Title:	Updated Wideband System Level Model and Statistics
File:	SCM-045-LUC-WidebandSCM-Update

Source:

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1. INTRODUCTION

A wideband system level channel model that was originally proposed in [3] is presented with updated information. The objective is to describe a method for specifying the PDP, the per-path and narrowband angle spreads per realization that is consistent with measurements and that follows the current discussions in the SCM adhoc group. A recommended set of parameter values is also proposed that are supported by measurement data.

Three channel scenarios are proposed. The suburban and urban macro channel scenarios are described in Section 2 and the urban microcellular scenario is described separately in Section 3.

2. WIDEBAND MODEL DESCRIPTION FOR SUBURBAN AND URBAN MACRO

The following sequence of numbered steps defines the proposed procedure for generating a randomized PDP, composite and per path angle spreads in the suburban and urban macro channel scenarios. The assumption is to generate a finite number of paths with temporal and spatial statistics that match the wideband distributions that have been reported in the literature. Particularly, the suburban macro scenario rms delay spread has been chosen based on [2].

Step 1: Choose the channel scenario from Table 1. All drops in a simulation run will use the parameters for the chosen scenario.

Step 2: Generate correlated values for the narrowband AS, DS, LN. An independent set of values is assigned for each user in each drop.

$$s_{DSk} = 10^{\left(e_D a_k + m_D\right)} \quad m_{\mathrm{D}} = E\{\log_{10}(s_{DS})\} \quad e_{\mathrm{D}} = Std\{\log_{10}(s_{DS})\}$$

$$s_{ASk} = 10^{\left(e_A b_k + m_A\right)} \quad m_{\mathrm{A}} = E\{\log_{10}(s_{AS})\} \quad e_{\mathrm{A}} = Std\{\log_{10}(s_{AS})\}$$

$$s_{LNk} = 10^{\left(\frac{s_{SF} g_k}{10}\right)}$$

$$\begin{bmatrix} a_k \\ b_k \\ g_k \end{bmatrix} = \begin{bmatrix} r_{aa} & r_{ab} & r_{ag} \\ r_{ba} & r_{bb} & r_{bg} \\ r_{ga} & r_{gb} & r_{gg} \end{bmatrix}^{1/2} \begin{bmatrix} w_{k1} \\ w_{k2} \\ w_{k3} \end{bmatrix}$$

$$\begin{aligned} r_{ab} &= \text{Correlation between DS \& AS} = +0.5 \\ r_{gb} &= \text{Correlation between LN \& AS} = -0.75 \\ r_{ga} &= \text{Correlation between LN \& DS} = -0.75 \end{aligned}$$

Step 3: Create a PDP for each user in each drop. Assign N=6 distinct paths for each realization. A value for the rms delay spread, σ_{DSk}, is given from Step 2.

Step 3A: Assign N (n=1,...,N) delays for each path: $t_1,...,t_N$. These times are taken from an exponential distribution with parameter $r s_{DSk}$ where r is given in Table 1. Thus the delay times can be written as

$$t_n = -r s_{DSk} \log z_n$$

where z_n is a uniform random variable between 0 and 1 and log(.) is the natural logarithm. Subsequently the τ_n are ordered and the minimum is subtracted from all to ensure that $\tau_1 = 0$. The value of r signifies the ratio of the un-power weighted standard deviation of paths as a function of delay (rs_{DSk}) to the full, power-weighted variance of the PDP (s_{DSk}). This ratio is fixed for each realization of paths and described in [1].

Step 3B: Assign a mean power p_n for each generated path. The mean power of the path is an exponentially decaying function of the path delay described below. The time constant for this distribution is given an a priori value (independent of the realization time delays) equal to $r/(r-1)s_{DSk}$. Thus the powers for each path can be given by

$$p_n = e^{-\frac{r-1}{rs_{DSk}}t_n} = z_n^{\ r-1}$$

For the particular realization of delay times τ_n and s_{DSk} the delay spread can be expressed as

$$\Sigma^2 = \left(rs_{DSk}\right)^2 \left[\frac{\sum_n z_n^{\ r-1} (\log z_n)^2}{\sum_n z_n^{\ r-1}} - \left(\frac{\sum_n z_n^{\ r-1} \log z_n}{\sum_n z_n^{\ r-1}} \right)^2 \right]$$

If the number of paths were infinite, then the distributions of delays and powers above become deterministic and the bracketed term in the right-hand side would become equal to r^{-2} . For finite N however one has to account explicitly for the variability of the bracketed terms. Thus in order for the distribution of Σ to match the narrowband data (i.e. the distribution of the measured s_{DS}^{0} as indicated in Table 1) a shift has to be made to the distribution of s_{DSk} . The optimal choice of s_{DSk} is given in Table 1.

Step 4: Assign a mean AOD, $d_{n,k}$, for each path -n- at the BS/NodeB. The AOD per path is a Gaussian random variable with zero mean and standard deviation given by s_{ASk}. Thus $d_{n,k} : N(0,\ s_{ASk})$. The value for s_{ASk} is generated in Step 2 above and picked to match the overall narrow-band angle spread distribution.

Step 4A: Order the AODs $d_{n,k}$ according to their power, i.e. the smallest $d_{i,k}$ is associated to p_1 etc.

Step 5: Assign a fixed rms angle spread for each path n based on a Laplacian distribution with value

$$s_{ASn,k} = 2^0$$

Step 6: At the BS/NodeB generate the channel realization for each path by superposition of M=20 sub-paths. All sub-paths have identical powers $P_{m,n,k} = \frac{P_n}{M}$ with an exponentially distributed density in their relative angle. The AOD realization of each sub-path in the sector is given below and illustrated in Figure 1.

$$q_{m,n} = \frac{s_{ASn,k}}{\sqrt{2}} \cdot x_{m,n} \cdot \log z_{m,n} + q_o + d_n$$

where $z_{m,n}$ is a uniform random variable between 0 and 1 and $x_{m,n}$ is an equi-probable binary random number $x_{m,n} = \pm 1$, so that $q_{m,n}$ follows the exponential distribution

$$P(q) \propto \exp\left[-\frac{\sqrt{2}\left|q - q_o - d_n\right|}{s_{ASn,k}}\right].$$

Step 7: Assign a mean AOD ,$d^{UE}_{n,k}$, for each path at the UE. The AOD per path is a uniform random variable over 360^0.

3. WIDEBAND MODEL DESCRIPTION FOR URBAN MICRO

A separate description of the steps is given for the urbancellular micro channel scenario. The parameters assigned are shown in Table 1. Parameter values and the method proposed use elements from [4] and [5].

Step 1, Step 2: identical to those in Section 2.

Step 3: The PDP consists of N=3 distinct paths that are uniformly distributed between 0 and 0.8µs. The powers for each path are exponentially decaying in time with the addition of a lognormal randomness, which is independent of the path delay:

$$P_n = 10^{-\frac{t_n}{m\sec}} \cdot 10^{-z_n} \quad \text{where} \quad z_n : N(0,0.9)$$

The lognormal variation of each path substitutes the large scale lognormal shadowing that is used in the other channel scenarios (applied in common to all paths). Essentially, in urban micro each path is shadowed independently.

Step 4: Assign a mean AOD,$d_{n,k}$, for each path -n- at the BS/NodeB. The AOD per path is a uniform random variable centered around the LOS direction q_o: $U(-30^o + q_o, 30^o + q_o)$.

Step 5: Assign a fixed rms angle spread for each path n:

$$s_{ASn,k} = 5^0$$

Step 6, Step 7: identical to those in Section 2.

Channel Scenario	**Suburban Macro**	**Urban Macro**	**Urban Micro**
Mean composite AS at BS	$E\{\sigma_{AS}\} = 5^o$	$E\{\sigma_{AS}\} = 8^o$	N/A
Measured overall composite AS at BS (lognormal distribution) σ^0_{AS}	$\mu^0_A=0.66$ $\varepsilon^0_A=0.18$	$\mu^0_A=0.77$ $\varepsilon^0_A=0.37$	N/A
Composite AS at BS as a lognormal RV, generated in Step 2, $\sigma_{AS}=10^{\varepsilon_A x+\mu_A}$, $x\sim N(0,1)$	$\mu_A=0.69$ $\varepsilon_A=0.17$	$\mu_A=0.87$ $\varepsilon_A=0.36$	Number of Paths = 3
Per Path AS at BS (Fixed)	2^0	2^0	5^0
Per Path AOD Distribution St.Dev. σ_{AS}	$N(0, \sigma_{AS})$	$N(0, \sigma_{AS})$	$U(30^o,30^o)$
Mean total rms delay spread	$E\{\sigma_{DS}\}=0.1$ μsec	$E\{\sigma_{DS}\}=0.5$ μsec	U(0, 0.8) μsec
Measured over all narrowband composite Delay Spread at BS (lognormal distribution) σ^0_{DS} (μsec)	$\mu^0_D=-0.92$ $\varepsilon^0_D=0.363$	$\mu^0_D=-0.4$ $\varepsilon^0_D=0.3$	$P_n = 10^{-\frac{t_n}{\mu sec}} \cdot 10^{-z_n}$ $z_n = N(0,0.9)$
Ratio of power weighted and non-power weighted Delay Spreads, r	r=1.17	r=1.41	N/A
Delay spread as a Lognormal RV (microsec) generated in Step 2, $\sigma_{DS}=10^{\varepsilon_D x+\mu_D}$, $x\sim N(0,1)$	$\mu_D=-0.8$ $\varepsilon_D=0.288$	$\mu_D=-0.33$ $\varepsilon_D=0.25$	N/A
Lognormal shadowing standard deviation	8dB	8dB	N/A
Mean Composite AS at UE	$E\{\sigma_{AS}\} = 72^o$	$E\{\sigma_{AS}\} = 72^o$	$E\{\sigma_{AS}\} = 72^o$
Per Path AS at UE (Fixed)	35^0	35^0	35^0
Per Path AOA at UE	Uniform in 360^0	Uniform in 360^0	Uniform in 360^0

Table 1. Environment parameters

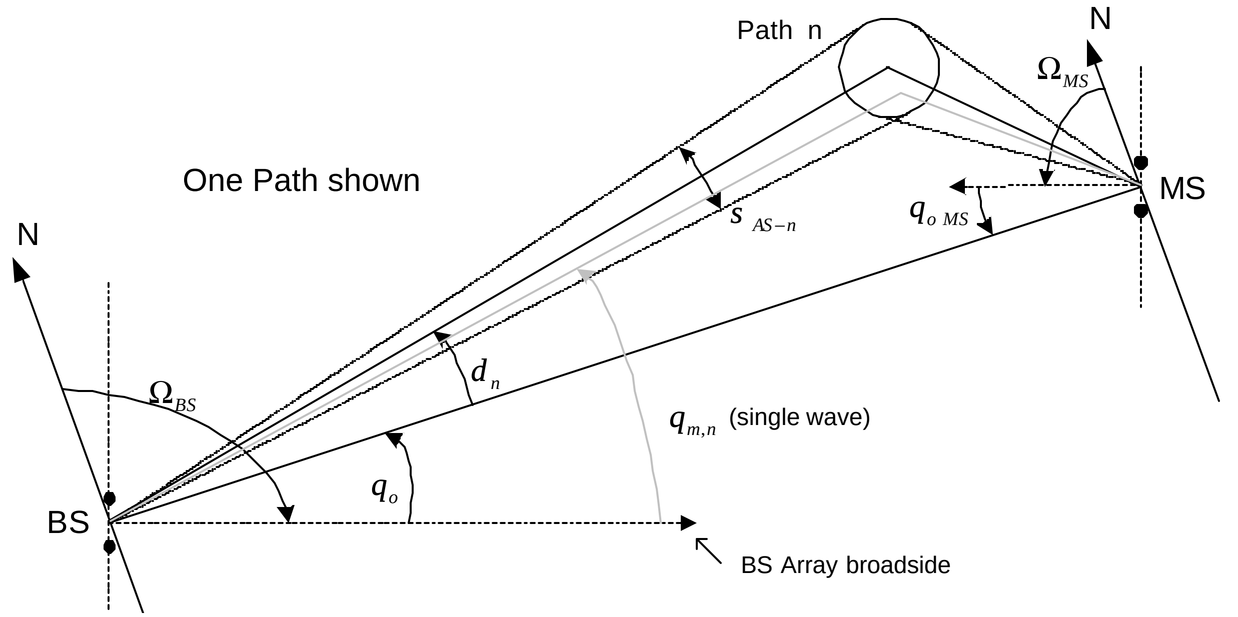

Figure 1. Example of one path and its associates angular parameters. The drop index k has been dropped for simplicity.

Figure 1 gives a geometric description of the angular variables used in the proposed model. The following definitions are used in Figure 1:

- Ω_{BS} : Base Station orientation. It is defined as the difference between the broadside of the BS array and a North (N) reference direction.
- q_o: mean composite angle of arrival. It is derived from geometry as the difference between the BS-MS LOS and the BS array broadside. Note that for channel models with unequal powers per path the LOS-based mean composite AOA may not coincide with the mean composite angle of arrival. More details are given later in the text.
- d_n : per path mean angle of arrival difference relative to the mean composite AOA q_o.
- $q_{m,n}$: Absolute AOA for each sub-path at the BS with respect to the BS broadside.
- $q_{o\ MS}$: mean composite angle of arrival at the mobile station. It is derived from geometry as the difference between the BS-MS LOS and the MS broadside.
- Ω_{MS} : MS orientation. It is defined as the difference between the broadside of the MS array and the North reference direction.

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

4. RESULTING PER RESOLVABLE PATH DELAY AND ANGLE SPREAD STATISTICS

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 –15dB 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.

5. CONCLUSION

The described wideband system level channel model offers a close match between distributions of measured data and a corresponding simulation approach. The resulting per-resolvable path statistics also show to be in accordance with earlier ITU specified temporal models.

6. REFERENCES

[1] Pedersen et al, IEEE Transaction on VT, Vol 49, No. 2, pp. 437-447, March 2000.

[2] Cheon et al., IEEE JSAC, vol 19, No 11, p. 2191, November 2001.

[3] SCM-042-LUC Wideband System Channel Model, SCM Conf. Call #5, August 1, 2002.

[4] M. Toeltsch, J. Laurila, K. Kalliola, A. F. Molisch, P. Vainikainen, and E. Bonek, "Statistical Characterization of Urban Spatial Radio Channels," IEEE JSAC, vol. 20, No. 3, p. 539, April 2002.

[5] Andreas Molisch, SCM-039-MIMO-HSDPA-ChannelModel, Mitsubishi.

-Channel Scenario: Suburban Macro

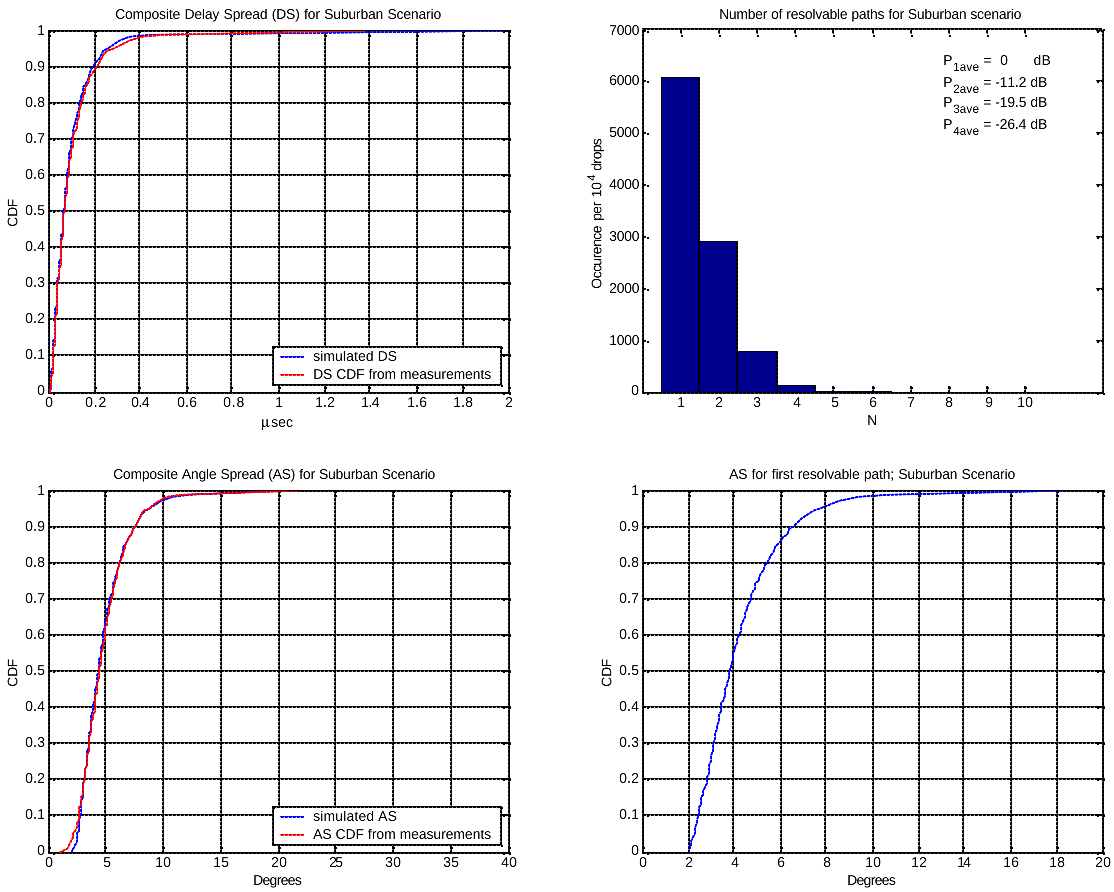

Figure 2. Statistics for Suburban Macro Channel for chip-rate frequency = 3.84MHz (clockwise from top left)**: (a) CDF of total rms DS, (b) Probabilities for number of resolvable paths present (in occurrences per 10,000 drops). (c) CDF of 1^{st} resolvable path's AS, (d) CDF of Composite AS**

-Channel Scenario: Urban Macro

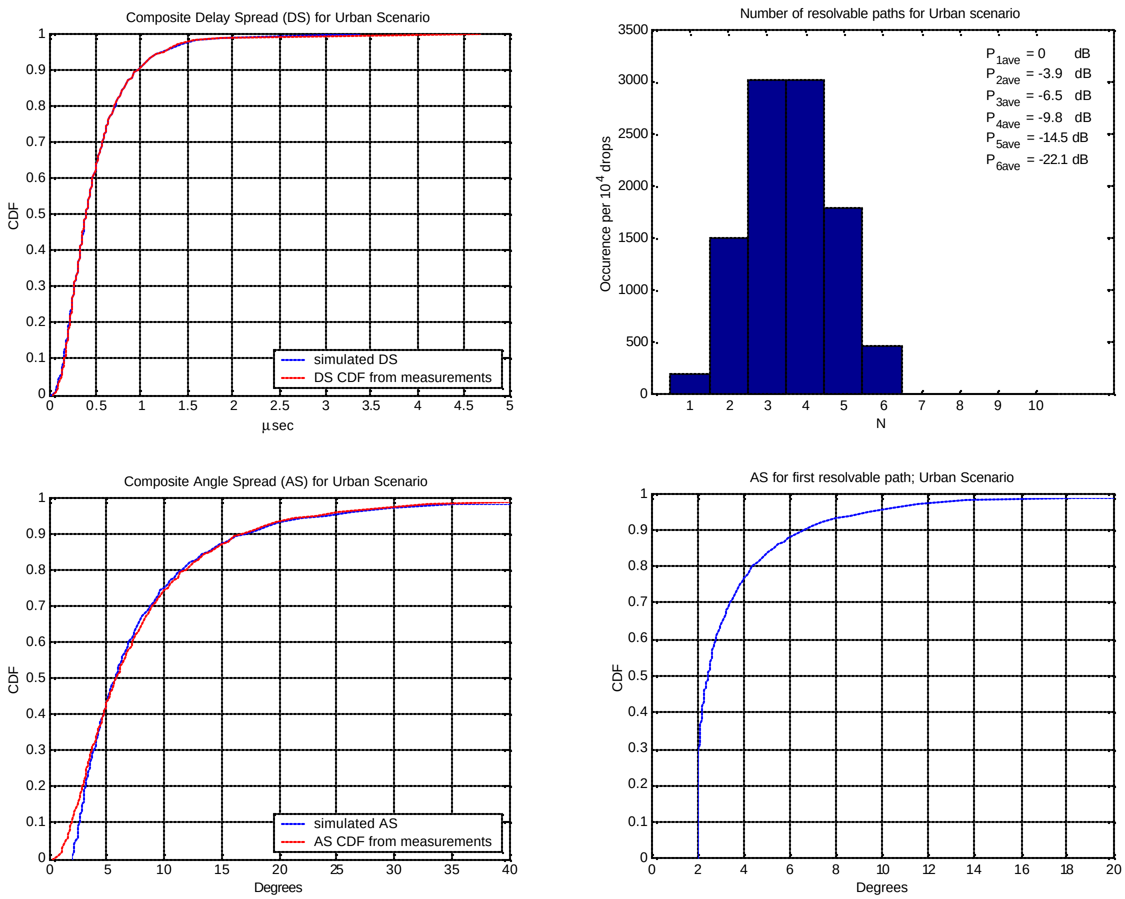

Figure 3. Statistics for Urban Macro Channel for chip-rate frequency = 3.84MHz (clockwise from top left)**: (a) CDF of total rms DS, (b) Probabilities for number of resolvable paths present (in occurrences per 10,000 drops). (c) CDF of 1st resolvable path's AS, (d) CDF of Composite AS**

Channel Scenario: Urban Microcellular

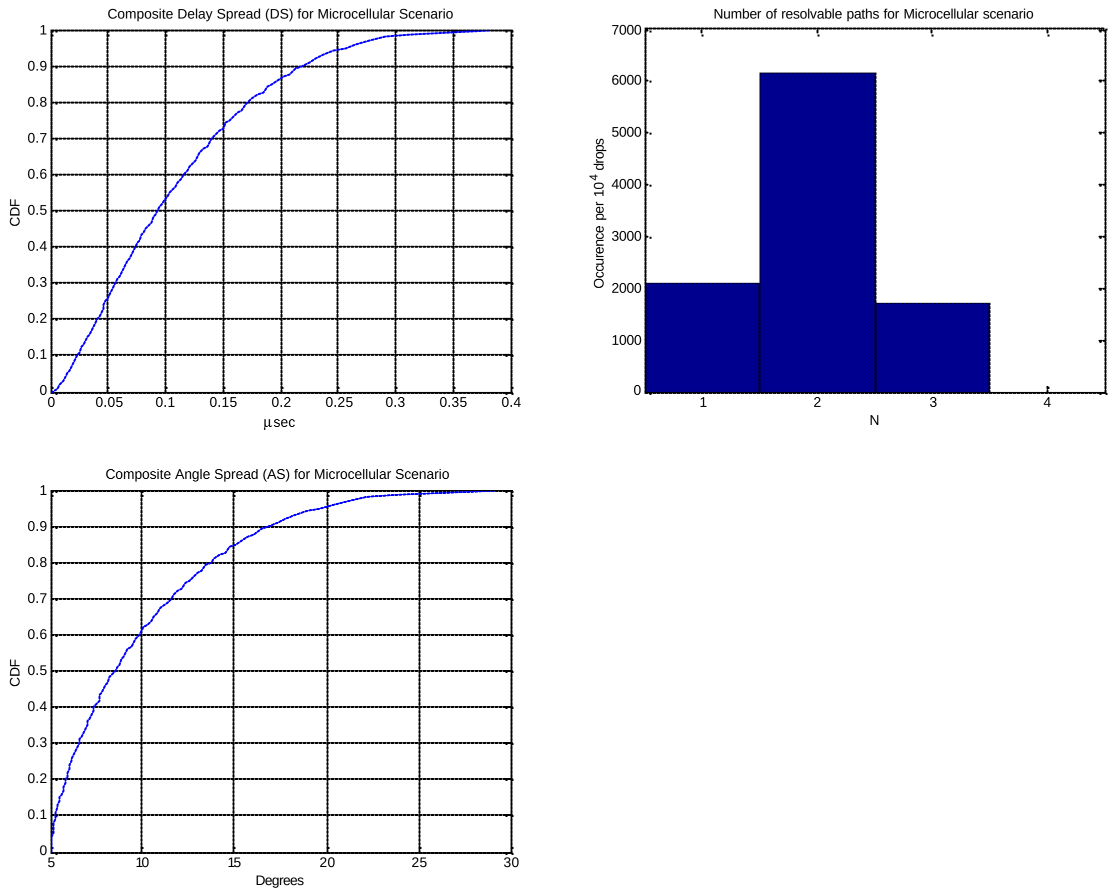

Figure 4 Statistics for Urban Microcellular Environment with chip-rate frequency = 3.84MHz (clockwise from top left)**: (a) CDF of total rms DS, (b) Probabilities for number of resolvable paths present (in occurrences per 10,000 drops). (c) CDF of Composite AS**