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1

2 **1 INTRODUCTION**

3 This document details the current discussion of the combined 3GPP-3GPP2 Spatial Channel
4 Ad-hoc group. A similar document¹, developed independently in the 3GPP2 Spatial Channel
5 Modeling Ad-hoc group, was used for reference.

6 **1.1 Terminology (usage in 3GPP & 3GPP2)**

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

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

11 BS = Base Station = Node-B = BTS

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

13 Path = Ray

14 Path Component = Sub-ray

15 PAS = Power Azimuth Spectrum

16 DoT = Direction of Travel

17 AoA = Angle of Arrival

18 PDP = Power Delay Profile

19

20 **1.2 Scope**

21 The scope of the 3GPP-3GPP2 SCM AHG is to develop and specify parameters and methods
22 associated with the spatial channel modeling that are common to the needs of the 3GPP and
23 3GPP2 organizations (harmonization). The scope includes development of specifications for:

24 1.2.1 System level evaluation.

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

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

29 b. System evaluation methodology.

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

31 d. Some framework (air interface) dependent parameters.

1 1.2.2 Link level evaluation.

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

5

6 **2 LINK LEVEL CHANNEL MODELS FOR CALIBRATION PURPOSES**

7 (Editor's Note: A harmonized link level model is being proposed, and further discussion is
8 expected prior to agreement. This includes all aspects of the link level model described in
9 Section 2.)

10 **2.1 Purpose**

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

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

19 **2.2 Link Level Channel Model Parameter Summary**

20 (Editor's Note: The following table is under discussion as a harmonized set of link level
21 parameters and values.)

22

Table 2-1. Summary of Suggested SCM Link Level Parameters for Calibration Purposes

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 0.5?	Reference 0.5?	Reference 0.5?	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 0.5?-spacing or 4?-spacing or 10?-spacing			N/A
	PAS	Laplacian distribution with RMS angle spread of 2 degrees or 5 degrees, per path depending on AoA/AoD			N/A
	AoD/AoA (degrees)	50° for 2° RMS angle spread per path 20° for 5° RMS angle spread per path			N/A

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

3 **2.3 Spatial Parameters per Path**

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

8 **2.4 BS and MS Array Topologies**

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

12 Calibrating simulators at the link level requires a common set of assumptions including a
13 specific set of antenna topologies to define a baseline case. At the MS, the reference element
14 spacing is 0.5λ . At the BS, three values for reference element spacing are defined: 0.5λ , 4λ , and
15 10λ .

17 **2.5 Spatial Parameters for the BS**

18 2.5.1 BS Antenna Pattern

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

$$A(\mathbf{q}) = -\min \left[12 \left(\frac{\mathbf{q}}{\mathbf{q}_{3dB}} \right)^2, A_m \right] \quad \text{where } -180 \leq \mathbf{q} \leq 180 \quad (1)$$

\mathbf{q} is defined as the angle between the direction of interest and the boresight of the antenna, \mathbf{q}_{3dB} is the 3dB beamwidth in degrees, and A_m is the maximum attenuation. For a 3 sector scenario \mathbf{q}_{3dB} is 70° , $A_m = 20dB$, and the antenna boresight pointing direction is given by Figure 2-2. For a 6 sector scenario \mathbf{q}_{3dB} is 35° , $A_m = 23dB$, which results in the pattern shown in Figure 2-3, and the boresight pointing direction defined by Figure 2-4. The boresight is defined to be the direction to which the antenna shows the maximum gain. The gain specified by previous 3GPP documents[2] 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.

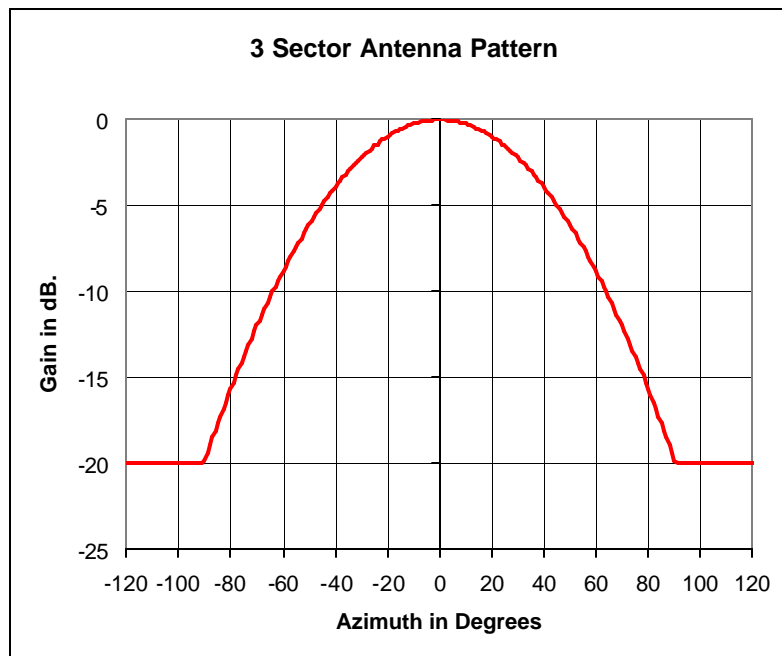


Figure 2-1 Antenna Pattern for 3-Sector Cells

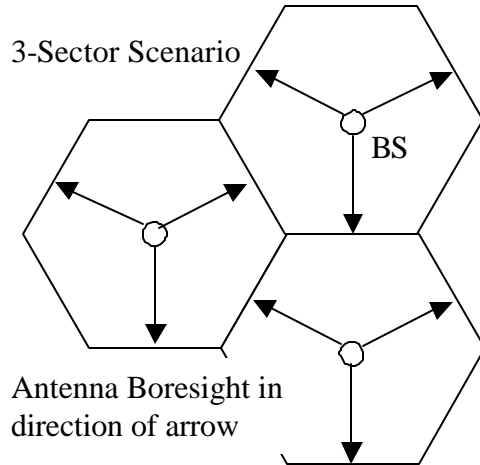


Figure 2-2 Boresight pointing direction for 3-sector cells

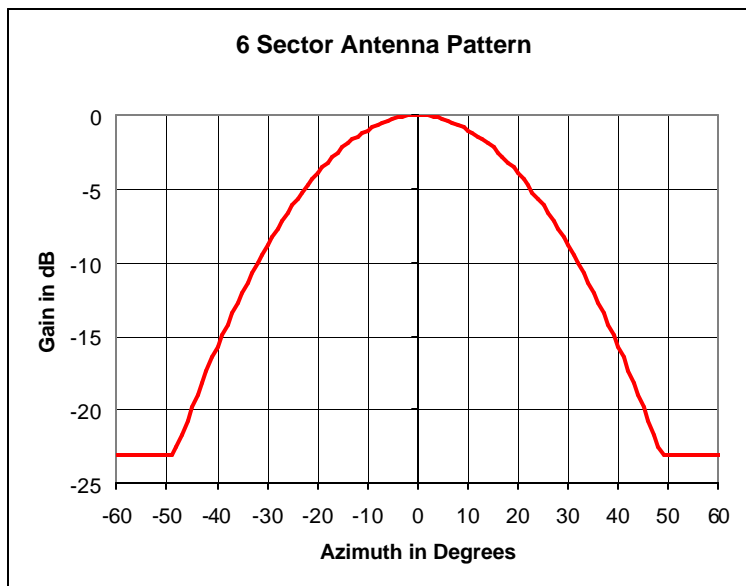


Figure 2-3 Antenna Pattern for 6-Sector Cells

1
2
3

4
5
6

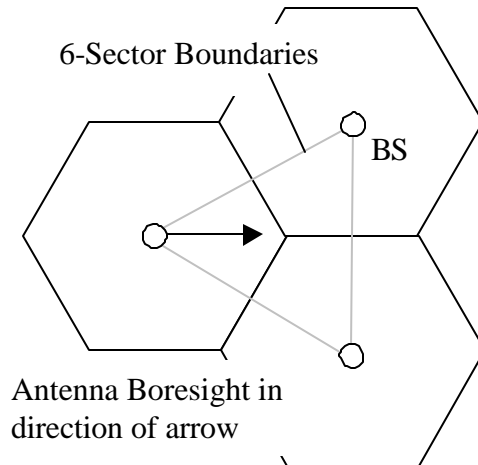


Figure 2-4 Boresight Pointing direction for 6-Sector Cells

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. 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.

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 $\bar{\mathbf{q}}$ and RMS angle-spread σ , the BS per path PAS value at an angle θ is given by expression (1) below:

$$P(\mathbf{q}, \mathbf{s}, \bar{\mathbf{q}}) = N_o \exp \left[\frac{-\sqrt{2} |\mathbf{q} - \bar{\mathbf{q}}|}{\mathbf{s}} \right] G(\mathbf{q}) \quad (1)$$

where both angles $\bar{\mathbf{q}}$ 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

$$G(\mathbf{q}) = 10^{0.1A(\mathbf{q})} \quad (2)$$

Finally, N_o is the normalization constant:

$$N_o^{-1} = \int_{-p}^p P(\mathbf{q}, \mathbf{s}, \bar{\mathbf{q}}) d\mathbf{q} \quad (3)$$

In the above equation, θ represents path components (sub-rays) of the path power arriving at an incoming AoA $\bar{\mathbf{q}}$. 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 omnidirectional 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 2-5.

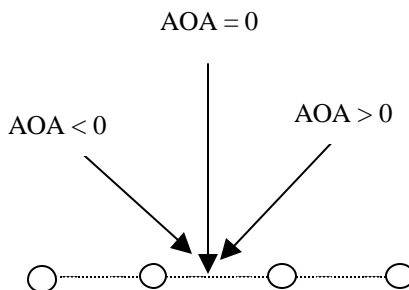


Figure 2-5. Angle of Arrival orientation at the MS.

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

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

7 2.6.4 Per Path MS Power Azimuth Spectrum

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

10 The Power Azimuth Spectrum (PAS) of a path arriving at the MS is modeled as either a
11 Laplacian distribution or a uniform over 360 degree distribution. Since an omni directional MS
12 antenna gain is assumed, the received per path PAS will remain either Laplacian or uniform.
13 For an incoming AOA \bar{q} and RMS angle-spread σ , the MS per path Laplacian PAS value at an
14 angle θ is given by expression (4) below:

$$15 \quad P(q, s, \bar{q}) = N_o \exp \left[\frac{-\sqrt{2} |q - \bar{q}|}{s} \right], \quad (4)$$

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

$$19 \quad N_o^{-1} = \int_{-p}^p P(q, s, \bar{q}) dq . \quad (5)$$

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

22 2.6.5 MS Direction of Travel

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

25 2.6.6 Per Path Doppler Spectrum

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

29 **2.7 Generation of Channel Model**

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

32 Further details on examples of the model implementation are TBD.

33 Outline of methodology, including doppler spectrum filter 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. 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. Nokia to provide formulas for computing correlation matrices

Table 2-2. Reference Correlation Values.

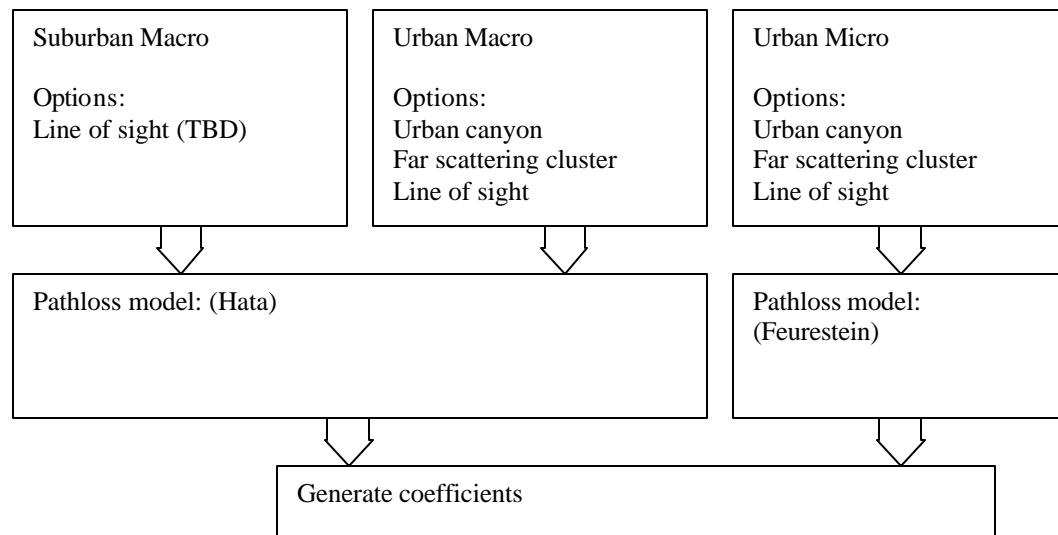
	Antenna Spacing	AS (degrees)	AOA (degrees)	Correlation (magnitude)	Complex Correlation
BS	0.5 <i>l</i>	5	20	0.9688	0.4743+0.8448i
	0.5 <i>l</i>	2	50	0.9975	-0.7367+0.6725i
	4 <i>l</i>	5	20	0.3224	-0.2144+0.2408i
	4 <i>l</i>	2	50	0.8624	0.8025+0.3158i
	10 <i>l</i>	5	20	0.0704	-0.0617+i0.034
	10 <i>l</i>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

3 SYSTEM LEVEL SPATIAL CHANNEL MODEL

A Spatial Channel Model for use at the system level is described below. Parameter values and their ranges are specified to enable the generation of a Spatio-Temporal channel model for use in evaluating the system-level performance of multiple antenna schemes. The goal of this section is to define the methodology for generating the spatial channel coefficients between a given base and mobile for use in system level simulations. For a given base and mobile pair, this procedure consists of three basic steps

1. Specify an environment, either suburban macro, urban macro, or urban micro.
2. Obtain the parameters associated with that environment.
3. Generate the channel coefficients based on the parameters.

The remainder of this section gives the details for these steps. Figure X 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.)



3.1 System Wide Definitions and Parameters

4 The received signal at the MS consists of N time-delayed multipath replicas of the transmitted
 5 signal. These N paths are defined by powers and delays and are chosen randomly according to
 6 the channel generation procedure. Each path consists of M subpaths which will be described
 7 later.
 8

9 Figure 3-1 shows the angular parameters used in the proposed model. The following definitions
 10 are used:
 11

12 Ω_{BS} Base Station orientation. It is defined as the difference between the broadside of the BS
 13 array and a North (N) reference direction.

14 q_0 Angle of the LOS direction between the BS and MS, referenced to the broadside of the
 15 BS array.

16 d_i mean angle of arrival difference for the n th ($n = 1 \dots N$) path relative to the LOS AOA q_0 .

17 $q_{l,i}$ Absolute AOA for the m th ($m = 1 \dots M$) subpath of the n th path at the BS with respect to
 18 the BS broadside.

19 $q_{0,MS}$ Angle between the BS-MS LOS and the MS broadside.

20 Ω_{MS} MS orientation. It is defined as the difference between the broadside of the MS array and
 21 the North reference direction.

22 $q_{v,MS}$ The angle reference of the MS velocity vector.

23 The angles shown in Figure 1 that are measured in a clockwise direction are assumed to be
 24 negative in value.
 25

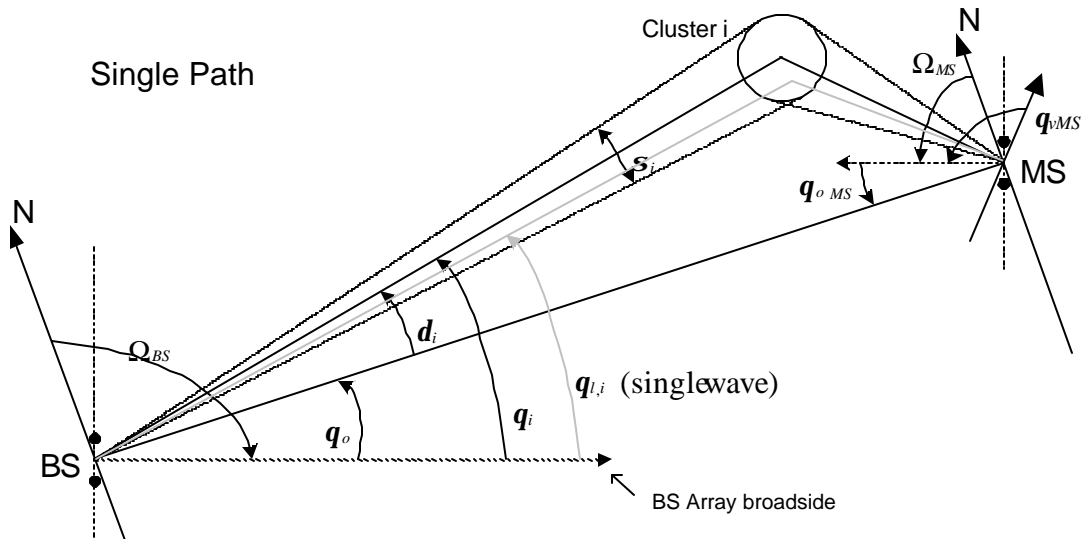


Figure 3-1 BS and MS angle parameters

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.

3.2 Scenarios

To limit the number of cases for consideration, the following represent a definition of the unique environments for simulation.

- a. Suburban Macro (approximately 3Km distance BS to BS)
- b. Urban Macro (approximately 3Km distance BS to BS)
- c. Urban Micro (less than 1Km distance BS to BS)

The macro cell definition applies when the base station antennas are above rooftop height. The micro cell definition applies otherwise. Table 3-1 Scenario parameters describes the parameters used in each of the scenarios.

Table 3-1 Scenario parameters

Channel Scenario	Suburban Macro	Urban Macro	Urban Micro
Mean composite AS at BS	$E(\sigma_{AS})=5^0$	$E(\sigma_{AS})=8^0, 15^0$	N/A
Composite AS at BS as a lognormal RV when simulating with 6 paths	$\mu_A= 0.69$ $\epsilon_A= 0.17$	$\mu_A= 0.87$ $\epsilon_A= 0.36$	N/A
$\sigma_{AS}=10^{\epsilon_A x + \mu_A}$, $x \sim N(0, 1)$			

Per path AS at BS (Fixed)	2 deg	2 deg	5 deg
Per path AoD Distribution st dev	$N(0, \sigma_{AS})$	$N(0, \sigma_{AS})$	$U(-30\text{deg}, 30\text{deg})$
Mean of RMS composite AS at UE	$E(\sigma_{AS, \text{comp}, UE})=72^0$	$E(\sigma_{AS, \text{comp}, UE})=72^0$	$E(\sigma_{AS, \text{comp}, UE})=72^0$
Per path AS at UE (fixed)	35^0	35^0	35^0
Per path AoA Distribution	$N(0, \sigma_{AoA}^2(P_r))$ Note 1	$N(0, \sigma_{AoA}^2(P_r))$ Note 1	$N(0, \sigma_{AoA}^2(P_r))$ Note 1
Mean total RMS Delay Spread	$E(\sigma_{DS})=0.17 \mu\text{s}$	$E(\sigma_{DS})=0.65 \mu\text{s}$	$U(0, 0.8) \mu\text{s}$
Narrowband composite delay spread as a lognormal RV when simulating with 6 paths $\sigma_{DS}=10^{\epsilon_D x + \mu_D}$, $x \sim N(0, 1)$	$\mu_D = -0.80$ $\epsilon_D = 0.288$	$\mu_D = -0.175$ $\epsilon_D = 0.17$	
Lognormal shadowing standard deviation	8dB	8dB	N/A

- 1 Note 1, Per path AoA is chosen from Normal distribution whose sigma is a function of the
2 relative of path power, $N(0, \sigma_{AoA}^2(P_r))$, where 0 = LOS, and $\sigma_{AoA} = 104.12(1 - \exp(-0.2175 * |P_r|))$,
3 with P_r equal to the fraction of power in the given path in dBr.

4 3.3 Channel Generation Steps

5 From these parameters, realizations of the user parameters such as the path delays, powers,
6 and subpath angles of departure and arrival can be derived using the following 12-step
7 procedure.

- 8 - **Step 1:** Choose a single channel scenario common to all drops (i.e. to be applied to the entire
9 simulation).
10 - **Step 2:** Generate Drops. Assign geometry (LOS direction and distance of UE from NodeB), UE
11 antenna structure orientation, UE speed vector direction and magnitude.
12 - **Step 3:** Select lognormal random draws for DS, AS (at NodeB: \mathbf{s}_{ASK}), LN as described in
13 Section 3.4.2 below.
14 - **Step 4:** Assign $N = 6$ paths (for macro channels). Assign 6 random delays. Delays are ordered
15 and the minimum delay is subtracted from all so that the first delay is always zero. k is the
16 drop and UE index.

17 Ratio values r_{ds} are $r_{ds} = 1.17$ suburban macro, $r_{ds} = 1.41$ urban macro. Realization of random
18 delays are made according to the model below:

$$19 \quad \mathbf{t}_n = -r_{DS} \mathbf{s}_{DSk} \log z_n \quad z_n : U(0,1)$$

20 Note that while there is some evidence that delay spread may depend on distance between
21 the transmitter and receiver, the effect is considered to be minor (compared to other
22 dependencies: DS-AS, DS-LN.) Various inputs based on multiple data sets indicate that the
23 trend of DS can be either slightly positive or negative, and may sometimes be relatively flat
24 with distance. For these reasons and also for simplicity, a distance dependence on DS is not
25 modeled.
26

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 $r_{as} = \sigma_{AoDs}/\sigma_{PAS}$ that were based on measurements. (the r value is calculated by a ratio of statistically biased estimators).

- **Step 5:** Assign a power to each path n:

$$P_n = e^{\frac{(1-r_{DS})t_n}{r_{DS} \cdot \mathbf{S}_{DSk}}} \cdot 10^{-x_n} \quad \text{where} \quad \mathbf{x}_n : N(0, \mathbf{S}_{RND}^2)$$

where \mathbf{S}_{RND} is a shadowing randomization effect on the per-path powers. Value is TBD. Powers are normalized so that total power (for all six paths is equal to one).

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.

Values for $\sigma = 3$ dB to 4 dB have been proposed. Value is TBD.

- **Step 6:** Generation of AODs per path and ordering at NodeB. Random draws of AODs from $N(0, r_{AOD,CS}^2 \cdot \mathbf{S}_{ASK}^2)$. The $r_{AOD,CS} = 1.07$ (0.3 in dB) (Suburban macro), $r_{AOD,CS} = 1.3$ (1.0 in dB) (urban macro).
- **Step 7:** The 6 AODs generated in Step 6 are ordered in increasing absolute value and each of the six delays (Step 4) is assigned to each AOD. Increasing delays are matched to increasing relative AOD angle \mathbf{d}_n is defined in Figure 3-1 based on their absolute value and deterministically.
- **Step 8:** 20 sub-rays are used to generate a 2° Laplacian spread for each path (ray) at the NodeB. All 20 sub-rays have identical powers (1/20 of the path power) but random phase. Sub-components have a predefined fixed angle distribution as shown in Table 3-2.
- **Step 9:** At the UE, assign per-path (ray) AOA variance as a function of the path (ray) relative power. Draw the relative AOA (with respect to LOS) from a distribution: $N(0, \mathbf{S}_{AOA}^2)$. Where 0 = LOS, and $\sigma_{AOA} = 104.12(1 - \exp(-0.2175 * |P_r|))$, with P_r equal to the fraction of power in the given path in dB.
- **Step 10:** 20 sub-rays are used to generate a 35° Laplacian spread for each path (ray) at the UE. All 20 sub-rays have identical powers (1/20 of the path power) but random phase. Sub-components have a predefined fixed angle distribution as shown in Table 3-2.
- **Step 11:** Pairing of each NodeB sub-ray with a corresponding UE sub-ray is made to create the actual channel gain. Random pairing is used.
- **Step 12:** Assign antenna gains to NodeB paths (rays). Assign the antenna gain to each UE sub-ray.

Table 3-2. Fixed Sub-path components to produce per-path spreads

Sub-path #	(+/-) degrees for a 2 deg Laplacian (Node-B Macro-cell)	(+/-) degrees for a 5 deg Laplacian (Node-B Micro-cell)	(+/-) degrees for a 35 deg Laplacian (UE)
1, 2	0.08716	0.2179	1.525
3, 4	0.2754	0.6884	4.819
5, 6	0.4858	1.215	8.502
7, 8	0.7243	1.811	12.68
9, 10	0.9997	2.499	17.49
11, 12	1.325	3.313	23.19
13, 14	1.724	4.310	30.17
15, 16	2.238	5.595	39.16
17, 18	2.962	7.405	51.84
19, 20	4.201	10.50	73.51

1

2 3.4 BS and MS Array Topologies

3 The spatial channel model should allow any type of antenna configuration to be selected,
4 although details of a given configuration must be shared to allow others to reproduce the model
5 and verify the results. It is intended that the spatial channel model be capable of operating on
6 any given antenna array configuration.

7 3.4.1 Polarized arrays

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

11 A method of describing polarized antennas is presented, which is compatible with the 12 step
12 procedure given in section 3.3. The following steps extend the original 12 to add the additional
13 polarized components necessary.

14 - **Step 13:** For each of the 6 paths of step 4, generate 20 sub-rays at the MS and 20 sub-rays
15 at the BS, to represent the portion of each signal that leaks into the quadrature antenna
16 orientation due to scattering. Randomly pair each of the new sub-rays with a corresponding
17 sub-ray that was generated in step 8 for the BS and step 10 for the MS.

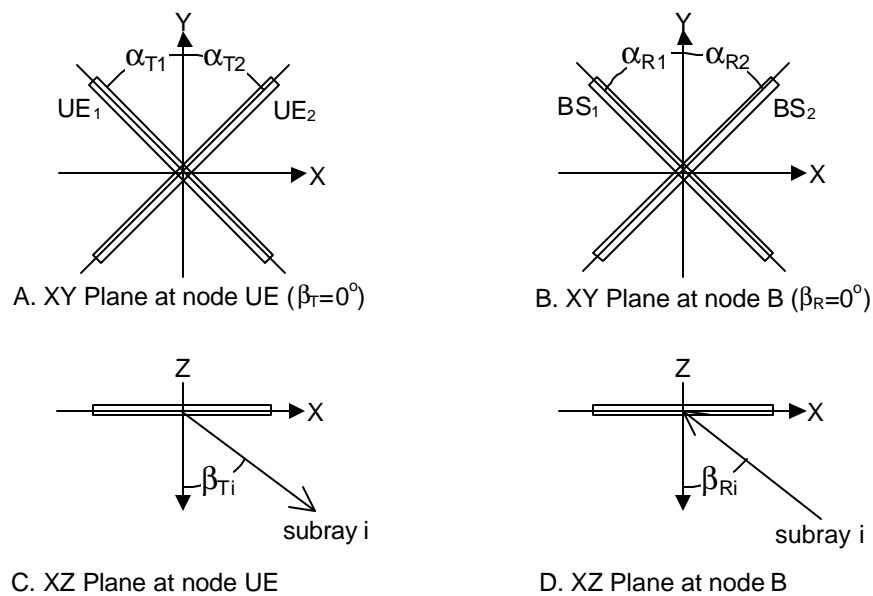
18 - **Step 14:** Set the AoD and AoA of each sub-ray in step 13 equal to that of the corresponding
19 sub-ray of the inline antenna orientation. (Orthogonal sub-rays arrive/depart at common
20 angles.)

21 - **Step 15:** Set the phase angle of each sub-ray in step 13 to a random angle drawn from
22 $U(0, 2\pi)$.

- 1 - **Step 16:** The power P_2 of each ray in the quadrature orientation is set relative to the power P_1 of each ray in the in-line orientation according to an XPD ratio, defined as $XPD = P_1/P_2$.
- 2 For urban macrocells: $P_2 = P_1 - A - B \cdot N(0,1)$, where $A = 0.34 \cdot (\text{mean relative path power}) + 7.2$
- 3 dB, and $B = 5.5$ dB is the standard deviation of the XPD variation.
- 4
- 5 For urban microcells: $P_2 = P_1 - A - B \cdot N(0,1)$, where $A = 8$ dB, and $B = 8$ dB is the standard
- 6 deviation of the XPD variation.
- 7 - **Step 17:** Decompose each of the in-line and quadrature sub-rays into vertical and horizontal
- 8 components based on the in-line and quadrature orientations.
- 9 - **Step 18:** At the receive antennas, decompose each of the vertical and horizontal components
- 10 into components that are in-line and quadrature with the receive antennas and sum the in-
- 11 line components.

12 The fading behavior between the cross pol elements will be a function of the per-ray spreads
 13 and the Doppler. The fading between orthogonal polarizations has been observed to be
 14 independent and therefore the sub-rays phases are chosen randomly.

15



16
17 **Figure 3-2 Dual Polarization Example**

18
19 Additional description of the polarization model will be included in this section with equations
 20 describing the various components.

21

22 **3.4.2 Reference Antenna Configurations**

23 In order to compare algorithms, reference antenna configurations based on uniform linear
 24 array configurations with 0.5, 4, and 10 wavelength inter-element spacing will be used.

3.4.3 General Modeling Assumptions

1. Mapping of paths to resolvable paths. TBD
2. Fractional Unrecovered Power (FURP) is TBD.
3. The macrocell pathloss from 3GPP2 evaluation methodology will be used for the SCM model as shown below.

Propagation Model (BTS Ant Ht=32m, MS=1.5m)	$28.6 + 35 \log_{10}(d)$ dB, d in meters	Modified Hata Urban Prop. Model @1.9GHz (COST 231). Minimum of 35 meters separation between MS and BS. ¹
--	---	---

4. Uplink-Downlink Reciprocity: The AOD/AOA values are identical between uplink and downlink.
5. Random path phases between UL, DL are uncorrelated.
6. mobile-to-mobile shadowing is uncorrelated.

3.4.4 Micro-cell Assumptions

- (a) The BS antenna is always located at rooftop.
- (b) The pathloss model is TBD
- (c) Antenna patterns at BS/NodeB will be those already defined in the SCM-Text. Question about backlobes remain since micro-cells typically have poor backlobes. TBD.
- (d) Site-to-site correlation. Shadowing between different paths (delay) are iid. Site-to-site correlation for the same delay follows the macro model (50% correlation). Some questions remain on this method.
- (e) Shadowing St.Dev 4-5dB per path should be used so that the resulting narrowband shadowing has St.Dev=9dB.
- (f) The hexagonal cell repeats will be the assumed layout.

3.5 Options for Urban Macro and Micro Environments

3.5.1 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 1. There is a reduction in the number of paths in the primary cluster from $N = 6$ to $N = 4$, with
2 the far scattering cluster then having $N = 2$. Thus the total number of paths will stay the
3 same, now $N = 4 + 2$. This is a modification to the SCM channel generation procedure in
4 section 3.3.
- 5 2. FSCs will lie only outside a 1000m radius from the BS/NodeB. (the 500-600m radius is
6 under consideration also but not finalized).
- 7 3. The model statistics of the two clusters are identical (cluster DS, AS, PDP) but
8 independently drawn. The FSC also has independent shadowing.
- 9 4. The FCS is attenuated by 1dB/microsec delay with respect to the 1st cluster with a 10dB
10 maximum.
- 11 5. There will be one FSC modeled within each cell and dropped following a uniform
12 distribution. FSCs will be modeled for all the cells in the simulation in order to capture the
13 loc spatial characteristics.

15 3.5.2 Line of sight

16 The Line-of-sight model an option that is switch selectable. It can be selected for the urban
17 macro and micro cases. Suburban is TBD. It uses the following description when this
18 function is selected.

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

21 For the LOS case, the Rice factor is based on a simplified version of [Foster 1994], and is
22 applied based on a probability factor:

$$23 K = 13 - 0.03 * d \text{ (dB)}$$

24 where d is the distance between MS and BS in meters.

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

$$29 P(\text{LOS}) = (300 - d)/300, \text{ for } 0 < d < 300\text{m}.$$

$$30 0, \text{ for } d > 300\text{m}.$$

31 The K-factor will be formed by adding a direct component (sine wave) at the average AoD and
32 AoA of the path such that the ratio of the power assigned to the direct component to the power
33 assigned to the 6 paths is equal to the K-factor measured in dB. After the power of the direct
34 component is added, the total power in the channel is normalized to unity power. When
35 pairing sub-rays between transmitter and receiver, the direct components are paired
36 representing the LOS path.

3.5.3 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 below-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:

Step 9a. Pick a random direction of travel from a uniform random variable $U(-180,180)$. This is going to be also the assumed street orientation for this subscriber, and their direction of travel.

Step 9b. Pick the AoA corresponding to the strongest ray in the channel impulse response according to the CDF depicted in Figure 3-3. Note that \pm angles are equally likely.

Step 9c. For the remaining 5 weaker paths, pick the AoAs according to the CDF shown in Figure 3-4, where zero degrees is defined to be AoA of the strongest path from step 9b.

Step 9d. For interferers, steps 9b and 9c are repeated, assuming the street orientation and direction of travel did not change from step 9a.

The fixed 35 degree per-path Azimuth Spread is applied after the six ray AoA are defined.

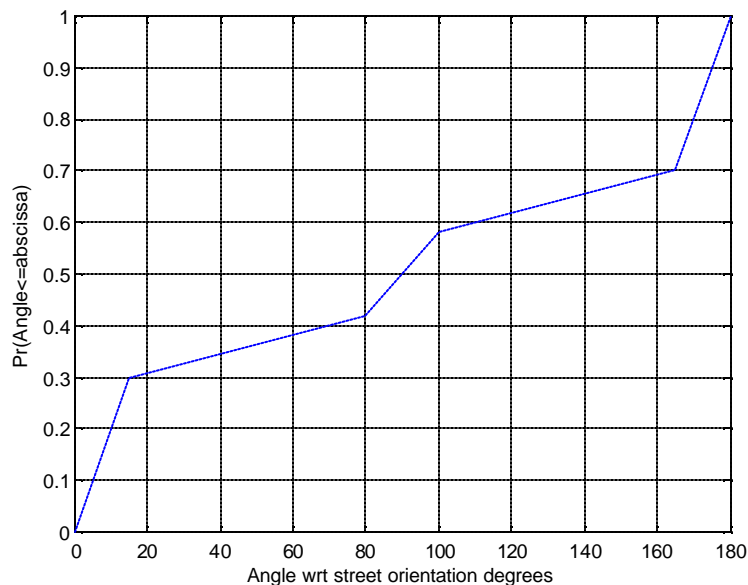


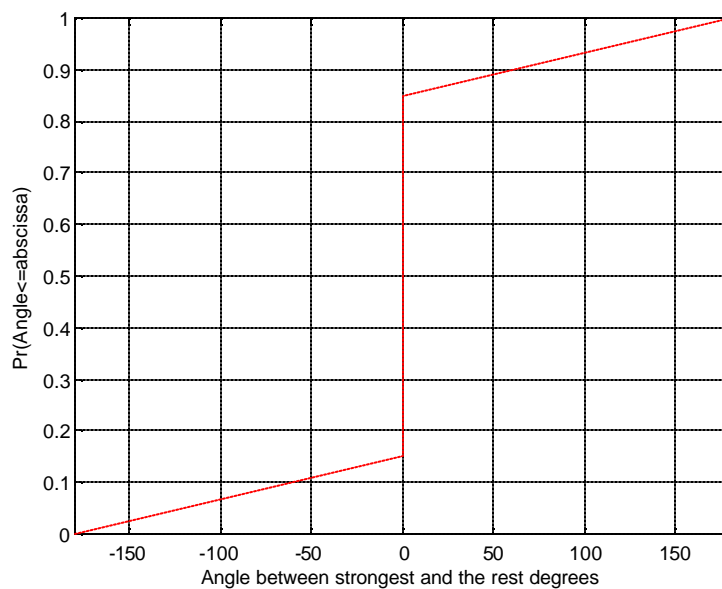
Figure 3-3, AoA of Strongest Path (+ & - angles have equal probability)

1

2 The CDF for the function given in Figure 3-3, is defined by:

$$F_x(x) = \begin{cases} x/50 & 0^\circ \leq x < 15^\circ \\ x/541.66 + 0.2723 & 15^\circ \leq x < 80^\circ \\ x/125 - 0.22 & 80^\circ \leq x < 100^\circ \\ x/541.66 + 0.3954 & 100^\circ \leq x < 165^\circ \\ x/50 - 2.6 & 165^\circ \leq x < 180^\circ \end{cases}$$

4



5

6 **Figure 3-4, Angle difference between Strongest Path and remaining paths**

7

8 The CDF of the function given in Figure 3-4, is defined by:

$$F_x(x) = \begin{cases} x/1200 + 0.15 & -180^\circ \leq x < 0^\circ \\ 0.7 & x = 0 \\ x/1200 + 0.85 & 0^\circ < x < 180^\circ \end{cases}$$

10

11 **3.6 Correlation Between Channel Parameters**12 **3.6.1 Correlation between Delay Spread, Angle Spread, and Log Normal Shadowing**

13 In [3], Greenstein presents a model for correlating delay spread (DS) with log normal (LN)
 14 shadow fading. Since both are shown to be log-normal distributed, the correlation between the

1 DS and LN are correlated by the coefficient ρ . The best value for suburban and urban data was
2 shown to be $\rho = -0.75$, presented in [3] from data measured by [4].

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

6 Cost 259[5] presents the azimuth spread (AS) as also being log-normal distributed, and
7 likewise being correlated to the DS and LN. Since the correlation of these parameters is quite
8 high, a spatial channel model needs to be specified that can reproduce this correlation
9 behavior along with the expected probability and range of each parameter. For a macro-cell
10 environment, the following values are given in [5]:

11
12 $\rho_{\alpha\beta} = \text{Correlation between DS \& AS} = +0.5$

13 $\rho_{\gamma\beta} = \text{Correlation between LN \& AS} = -0.75$

14 $\rho_{\gamma\alpha} = \text{Correlation between LN \& DS} = -0.75$

15 The random variables for correlating DS, AS, and LN shadowing are generated using

16
$$\begin{bmatrix} \mathbf{a}_n \\ \mathbf{b}_n \\ \mathbf{g}_n \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{bmatrix} w_{n1} \\ w_{n2} \\ w_{n3} \end{bmatrix}, \quad (1)$$

17 where n refers to the n th base station (BS). α , β , and γ are the correlated zero-mean unit
18 variance Gaussian distributed random variables associated with the DS, AS, and LN,
19 respectively, and w_{n1} , w_{n2} , and w_{n3} are unit-variance, independent Gaussian noise samples.
20 Equation 1 is performed once for each BS per drop.

21
$$\begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} = \begin{bmatrix} \mathbf{r}_{aa} & \mathbf{r}_{ab} & \mathbf{r}_{ag} \\ \mathbf{r}_{ba} & \mathbf{r}_{bb} & \mathbf{r}_{bg} \\ \mathbf{r}_{ga} & \mathbf{r}_{gb} & \mathbf{r}_{gg} \end{bmatrix}^{\frac{1}{2}}, \quad (2)$$

22 Equation 2 incorporates the matrix square root function of correlation coefficients.

23 The LN shadow fading component is typically correlated between Base Stations (BS). To
24 produce correlated shadow fading components (γ) between BS_1 and BS_2 , a simplified approach
25 is shown where the independent unit-variance Gaussian noise samples w_{13} and w_{23} are
26 replaced with correlated, unit-variance Gaussian noise samples that are generated using:

27
$$w_{13} = \mathbf{x}_c \frac{\sqrt{cc}}{c_{33}} + \sqrt{1 - \frac{cc}{c_{33}^2}} \mathbf{x}_1 \quad (3)$$

28 and

$$w_{23} = \mathbf{x}_c \frac{\sqrt{cc}}{c_{33}} + \sqrt{1 - \frac{cc}{c_{33}^2}} \mathbf{x}_2, \quad (4)$$

where ξ_c , ξ_1 , ξ_2 are independent, unit-variance Gaussian noise samples and cc is the desired site-to-site shadow fading correlation between the MS and nodes BS_1 and BS_2 . A value for the common component $cc=0.5$ or 50% site-to-site correlation will be assumed. The cumulative distribution functions of DS, LN, and AS are described in terms of the correlated Gaussian random variables that characterize their distributions [3][4][6].

Using nomenclature from[6] the distribution of DS is given by:

$$\sigma_{Dn} = 10^{(\epsilon_D \alpha_n + \mu_D)} \quad (5)$$

where α_n is the correlated zero-mean unit variance Gaussian distributed random variable associated with the DS for the n th BS, $\mu_D = E\{\log_{10}(\sigma_{DS})\}$ is the logarithmic mean of the distribution of DS, and $\epsilon_D = \text{Std}\{\log_{10}(\sigma_{DS})\}$ is the logarithmic standard deviation of the distribution of DS.

Similarly the distribution of AS is given by:

$$\sigma_{An} = 10^{(\epsilon_A \beta_n + \mu_A)} \quad (6)$$

where β_n is the correlated zero-mean unit variance Gaussian distributed random variable associated with the AS, $\mu_A = E\{\log_{10}(\sigma_{AS})\}$ is the logarithmic mean of the distribution of AS, and $\epsilon_A = \text{Std}\{\log_{10}(\sigma_{AS})\}$ is the logarithmic standard deviation of the distribution of AS.

Finally, the distribution for the LN is given by:

$$\sigma_{LN} = 10^{(\sigma_{SF} \gamma_n / 10)}, \quad (7)$$

where γ_n is the correlated zero-mean unit variance Gaussian distributed random variable associated with the LN, σ_{SF} (shadow fading) is obtained from analysis of the standard deviation from the regression line of the path loss versus distance, and the value is given in dB. Since the LN is normally used as a dB value, there is no need to convert it to linear, but rather simply use the quantity $\sigma_{SF} \gamma_n$.

Correlated channel parameters may be drawn within a system simulation based on the equations described above.

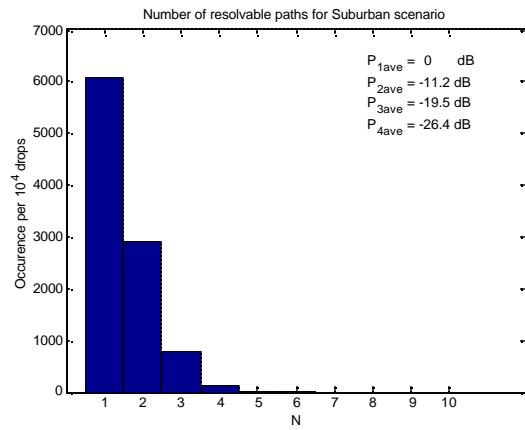
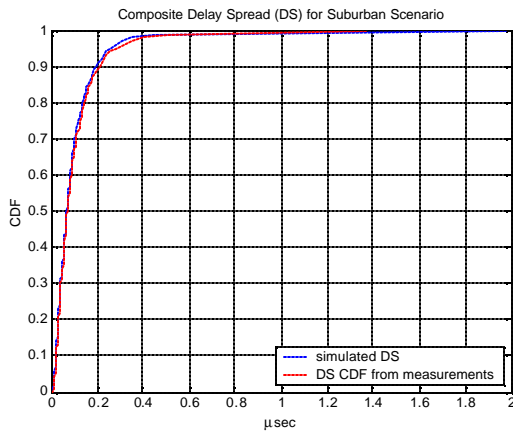
3.7 System Level Calibration

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. Only the paths with power higher than -15 dB relative to the strongest path are recorded. The shown statistics are the non-power weighted ones. In the same plots, the average relative powers of each resolvable path are given in the upper right corner. Per-resolvable path angle spread statistics at the BS/NodeB are also reported.

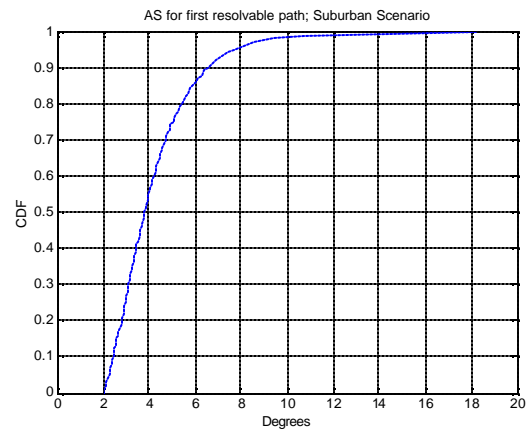
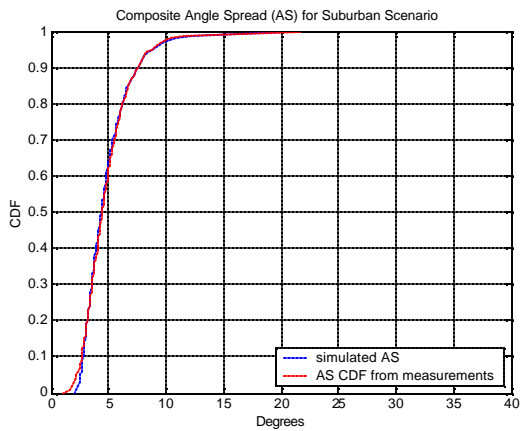
(The following figures labeled 2,3, & 4, are to be considered place holders until updated plots can be generated, which incorporate all the parameter values and attributes described above in the 12 step process and the table of parameters.)

1 -Channel Scenario: Suburban Macro

2



3

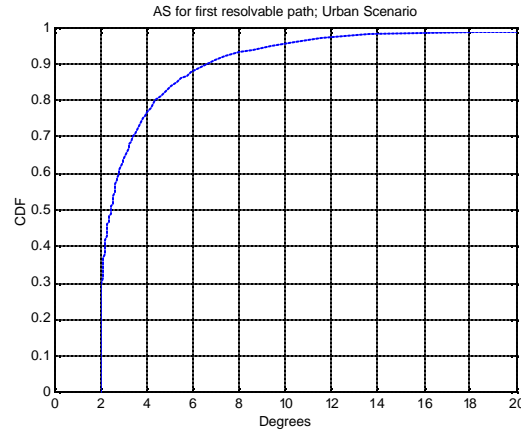
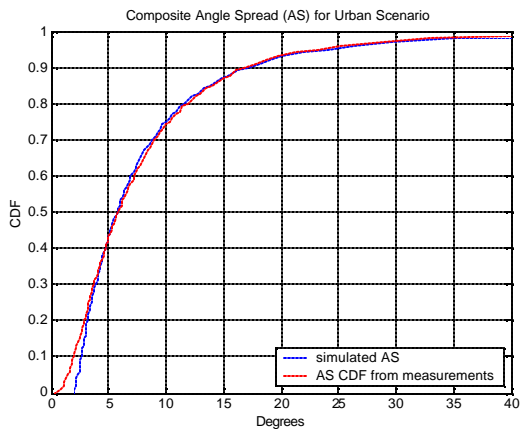
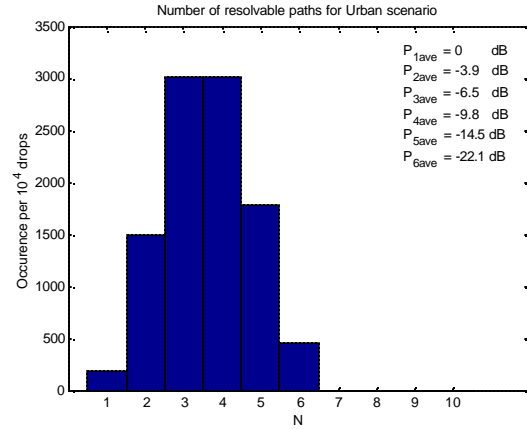
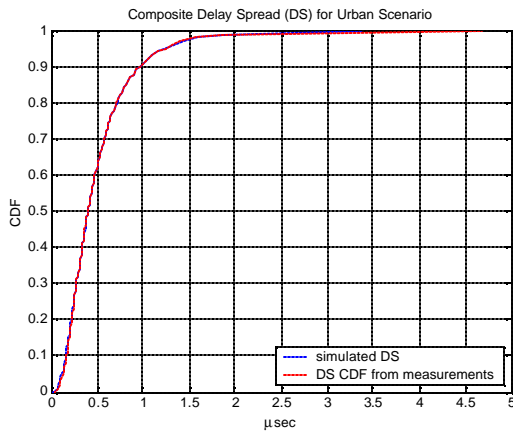


4

5 **Figure 2. Statistics for Suburban Macro Channel for chip-rate frequency = 3.84MHz**
 6 (clockwise from top left): (a) **CDF of total rms DS**, (b) **Probabilities for number of resolvable**
 7 **paths present (in occurrences per 10,000 drops)**. (c) **CDF of 1st resolvable path's AS**, (d)
 8 **CDF of Composite AS**

9

1 -Channel Scenario: Urban Macro



2

3

4 **Figure 3. Statistics for Urban Macro Channel for chip-rate frequency = 3.84MHz** (clockwise
 5 from top left): **(a) CDF of total rms DS, (b) Probabilities for number of resolvable paths**
 6 **present (in occurrences per 10,000 drops). (c) CDF of 1st resolvable path's AS, (d) CDF of**
 7 **Composite AS**

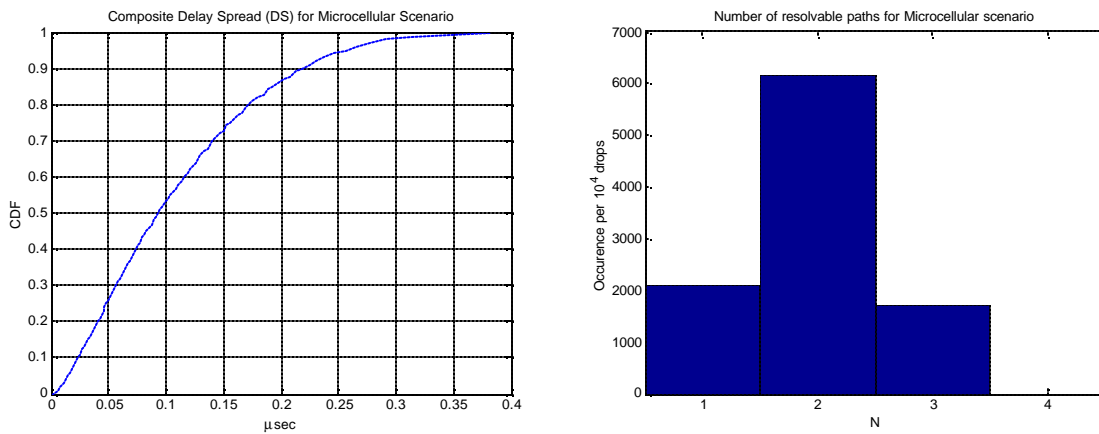
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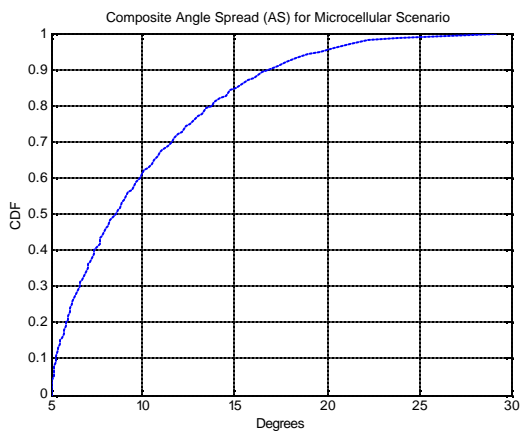
10

1 Channel Scenario: Urban Microcellular

2



3



4

5 **Figure 4 Statistics for Urban Microcellular Environment with chip-rate frequency =**
 6 **3.84MHz (clockwise from top left): (a) CDF of total rms DS, (b) Probabilities for number of**
 7 **resolvable paths present (in occurrences per 10,000 drops). (c) CDF of Composite AS**

8

9 **4 APPENDIX A: MMSE RECEIVER DESCRIPTION**

10

11

12

13 **5 REFERENCE**

14

[1] WG5 Evaluation Methodology – Addendum (V6), WG5 Evaluation AHG, July 25, 2001

[2] Nokia, Ericsson, Motorola. Common HSDPA system simulation assumptions. TSG-R1 document, TSGR#15(00)1094, 22-25th, August, 2000, Berlin, Germany, 12 pp.

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