_{\mathrm{Tx}}, \quad w = 1...W, \qquad \mathbf{(1.1\text{-}5)}$$

where $\mathbf{H}_{\mathrm{un,w}}$, w=1..W, denotes the NxM MIMO channel matrix created by the N·M uncorrelated channel impulse responses at delay w, w=1..W.

Although the correlation matrix of each multipath component may be selected independently depending on the propagation environment, a more straightforward approach is used here that selects all correlation matrices to be the same. In the case of uniformly spaced antenna elements, the correlation matrices can be selected as Hermitian Tœplitz and determined by a single correlation factor ρ, with their first row being equal to [1 ρ ρ^2 … ρ^{K-1}] and K being equal to M or N. As an example for the 2x2 MIMO case of $\mathbf{R}_{\mathrm{Tx}}$ and $\mathbf{R}_{\mathrm{Rx}}$, can be chosen as

$$\mathbf{R}_{\mathrm{Tx}} = \begin{bmatrix} 1 & r \\ r^{*} & 1 \end{bmatrix}, \quad \mathbf{R}_{\mathbf{Rx}} = \begin{bmatrix} 1 & m \\ m^{*} & 1 \end{bmatrix}, \qquad (1.1\text{-}6)$$

where ρ and μ are the complex correlation factors at the transmit BS and receive MS side, respectively.

Letting ρ and μ take values within [0, 1] for the amplitude and [0, 2π] for the phase, enables the investigation of the influence of different propagation environments on the MIMO performance, e.g., in line-of-sight (LOS) links, ρ and μ in (4) can be chosen to have amplitudes close to 1. As a final remark regarding the practical parameters of the described MIMO channel model, the ITU power delay profiles and the Doppler spectrum according to [24] are employed, while ρ and μ take values within [0, 1] for the amplitude and [0, 2π] for the phase.

Channel Models Based on SCM

Channel Model for System-Level Simulations

The spatial channel model (SCM) may be used for system-level simulations. If SCM channel model is utilized, the urban macro-cellular environment should be used and the parameters of Table 1-6 should be used for configuring the model.

Channel Scenario	**Urban Macro**
Number of paths (N)	6
Number of sub-paths (M) per-path	20

Mean AS at BS	E($_{AS}$)=15 deg
AS at BS as a lognormal RV $s_{AS} = 10^{\wedge}\left(e_{AS}x + m_{AS}\right), x \sim h(0,1)$	15deg $_{AS}$ = 1.18, $_{AS}$ = 0.210
r_{AS} $_{AoD}$ / $_{AS}$	1.3
Per-path AS at BS (Fixed)	2 deg
BS per-path AoD Distribution standard distribution	$(0, \ {}^{2}_{AoD})$ where $_{AoD}$ r_{AS} $_{AS}$
Mean AS at MS	E(AS, MS)=68 deg
Per-path AS at MS (fixed)	35 deg
MS Per-path AoA Distribution	$(0, \ {}^{2}_{AoA}(\mathrm{Pr}))$
Delay spread as a lognormal RV $s_{DS} = 10^{\wedge}\left(e_{DS}x + m_{DS}\right), x \sim h(0,1)$	DS = -6.18 DS = 0.18
Mean total RMS Delay Spread	E($_{DS}$)=0.65 s
r_{DS} $_{delays}$ / $_{DS}$	1.7
Lognormal shadowing standard deviation, $_{SF}$	8.9dB
Path loss model (dB), d is in meters	28.6 + 35log10(d)

Table 1-6 Macro-cellular Environment Parameters

The velocity profile is shown in Table 1-7. Because of the choice of urban macrocell, velocities are biased towards pedestrian speeds.

Percentage	Velocity (km/h)
35%	3
30%	30
20%	60
15%	120

Table 1-7 Quantized Velocity Profile

The RF carrier frequency for all link-level and system-level simulations shall be 2.5 GHz.

Channel Model for Link-Level Simulations

As mentioned earlier, for link-level simulations, spatially extended ITU profiles shall be used.

ITU Model	Velocity (km/h)
AWGN	0
Ped-A	3
Ped-B	{3,30}
Veh-A	{30,120,250}
Veh-B	{30,120,250}

Table 1-8: ITU Profiles for Link Level Simulations

Channel Scenario	Urban Macro-Cellular
AS at BS	$_{AS}$ = 15^{0}
Per-path AS at BS (Fixed)	2 deg

AS at MS	$_{AS, MS}= 68^0$
Per-path AS at MS (fixed)	35^0
AoDs	As specified in Table 1-10
AoAs	As specified in Table 1-10

Table 1-9 ITU Profiles Spatial Extension Parameters

	Path Power	Path AOD (rad)	Path AoA (rad)
Ped-A	0.889345301	0.346314033	1.737577272
	0.095295066	-0.05257642	-1.55645
	0.010692282	-1.817837659	-1.049078459
	0.00466735	-0.836999548	0.345571431
Ped-B	0.405688403	-0.13638548	1.319340881
	0.329755914	0.302249557	-0.119072067
	0.131278194	0.496051618	0.901442565
	0.064297279	0.544719913	-1.424448314
	0.067327516	0.212670549	-3.062670939
	0.001652695	-0.604134536	-1.202289294
Veh-A	0.48500285	-0.46084874	-0.780118399
	0.385251458	-0.897480352	-1.729577654
	0.061058241	-0.525726742	1.792547973
	0.048500285	0.00282531	1.776985779
	0.015337137	-1.016095677	1.386034573
	0.004850029	0.245512493	3.50389557
Veh-B			

Table 1-10 Path Power, AoD, AoA

The fading coefficient generation will be the one described on section 5.3 of the 3GPP2/3GPP SCM.