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Re:	[Response to the call for comments on the 16m system evaluation methodology]
Abstract	This document proposes some modifications and improvements of the currently discussed version of the IEEE 802.16m channel model. In particular, we suggest that (i) a full description of the temporal Rice factor (which is required to model stationary devices), (ii) a description of the elevation spectrum of the arriving waves for all environments, (iii) taking into account the random nature of the conventional (space-variant) Rice factor, (iv) define the probabilities of LOS.
Purpose	[Description of what *specific* action is requested of the 802.16 Working Group or subgroup.]
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Proposed modifications to the 16m channel model

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1. Introduction

This document proposes some modifications and improvements of the currently discussed version of the IEEE 802.16m channel model. In particular, we suggest that (i) a full description of the temporal Rice factor (which is required to model stationary devices), (ii) a description of the elevation spectrum of the arriving waves for all environments, (iii) taking into account the random nature of the conventional (space-variant) Rice factor.

The following sections first contain a motivation and intuitive description of the changes, followed by the explicit text modifications whose inclusion into the system evaluation methodology we propose.

2. Motivation

The channel model as proposed in the current (June 2007) version of the system evaluation methodology gives a good approximation to reality, but there are a number of points where improvements are important.

First and foremost, the current definition of the temporal channel variations of stationary devices is incomplete. A complete specification requires not only the definition of the Doppler spectrum, but also of the “temporal K factor”, which describes the ratio of the energies of temporally variant contributions to the impulse response over that of the temporally invariant contributions. We propose a simple equation for this temporal K factor that is parameterized (based on data from the peer-reviewed literature) for different environments. Without the adoption of an equation for temporal Rice factors, system simulations are not possible (note that all environments include a finite percentage of users with zero mobility).

Next, we note that the current specifications do not contain elevation spectra for all the environments. We therefore propose deterministic elevation spectra, and suggest a simple way of including them in the current simulation procedure. We postulate that the absence of elevation spectra leads to inaccuracies in the

Last, but not least, extensive experiments have shown that the Rice factor is not a fixed value even in deterministic environments, but rather a random variable. We therefore suggest a simple model (lognormal distribution) for a random Rice factor. We furthermore also suggest an explicit model for the probability of line-of-sight.

3. Suggested text

The geometry-based stochastic models are created using the parameters listed in the Table 3. The channel realizations are obtained by a step-wise procedure described in the reference [Winner II].

In addition to the procedure described there, the following steps need to be used:

1. Each path is associated with an elevation at both BS and MS. The elevation angles are chosen at random from the distribution specified in Table III.

2. If a LOS component is present, then we first generate the Rice factor at random from a lognormal distribution whose mean and variance is given in Table 3. The total combined power of the LOS component and the diffuse components is normalized to unity power so the coherent LOS component will have a relative amplitude

$$\sqrt{\frac{K}{K+1}}$$

3: If the TX and the RX are stationary, and the channel at time t is to be computed, then each cluster is made of a number of coherent (fixed) rays N_c and a number of scattered (variable) rays N_s ($N_c + N_s$ = total number of rays per clusters).

The variable rays are ascribed a bell-shaped Doppler spectrum as described in [Erceg et al. 2001]:

$$S(f) = \begin{cases} 1 - 1.72 f_0^2 + 0.785 f_0^4 & f_0 \le 1 \\ 0 & f_0 > 1 \end{cases} \qquad \text{where} \quad f_0 = \frac{f}{f_m}$$

where f_m is the maximum Doppler rate (suggested value: 2 Hz [Erceg et al. 2001]). The fixed rays within a cluster share the same amplitude and phase, and their Doppler spectrum is a Dirac impulse at $f = 0$ Hz.

To determine the power of the coherent and scattered rays, we fix $N_c = N_s = N$. The n^{th} cluster is associated with a temporal K-factor K_n [dB]. The power in [dB] of each scattered ray is then given by

$P_n - 10 \log_{10}(N) - K_n$

while the power of each coherent ray is then given by

$P_n - 20 \log_{10}(n)$

All coherent rays within a given cluster are then ascribed equal amplitude (according to the above power) and equal phase, this phase being randomly distributed between clusters over $[0, 2\pi]$.

The cluster K-factor is a lognormally distributed variable whose variance is equal to 8 dB and whose mean $\overline{K}_n$ is computed as follows.

a) in the absence of a LOS:

- **for indoor scenarios**

$$\overline{K}_n\,[dB] = K_0 - \beta\tau_n[ns]$$

- **for outdoor scenarios**

$$\overline{K}_n\,[dB] = K_0 - \beta\tau_n$$

where τ_n [ns] is the average cluster delay. The values of K_0 and β are given in Table 3 [Oestges et al. 2007, Oestges et al. 2006, Oestges et al. 2005, Ahumada et al. 2005, Erceg et al., 2004].

b) if a LOS is present (both for indoor and outdoor cases), the mean K-factor of the LOS cluster is given by $K_{LOS}\,[dB]$.

$$\overline{K}_1\,[dB] = K_{LOS}$$

The other clusters have a mean K-factor as given by the above relationships. The values of $K_{LOS}\,[dB]$ are given in Table 3 [Oestges et al. 2007, Oestges et al. 2006, Oestges et al. 2005, Ahumada et al. 2005, Erceg et al., 2004].

c) in bad urban scenarios (outdoor microcells and macrocells), the far scatterer clusters are given a specific mean K-factor K_{far} [dB]

$$\overline{K}_n\,[dB] = K_{far}$$

The values of $K_{far}\,[dB]$ are given in Table 3 [Ahumada et al. 2005].

d) for outdoor scenarios, the above formulas are valid for a TX-RX range *d* [m] of 200 m and a UE antenna height *h* [m] of 3 m. For alternative ranges and UE antenna heights, all mean K-factors above are modified as follows [Erceg et al. 2001]:

$$\overline{K}_n(d,h)\,[dB] = \overline{K}_n(d = 200m; h = 3m) - 5\log_{10}(d[m]/200) + 4.6\log_{10}(h[m]/3)$$

ADDITION IN PARAMETER TABLES: ELEVATION

For all environments, an elevation spectrum is defined, with a deterministic angular spread. Only the elevation spread of the NLOS scenario is given. The elevation spread for the diffuse components in LOS is the same; the presence of the LOS component reduces the elevation spread in an implicit manner

*** A1** Indoor:
BS: Laplacian angular spectrum. Angular spread: 11 degrees. Source [Winner 2007]
MS: Laplacian angular spectrum: Angular spread 13 degrees. Source [Winner 2007]
*** B1** Microcell:
BS: Laplacian angular spectrum. Angular spread: 5 +35*(h_roof-h_BS)/h_roof degrees. Linear interpolation between [Toeltsch et al. 2002] (for h_BS=h_roof) and [Laitinen et al.] (for h_BS very small).
MS: Uniform angular spectrum between 0 and 60 degrees [Kalliola et al. 2003], [Kuchar 2000], [Medbo et al. 2005]
*** B2** bad microcell
same as B1
*** B4**: outdoor-to-indoor
BS: same as B!
MS: Laplacian angular spectrum. Angular spread: 7 degrees [Kalliola et al. 2002].
*** C1** suburban:
same as D1
*** C2** urban
BS: Laplacian angular spectrum: Angular spread: 0.5 degrees [Asplund et al. 2006]
MS: uniform angular spectrum between 0 and 60 degrees [Kuchar et al. 2000]
*** C3** bad macrocell urban:
same as C2
*** D1** Highway (rural):

BS: same as BS in macrocell urban
MS: Laplacian angular spectrum, mean 6 degrees, angular spread 8 degrees [Kalliola et al. 2002]
*** D2**: high-speed
for both BS and MS, we use the values of the MS in D1

MODIFICATION OF RICE FACTOR

The Rice factor is modeled as a lognormally distributed random variable. It has a mean as suggested in Table 3, and a standard deviation of 6 dB [Asplund et al. 2006].

PROBABILITIES OF LINE-OF-SIGHT

The probabilities for the LOS are given by the following table:

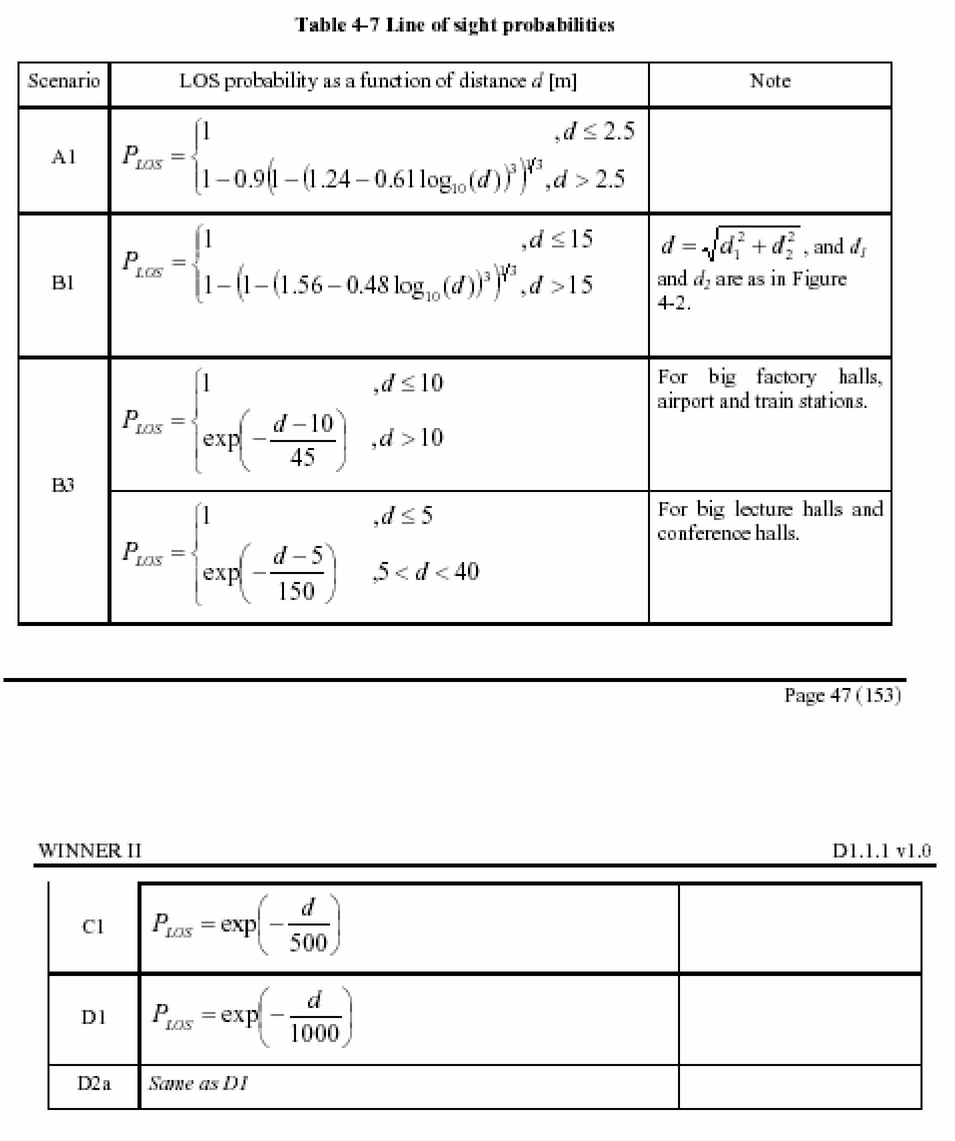

Table 4-7 Line of sight probabilities

Scenario	LOS probability as a function of distance d [m]	Note
A1	$P_{LOS} = \begin{cases} 1 & ,d \le 2.5 \\ 1 - 0.9\left(1 - \left(1.24 - 0.61\log_{10}(d)\right)^3\right)^{1/3} & ,d > 2.5 \end{cases}$	
B1	$P_{LOS} = \begin{cases} 1 & ,d \le 15 \\ 1 - \left(1 - \left(1.56 - 0.48\log_{10}(d)\right)^3\right)^{1/3} & ,d > 15 \end{cases}$	$d = \sqrt{d_1^2 + d_2^2}$, and d_1 and d_2 are as in Figure 4-2.
B3	$P_{LOS} = \begin{cases} 1 & ,d \le 10 \\ \exp\left(-\dfrac{d-10}{45}\right) & ,d > 10 \end{cases}$	For big factory halls, airport and train stations.
	$P_{LOS} = \begin{cases} 1 & ,d \le 5 \\ \exp\left(-\dfrac{d-5}{150}\right) & ,5 < d < 40 \end{cases}$	For big lecture halls and conference halls.
C1	$P_{LOS} = \exp\left(-\dfrac{d}{500}\right)$	
D1	$P_{LOS} = \exp\left(-\dfrac{d}{1000}\right)$	
D2a	*Same as D1*	

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WINNER II D1.1.1 v1.0

[Winner 2007]

C2 and C3:

$$p_{LOS}(d) = \max\left(\frac{h_{BS} - h_B}{h_{BS}} \frac{d_{CO} - d}{d_{CO}}, 0\right)$$

d_CO=500m [Asplund et al. 2006]
B2: as for B1

MODIFICATION OF TEMPORAL RICE FACTOR

The Rice factor for stationary TX-RX is modelled as a lognormally distributed random variable, whose mean is computed based on the following values of K_0, β, K_{far}, and K_{LOS} (see Table 3-next page)

Clustered Delay Line model

Scenario A1: LOS Clustered delay line model, indoor environment.

Cluster #	Delay [ns]			Power [dB]			AoD [°]	AoA [°]	Ray power [dB]		Temporal K-factor [dB]	Cluster ASD = 5°	Cluster ASA = 5°
1	0			0.0			0	0	-0.08*	-30.2**	30		
2	20			-25.3			-160	164	-38.3		29.80		
3	35	40	45	-15.7	-17.9	-19.7	-113	-116	-25.7		29.60		
4	45			-21.0			-146	149	-34.0		29.55		
5	45			-19.4			140	143	-32.4		29.55		
6	90			-23.3			153	157	-36.3		29.10		
7	110	115	120	-18.8	-21.0	-22.7	148	151	-28.8		28.85		
8	155			-25.2			-159	163	-38.2		28.45		
9	190			-21.6			148	151	-34.7		28.1		
10	245			-19.1			-139	-142	-32.1		27.55		
11	255			-27.9			-168	-172	-40.9		27.45		
12	320			-30.5			176	-180	-43.5		26.80		

* Power of dominant ray,
** Power of each other ray

Scenario A1 NLOS Clustered delay line model, indoor environment.

Cluster #	Delay [ns]			Power [dB]			AoD [°]	AoA [°]	Ray power [dB]	Temporal K-factor [dB]	Cluster ASD = 5°	Cluster ASA = 5°
1	0	5	10	-3.0	-5.2	-7.0	0	0	-13.0	20.0		
2	5			-4.0			59	-55	-17.0	19.95		

3	20			-4.7			-64	-59	-17.7	19.8		
4	25			-9.0			89	-82	-22.0	19.75		
5	30			-8.0			83	-77	-21.0	19.70		
6	30	35	40	-4.0	-6.2	-8.0	-67	62	-14.0	19.65		
7	35			-1.1			32	29	-14.2	19.65		
8	45			-5.2			-67	62	-18.2	19.55		
9	55			-9.5			-91	-84	-22.5	19.45		
10	65			-7.9			-83	77	-20.9	19.35		
11	75			-6.8			-77	-71	-19.8	19.25		
12	90			-14.8			-113	105	-27.8	19.10		
13	110			-12.8			-106	98	-25.8	18.90		
14	140			-14.1			111	-103	-27.2	18.60		
15	210			-26.7			-152	141	-39.7	17.90		
16	250			-32.5			-168	-156	-45.5	17.5		

Scenario B1: NLOS Clustered delay line model.

Cluster #	Delay [ns]			Power [dB]			AoD [º]	AoA [º]	Ray power [dB]	Temporal K-factor [dB]	Cluster ASD =10º	Cluster ASD = 22º
1	0			-1.0			8	-20	-14.0	21		
2	90	95	100	-3.0	-5.2	-7.0	0	0	-13.0	20.05		
3	100	105	110	-3.9	-6.1	-7.9	-24	57	-13.9	19.95		
4	115			-8.1			-24	-55	-21.1	19.85		
5	230			-8.6			-24	57	-21.6	18.7		
6	240			-11.7			29	67	-24.7	18.6		
7	245			-12.0			29	-68	-25.0	18.55		
8	285			-12.9			30	70	-25.9	18.15		
9	390			-19.6			-37	-86	-32.6	17.1		
10	430			-23.9			41	-95	-36.9	16.7		
11	460			-22.1			-39	-92	-35.1	16.4		
12	505			-25.6			-42	-99	-38.6	15.95		
13	515			-23.3			-40	94	-36.4	15.85		
14	595			-32.2			47	111	-45.2	15.05		
15	600			-31.7			47	110	-44.7	15.00		
16	615			-29.9			46	-107	-42.9	14.85		

Scenario B4: NLOS Clustered delay line model, outdoor to indoor environment

Cluster #	Delay [ns]			Power [dB]			AoD [º]	AoA [º]	Ray power [dB]	Temporal K-factor [dB]	Cluster ASD = 5º	Cluster ASA = 8º
1	0			-7.7			29	102	-20.8	16		
2	10	15	20	-3.0	-5.2	-7.0	0	0	-13.0	15.85		
3	20			-3.7			20	70	-16.7	16		
4	35			-3.0			-18	-64	-16.0	15.65		

5	35			-3.0			18	-63	-16.0	15.65		
6	50			-3.7			20	70	-16.7	15.5		
7	55	60	65	-5.4	-7.6	-9.4	29	100	-15.4	15.4		
8	140			-5.3			24	84	-18.3	14.6		
9	175			-7.6			29	100	-20.6	14.25		
10	190			-4.3			-21	76	-17.3	14.1		
11	220			-12.0			36	-126	-25.0	13.8		
12	585			-20.0			46	163	-33.0	10.15		

Scenario C1: LOS Clustered delay line model, suburban environment.

Cluster #	Delay [ns]			Power [dB]			AoD [º]	AoA [º]	Ray power [dB]		Cluster ASD = 5º	Cluster ASD = 5º
1	0	5	10	0.0	-25.3	-27.1	0	0	-0.02*	-33.1**		
2	85			-21.6			-29	-144	-34.7			
3	135			-26.3			-32	-159	-39.3			
4	135			-25.1			-31	155	-38.1			
5	170			-25.4			31	156	-38.4			
6	190			-22.0			29	-146	-35.0			
7	275			-29.2			-33	168	-42.2			
8	290	295	300	-24.3	-26.5	-28.2	35	-176	-34.3			
9	290			-23.2			-30	149	-36.2			
10	410			-32.2			35	-176	-45.2			
11	445			-26.5			-32	-159	-39.5			
12	500			-32.1			35	-176	-45.1			
13	620			-28.5			33	-165	-41.5			
14	655			-30.5			34	-171	-43.5			
15	960			-32.6			35	177	-45.6			

* Power of dominant ray,

** Power of each other ray

Clustered delay-line model for Scenario C1 NLOS

Cluster #	Delay [ns]			Power [dB]			AoD [º]	AoA [º]	Ray power [dB]	Cluster ASD = 2º	Cluster ASD = 10º
1	0	5	10	-3.0	-5.2	-7.0	0	0	-13.0		
2	25			-7.5			13	-71	-20.5		
3	35			-10.5			-15	-84	-23.5		
4	35			-3.2			-8	46	-16.2		
5	45	50	55	-6.1	-8.3	-10.1	12	-66	-16.1		
6	65			-14.0			-17	-97	-27.0		
7	65			-6.4			12	-66	-19.4		
8	75			-3.1			-8	-46	-16.1		
9	145			-4.6			-10	-56	-17.6		
10	160			-8.0			-13	73	-21.0		

11	195	-7.2	12	70	-20.2		
12	200	-3.1	8	-46	-16.1		
13	205	-9.5	14	-80	-22.5		
14	770	-22.4	22	123	-35.4		

Scenario C2: NLOS clustered delay line model.

Cluster #	Delay [ns]			Power [dB]			AoD [º]	AoA [º]	Ray power [dB]	Cluster ASD = 2º	Cluster ASD = 15º
1	0			-6.4			11	61	-19.5		
2	60			-3.4			-8	44	-16.4		
3	75			-2.0			-6	-34	-15.0		
4	145	150	155	-3.0	-5.2	-7.0	0	0	-13.0		
5	150			-1.9			6	33	-14.9		
6	190			-3.4			8	-44	-16.4		
7	220	225	230	-3.4	-5.6	-7.4	-12	-67	-13.4		
8	335			-4.6			-9	52	-17.7		
9	370			-7.8			-12	-67	-20.8		
10	430			-7.8			-12	-67	-20.8		
11	510			-9.3			13	-73	-22.3		
12	685			-12.0			15	-83	-25.0		
13	725			-8.5			-12	-70	-21.5		
14	735			-13.2			-15	87	-26.2		
15	800			-11.2			-14	80	-24.2		
16	960			-20.8			19	109	-33.8		
17	1020			-14.5			-16	91	-27.5		
18	1100			-11.7			15	-82	-24.7		
19	1210			-17.2			18	99	-30.2		
20	1845			-16.7			17	98	-29.7		

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