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Channel Models for IEEE 802.20 MBWA System Simulations

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Contents

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1 Overview

[Editor's Note: There have been 6 contributions on this topic so far. For SISO modeling, contributions C802.20-03/48, C802.20-03/43, and C802.20-03/46r1 suggested that ETSI UMTS Terrestrial Radio Access (UTRA) channel models should be adopted, and contribution C802.20-03/09 described a few path loss models based on experimental data. For MIMO modeling, contributions C802.20-03/42 and C802.20-03/50 indicated that correlation model should be adopted due to the simplicity. In the straw-man sections below, text pieces enclosed in [square brackets] are edited excerpts from these contributions which are representative of the particular sections that they appear in.]

1.1 Purpose

This document specifies a set of mobile broadband wireless channel models in order to facilitate the MBWA system simulations.

1.2 Scope

The scope of this document is to define the specifications of mobile broadband wireless channel models.

1.3 Abbreviations and Definitions

SISO = Single-Input Single Output
MIMO = Multiple-Input Multiple Output
MS = Mobile Station
BS = Base Station
TE = Test Environment
PDP = Power Delay Profile
AS = Angle Spread
DS = Delay Spread
Path = Ray
Path Component = Sub-ray
PL = Path Loss
PAS = Power Azimuth Spectrum
DoT = Direction of Travel
AoA = Angle of Arrival
AoD = Angle of Departure

2 Channel Models for SISO System Simulation

2.1 Introduction

This section specifies a set of channel models for Single-Input Single Output (SISO) simulations.

2.2 Channel Model Ensemble for SISO System Simulation

[**C802.20-03/48:** For SISO channel modeling, we propose that IEEE 802.20 WG adopt, essentially unchanged, the test environments and associated SISO channel models put forth for UMTS Terrestrial Radio Access (UTRA) as described in Annex B of [14]. Our motivations for this choice are straightforward: The deployment and propagation scenarios for which the UTRA models were developed are so similar to those currently envisioned for IEEE 802.20 MBWA, that developing new models seems unwarranted, at least at this time.]

2.2.1 Overview of the UTRA Test Environments and Channel Models

[**C802.20-03/48:** Reference [14] defines three broad deployment/propagation scenarios, referred to therein as "Test Environments" (TEs), in which the performance of candidate UTRA radio transmission technologies (RTTs) are to be evaluated. These Test Environments are labeled *Indoor Office*, *Outdoor-to-Indoor and Pedestrian*, and *Vehicular.* Each Test Environment broadly defines a particular wireless propagation scenario, and each scenario in turn has an associated channel model.] The TEs are qualitatively characterized as shown in Table 1.

Test Environment	**Qualitative description from [14]**
Indoor	Base stations and mobile stations located within buildings. "Small" cell sizes. "Low" transmit powers. Doppler rate set by walking speeds.
Pedestrian	Base stations with low antenna heights, located outdoors. "Small" cell sizes. "Low" transmit powers. Doppler rate set by walking speeds, with occasional higher rates due to vehicular reflections.
Vehicular	Base stations with roof antennas; users are in vehicles, walking, or stationary. "Larger" cells. "Higher" transmit powers. Maximum Doppler rate set by vehicular speeds; lower rates for walking or stationary users.

Table 1. Qualitative Descriptions of the UTRA Test Environments

The channel model associated with each Test Environment is comprised of the following:

- A deterministic *mean path loss* formula, which specifies the average path loss as a function of BS-MS distance, operating frequency, and in some cases other parameters relevant to the particular TE.

- A pair of representative tapped delay line impulse response specifications, labeled *A* and *B*, which characterize *delay spread*. The *A* model represents a frequently occurring low delay spread situation, and the *B* model a frequently occurring high delay spread situation within that TE. A Doppler velocity distribution model - in all cases, either flat or Jakes' – is also specified. Note that numerical values for velocities are *not* specified; the only guidance on this are the qualitative hints given in Table 1 above. This is discussed further in Section 2.4.

- A statistical model which characterizes *long-term (shadow) fading*. For all TEs, shadow fading loss is assumed to be log-normally distributed with a mean of zero, and the specification consists of the standard deviation of this distribution. In addition, for simulations which need to model time evolution of shadow fading loss as a function of position, a positional correlation model for shadow fading is also specified. For all TEs, the form of the model is an exponential autocorrelation function

$$R(\Delta x) = \exp\left(-\frac{|\Delta x|}{d_{cor}} \cdot \ln 2 \right)$$

  where Δx is incremental distance (meters) and d_{cor} is a decorrelation length parameter specified for each TE.

2.3 Channel Model Details

The following sections provide the details of these Test Environments.

2.3.1 Indoor Test Environment

2.3.1.1 Path Loss

Mean path loss for the Indoor Office TE is given by

$$L = 30\log_{10} R + 18.3n^{((n+2)/(n+1)-0.46)} + 37$$

where L is the loss in dB, R is the BS-MS distance in meters, and n is the number of floors in the path.

2.3.1.2 Shadow Fading

Shadow fading loss for the Indoor TE is modeled as a log-normal random variable with zero mean and variance 12 dB. The positional correlation model is used, with parameter $d_{cor} = 5m$.

2.3.1.3 Impulse Response

The tapped-delay line impulse response parameters for the Indoor TE are given by Table 2. The Doppler spectrum for each tap is specified as flat. The *A* model has 6 rays, an RMS delay spread of 35 ns, and is specified as occurring 50% of the time. The *B* model has 6 rays, an RMS delay spread of 100 ns, and is specified as occurring 45% of the time. It is not clear from [14] how to account for the fact that the sum of the frequencies of occurrence do not sum to 100%.

Tap	Channel-A Relative Delay (nsec)	Channel-A Average Power (dB)	Channel-B Relative Delay (nsec)	Channel-B Average Power (dB)	Doppler Spectrum
1	0	0	0	0	Flat
2	50	-3.0	100	-3.6	Flat
3	110	-10.0	200	-7.2	Flat
4	170	-18.0	300	-10.8	Flat
5	290	-26.0	400	-18.0	Flat
6	310	-32.0	700	-25.2	Flat

Table 2. Indoor TE: Tapped delay line impulse response specification

2.3.2 Pedestrian Test Environment

2.3.2.1 Path Loss

Mean path loss for the Pedestrian TE is given by

$$L = 40\log_{10}(R) + 30\log_{10}(f) + 49$$

where R is the BS-MS distance in meters, and f is the carrier frequency in MHz.

This model is valid for non-line-of-sight (NLOS) case only and describes worse case propagation.

2.3.2.2 Shadow Fading

Shadow fading loss for the Pedestrian TE is modeled as a log-normal random variable with zero mean and variance 10 dB for outdoor users and 12 dB for indoor users. The positional correlation model Equation (1) is used, with parameter $d_{cor} = 5m$. The average building penetration loss is specified as 12 dB with a standard deviation of 8 dB.

2.3.2.3 Impulse Response

The tapped-delay line impulse response parameters for the Pedestrian TE are given by Table 3. The Doppler spectrum is specified as classic Jakes' model. The *A* model has 4 rays, an RMS delay spread of 45 ns, and is specified as occurring 40% of the time. The *B* model has 6 rays, an RMS delay spread of 750 ns, and is specified as occurring 55% of the time.

Tap	Channel-A Relative Delay (nsec)	Channel-A Average Power (dB)	Channel-B Relative Delay (nsec)	Channel-B Average Power (dB)	Doppler Spectrum
1	0	0	0	0	Jakes
2	110	-9.7	200	-0.9	Jakes
3	190	-19.2	800	-4.9	Jakes
4	410	-22.8	1200	-8.0	Jakes
5			2300	-7.8	Jakes
6			3700	-23.9	Jakes

Table 3. Pedestrian TE: Tapped delay line impulse response specification

2.3.3 Vehicular Test Environment

2.3.3.1 Path Loss

Mean path loss for the Vehicular TE is given by

$$L = 40(1 - 4\cdot 10^{-3}\cdot \Delta h_b)\log_{10}(R) - 18\log_{10}(\Delta h_b) + 21\log_{10} f + 80$$

where R is the BS-MS distance in km, f is the carrier frequency in MHz, and Δh_b is the base station antenna height in meters, measured from average rooftop level. This model is valid only over the range $0 \le \Delta h_b \le 50m$.

2.3.3.2 Shadow Fading

Shadow fading loss for the Vehicular TE is modeled as a log-normal random variable with zero mean and variance 10 dB in both urban and suburban environments. The positional correlation model Equation (1) is used, with parameter $d_{cor} = 20m$.

2.3.3.3 Impulse Response

The tapped-delay line impulse response parameters for the Vehicular TE are given by Table 4. The Doppler spectrum is specified as classic Jakes' model. The *A* model has 6 rays, an RMS delay spread of 370 ns, and is specified as occurring 40% of the time. The *B* model has 6 rays, an RMS delay spread of 4000 ns, and is specified as occurring 55% of the time.

Tap	Channel-A Relative Delay (nsec)	Channel-A Average Power (dB)	Channel-B Relative Delay (nsec)	Channel-B Average Power (dB)	Doppler Spectrum
1	0	0	0	-2.5	Jakes
2	310	-1.0	300	0	Jakes
3	710	-9.0	8900	-12.8	Jakes
4	1090	-10.0	12900	-10.0	Jakes
5	1730	-15.0	17100	-25.2	Jakes
6	2510	-20.0	20000	-16.0	Jakes

Table 4. Vehicular TE: Tapped delay line impulse response specification

2.4 Suggested Mobility Rates

[**C802.20-03/48:** the Test Environments given in [14] do not prescribe specific mobility rates. In the interest of compromising between the full range of commonly modeled rates (0, 3, 30, 120, and 250 km/h) and the desire to keep the test matrix to a reasonable size, we suggest the set of mobility rates vs. Test Environment shown in Table 5.]

Test Environment	**Suggested Mobility Rate for Simulations**
Indoor	0-3 km/h
Pedestrian	3, 30 km/h
Vehicular	0, 30, 120, 250 km/h

Table 5. Suggested Mobility Rates for MBWA Test Environments

2.5 Typical Urban (TU) Simulation Model

[**Motorola's Proposal on 04/28/2003 teleconference:** A Typical Urban (TU) channel model has been developed for simulation purpose in the GSM standard [12]. This model is designed to model high delay spread urban environments for all the GSM frequency bands, including GSM 450, GSM 850, GSM 900, DCS 1800, and PCS 1900.] The tapped-delay line impulse response parameters for this TU model is given by Table 6.

Tap	Relative Delay (nsec)	Average Relative Power (dB)
1	0	-4.0
2	100	-3.0
3	300	0
4	500	-2.6
5	800	-3.0
6	1100	-5.0
7	1300	-7.0
8	1700	-5.0
9	2300	-6.5
10	3100	-8.6
11	3200	-11.0
12	5000	-10.0

Table 6. Typical Urban (TU) Channel Model

3 Channel Models for MIMO System Simulations

3.1 Introduction

[**Editor's note:** In this Chapter a set of spatial channel models are specified that have been developed to characterize the particular features of MIMO radio channels. SISO channel models provide information on the distributions of signal power level and Doppler shifts of received signals. MIMO channel models build on the classical understanding of multi-path fading and Doppler spread by incorporating additional concepts such as angle spread, angle of arrival, Power-Azimuth-Spectrum (PAS), and the physical geometry of scattering objects in the vicinity of MIMO antenna array.]

3.2 Spatial Channel Characteristics

[**C802.20-03/12 & 03/42:** Mobile broadband radio channel is a challenging environment, in which the high mobility causes rapid variations across the time-dimension, multipath delay spread causes severe frequency-selective fading, and multipath angular spread causes significant variations in the spatial channel responses. For best performance, the Rx & Tx algorithms must accurately track all dimensions of the channel responses (space, time, and frequency). Therefore, a MIMO channel model must capture all the essential channel characteristics, including

- Spatial characteristics (Angle Spread, Power Azimuth Spectrum, Spatial correlations),
- Temporal characteristics (Power Delay Profile),
- Frequency-domain characteristics (Doppler spectrum).

In MIMO systems, the spatial (or angular) distribution of the multi-path components is important in determining system performance. System capacity can be significantly increased by exploiting rich multi-path scattering environments.]

3.3 MIMO Channel Model Classification

[**C802.20-03/50:** There are three main approaches to MIMO channel modeling: the correlation model, the ray-tracing model, and the scattering model. The properties of these models are briefly described as follows:

- **Correlation Model**: This model characterizes spatial correlation by combining independent complex Gaussian channel matrices at the transmitter and receiver. For multipath fading, the ITU model is used to generate the power delay profile and Doppler spectrum. Since this model is based on ITU's generalized tap delay line channel model, the model is simple to use and backward compatible with existing ITU channel profiles.
- **Ray-Tracing Model**: In this approach, exact locations of the primary scatterers are assumed known. The resulting channel characteristics are then predicted by summing the contributions from a large number of the paths through the simulated environment from each transmit antenna to each receive antenna. This technique provides fairly accurate channel prediction by using site-specific information, such as building databases of architectural drawings. However, it is too complex to use this approach to modeling outdoor environment because of the difficulty in obtaining detailed terrain and building databases.
- **Scattering Model**: This model assumes a particular statistical distribution of scatterers. Using this distribution, channel models are generated through simulated interaction of scatterers and planar wave-fronts. This model requires a large number of parameters.]

3.4 MIMO Channel Environments

[**C802.20-03/42:** The following channel environments will be considered for system level simulations:]

3.4.1 Suburban Macro-cell Environment

The characteristics of suburban macro-cell environment are

- Large cell radius (approximately 1-2 km);
- High BS antenna positions (above rooftop height, approximately between 10-80m);
- Low delay and angle spreads;
- High range of mobility (0-250 km/h);

- [Editor's note: The pathloss is based on the modified COST231 Hata urban propagation model with constant factor 0dB.]

3.4.2 Urban Macro-cell Environment

- Large cell radius (approximately 1-2 km);
- High BS antenna positions (above rooftop height, approximately between 10-80m);
- Moderate (to high) delay and angle spreads;
- High range of mobility (0-250 km/h);
- [Editor's note: The pathloss is based on the modified COST231 Hata urban propagation model with constant factor 3dB.]

3.4.3 Urban Micro-cell Environment

- Small cell radius (approximately 0.3-0.5 km);
- BS antenna positions (at rooftop height or lower);
- High angle spread and moderate delay spread;
- Medium range of mobility;
- [Editor's note: The NLOS pathloss is based on the COST231 Walfish-Ikegami NLOS model. The LOS pathloss is based on the COST231 Walfish-Ikegami street canon model.]
- The model is sensitive to antenna height and scattering environment (depending on street layout, line of sight effects).

3.5 Spatial Parameters for the Base Station

3.5.1 BS Antenna Topologies

3.5.2 BS Angle Spread

3.5.3 BS Angle of Departure

3.5.4 BS Power Azimuth Spectrum

3.6 Spatial Parameters for the Mobile Station

3.6.1 MS Antenna Topologies

3.6.2 MS Angle Spread

3.6.3 MS Angle of Arrival

3.6.4 MS Power Azimuth Spectrum

3.6.5 MS Direction of Travel

3.6.6 Doppler Spectrum

[**C802.20-03/42:** There is non-uniform PAS at the mobile. Doppler spectrum is affected by the PAS and the Angle of Arrival. Doppler spectrum affects the time-domain behavior of the channel.]

3.7 Link Level Spatial Channel Model Parameter Summary and Reference Values

3.8 A Wave-Based MIMO Channel Model for MBWA System Simulations

3.8.1 Introduction

[**C802.20-03/42:** A time-domain description of the wideband characteristics (of MIMO channel models) can be supported by a broad base of measurement data.]

3.8.2 Generation of Channel Model Parameters

Step 1: Choose MIMO channel environment.

Step 2: Determine various distance and orientation parameters.

Step 3: Assign a finite set on N discrete paths induced by the scattering environment. Every path is described by its own:

- Relative delay and relative path power
- Angle of Arrival (at base and mobile)
- Power Azimuth Spectrum (at base and mobile)

Step 4: Each path modeled by an ensemble of M waves (oscillators). The M waves emulate the desired PAS.

Note 1: Power Azimuth Spectrum at base exhibits Laplacian decay (macro-cells).

Note 2: Path AoA has been observed to be Gaussian distributed around the mean AoA of the narrowband signal at the base.

Note 3: Further trends from measurement campaigns can be utilized to produce an accurate model of a wideband space-time channel.]

3.8.3 Implementation of MIMO Channel Model

[**C802.20-03/42:** In wave-based model, scatterers are abstractly located in the two dimensional space. The impact at the base or mobile is abstractly determined by angle of arrivals, angle spreads, PAS, and power delay profile. Statistics and physical parameters from measurement data are directly usable here. The wave-based model captures all important wideband behaviors of the channel and produces accurate channel realization. It accommodates any antenna array topology. Wave-based model is inherently less complex than a geometrical-based model. Channel model initialization is performed once per drop.]

3.8.4 Validation of MIMO Channel Models

3.9 Optional System Simulation Cases

3.9.1 Antenna Polarization

3.9.2 Line of Sight

3.9.3 Far Scatterer Clusters

3.9.4 Urban Canyon

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