Project	**IEEE 802.20 Working Group on Mobile Broadband Wireless Access** **<http://grouper.ieee.org/groups/802/20/>**
Title	**Simplified Space Channel Model for the System Evaluation in MBWA**
Date Submitted	**2004-06-22**
Source(s)	David Huo 67 Whippany Road Whippany, NJ 07981 Voice: +1 973 428 7787 Fax: +1 973 386 4555 Email: dhuo@lucent.com
Re:	Link- level and system-level simulation in evaluation criteria.
Abstract	This document proposes a simplified version for the use by system level as well as the link level simulation. It is compliant with the ITU model and takes into account of the space channel components.
Purpose	Discuss and adopt.
Notice	
Release	
Patent Policy	

1 Introduction

Contribution [1] has proposed to simplify the channel model developed in [5] for both link-level simulation and system-level simulation. In [2] we have proposed and evaluated a mathematical formulation of the fading channel model that can be used for the link level simulation. Based on that result, here we propose the model that can be used by the system-level simulation. The proposed model simplifies the space channel model of [5] in a manor that complies with the ITU model, while having the potential to absorb more components from [5] whenever needs occur. The proposal focuses on aspects that concern both link and system level simulation. The macroscopical aspects that is of interest only for the system level simulation, such as slow fading and cell correlation etc., are not considered here. See[4].

2 Principle

The current space channel model as defined in [5]is complex due to the multiple conditioned statistical processes, and as such, its implementation during a computer simulation would require extensive convergence time for the collection of sufficient statistics. On the other hand, there is the ITU model, which is straight forward to implement with less details than the SCM. Therefore, the simplification is measured by the compliance with the ITU channel model and the capability of extending to full SCM. The model to be proposed in the following is constructed based on this principle: it extends the ITU model as described in [2], but has parameters that can be related to the corresponding statistic variables of the SCM, such as AoA, AoD, PAS, DoT and PDP.

3 Model Extension

The model of [2] can be extended to incoporate the variables angle of arrival and angle of departure. For this purpose, the following variables are used:

- $\mathbf{k}_T$, $\mathbf{k}_R$: the wave vector of the angle of departure at TX and wave vector of angel of arrival at RX, respectively. For radian frequency ω, light speed c and wave length λ, we have $|\mathbf{k}_T| = |\mathbf{k}_R| = \omega/c = 2\pi/\lambda =: k$. In a space channel model, the unit vectors $\hat{\mathbf{k}}_T = \mathbf{k}_T/|\mathbf{k}_T|, \hat{\mathbf{k}}_R = \mathbf{k}_R/|\mathbf{k}_R| \in [0, 2\pi)$ are random variables.

- $\mathbf{d}$: the antenna element vector from the reference point of the antenna array ($\mathbf{d} = 0$). Under the far field assumption, the relative phase of wave comming from this element is $\mathbf{k}' \cdot \mathbf{d} = kd \sin\theta$, where $\mathbf{k}$ is the wave vector originated from the refrence point of the array and $\mathbf{k}'$ is its $\pi/2$ clockwise rotated version, i.e. $\mathbf{k} \cdot \mathbf{k}' = 0$ and $|\mathbf{k}| = |\mathbf{k}'|$. Obviously, $\theta = \cos^{-1}(\hat{\mathbf{k}} \cdot \hat{\mathbf{d}})$.
- $\mathbf{v}$: the mobile speed vector with $|\mathbf{v}| = v$.
- N: number of sub-paths (multipath components) originated from the same cluster. A cluster corresponds to a single tap of the power-delay model
- M: number of paths (scatter clusters), each associated with a given (or random) delay in time.
- $D_T(\theta), D_R(\theta)$ are the antenna directivity of the transmitter and receiver, respectively.

The channel model between the T-th transmit antenna element and the R-th receive antenna element is

$$h_{T,R}(t) = \sum_{n=0}^{N-1} D_T(\hat{\mathbf{k}}_{T,n} \cdot \hat{\mathbf{a}}_T) e^{j(\mathbf{k}'_{T,n} \cdot \mathbf{d}_T + \phi_n)} D_R(\hat{\mathbf{k}}_{R,n} \cdot \hat{\mathbf{a}}_R) e^{j\mathbf{k}'_{R,n} \cdot \mathbf{d}_R} c_n e^{j(\mathbf{k}_{R/T,n} \cdot \mathbf{v})t} \tag{1}$$

where the doppler phase slope is

$$\mathbf{k}_{T,n,m} \cdot \mathbf{v} \text{ for TX=MS}$$
$$\mathbf{k}_{R,n,m} \cdot \mathbf{v} \text{ for RX=MS}$$

and c_n is uniformly distributed over $[0, 1)$ for $n = 0, 1, ..., N-1$ with $E\{|\mathbf{c}|^{\mathbf{2}}\} = \mathbf{1}$. It is assumed that each element antenna has an indpendent antenna gain, the reference antenna has $\mathbf{d}_0 = 0$, and $\hat{\mathbf{a}}_T$ and $\hat{\mathbf{a}}_R$ are the normal directions of the boreside of TX and RX, respectively. This quantity is Rayleigh faded at each given time t and corresponds a single tap in the power-delay model. Let denote (1) by $h_{T,R,\tau}$ to indicate the Rayleigh fading at time delay τ. Then the channel model between T-th element of the TX antenna and R-th element of the RX antenna becomes

$$h_{T,R} = \sum_{m=0}^{M-1} \alpha_m h_{T,R,\tau_m}(t)\delta(t-\tau_m) \tag{2}$$

where $(\alpha_m, \tau_m) \in [0,1] \times [0,\infty)$ and $(\alpha_0, \tau_0) = (1,0)$. Thus,

$$\begin{aligned} h_{T,R}(t) &= \sum_{m=0}^{M-1} \alpha_m \delta(t-\tau_m) \sum_{n=0}^{N-1} D_T(\hat{\mathbf{k}}_{T,n,m} \cdot \hat{\mathbf{a}}_T) D_R(\hat{\mathbf{k}}_{R,n,m} \cdot \hat{\mathbf{a}}_R) c_{m,n} \\ & \quad e^{j[\mathbf{k}'_{R,n,m} \cdot \mathbf{d}_R + \mathbf{k}'_{T,n,m} \cdot \mathbf{d}_T + \phi'_{n,m} + (\mathbf{k}_{R/T,n,m} \cdot \mathbf{v})t]} \end{aligned}$$

Compared to the simple ITU model[2], the difference consists in the extension of the following parameters

$$\begin{aligned} c_{m,n} &\rightarrow D_T(\hat{\mathbf{k}}_{T,n,m} \cdot \hat{\mathbf{a}}_T) D_R(\hat{\mathbf{k}}_{R,n,m} \cdot \hat{\mathbf{a}}_R) c_{m,n} \\ \phi_{n,m} &\rightarrow \mathbf{k}'_{R,n,m} \cdot \mathbf{d}_R + \mathbf{k}'_{T,n,m} \cdot \mathbf{d}_T + \phi'_{n,m} \end{aligned}$$

Now, with the power-delay profile remain the same $(c_{m,n}, \tau_m)$, the extended model requires parameters of the antenna pattern D_T and D_R. The random phase in the extended model contains components of known distribution, i.e. $\mathbf{k}'_{R,n,m} \cdot \mathbf{d}_R + \mathbf{k}'_{T,n,m} \cdot \mathbf{d}_T$. Parameter $\phi'_{n,m}$ on the right hand is set to zero, when AoD/AoA are uniformly random, and can be set to fixed non-zero offset when AoD/AoA are given.

4 Parameters

Conceptual difference to the SCM is the assumption that the power-delay profile is fixed and given. This removes the necessity of the radom instance of the path delay and path power together with its conditioned statistics. The generation of fixed AoA/AoD and sub-path AoA/AoD is made optional with given default values. The optional values are summarized in table 1, which is an extension of table 21 in [3]. The correlation of the antenna elements is fixed and its value for the given separation is given in 2, which is taken from table 22 in [3].

5 Recommendation

We recommend to adopt the proposed approach as the default assumptions for the link/system level simulation and incorporate the formula given here into the evaluation criteria document [4].

References

[1] IEEE C802.20-04/39: Proposal for Link-System Interface

[2] IEEE C802.20-04/52: Model of Fading Channels for the Link Level Simulation

[3] IEEE C802.20-03/92: Channel Models for IEEE 802.20 MBWA System Simulations

[4] IEEE C802.20-04/21: Evaluation Document for IEEE 802.20 MBWA System Simulations

[5] 3GPP/3GPP2: SCM Text ver.7.0

[6] S.O.Rice, "Statistical Properties of a Sine Wave Plus Random Noise", Bell System Technical Journal, Vol. XXXVII, No.3, 1958.

[7] W.C.Jakes,"Microwave Mobile Communications", New York Plenum, 1974.

Models		case-i	case-ii			case-iii		case-iv		case-v	
PDP		Modified Pedestrian-A	Vehicular-A			Pedestrian-B		Typical Urban (optional)		Vehicular-B (optional)	
Doppler Spectrum		Classical; Optional: Path#1 = Rician (K=6)	Classical;			Classical		Classical		Classical	
Number of Paths		4+1 (LOS on, K = 6dB)	6			6		11		6	
Relative Path power (dB)	Delay (ns)	0	0	0	0	0	0	-4.0	0	-2.5	0
		-6.51	0	-1.0	310	-0.9	200	-3.0	100	0	300
		-16.21	110	-9.0	710	-4.9	800	0	300	-12.8	8900
		-25.71	190	-10.0	1090	-8.0	1200	-2.6	500	-10.0	12900
		-29.31	410	-15.0	1730	-7.8	2300	-3.0	800	-25.2	17100
				-20.0	2510	-23.9	3700	-5.0	1100	-16.0	20000
								-7.0	1300		
								-5.0	1700		
								-6.5	2300		
								-8.6	3100		
								-11.0	3200		
Speed (km/h)		3	30, 120, 250			3, 30, 120,		3, 30, 120		30, 120	
Mobile Station	Topology	0.5λ	0.5λ			0.5λ		0.5λ		0.5λ	

	PAS	LOS on: Fixed AoA for LOS component, remaining power has 360 degree uniform PAS.	RMS angle spread of 35 degrees per path with a Laplacian distribution Default: 360 degree uniform PAS	RMS angle spread of 35 degrees per path with a Laplacian distribution Default: 360 degree uniform PAS	RMS angle spread of 35 degrees per path with a Laplacian distribution Default: 360 degree uniform PAS	RMS angle spread of 35 degrees per path with a Laplacian distribution Default: 360 degree uniform PAS
	DoT (degrees)	0	22.5 Default: 0	-22.5 Default: 0	22.5 Default: 0	22.5 Default: 0
	AoA (degrees)	Uniform distribution in [0, 360)	Uniform distribution in [0, 360)	Uniform distribution in [0, 360)	Uniform distribution in [0, 360)	Uniform distribution in [0, 360)
Base Station	Topology	Reference: ULA with 0.5λ-spacing or 4λ-spacing or 10λ-spacing Default: >> 10λ				
	PAS	Laplacian distribution with RMS angle spread of 2 degrees or 5 degrees, per path depending on AoA/AoD Default: Using table 3-2 in SCM document for PAS of different sub-paths (*) or None explicit				
	AoD /AoA (degrees)	50^{o} for 2^{o} RMS angle spread per path 20^{o} for 5^{o} RMS angle spread per path Default: Uniform distribution (within the sector)				

Table 1: Parameters for ITU Models

	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: Reference Correlation Values.