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Title:	**3GPP 25.996 v6.0.0 "Spatial Channel Model for Multiple-Input Multiple-Output Simulations"**
Source:	WI Editor (Lucent Technologies)
Agenda Item:	9.1.3
Document for:	Information

The TR version attached was presented in RAN1#31 (R1-030347) as the output of SCM ad hoc. RAN1 decided to forward it to RAN#19 to be presented for approval but following some email discussions on the reflector and within the SCM ad hoc it was agreed that this TR would be presented to RAN#19 for information.

Presentation of Specification to TSG or WG

Presentation to:	**TSG RAN Meeting #19**
Document for presentation:	**TR 25.996, Version 1.0.0**
Presented for:	**Information**

Abstract of document:

This document is part of the RAN WI "**Multiple Input Multiple Output work item**” and contains the Spatial Channel Model which were address in the SCM ad hoc as part of the harmonisation meeting between 3GPP and 3GPP2.

Based on the last SCM ad hoc some minor changes are still needed before approving the document.

Outstanding Issues:

SCM ad hoc will finish its work by the end of March and agree a final version.

Some comments on the use of the evaluation methodology were made on the reflector. This issue is expected to be addressed in the next SCM adhocs and reflected in the final version of the TR.

Contentious Issues:

Annex A was removed. All relevant texts related to the Annex will be removed in the next SCM ad hoc.

3GPP TR 25.996 V 1.0.0(2003-03)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Spatial Channel Model for Multiple-Input Multiple Output Simulations
(Release 6)

3GPP

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

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FOREWORD

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

1.1 Scope

This document details the current discussion of the combined 3GPP-3GPP2 Spatial Channel Ad-hoc group. A similar document, developed independently in the 3GPP2 Spatial Channel Modeling Ad-hoc group, was used for reference.

The scope of the 3GPP-3GPP2 SCM AHG is to develop and specify parameters and methods associated with the spatial channel modeling that are common to the needs of the 3GPP and 3GPP2 organizations (harmonization). The scope includes development of specifications for:

System level evaluation.

Within this category, a list of four focus areas are identified, however the emphasis of the SCM AHG work is on items a & b.

a. Physical parameters (e.g. power delay profiles, angle spreads, dependencies between parameters)

b. System evaluation methodology.

c. Antenna arrangements, reference cases and definition of minimum requirements.

d. Some framework (air interface) dependent parameters.

Link level evaluation.

The link level models are defined only for calibration purposes. It is a common view within the group that the link level simulation assumptions will not be used for evaluation and comparison of proposals.

1.2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] L. Greenstein, V. Erceg, Y. S. Yeh, M. V. Clark, “A New Path-Gain/Delay-Spread Propagation Model for Digital Cellular Channels,” IEEE Transactions on Vehicular Technology, VOL. 46, NO.2, May 1997, pp.477-485.

[2] E. Sousa, V. Jovanovic, C. Daigneault, “Delay Spread Measurements for the Digital Cellular Channel in Toronto,” IEEE Transactions on Vehicular Technology, VOL. 43, NO.4, Nov 1994, pp.837-847.

[3] L. M. Correia, Wireless Flexible Personalized Communications, COST 259: European Co-operation in Mobile Radio Research, Chichester: John Wiley & Sons, 2001.

1.3 Definitions, symbols, and abbreviations

In this document the following are terms that are commonly used interchangeably and are equivalent. To promote consistency, the term on the left will be preferred in this document unless otherwise stated.

MS = Mobile Station = UE = User Equipment = Terminal = Subscriber Unit

BS = Base Station = Node-B = BTS

AS = Angle Spread = Azimuth Spread = σ_{AS}

DS = delay spread = σ_{DS}

LN = lognormal shadow fading = σ_{AS}

Path = Ray

Path Component = Sub-ray

PAS = Power Azimuth Spectrum

DoT = Direction of Travel

AoA = Angle of Arrival

AoD = Angle of Departure

PDP = Power Delay Profile

2 SPATIAL CHANNEL MODEL FOR CALIBRATION PURPOSES

This section describes physical parameters for link level modeling for the purpose of calibration.

2.1 Purpose

Link level simulations alone will not be used for algorithm comparison because they reflect only one snapshot of the channel behavior. Furthermore, they do not account for system attributes such as scheduling and HARQ. For these reasons, link level simulations do not allow any conclusions about the typical behavior of the system. Only system level simulations can achieve that. Therefore we require system level simulations for the final algorithm comparison.

Link level simulations will not be used to compare performance of different algorithms. Rather, they will be used only for calibration, which is the comparison of performance results from different implementations of a given algorithm.

2.2 Link Level Channel Model Parameter Summary

The table below summarizes the physical parameters to be used for link level modeling.

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Model		Case I		Case II		Case III		Case IV	
Corresponding 3GPP Designator*		Case B		Case C		Case D		Case A	
Corresponding 3GPP2 Designator*		Model A, D, E		Model C		Model B		Model F	
PDP		Modified Pedestrian A		Vehicular A		Pedestrian B		Single Path	
# of Paths		1) 4+1 (LOS on, K = 6dB) 2) 4 (LOS off)		6		6		1	
Relative Path Power (dB)	Delay (ns)	1) 0.0 2) -Inf	0	0,0	0	0.0	0	0	0
		1) -6.51 2) 0.0	0	-1.0	310	-0.9	200		
		1) -16.21 2) -9.7	110	-9.0	710	-4.9	800		
		1) -25.71 2) –19.2	190	-10.0	1090	-8.0	1200		
		1) -29.31 2) -22.8	410	-15.0	1730	-7.8	2300		
				-20.0	2510	-23.9	3700		
Speed (km/h)		1) 3 2) 30, 120		3, 30, 120		3, 30, 120		3	
UE/Mobile Station	Topology	Reference 0.5λ		Reference 0.5λ		Reference 0.5λ		N/A	
	PAS	1) LOS on: Fixed AoA for LOS component, remaining power has 360 degree uniform PAS. 2) LOS off: PAS with a Lapacian distribution, RMS angle spread of 35 degrees per path		RMS angle spread of 35 degrees per path with a Lapacian distribution Or 360 degree uniform PAS.		RMS angle spread of 35 degrees per path with a Lapacian distribution		N/A	
	DoT (degrees)	0		22.5		-22.5		N/A	

Model		Case I	Case II	Case III	Case IV
	AoA (degrees)	22.5 (LOS component) 67.5 (all other paths)	67.5 (all paths)	22.5 (odd numbered paths), -67.5 (even numbered paths)	N/A
Node B/ Base Station	Topology	Reference: ULA with 0.5λ-spacing or 4λ-spacing or 10λ-spacing			N/A
Node B/ Base Station	PAS	Lapacian distribution with RMS angle spread of 2 degrees or 5 degrees, per path depending on AoA/AoD			N/A
Node B/ Base Station	AoD/AoA (degrees)	50^o for 2^o RMS angle spread per path 20^o for 5^o RMS angle spread per path			N/A

Table 2-1. Summary of suggested SCM link level parameters for calibration purposes

*Designators correspond to channel models previously proposed in 3GPP and 3GPP2 ad-hoc groups.

2.3 Spatial Parameters per Path

Each resolvable path is characterized by its own spatial channel parameters (angle spread, angle of arrival, power azimuth spectrum). All paths are assumed independent. These assumptions apply to both the BS and the MS specific spatial parameters. The above assumptions are in effect only for the Link Level channel model.

2.4 BS and MS Array Topologies

The spatial channel model should allow any type of antenna configuration to be selected, although details of a given configuration must be shared to allow others to reproduce the model and verify the results.

Calibrating simulators at the link level requires a common set of assumptions including a specific set of antenna topologies to define a baseline case. At the MS, the reference element spacing is 0.5λ. At the BS, three values for reference element spacing are defined: 0.5λ, 4λ, and 10λ.

2.5 Spatial Parameters for the BS

2.5.1 BS Antenna Pattern

The 3-sector antenna pattern used for each sector, Reverse Link and Forward Link, is plotted in Figure 2-1Figure 2-1 and is specified by

$$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, \ A_m\right] \quad \text{where} \quad -180 \le \theta \le 180$$

θ is defined as the angle between the direction of interest and the boresight of the antenna, θ_{3dB} is the 3dB beamwidth in degrees, and A_m is the maximum attenuation. For a 3 sector scenario θ_{3dB} is 70°, $A_m = 20dB$, and the antenna boresight pointing direction is given by Figure 2-2Figure 2-2. For a 6 sector scenario θ_{3dB} is 35°, $A_m = 23dB$, which results in the pattern shown in Figure 2-3Figure 2-3, and the boresight pointing direction defined by Figure 2-4Figure 2-4. The boresight is defined to be the direction to which the antenna shows the maximum gain. The gain specified for the 3-sector 70° antenna is 14dBi. By reducing the beamwidth by half to 35°, the corresponding gain will be 3dB higher resulting in 17dBi. The antenna pattern shown is targeted for diversity oriented implementations (i.e. large inter-element spacings). For beamforming applications that require small spacings, alternative antenna designs may have to be considered leading to a different antenna pattern.

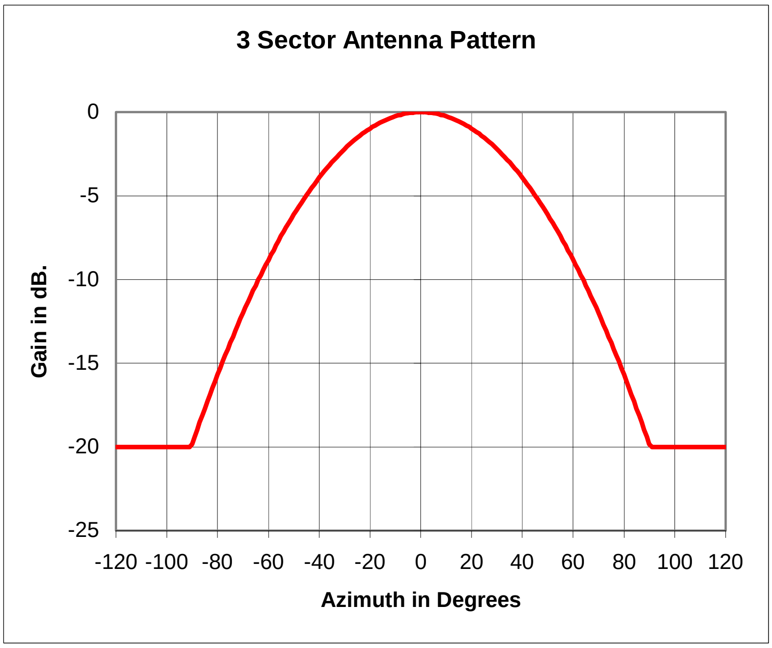

Figure 2-1. Antenna pattern for 3-sector cells

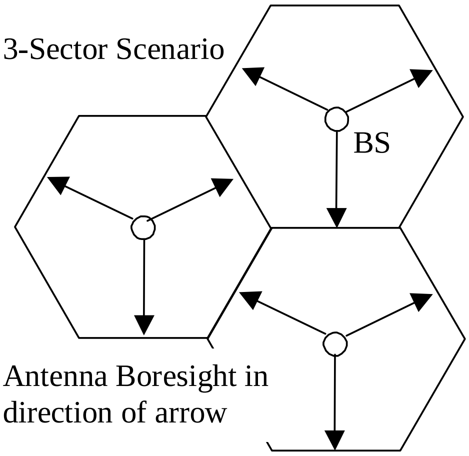

Figure 2-2. Boresight pointing direction for 3-sector cells

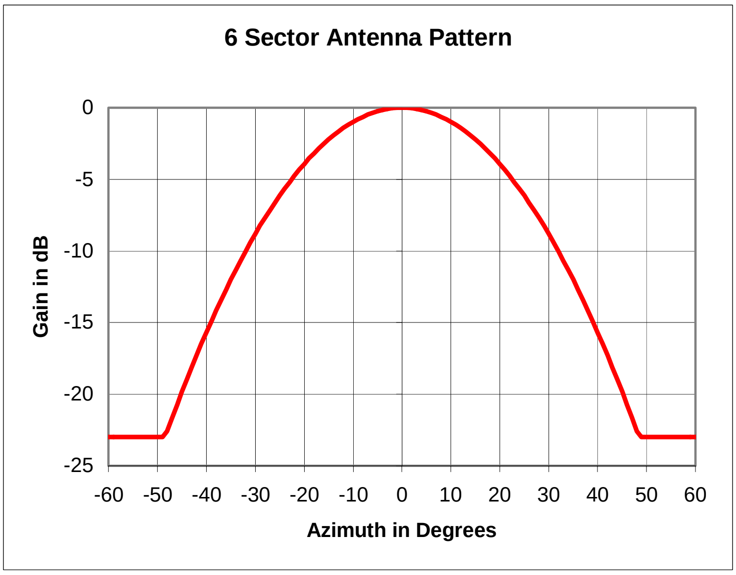

Figure 2-3. Antenna pattern for 6-sector cells

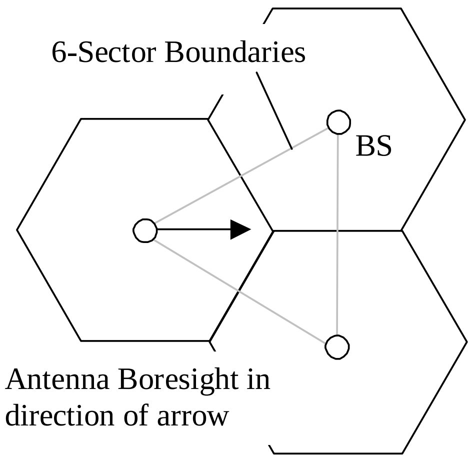

Figure 2-4. Boresight pointing direction for 6-sector cells

2.5.2 Per Path BS Angle Spread (AS)

The base station per path angle spread is defined as the root mean square (RMS) of angles with which an arriving path's power is received by the base station array. The individual path powers are defined in the temporal channel model described in Table 2-1~~Table 2-1~~. Two values of BS angle spread (each associated with a corresponding mean angle of arrival, AoA) are considered:

- AS: 2 degrees at AoA 50 degrees
- AS: 5 degrees at AoA 20 degrees

It should be noted that attention should be paid when comparing the link level performance between the two angle spread values since the BS antenna gain for the two corresponding AoAs will be different. The BS antenna gain is applied to the path powers specified in Table 2-1~~Table 2-1~~.

2.5.3 Per Path BS Angle of Arrival

The Angle of Arrival (AoA) or Angle of Departure (AoD) is defined to be the mean angle with which an arriving or departing path's power is received or transmitted by the BS array with respect to the boresite. The two values considered are:

- AoA: 50 degrees (associated with the RMS Angle Spread of 2 degrees)
- AoA: 20 degrees (associated with the RMS Angle Spread of 5 degrees)

2.5.4 Per Path BS Power Azimuth Spectrum

The Power Azimuth Spectrum (PAS) of a path arriving at the base station is assumed to have a Laplacian distribution. For an incoming AOA $\bar{\theta}$ and RMS angle-spread σ, the BS per path PAS value at an angle θ is given by:

$$P(\theta,\sigma,\overline{\theta}) = N_o \exp\left[\frac{-\sqrt{2}\left|\theta-\overline{\theta}\right|}{\sigma}\right] G(\theta)$$

where both angles $\overline{\theta}$ and θ are given with respect to the boresight of the antenna elements. It is assumed that all antenna elements' orientations are aligned. Also, P is the average received power and G is the numeric base station antenna gain described in Section 2.5.1 by

$$G(\theta) = 10^{0.1A(\theta)}$$

Finally, N_o is the normalization constant:

$$N_o^{-1} = \int_{-\pi+\overline{\theta}}^{\pi+\overline{\theta}} \exp\left[\frac{-\sqrt{2}\left|\theta-\overline{\theta}\right|}{\sigma}\right] \cdot G(\theta)d\theta$$

In the above equation, θ represents path components (sub-rays) of the path power arriving at an incoming AoA $\overline{\theta}$. The distribution of these path components is TBD.

2.6 Spatial Parameters for the MS

2.6.1 MS Antenna Pattern

For each and every antenna element at the MS, the antenna pattern will be assumed omni directional with an antenna gain of -1 dBi.

2.6.2 Per Path MS Angle Spread (AS)

The MS per path AS is defined as the root mean square (RMS) of angles of an incident path's power at the MS array. Two values of the path's angle spread are considered:

- AS: 104 degrees (results from a uniform over 360 degree PAS),
- AS: 35 degrees for a Laplacian PAS with a certain path specific Angle of Arrival (AoA).

2.6.3 Per Path MS Angle of Arrival

The per path Angle of Arrival (AOA) is defined as the mean of angles of an incident path's power at the UE/Mobile Station array with respect to the broadside as shown Figure 2-5Figure 2-5.

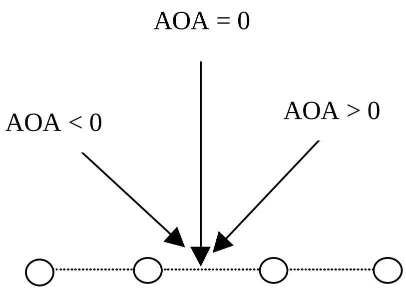

Figure 2-5. Angle of arrival orientation at the MS.

Three different per path AoA values at the MS are suggested for the cases of a non-uniform PAS, see Table 2-1~~Table 2-1~~ for details:

- AoA: -67.5 degrees (associated with an RMS Angle Spread of 35 degrees)
- AoA: +67.5 degrees (associated with an RMS Angle Spread of 35 degrees)
- AoA: +22.5 degrees (associated with an RMS Angle Spread of 35 degrees or with an LOS component)

2.6.4 Per Path MS Power Azimuth Spectrum

The Laplacian distribution and the Uniform distribution are used to model the per path Power Azimuth Spectrum (PAS) at the MS.

The Power Azimuth Spectrum (PAS) of a path arriving at the MS is modeled as either a Laplacian distribution or a uniform over 360 degree distribution. Since an omni directional MS antenna gain is assumed, the received per path PAS will remain either Laplacian or uniform. For an incoming AOA $\overline{\theta}$ and RMS angle-spread σ, the MS per path Laplacian PAS value at an angle θ is given by:

$$P(\theta,\sigma,\overline{\theta}) = N_o \exp\left[\frac{-\sqrt{2}\left|\theta-\overline{\theta}\right|}{\sigma}\right],$$

where both angles $\overline{\theta}$ and θ are given with respect to the boresight of the antenna elements. It is assumed that all antenna elements' orientations are aligned. Also, P is the average received power and N_o is the normalization constant:

$$N_o^{-1} = \int_{-\pi+\overline{\theta}}^{\pi+\overline{\theta}} \exp\left[\frac{-\sqrt{2}\left|\theta-\overline{\theta}\right|}{\sigma}\right] d\theta .$$

In the above equation, θ represents path components (sub-rays) of the path power arriving at an incoming AoA $\overline{\theta}$. The distribution of these path components is TBD.

2.6.5 MS Direction of Travel

The mobile station direction of travel is defined with respect to the broadside of the mobile antenna array as shown in **Figure 2-5**~~**Figure 2-5**~~.

2.6.6 Per Path Doppler Spectrum

The per path Doppler Spectrum is defined as a function of the direction of travel and the per path PAS and AoA at the MS. This should correspond to the per path fading behavior for either the correlation-based or ray-based method.

2.7 Generation of Channel Model

The proponent can determine the model implementation. Examples of implementations include correlation or ray-based techniques.

Outline of methodology, including doppler spectrum filter is required for correlation method.

2.8 Calibration and Reference Values

For the purpose of link level simulations, reference values of the average correlation are given below in Table 2-2~~Table 2-2~~. The reference values are provided for the calibration of the simulation software and to assist in the resolution of possible errors in the simulation methods implemented. Specifically, the average complex correlation and magnitude of the complex correlation is reported between BS antennas and between MS antennas. The spatial parameter values used are those defined already throughout Section 2.

	Antenna Spacing	AS (degrees)	AOA (degrees)	Correlation (magnitude)	Complex Correlation
BS	0.5 λ	5	20	0.9688	0.4743+0.8448i
	0.5 λ	2	50	0.9975	-0.7367+0.6725i
	4 λ	5	20	0.3224	-0.2144+0.2408i
	4 λ	2	50	0.8624	0.8025+0.3158i
	10 λ	5	20	0.0704	-0.0617+i0.034
	10 λ	2	50	0.5018	-0.2762-i0.4190
MS	λ /2	104	0	0.3042	-0.3042
	λ /2	35	-67.5	0.7744	-0.6948-i0.342
	λ /2	35	22.5	0.4399	0.0861+0.431i
	λ /2	35	67.5	0.7744	-0.6948+i0.342

Table 2-2. Reference correlation values.

3 SPATIAL CHANNEL MODEL FOR SIMULATIONS

The spatial channel model for use in the system-level simulations is described in this section.

As opposed to link simulations which simply consider a single BS transmitting to a single MS, the system simulations typically consist of multiple cells, BSs, and MSs. Performance metrics such as throughput and delay are collected over *D* drops, where a "drop" is defined as a simulation run for a given number of cells, BSs, and MSs, over a specified number of frames. During a drop, the channel undergoes fast fading according to the motion of the MSs. Channel state information is fed back from the MSs to the BSs, and the BSs use schedulers to determine which user(s) to transmit to. Typically, over a series of *D* drops, the cell layout and locations of the BSs are fixed, but the locations of the MSs are randomly varied at the beginning of each drop. To simplify the simulation, only a subset of BSs will actually be simulated while the remaining BSs are assumed to transmit with full power. (Questions remain about how to model interfering BS powers.)

The goal of this section is to define the methodology and parameters for generating the spatial and temporal channel coefficients between a given base and mobile for use in system level simulations. For an *S* element BS array and a *U* element MS array, the channel coefficients for one of N multipath components (note that these components are not necessarily time resolvable, meaning that the time difference between successive paths may be less than a chip period) are given by an S -by- U matrix of complex amplitudes. We denote the channel matrix for the nth multipath component (n = 1,…,N) as $\mathbf{H}_n(t)$. It is a function of time t because the complex amplitudes are undergoing fast fading governed by the movement of the MS. The overall procedure for generating the channel matrices consists of three basic steps:

1. Specify an environment, either suburban macro, urban macro, or urban micro (Section 3.2).
2. Obtain the parameters to be used in simulations, associated with that environment (Section 3.3).
3. Generate the channel coefficients based on the parameters (Section 3.4).

Sections 3.2, 3.3, and 3.4 give the details for the general procedure. Figure 3-1~~Figure 3-1~~below provides a roadmap for generating the channel coefficients. (This diagram should be greatly expanded and should show which section numbers each of the items is discussed.) Section 3.5 considers options for modifying the general procedure. Section 3.6 describes the procedure for generating correlated log normal user parameters used in Section 3.3. Section 3.7 describes the method for accounting for intercell interference. Section 3.8 presents calibration results.

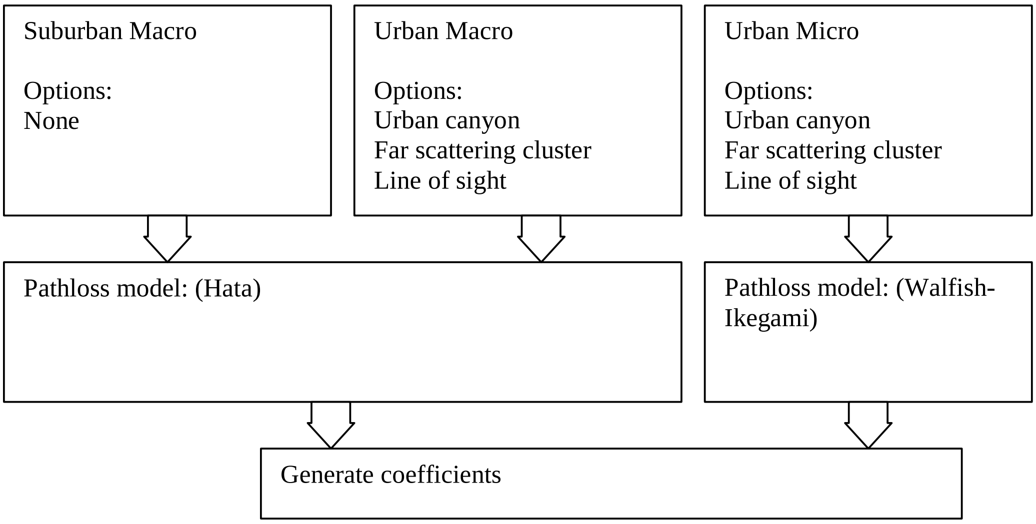

Figure 3-1. Channel model overview for simulations

3.1 General definitions, parameters, and assumptions

The received signal at the MS consists of N time-delayed multipath replicas of the transmitted signal. These N paths are defined by powers and delays and are chosen randomly according to the channel generation procedure. Each path consists of M subpaths.

Figure 3-2~~Figure 3-2~~ shows the angular parameters used in the model. The following definitions are used:

Ω_{BS} BS antenna array orientation, defined as the difference between the broadside of the BS array and the absolute North (N) reference direction.

θ_{BS} LOS AoD direction between the BS and MS, with respect to the broadside of the BS array.

$\delta_{n,AoD}$ AoD for the *n*th (n = 1 … N) path with respect to the LOS AoD θ_0 .

$\Delta_{n,m,AoD}$ Offset for the *m*th (m = 1 … M) subpath of the *n*th path with respect to $\delta_{n,AoD}$.

$\theta_{n,m,AoD}$ Absolute AoD for the *m*th (m = 1 … M) subpath of the *n*th path at the BS with respect to the BS broadside.

Ω_{MS} MS antenna array orientation, defined as the difference between the broadside of the MS array and the absolute North reference direction.

θ_{MS} Angle between the BS-MS LOS and the MS broadside.

$\delta_{n,AoA}$ AoA for the *n*th (n = 1 … N) path with respect to the LOS AoA $\theta_{0,MS}$.

$\Delta_{n,m,AoA}$ Offset for the *m*th (m = 1 … M) subpath of the *n*th path with respect to $\delta_{n,AoA}$.

$\theta_{n,m,AoA}$ Absolute AoA for the *m*th (m = 1 … M) subpath of the *n*th path at the BS with respect to the BS broadside.

v MS velocity vector.

θ_v Angle of the velocity vector with respect to the MS broadside: θ_v =arg(**v**).

The angles shown in Figure 1 that are measured in a clockwise direction are assumed to be negative in value.

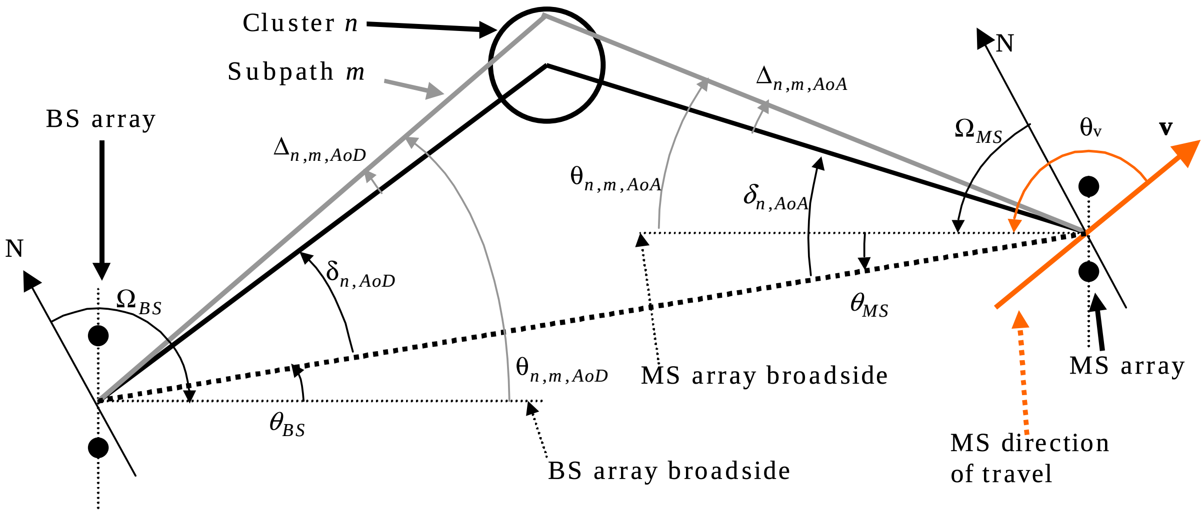

Figure 3-2. BS and MS angle parameters

For system level simulation purposes, the fast fading per-path will be evolved in time, although bulk parameters including angle spread, delay spread, log normal shadowing, and MS location will remain fixed during the evaluation of the given MS.

The following are general assumptions made for all simulations, independent of environment:

1. Uplink-Downlink Reciprocity: The AoD/AoA values are identical between the uplink and downlink.

2. Random path phases between UL, DL are uncorrelated.
3. Mobile-to-mobile shadowing is uncorrelated.
4. The spatial channel model should allow any type of antenna configuration to be selected, although details of a given configuration must be shared to allow others to reproduce the model and verify the results. It is intended that the spatial channel model be capable of operating on any given antenna array configuration. In order to compare algorithms, reference antenna configurations based on uniform linear array configurations with 0.5, 4, and 10 wavelength inter-element spacing will be used.

3.2 Environments

We consider the following three environments.

1. Suburban macrocell (approximately 3Km distance BS to BS)
2. Urban macrocell (approximately 3Km distance BS to BS)
3. Urban microcell (less than 1Km distance BS to BS)

The characteristics of the macro cell environments assume that BS antennas are above rooftop height. For the urban microcell scenario, we assume the BS antenna is at rooftop height. Table 3-1Table 3-1 describes the parameters used in each of the environments.

Channel Scenario	**Suburban Macro**	**Urban Macro**	**Urban Micro**
Number of paths (*N*)	6	6	6
Number of sub-paths (*M*) per path	20	20	20
Mean composite AS at BS	$E(\sigma_{AS})=5^0$	$E(\sigma_{AS})=8^0$, 15^0	NLOS: $E(\sigma_{AS})=19^0$
r_{DS} ($\sigma_{delays}/\sigma_{DS}$)	1.4	1.7	N/A
r_{AS} ($\sigma_{AoD}/\sigma_{PAS}$)	1.2	1.3	N/A
Composite AS at BS as a lognormal RV when simulating with 6 paths $\sigma_{AS} = 10\wedge(\varepsilon_{AS}x + \mu_{AS}),\ x \sim \eta(0,1)$	μ_{AS}= 0.69 ε_{AS}= 0.13	8^0 μ_{AS}= 0.810 ε_{AS}= 0.3295 15^0 μ_{AS}= 1.18 ε_{AS}= 0.210	N/A
Per path AS at BS (Fixed)	2 deg	2 deg	5 deg (LOS and NLOS)
BS Per path AoD Distribution st dev	$N(0, \sigma^2_{AoD})$, where $\sigma_{AoD} = r_{AS}*\sigma_{AS}$	$N(0, \sigma^2_{AoD})$, where $\sigma_{AoD} = r_{AS}*\sigma_{AS}$	U(-40deg, 40deg)
Mean of RMS composite AS at MS	$E(\sigma_{AS,\,comp,UE})=72^0$	$E(\sigma_{AS,\,comp,\,UE})=72^0$	$E(\sigma_{AS,\,comp,\,UE})=72^0$
Per path AS at MS (fixed)	35^0	35^0	35^0
MS Per path AoA Distribution	$N(0, \sigma^2_{AoA}(P_r))$	$N(0, \sigma^2_{AoA}(P_r))$	$N(0, \sigma^2_{AoA}(P_r))$

Mean total RMS Delay Spread	$E(\sigma_{DS})$=0.17 μs	$E(\sigma_{DS})$=0.65 μs	N/A
Distribution for path delays			U(0, 1.2μs)
Narrowband composite delay spread as a lognormal RV when simulating with 6 paths $\sigma_{DS} = 10 \wedge (\varepsilon_{DS} x + \mu_{DS}), x \sim \eta(0,1)$	μ_{DS} = - 6.80 ε_{DS} = 0.288	μ_{DS} = -6.18 ε_{DS} = 0.18	N/A
Lognormal shadowing standard deviation	8dB	8dB	NLOS: 10dB LOS: 4dB
Pathloss model (dB), *d* is in meters	NLOS and LOS: 28.6 + 35log10(*d*)	NLOS and LOS: 28.6 + 35log10(*d*)	NLOS: 36 + 38log10(*d*) LOS: 30.6 + 26*log10(*d*)

Table 3-1. Environment parameters

The following are assumptions made for the *suburban macrocell* and *urban macrocell* environments.

1. The macrocell pathloss from 3GPP2 evaluation methodology will be used, based on a modified Hata urban propagation model at 1.9 GHz carrier frequency (COST 231). Assuming the BS antenna height is 32m, and the MS antenna height is 1.5m, the pathloss is 28.6 + 35log10(*d*) dB, where *d* is distance between the BS and MS in meters. The distance *d* is at least 35m.

2. Antenna patterns at the BS are the same as those used in the link simulations given in Section 2.5.1.

3. Site-to-site LN correlation is $\eta = 0.5$. This parameter is used in Section 3.6.2.

The following are assumptions made for the *microcell* environment.

1. Antenna patterns at the BS are the same as those used in the link simulations given in Section 2.5.1.

2. Site-to-site correlation follows the macrocell model ($\eta = 0.5$).

3. The hexagonal cell repeats will be the assumed layout.

For the microcell NLOS environment, a Walfish-Ikegami model is used with the following parameters: BS antenna height 12.5m, building to building distance 50m, street width 25m, MS antenna height 1.5m, orientation 30deg for all paths, frequency 2GHz. The resulting pathloss equation is 36 + 38*log10(*d*), where *d* is in meters. A bulk log normal shadowing applying to all paths has a standard deviation of 10dB.

For the microcell LOS environment, a Walfish-Ikegami street canyon model is used. The pathloss is 30.6 + 26*log10(*d*), where *d* is in meters. A bulk log normal shadowing applying to all paths has a standard deviation of 4dB.

3.3 Generating User Parameters

For a given scenario and set of parameters given by a column of Table 3-1, realizations of each user's parameters such as the path delays, powers, and subpath angles of departure and arrival can be derived using the procedure described here in Section 3.3. In particular, Section 3.3.1 gives the steps for the urban macrocell and suburban macrocell environments, and Section 3.3.2 gives the steps for the urban microcell environments.

3.3.1 Generating user parameters for urban macrocell and suburban macrocell environments

Step 1: *Choose either an urban macrocell or suburban macrocell environment.*

Step 2: *Determine various distance and orientation parameters*. The placement of the MS with respect to each BS is to be determined according to the cell layout. From this placement, the distance between the MS and the BS (*d*) and the LOS directions with respect to the BS and MS (θ_{BS} and θ_{MS} , respectively) can be determined. The MS antenna array orientations (Ω_{MS}), are i.i.d., drawn from a uniform 0 to 360 degree distribution. The MS velocity vector **v** has a magnitude $\|\mathbf{v}\|$ drawn according to a velocity distribution (to be determined) and direction θ_v drawn from a uniform 0 to 360 degree distribution.

Step 3: *Determine the DS, AS, and LN.* These variables, given respectively by σ_{DS} , σ_{AS} , and σ_{LN} , are generated as described in Section 3.6 below. Note that 10^(μ_{DS})is in units of seconds so that the narrowband composite delay spread σ_{DS} is in units of seconds. Note also that we have dropped the BS indicies used in Section 3.6.1 to simplify notation.

Step 4: *Determine random delays for each of the N multipath components*. For macrocell environments, *N* = 6 as given in Table 3.1. Generate random variables $\tau'_1,\ldots,\tau'_N$ according to

$$\tau'_n = -r_{DS}\sigma_{DS}\log z_n \qquad n = 1,\ldots,N$$

where z_n (n = 1,…,N) are i.i.d. random variables with uniform distribution$U$(0,1), r_{DS} is given in Table 3-1~~Table 3-1~~, and σ_{DS} is derived in Step 2 above. These variables are ordered so that $\tau'_{(N)} > \tau'_{(5)} > \ldots > \tau'_{(1)}$ and the minimum of these is subtracted from all so that the first delay is always zero. The delays are quantized in time to the nearest 1/16th chip interval. Then the 6 delays are given by:

$$\tau_n = \frac{T_c}{16}\cdot \mathrm{floor}\left(\frac{\tau'_{(n)} - \tau'_{(1)}}{T_c/16} + 0.5\right), \qquad n = 1,\ldots,N\ ,$$

where floor(x) is the integer part of x, and T_c is the chip interval (T_c = 1/3.84x10^6 sec for 3GPP and T_c = 1/1.2288x10^6 sec for 3GPP2). Then the 6 delays are given by:

$$\tau_n = \tau'_{(n)} - \tau'_{(1)}, \qquad n = 1,\ldots,N\ .$$

Note that these delays are ordered so that $\tau_N > \tau_5 > \ldots > \tau_1 = 0$. (See notes 1 and 2 at the end of Section 3.3.1.) Quantization to 1/16 chip is the default value. For special purpose implementations, possibly higher quantization values may be used if needed.

Step 5: *Determine random average powers for each of the N multipath components*. Let the unnormalized powers be given by

$$P'_n = e^{\frac{(1-r_{DS})\cdot(\tau'_{(n)}-\tau'_{(1)})}{r_{DS}\cdot\sigma_{DS}}}\cdot 10^{-\xi_n},\ n = 1,\ldots,6$$

where ξ_n (n = 1,…,6) are i.i.d. Gaussian random variables with variance σ^2_{RND} = 3 dB, which is a shadowing randomization effect on the per-path powers. Note that the powers are determined using the unquantized channel delays. Average powers are normalized so that total average power for all six paths is equal to one:

$$P_n = \frac{P'_n}{\sum_{n=1}^{6} P'_n}.$$

(See note 3 at the end of Section 3.3.1.)

Step 6: *Determine AoDs for each of the N multipath components*. First generate i.i.d. zero-mean Gaussian random variables:

$$\delta'_n \sim \eta(0,\sigma^2_{AoD}),\qquad n = 1,\ldots, N,$$

where $\sigma_{AoD} = r_{AS}*\sigma_{AS}$. The value r_{AS} is given in Table 3-1 and depends on whether the urban or suburban macrocell environment is chosen. The angle spread σ_{AS} is generated in Step 3. These variables are given in degrees. They are ordered in increasing absolute value so that $|\delta'_{(1)}| < |\delta'_{(2)}| < \ldots < |\delta'_{(N)}|$. The AoDs $\delta_{n,AoD}$, n = 1,…, N are assigned to the ordered variables so that $\delta_{n,AoD} = \delta'_{(n)}$, n = 1,…,N. (See note 4 at the end of Section 3.3.1.)

Step 7: *Associate the multipath delays with AoDs*. The nth delay τ_n generated in Step 3 is associated with the nth AoD $\delta_{n,AoD}$ generated in Step 6.

Step 8: *Determine the powers, phases, and offset AoDs of the M = 20 sub-paths for each of the N paths at the BS*. All 20 sub-path associated with the nth path have identical powers ($P_n/20$ where P_n is from Step 5) and i.i.d phases $\Phi_{n,m}$ drawn from a uniform 0 to 360 degree distribution. The relative offset of the mth subpath (m = 1,…, M) $\Delta_{n,m,AoD}$ is a fixed value given in Table 3-2~~Table 3-2~~. For example, for the urban and suburban macrocell cases, the offsets for the first and second sub-paths are respectively $\Delta_{n,1,AoD}$ = 0.0894 and $\Delta_{n,2,AoD}$ = -0.0894 degrees. These offsets are chosen to result in the desired per path angle spread (2 degrees for the macrocell environments, and 5 degrees for the microcell environment).

Step 9: *Determine the AoAs for each of the multipath components*. The AoAs are i.i.d Gaussian random variables

$$\delta_{n,AoA} \sim \eta(0,\sigma^2_{n,AoA}),\qquad n = 1,\ldots, N,$$

where $\sigma_{n,AoA} = 104.12\left(1\text{-}\exp\left(\text{-}0.2175\left|10\log_{10}(P_n)\right|\right)\right)$ and P_n is the relative power of the nth path from Step 5.

Step 10: *Determine the offset AoAs at the UE of the M = 20 sub-paths for each of the N paths at the MS*. As in Step 8 for the AoD offsets, the relative offset of the *m*th subpath (m = 1,..., M) $\Delta_{n,m,AoA}$ is a fixed value given in Table 3-2Table 3-2. These offsets are chosen to result in the desired per path angle spread of 35 degrees.

Step 11: *Associate the BS and MS paths and sub-paths*. The *n*th BS path (defined by its delay τ_n, power P_n, and AoD $\delta_{n,AoD}$) is associated with the *n*th MS path (defined by its AoA $\delta_{n,AoA}$). For the *n*th path pair, randomly pair each of the M BS sub-paths (defined by its offset $\Delta_{n,m,AoD}$ and phase $\Phi_{n,m}$) with a MS sub-path (defined by its offset $\Delta_{n,m,AoA}$). To simplify the notation, we renumber the M MS sub-path offsets with their newly associated BS sub-path. In other words, if the first (m = 1) BS sub-path is randomly paired with the 10th (m = 10) MS sub-path, we re-associate $\Delta_{n,1,AoA}$ (after pairing) with $\Delta_{n,10,AoA}$ (before pairing).

Step 12: *Determine the antenna gains of the BS and MS sub-paths as a function of their respective sub-path AoDs and AoAs*. For the *n*th path, the AoD of the *m*th sub-path (with respect to the BS antenna array broadside) is

$$\theta_{n,m,AoD} = \theta_{BS} + \delta_{n,AoD} + \Delta_{n,m,AoD}.$$

Similarly, the AoA of the *m*th sub-path for the *n*th path (with respect to the MS antenna array broadside) is

$$\theta_{n,m,AoA} = \theta_{MS} + \delta_{n,AoA} + \Delta_{n,m,AoA}.$$

The antenna gains are dependent on these sub-path AoDs and AoAs. For the BS and MS, these are given respectively as $G_{BS}(\theta_{n,m,AoD})$ and $G_{MS}(\theta_{n,m,AoA})$.

Notes:

Note 1: In the development of the Spatial Channel Model, care was taken to include the statistical relationships between Angles and Powers, as well as Delays and Powers. This was done using the proportionality factors $r_{DS} = \sigma_{delays}/\sigma_{DS}$ and $r_{AS} = \sigma_{AoD}/\sigma_{PAS}$ that were based on measurements.)

Note 2: While there is some evidence that delay spread may depend on distance between the transmitter and receiver, the effect is considered to be minor (compared to other dependencies: DS-AS, DS-LN.). Various inputs based on multiple data sets indicate that the trend of DS can be either slightly positive or negative, and may sometimes be relatively flat with distance. For these reasons and also for simplicity, a distance dependence on DS is not modeled.

Note 3: The equations presented here for the power of the nth path are based on an power-delay envelope which is the average behavior of the power-delay profile. Defining the powers to reproduce the average behavior limits the dynamic range of the result and does not reproduce the expected randomness from trial to trial. The randomizing noise ξ_n is used to vary the powers with respect to the average envelope to reproduce the variations experienced in the actual channel. This parameter is also necessary to produce a dynamic range comparable to measurements.

Note 4: The quantity r_{AS} describes the distribution of powers in angle and $r_{AS} = \sigma_{AoD}/\sigma_{AS}$, i.e. the spread of angles to the power weighted angle spread. Higher values of r_{AS} correspond to more power being concentrated in a small AoD or a small number of paths that are closely spaced in angle.

3.3.2 Generating user parameters for urban microcell environments

Urban microcell environments differ from the macrocell environments in that the individual multipaths are independently shadowed. Also, only N = 3 (instead of 6) paths are modeled because of the reduced delay spread in microcells. We list the entire procedure but only describe the details of the steps that differ from the corresponding step of the macrocell procedure.

Step 1: *Choose the urban microcell environment.*

Step 2: *Determine various distance and orientation parameters.*

Step 3: *Determine the DS, AS, and LN.*

Step 4: *Determine the random delays for each of the N multipath components*. For the microcell environment, N = 6. The delays τ_n, n = 1, … ,N are i.i.d. random variables drawn from a uniform distribution from 0 to 1.2 µs.

Step 5: *Determine random average powers for each of the N multipath components*. The PDP consists of N=6 distinct paths that are uniformly distributed between 0 and 1.2µs. The powers for each path are exponentially decaying in time with the addition of a lognormal randomness, which is independent of the path delay:

$$P_n = 10^{-(\tau_n + z_n)}$$

where τ_n is given in units of microseconds, and z_n (n = 1,…,N) are i.i.d. zero mean Gaussian random variables with variance of (3dB)^2. The lognormal variation of each path produces the variation seen in the path powers, and a separate log normal shadowing value is applied in common to all paths.

Step 6: *Determine AoDs for each of the N multipath components*. The AoDs (with respect to the LOS direction) are i.i.d. random variables drawn from a uniform distribution over –40 to +40 degrees:

$$\delta_{n,AoD} \sim U(-40\ ,+40\ ), \qquad n = 1,\ldots, N,$$

Associate the AoD of the nth path $\delta_{n,AoD}$ with the power of the nth path P_n. Note unlike the macrocell environment, the AoDs do not need to be sorted before being assigned to a path power.

Step 7: *Associate the multipath delays with AoDs.*

Step 8: *Determine the powers, phases, and offset AoDs of the M = 20 sub-paths for each of the N paths at the BS*. The offsets are given in Table 3-2, and the resulting per path AS is 5 degrees instead of 2 degrees for the macrocell case.

Step 9: *Determine the AoAs for each of the multipath components*. The AoAs are i.i.d Gaussian random variables

$$\delta_{n,AoA} \sim \eta(0, \sigma^2_{n,AoA}), \qquad n = 1,\ldots, N,$$

where $\sigma_{n,AoA} = 104.12\left(1\text{-exp}\left(-0.265\left|10\log_{10}(P_n)\right|\right)\right)$ and P_n is the relative power of the nth path from Step 5.

Step 10: *Determine the offset AoAs of the M = 20 sub-paths for each of the N paths at the MS.*

Step 11: *Associate the BS and MS paths and sub-paths.*

Step 12: *Determine the antenna gains of the BS and MS sub-paths as a function of their respective sub-path AoDs and AoAs.*

Sub-path # (m)	Offset for a 2 deg AS at BS (Macrocell) $\Delta_{n,m,AoD}$ (degrees)	Offset for a 5 deg AS at BS (Microcell) $\Delta_{n,m,AoD}$ (degrees)	Offset for a 35 deg AS at MS $\Delta_{n,m,AoA}$ (degrees)
1, 2	± 0.0894	± 0.2236	± 1.5649
3, 4	± 0.2826	± 0.7064	± 4.9447
5, 6	± 0.4984	± 1.2461	± 8.7224
7, 8	± 0.7431	± 1.8578	± 13.0045
9, 10	± 1.0257	± 2.5642	± 17.9492
11, 12	± 1.3594	± 3.3986	± 23.7899
13, 14	± 1.7688	± 4.4220	± 30.9538
15, 16	± 2.2961	± 5.7403	± 40.1824
17, 18	± 3.0389	± 7.5974	± 53.1816
19, 20	± 4.3101	± 10.7753	± 75.4274

Table 3-2. Sub-path AoD and AoA offsets

The values in Table 3-2~~Table 3-2~~ are selected to produce a biased standard deviation equal to 2, 5, and 35 degrees, which is equivalent to the per-path power weighted azimuth spread for equal power sub-paths.

3.4 Generating channel coefficients

Given the user parameters generated in Section 3.3, we use them to generate the channel coefficients. For an S element BS array and a U element MS array, the channel coefficients for one of N multipath components are given by an S -by- U matrix of complex amplitudes. We denote the channel matrix for the nth multipath component (n = 1,…,N) as $\mathbf{H}_n(t)$. The (s,u)th component (s = 1,…,S; u = 1,…,U) of $\mathbf{H}_n(t)$ is given by

$$h_{s,u,n}(t) = \sqrt{\frac{P_n}{M}} \sum_{m=1}^{M} \left(\begin{array}{l} \sqrt{G_{BS}(\theta_{n,m,AoD})}\exp\left(jkd_s \sin(\theta_{n,m,AoD})\right)\times \\ \sqrt{G_{MS}(\theta_{n,m,AoA})}\exp\left(j\left[kd_u \sin(\theta_{n,m,AoA}) + \Phi_{n,m}\right]\right) \end{array} \right) \cdot \exp\left(jk\left\|\mathbf{v}\right\|\cos(\theta_{m,n,AoA} - \theta_v)\, t\right)$$

where

P_n is the power of the nth path (Step 5).

M is the number of subpaths per path.

$\theta_{n,m,AoD}$ is the the AoD for the mth subpath of the nth path (Step 12).

$\theta_{n,m,AoA}$ is the the AoA for the mth subpath of the nth path (Step 12).

$G_{BS}(\theta_{n,m,AoD})$ is the BS antenna array gain (Step 12).

$G_{MS}(\theta_{n,m,AoA})$ is the MS antenna array gain (Step 12).

j is the square root of -1.

k is the wave number $2\pi/\lambda$ where λ is the carrier wavelength in meters.

d_s is the distance in meters from BS antenna element s from the reference (s = 1) antenna. For the reference antenna s = 1, d_1=0.

d_u is the distance in meters from MS antenna element u from the reference (u = 1) antenna. For the reference antenna u = 1, d_1=0.

$\Phi_{n,m}$ is the phase of the mth subpath of the nth path (Step 8).

$\|\mathbf{v}\|$ is the magnitude of the MS velocity vector (Step 2).

θ_v is the angle of the MS velocity vector (Step 2).

3.5 Optional system simulation features

3.5.1 Polarized arrays

Practical antennas on handheld devices require spacings much less than $\lambda/2$. Polarized antennas are likely to be the primary way to implement multiple antennas. A cross-polarized model is therefore included here.

A method of describing polarized antennas is presented, which is compatible with the 12 step procedure given in section 3.3. The following steps extend the original 12 to account for the additional polarized components. Each element of the S element BS array and U element MS array consists of cross-polarized elements.

- **Step 13:** *Generate additional cross-polarized subpaths.* For each of the 6 paths of Step 4, generate an addition M subpaths at the MS and M subpaths at the BS to represent the portion of each signal that leaks into the cross-polarized antenna orientation due to scattering.
- **Step 14:**. *Set subpath AoDs and AoAs.* Set the AoD and AoA of each subpath in Step 13 equal to that of the corresponding subpath of the co-polarized antenna orientation. (Orthogonal sub-rays arrive/depart at common angles.)
- **Step 15:** *Generate phase offsets for the cross-polarized elements.* We define $\Phi_{n,m}^{(x,y)}$ to be the phase offset of the mth subpath of the nth path between the x component (e.g. either the horizontal h or vertical v) of the BS element and the y component (e.g. either the horizontal h or vertical v) of the MS element. Set $\Phi_{n,m}^{(x,x)}$ to be $\Phi_{n,m}$ generated in Step 8 of Section 3.3.

Generate $\Phi_{n,m}^{(x,y)}$, $\Phi_{n,m}^{(y,x)}$, and $\Phi_{n,m}^{(y,y)}$ as i.i.d random variables drawn from a uniform 0 to 360 degree distribution. (x and y can alternatively represent the co-polarized and cross-polarized orientations.)

- **Step 16:** Decompose each of the co-polarized and cross-polarized sub-rays into vertical and horizontal components based on the co-polarized and cross-polarized orientations.
- **Step 17:** The power P2 of each ray in the cross-polarized orientation is set relative to the power P1 of each ray in the co-polarized orientation according to an XPD ratio, defined as XPD= P1/P2.
- For urban macrocells: P2 = P1 - A - B*N(0,1), where A=0.34*(mean relative path power)+7.2 dB, and B=5.5dB is the standard deviation of the XPD variation.
- For urban microcells: P2 = P1 - A - B*N(0,1), where A=8 dB, and B=8dB is the standard deviation of the XPD variation.
- **Step 18:** At the receive antennas, decompose each of the vertical and horizontal components into components that are co-polarized with the receive antennas and sum the components.

The fading behavior between the cross pol elements will be a function of the per-ray spreads and the Doppler. The fading between orthogonal polarizations has been observed to be independent and therefore the sub-rays phases are chosen randomly. The propagation characteristics of V-to-V paths are assumed to be equivalent to the propagation characteristics of H-to-H paths.

The polarization model can be illustrated by a matrix describing the propagation of and mixing between horizontal and vertical amplitude of each sub-path. The resulting channel realization is:

$$h_{s,u,n}(t) = \sqrt{\frac{P_n}{M}} \left(\sum_{m=1}^{M} \begin{bmatrix} \sqrt{G_{BS}^{(v)}(\theta_{n,m,AoD})} \\ \sqrt{G_{BS}^{(h)}(\theta_{n,m,AoD})} \end{bmatrix}^T \begin{bmatrix} \exp\left(\Phi_{n,m}^{(v,v)}\right) & \sqrt{r_n}\exp\left(\Phi_{n,m}^{(h,v)}\right) \\ \sqrt{r_n}\exp\left(\Phi_{n,m}^{(v,h)}\right) & \exp\left(\Phi_{n,m}^{(h,h)}\right) \end{bmatrix} \begin{bmatrix} \sqrt{G_{MS}^{(v)}(\theta_{n,m,AoD})} \\ \sqrt{G_{MS}^{(h)}(\theta_{n,m,AoD})} \end{bmatrix} \times \exp\left(jkd_s \sin(\theta_{n,m,AoD})\right) \times \exp\left(jkd_u \sin(\theta_{n,m,AoA})\right) \times \exp\left(jk\|\mathbf{v}\|\cos(\theta_{n,m,AoA} - \theta_v)\, t\right) \right)$$

where:

$G_{BS}^{(v)}(\theta_{n,m,AoD})$ is the BS antenna array gain for the vertically polarized component.

$G_{BS}^{(h)}(\theta_{n,m,AoD})$ is the BS antenna array gain for the horizontally polarized component.

$G_{MS}^{(v)}(\theta_{n,m,AoD})$ is the MS antenna array gain for the vertically polarized component.

$G_{MS}^{(h)}(\theta_{n,m,AoD})$ is the MS antenna array gain for the horizontally polarized component.

r_n is the average power ratio of waves of the nth path leaving the BS in the vertical direction and arriving at the MS in the horizontal direction (v-h) to those leaving in the vertical direction and arriving in the vertical direction (v-v). By symmetry, the power ratio of the opposite process (h-v over vv) is the same.

$\Phi_{n,m}^{(h,h)}$ phase offset of the mth subpath of the nth path between the x component (either the horizontal h or vertical v) of the BS element and the y component (either the horizontal h or vertical v) of the MS element.

The other variables are described in Section 3.4.

The 2x2 matrix represents the scattering phases and amplitudes of a plane wave leaving the UE with a given angle and polarization and arriving Node B with another direction and polarization. r_n is the average power ratio of waves leaving the UE in the vertical direction and arriving at Node B in the horizontal direction (v-h) to those arriving at Node B in the vertical direction (v-v). By symmetry the power ratio of the opposite process (h-v over v-v) is chosen to be the same. Note that: $r_n = 1/\text{XPD}$; for the macrocell model, the XPD is dependent on the path index; for the microcell model, the XPD is independent of path index.

Expression (2) assumes a random pairing of the of the sub-paths from the MS and BS. The random orientation of the MS (UE) array affects the value of the angle $\theta_{n,m,AoA}$ of each sub-path.

If for example, vertically polarized antennas are used only at both NodeB and UE then the antenna responses become $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$ and expression (2) becomes identical to (1). For an ideal dipole antenna at the NodeB tilted with respect to the z-axis at α degrees the above vector becomes $\begin{bmatrix} \cos(\alpha) \\ \sin(\alpha)\cdot\cos(\theta_{n,m,AoA}) \end{bmatrix}$.

The elevation spectrum is not modeled.

3.5.2 Far scatterer clusters

The Far scatterer cluster model is switch selectable. It represents the bad-urban case where additional clusters are seen in the environment. This model is limited to use with the urban macro-cell where the first cluster will be the primary cluster and the second will be the far scattering cluster (FSC). When the model is active, it will have the following characteristics:

1. There is a reduction in the number of paths in the primary cluster from N = 6 to N = 4, with the far scattering cluster then having N = 2. Thus the total number of paths will stay the same, now N = 4 + 2. This is a modification to the SCM channel generation procedure in section 3.3.
2. FSCs will lie only outside a 500m radius from the BS/NodeB.
3. The FSCs will only be modeled for the serving cell, with 3 independent FSCs in the cell uniformly applied to the area of the cell outside the minimum radius.
4. The model statistics of the two clusters are identical (cluster DS, AS, PDP) but independently drawn. The FSC also has independent shadowing per path with a site-to-site correlation of 50%.

5. The FCS is attenuated by 1dB/microsec delay with respect to the 1st cluster with a 10dB maximum. The excess delay will be defined as the difference in propagation time between the BS-MS LOS distance, and the BS-FSC-MS distance.

6. The FSC is modeled within the serving cell only and dropped following a uniform distribution.

The following method will be used to set the path powers: Draw the N=4 path powers from the channel generation procedure in section 3.3, then draw a separate set of N=2 path powers from the same procedure. The two groups are kept separate and un-normalized. Now the delay based attenuation is applied to the group of N=2 paths, and the N=6 total paths are normalized to unity power after accounting for the bulk log normal shadowing per cluster including site-to-site correlation

3.5.3 Line of sight

The Line-of-sight (LOS) model an option that is switch selectable. It can be selected for the micro cases. LOS modeling will not be defined for the suburban or urban cases. It uses the following description when this function is selected.

For the NLOS case, the Rice factor is set to 0, thus the fading is determined by the combination of sub-rays as described in section 3.3 of the model.

For the LOS case, the Rice factor K is based on a simplified version of [Foster 1994] : K = 13-0.03*d (dB) where d is the distance between MS and BS in meters.

The probability for LOS or NLOS depends on various environmental factors, including clutter, street canyons, and distance. For simplicity, the probability of LOS is defined to be unity at zero distance, and decreases linearly until a cutoff point at d=300m, where the LOS probability is zero.

$$P(LOS) = \begin{cases} (300-d)/300, & 0 < d < 300m \\ 0, & d > 300m \end{cases}$$

The K-factor, propagation slope, and shadow fading standard deviation will all be chosen based on the results of selecting the path to be LOS or NLOS.

The K-factor will be formed by adding a direct component (sine wave) at the average AoD and AoA of the path such that the ratio of the power assigned to the direct component to the power assigned to the 6 paths is equal to the K-factor measured in dB. After the power of the direct component is added, the total power in the channel is normalized to unity power. The K-factor is defined as the ratio of power in the LOS component to the total power in the diffused-NLOS component. The LOS path will coincide in time with the first (earliest) diffused path. When pairing sub-rays between transmitter and receiver, the direct components are paired representing the LOS path.

3.5.4 Urban canyon

The urban canyon model is switch selectable. When switched on, the model modifies the AoAs of the paths arriving at the subscriber unit. It is for use in both the urban macro and urban micro scenarios.

Urban-canyons exist in dense urban areas served by macro-cells, and for at-rooftop micro-cells. When this model is used, the spatial channel for all subscribers in the simulated universe will be defined by the statistical model given below. Thus for the SCM channel generation steps given in Section 3.3, Step 9 is replaced with steps 9a-d given below, which describe the AoAs of the paths arriving at the subscriber in the urban canyon scenario.

The following procedure is used to determine the subscriber mean AoAs of the six paths. This model does not use a building grid, but assigns angles based on statistical data presented in the figures below. The procedures is defined in terms of the subscriber terminal:

9a. Select a random street orientation from: U(0, 360˚) which also equals the direction of travel for the UE.

9b. Select a random orientation for the subscriber antenna array from U(0, 360).

9c. Given $\alpha = 0.9$, the predefined fraction of UEs to experience the urban canyon effect, Select a uniform random draw for the parameter β.

9d. If $\beta <= \alpha$, select the UE AoAs for all arriving paths to be equal, with 50% probability of being from the direction of the street orientation obtained in step 9a, and 50% the street orientation plus an offset of 180°. If $\beta > \alpha$, select the directions of arrival for all paths using the standard SCM UE AoA model given in Section 3.3, Step 9.

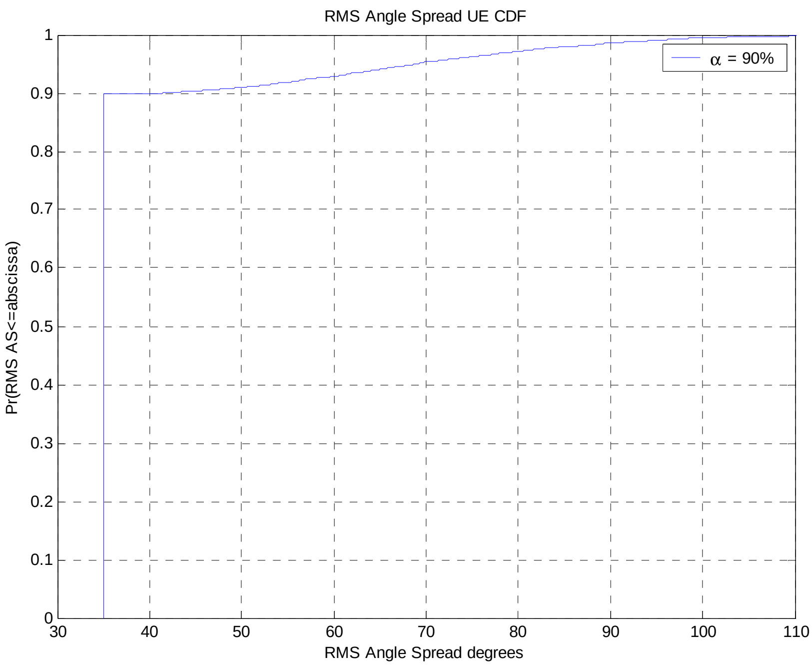

Figure 3-3. Simulated results of urban canyon algorithm

In Figure 3-3Figure 3-3, the urban canyon procedure is simulated to show the effects of the model on the composite UE angle spread. The parameter $\alpha = 0.9$, which describes the percentage of mobiles that will experience the urban canyon effects. The figure illustrates the result of selecting the AoAs, where each of the paths has a fixed 35° angle spread.

The parameter $\alpha = 0.9$, is set to a relatively high percentage of occurrence to emphasize the urban canyon effects, while the remaining occurrences assume some mixed arrivals to model various other conditions such as cross streets or where signals arrive from between buildings or from unknown paths at various angles.

3.6 Correlation Between Channel Parameters

In [1], Greenstein presents a model for correlating delay spread (DS) with log normal shadow fading (LN). Since both are shown to be log-normal distributed, the correlation between the DS and LN are correlated by the coefficient ρ. The best value for suburban and urban data was shown to be ρ = -0.75, presented in [1] from data measured by [2].

The result of the correlation between log normal shadowing and delay spread is significant because it indicates that for a strong signal (positive LN), the DS is reduced, and for a weak signal condition (negative LN), the DS is increased.

Cost 259[3] presents the azimuth spread (AS) as also being log-normal distributed, and likewise being correlated to the DS and LN. Since the correlation of these parameters is quite high, a spatial channel model needs to be specified that can reproduce this correlation behavior along with the expected probability and range of each parameter. For a macro-cell environment, the following values are given in [3]:

$\rho_{\alpha\beta}$ = Correlation between DS & AS = +0.5

$\rho_{\gamma\beta}$ = Correlation between LN & AS = -0.75

$\rho_{\gamma\alpha}$ = Correlation between LN & DS = -0.75

Suppose we wish to generate the values for DS, AS, and LN for the nth base station (n = 1 … N) with respect to a given mobile user. These values are given as $\sigma_{DS,n}$, $\sigma_{AS,n}$, and $\sigma_{LN,n}$, respectively. These valuesare a function of the respective correlated Gaussian random variables α_n, β_n, and γ_n. These correlated Gasussian random variables are in turn respectively generated from independent Gaussian random variables w_{n1}, w_{n2}, and w_{n3}. Note however, that because of correlated shadow fading from base to base, the variables w_{13} through w_{N3} are correlated and are given by:

$$w_{n3} = \xi_c \sqrt{\frac{\eta}{c_{33}^2}} + \xi_n \sqrt{1 - \frac{\eta}{c_{33}^2}}, \quad n = 1 \ldots N$$

where $\xi_c, \xi_1, \xi_2, \ldots, \xi_N$ are i.i.d. Gaussian random variables with zero mean and unit variance, η is the site-to-site correlation (assumed to be η= 0.5), and c_{33} is defined as the lower right component of the matrix square root of the correlation matrix:

$$\begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} = \begin{bmatrix} \rho_{\alpha\alpha} & \rho_{\alpha\beta} & \rho_{\alpha\gamma} \\ \rho_{\beta\alpha} & \rho_{\beta\beta} & \rho_{\beta\gamma} \\ \rho_{\gamma\alpha} & \rho_{\gamma\beta} & \rho_{\gamma\gamma} \end{bmatrix}^{1/2}.$$

Given w_{n3}, generate i.i.d. Gaussian random variables w_{n1} and w_{n2} with zero mean and unit variance. The variables α_n, β_n, and γ_n are given by:

$$\begin{bmatrix} \alpha_n \\ \beta_n \\ \gamma_n \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{bmatrix} w_{n1} \\ w_{n2} \\ w_{n3} \end{bmatrix}.$$

The distribution of DS for the *n*th BS is given by:

$$\sigma_{DS,n} = 10 \wedge \left(\varepsilon_{DS}\alpha_n + \mu_{DS}\right)$$

where α_n is generated above, $\mu_{DS} = E\left(\log_{10}(\sigma_{DS})\right)$ is the logarithmic mean of the distribution of DS, and $\varepsilon_{DS} = \sqrt{E\left[\log_{10}(\sigma^2_{DS,n})\right] - \mu^2_{DS}}$ = is the logarithmic standard deviation of the distribution of DS.

Similarly the distribution of AS is given by:

$$\sigma_{AS,n} = 10 \wedge \left(\varepsilon_{AS}\beta_n + \mu_{AS}\right)$$

where β_n is generated above, $\mu_{AS} = E\left(\log_{10}(\sigma_{AS})\right)$ is the logarithmic mean of the distribution of AS, and $\varepsilon_{AS} = \sqrt{E\left[\log_{10}(\sigma^2_{AS,n})\right] - \mu^2_{AS}}$ is the logarithmic standard deviation of the distribution of AS.

Finally, the distribution for the LN is given by:

$$\sigma_{LN,n} = 10 \wedge \left(\sigma_{SF}\gamma_n / 10\right)$$

where γ_n is given above, and σ_{SF} is the LN standard deviation given in dB. The value of σ_{SF} is obtained from analysis of the standard deviation from the regression line of the path loss versus distance. As shown in Table 3-1, these values are 8dB and 10dB for the macro and microcell cases, respectively. Note that the linear scale value for LN is simply $\sigma_{SF}\gamma_n$.

3.7 Modeling intercell interference

Sophisticated MIMO receivers account for the spatial characteristics of the signals from the desired sector as well as from the interfering sectors. The spatial characteristics of these signals can be modeled according to the channel matrix generated according to Sections 3.3, 3.4, and 3.5. However, it may be prohibitively complex to explicitly model the spatial characteristics of all interfering sectors, especially those whose received powers are relatively weak. It has been shown that by modeling the signals of relatively weak interferers as spatially white (and thereby ignoring their spatial characteristics), the resulting performance difference is negligible. The following five steps outlinee the procedure for modeling intercell interference.

- Determine the pathloss and shadowing of all sectors. (Note that "pathloss" implicitly includes antenna patterns as well.)
- Rank the sectors in order of received power (based on pathloss and shadowing).
- Assign the strongest sector as the serving sector.
- Model the next strongest B sectors as spatially correlated Gaussian noise processes whose covariances are determined by their channel matrices. These channel matrices are generated from Sections 3.3, 3.4, and 3.5 and account for the pathloss, shadowing, and fast fading variations.
- Model the remaining sectors as spatially white Gaussian noise processes whose variances are based on a flat Rayleigh fading process. Hence the variances are varying over the duration of a simulation drop.

Using the notation in Appendix A, suppose there are J transmit antennas, M receive antennas, N is the receiver tap length, and K is the impulse response length. In modeling the B strongest interfering sectors, let $\mathbf{G}$ be the MN by $(N+K-1)J$ MIMO channel impulse response matrix given by

$$\mathbf{G} = \begin{bmatrix} \mathbf{G}_1^{(1)} & \cdots & \mathbf{G}_1^{(J)} \\ \vdots & & \vdots \\ \mathbf{G}_M^{(1)} & \cdots & \mathbf{G}_M^{(J)} \end{bmatrix}$$

Hence, assuming the data symbols are normalized to have unit power, the equivalent Gaussian vector noise process is an MN-dimensional complex Gaussian random variable with zero mean and covariance $\mathbf{GG}^H$, where superscript H denotes the Hermitian transpose.

To model the remaining "weak" sectors, we assume that the mean power of the flat Rayleigh fading process is equal to the effects of pathloss and shadowing from each sector. Therefore if the received power from the bth sector due to pathloss and shadowing is P_b , then the Rayleigh fading process for the mth receive antenna (m = 1,..., M) as a function of time is given by $r_{b,m}(t)$ where the mean of $r_{b,m}(t)$ over time is P_b . The fading processes for each sector and receive antenna are independent, and the doppler rate is determined by the speed of the mobile. We assume that the fading is equivalent for each mobile receive antenna. The total received noise power per receive antenna due to all "weak" sectors at the mth antenna is

$$\sum_{b \in F} r_{b,m}(t)$$

where F is the set of indices for the "weak" sectors.

For 3-sector systems, we model the B = 8 strongest sectors. For 6-sector systems, we model B = 12 strongest sectors. The values for B are based on simulation results for the typical cell layout with a single hexagonal cell surrounded by two rings of cells (a total of 19 cells) and with users placed in the center cell. For other layouts, different values of *B* or an entirely different technique may be required to properly account for the intercell interference.

3.8 System Level Calibration

The following examples are given for calibration purposes. A resolvable path at the receiver is assumed to be the energy from one (or more) paths falling within one chip interval. The Chip rate in UMTS is 3.84Mcps. The PDF of the number of resulting resolvable paths is recorded.

The following table is for interim calibration purposes. "Ideal" signifies the value taken from measurements, "Input" signifies the value used in generating a random variable, "Output" signifies the resulting measured statistic.

Parameter	Suburban 5° $\square_{RND}$ = 3dB		Urban 8° $\square_{RND}$ = 3dB		Urban 15° $\square_{RND}$ = 3dB		Urban Micro	
r_{DS}	Input	Output	Input	Output		Output		
	1.4	1.29	1.7	1.54	1.7	1.54		
μ_{DS}	Input	Ideal	Input	Ideal	Input	Ideal		
	-6.80	-6.92	-6.18	-6.26	-6.195	-6.26		
ξ_{DS}	Input	Ideal	Input	Ideal	Input	Ideal		
	0.288	0.363	0.18	0.25	0.18	0.25		
r_{AS}	Input	Output	Input	Output	Input	Output		
	1.2	1.22	1.3	1.37	1.3	1.37		
μ_{AS}	Input	Ideal	Input	Ideal	Input	Ideal		
	0.69	0.66	0.810	0.75	1.18	1.0938		
ξ_{AS}	Input	Ideal	Input	Ideal	Input	Ideal		
	0.13	0.18	0.34	0.37	0.21	0.2669		
$E[\sigma_{DS}]$	Ideal	Output	Ideal	Output	Ideal	Output		Output
	0.17µs	0.172µs	0.65µs	0.63µs	0.65µs	0.63µs		0.251 µs
$E[\sigma_{AS\ Node\ B}]$	Ideal	Output	Ideal	Output	Ideal	Output	Ideal	Output
	5°	5.01°	8°	7.97°	15°	14.9°	19°	19.2°
$E[\sigma_{AS\ UE}]$	Ideal	Output	Ideal	Output	Ideal	Output	Ideal	Output
	72°	72.59°	72°	71.49°	72°	71.35°	72°	NLOS: 71.8°

Table 3-3. SCM parameter summary with simulated outputs

The following figures: Figure 3-4~~Figure 3-4~~, Figure 3-5~~Figure 3-5~~, Figure 3-6~~Figure 3-6~~, Figure 3-7~~Figure 3-7~~, Figure 3-8~~Figure 3-8~~, represent calibration cases for the current SCM model.

These curves correspond to the parameters presented in Table 3-3Table 3-3, and include the 3dB randomizing factor for the generation of path powers.

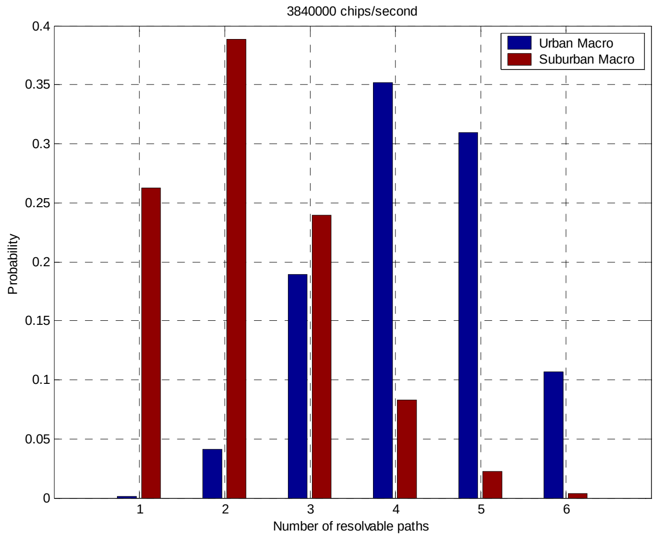

Figure 3-4. Probability of urban and suburban time resolvable paths

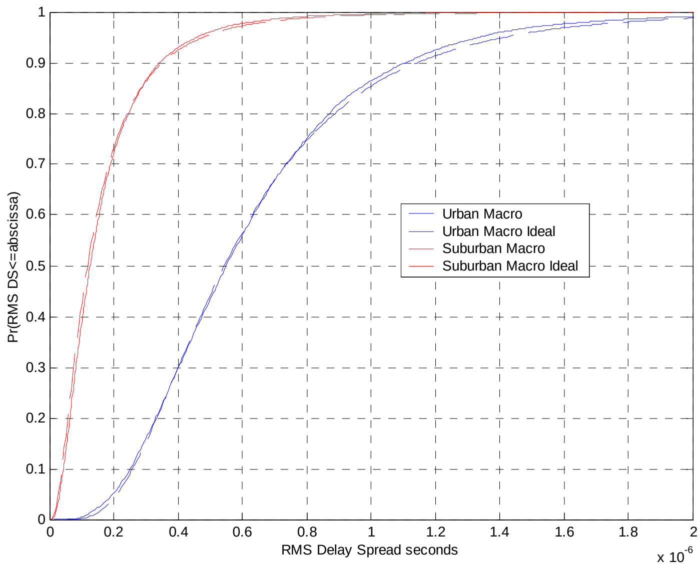

Figure 3-5. RMS delay spread, simulated versus ideal

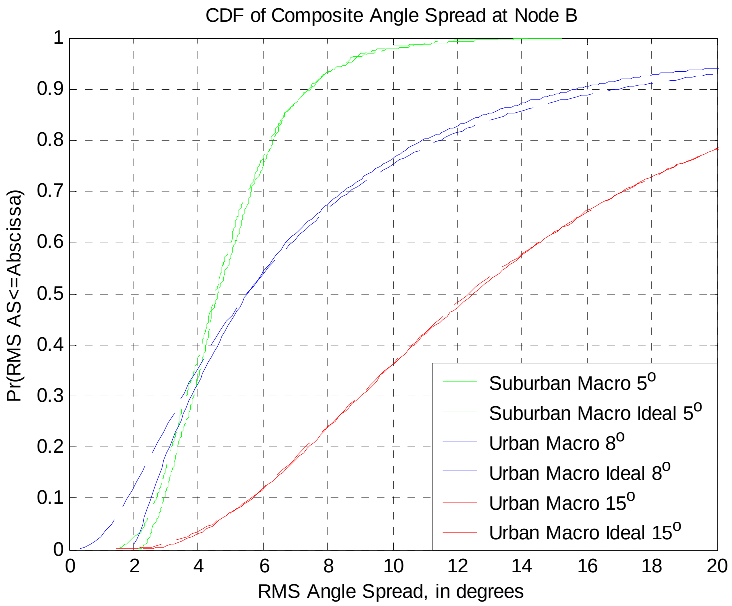

Figure 3-6. BS composite angle spread, simulated versus ideal

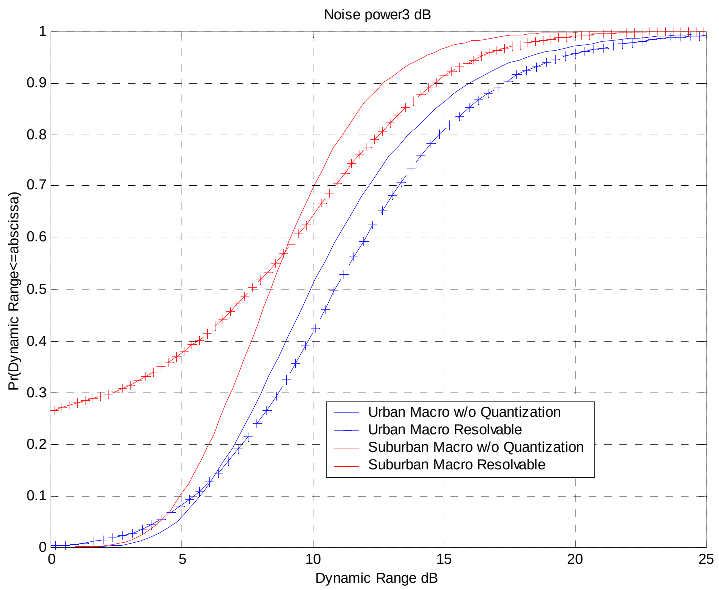

Figure 3-7. Dynamic range (dB) for each channel model

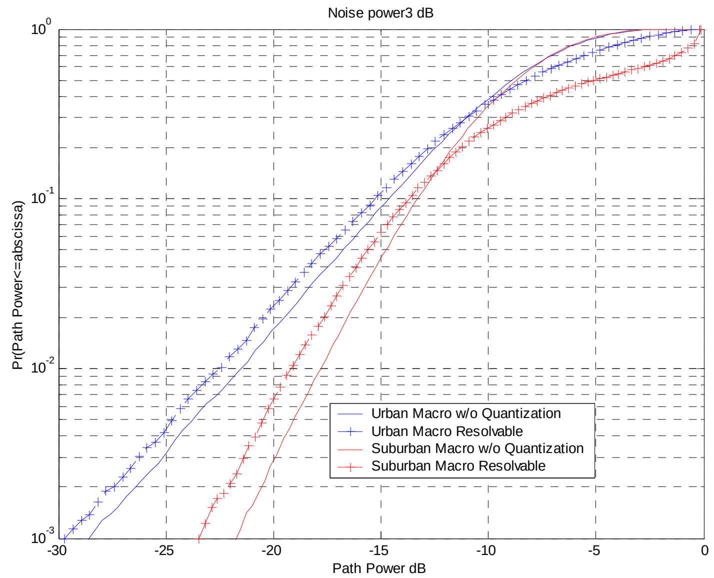

Figure 3-8. CDF of all path powers

Channel Scenario: Urban Microcellular

A number of parameters are shown in the following plots which are the result of simulations. Figure 3-9Figure 3-9 illustrates the dynamic range of each channel realization, plotted as a complementary cdf. The difference between the 1x and 3x channel bandwidths are shown in the resolvable dynamic range curves. (Powers are combined within a chip time as a simple way to estimate the resolvable powers.) The 1% highest value is approximately the same for both bandwidths. The dynamic range D is calculated from D = 10*log10(max pwr / min pwr) for each channel realization.

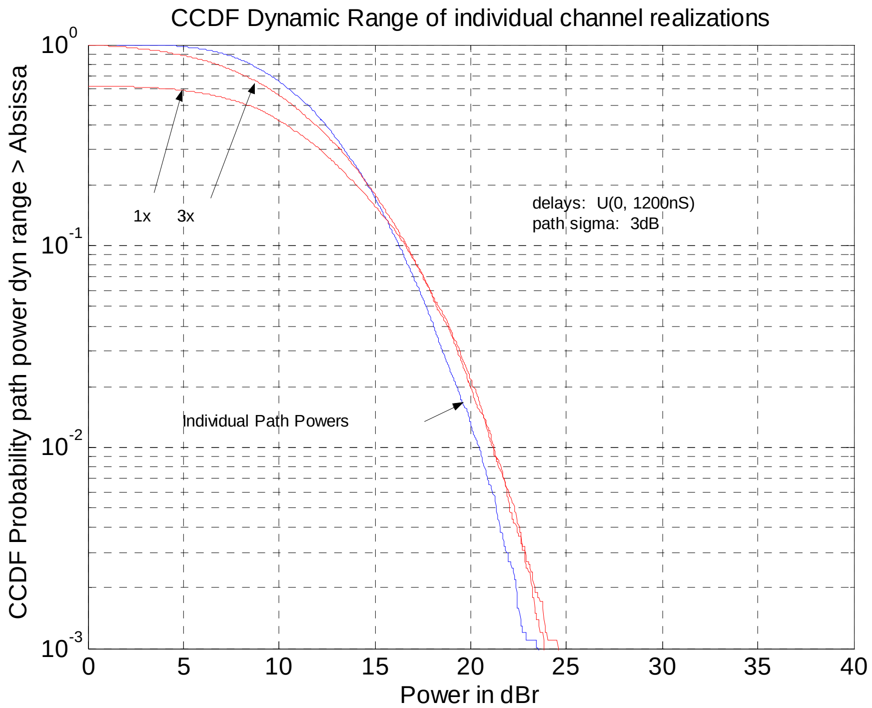

Figure 3-9. Dynamic range of path powers per channel realization, (NLOS)

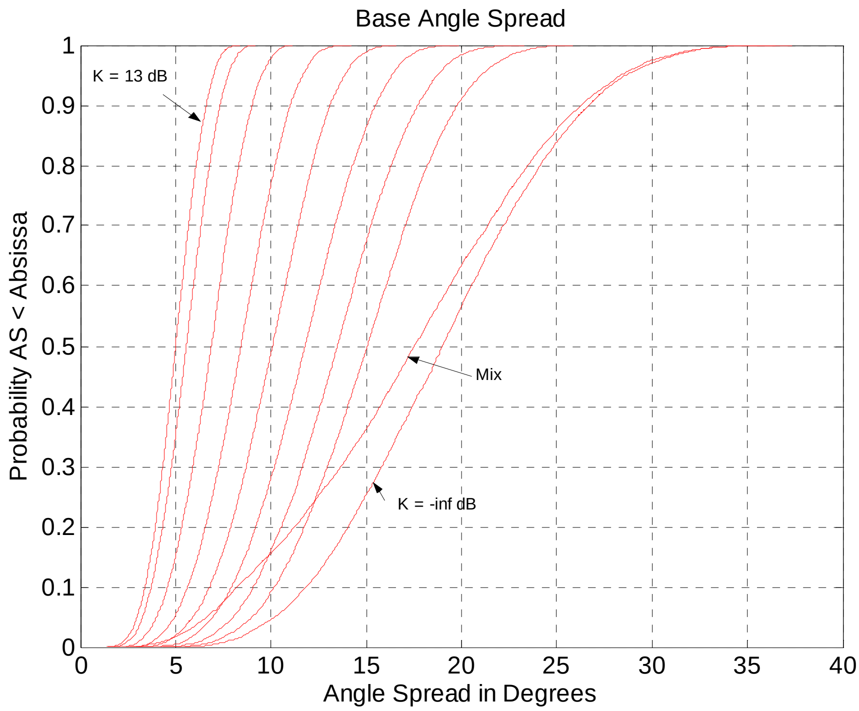

Figure 3-10. Composite BS angle spread

The composite angle spread at the base is described in Figure 3-10~~Figure 3-10~~ for the various K-factors that are seen in the micro-cell model, along with the LOS/NLOS mix expected when the cell radius is 500m. For the NLOS case, the average composite Base AS = 19°. When experiencing LOS paths with increased K-factors, the angle spreads are observed to decreased accordingly. The simulated average composite Base AS for the NLOS model is: 19.2˚, and the simulated average composite Base AS for the mixed propagation model is: 17.6˚.

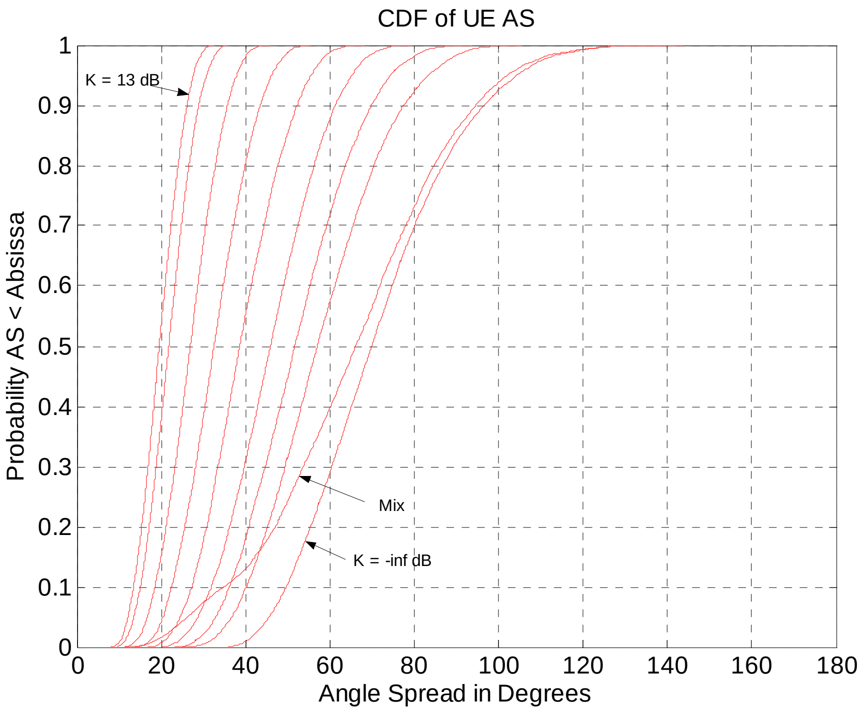

Figure 3-11. Composite MS angle spread

The composite UE angle spread is described in Figure 3-11Figure 3-11 for the various K-factors that are present in the micro-cell model. Increased K-factor from a LOS path, causes the composite AS to be decreased since more power is present in a single direct component. The mixed case is shown which has a slight decrease in the statistics due to the 15% of the locations experiencing the LOS condition. The simulated composite UE AS for the NLOS model is: 71.8˚, and the simulated composite UE AS for the mixed propagation model is: 65.8˚.

The delay spread is illustrated in Figure 3-12Figure 3-12, which is also affected by the presence of a direct path. The mix is produced by the combination of LOS and NLOS paths. The simulated average delay spread for the NLOS condition is: 251 nS, and the simulated average delay spread for the mixed case is: 231 nS

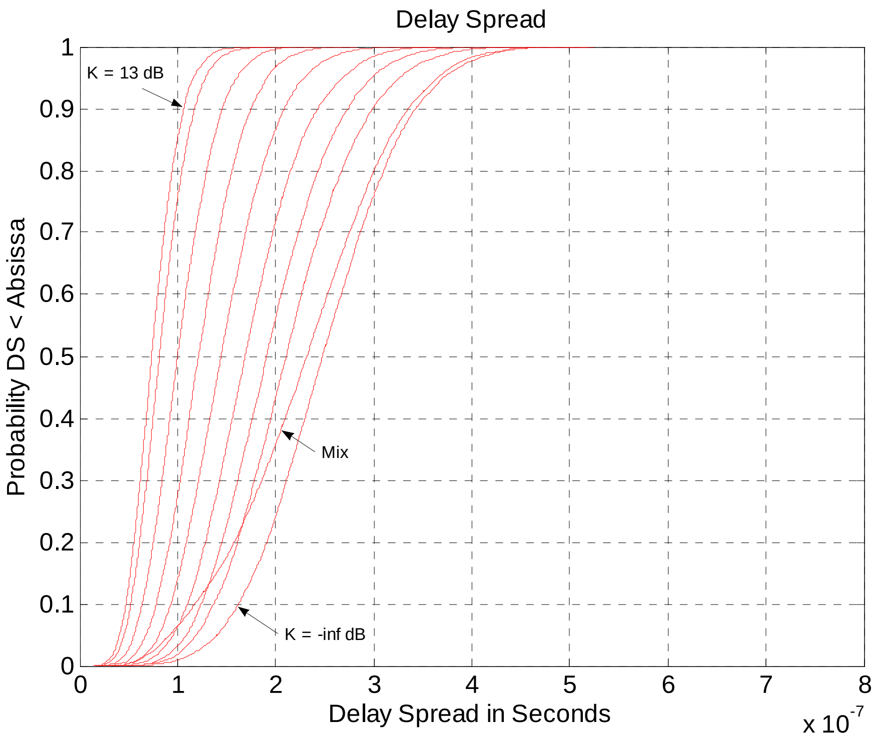

Figure 3-12. Micro-cell delay spread

Figure 3-13~~Figure 3-13~~ illustrates the propagation path loss model of the Urban Micro-cell which is characterized by the mixed mode between LOS and NLOS.

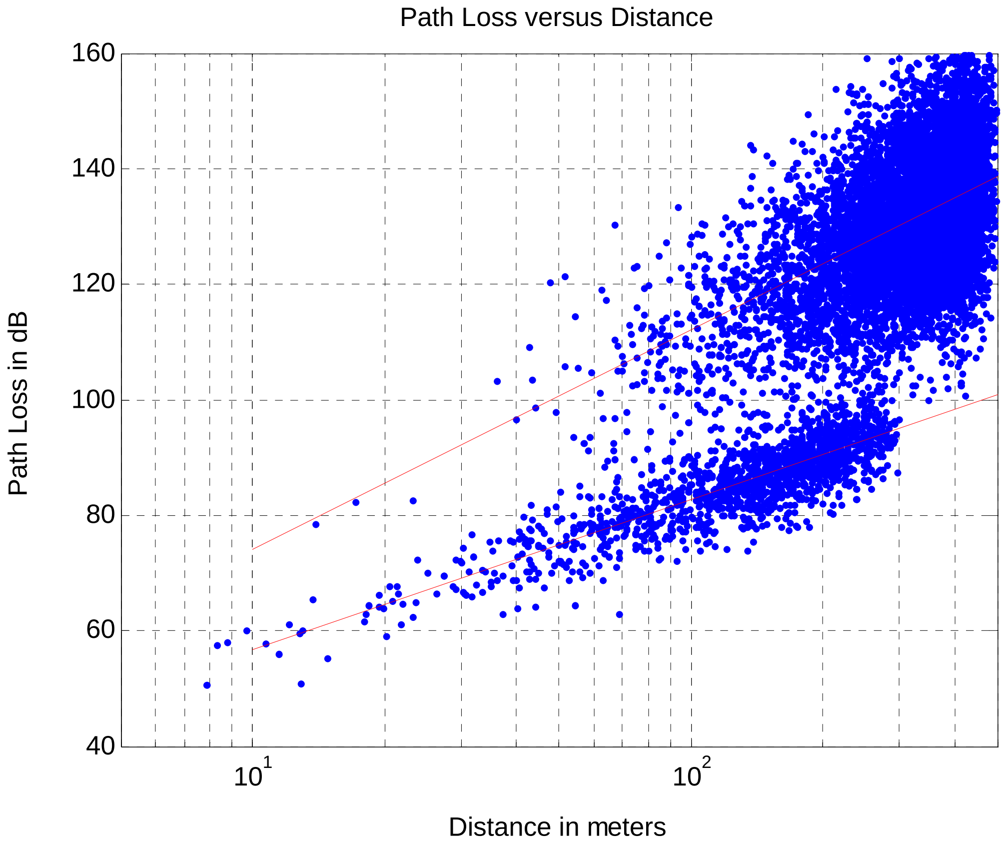

Figure 3-13, Microcell path loss versus distance

ANNEX B: CHANGE HISTORY

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**