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| TGah Outdoor Channel Models – Revised Text | | | | |
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# 3.0 Channel models

The outdoor channel models for TGah are based on channel models used by 3GPP and 3GPP2. Two catagories of channel models are defined below. The first category, Multipath Channel Models consists of simple SISO models which will facilitate rapid generation of early simulation results. The second category, Spatial Channel Models (SCM), provides detailed modeling of the spatio-temporal characteristics of the multi-antenna propagation channel. SCM is fully described in [1] and a freeware Matlab implementation can be downloaded from [2].

We provide here a brief description of the model and simulation assumptions for TGah below.

**3.1 Multipath Channel Models for Early Simulations**

The multipath channel channel models presented in this section provide temporal characterization of SISO links between an AP and a STA. Simulations based on these channel models will be used to evaluate and select fundeamental PHY features and parameters, such as the preamble fields, OFDM parameters, coding and modulation.

Four multi-path channel profiles, namely, Pedestrian A, Pedestrian B, Vehicular A and Typical Urban may be used for generating early non-MIMO simulations. The models represent low (Pedestrian A), medium (Pedestrian B/Vehicular A) and high (Typical Urban) delay spreads.

Each channel model consists of either 4 or 6 independent channel taps with fixed tap delays and fixed average power values, as given in Table 1. Each tap is modelled by a complex Gaussian variable, weighted by the corresponding average power. Doppler spread will be modelled using the Jakes model with a speed of TBD kmph.

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**Multi-path channel model parameters**

**3.2 Spatial Channel Model for Detailed Simulations**

The spatial channel model presented in this section provides spatio-temporal and interference characterization of MIMO links between multiple APs and STAs. These channel models will be typically used to evaluate 11ah system performance. In addition, the Spatial Channel Model can be also used to evaluate the 11ah PHY link performance.

Channel realizations are generated through the application of the geometrical principle by summing contributions of rays (plane waves) with specific small-scale parameters like delay, power, angle-of-arrival (AoA) and angle-of-departure (AoD). Superposition of rays generates correlation between antenna elements and temporal fading with geometry dependent Doppler spectrum.

The model can be used to generate SISO or MIMO links. Co-polarized antennas or cross polarized antennas are implemented in the model and enable most types of antennas to be simulated.

Figure 1 shows a high level depiction of channel realization and figure 2 shows a detailed representation of how paths are generated.



**Figure 1**



**Figure 2**

The basic formula to generate path is given below:

For an *S* element linear BS array and a *U* element linear MS array, the channel coefficients for one of *N* multipath components are given by a *U* -by- *S* matrix of complex amplitudes. We denote the channel matrix for the *n*th multipath component (*n* = 1,…,*N*) as . The (*u,s*)th component (*s* = 1,…,*S*; *u* = 1,…,*U*) of  is given by



where

 is the power of the *n*th path (Step 5).

 is the lognormal shadow fading (Step 3), applied as a bulk parameter to the n paths for a given drop.

M is the number of subpaths per-path.

 is the the AoD for the mth subpath of the nth path (Step 12).

 is the the AoA for the mth subpath of the nth path (Step 12).

 is the BS antenna gain of each array element (Step 12).

 is the MS antenna gain of each array element (Step 12).

j is the square root of -1.

k is the wave number where is the carrier wavelength in meters.

 is the distance in meters from BS antenna element s from the reference (s = 1) antenna. For the reference antenna s = 1, =0.

 is the distance in meters from MS antenna element u from the reference (u = 1) antenna. For the reference antenna u = 1, =0.

 is the phase of the mth subpath of the nth path (Step 8).

 is the magnitude of the MS velocity vector (Step 2).

 is the angle of the MS velocity vector (Step 2).

The SCM model assumes 6 paths each of which consists of 20 subpaths.

The model describes three environments that represent Suburban Macro, Urban Macro and Urban Micro deployments as shown in figure 3.



**Figure 3**

**Simulation Assumptions for TGah**

Tgah use cases involve up to pedestrian mobility. However as reported in [3] and [4], reflections from cars cause higher Doppler and can be represented by assigning one of the six paths in the SCM model a higher Doppler.

The following two simulation scenarios represent all outdoor TGah scenarios:

1. SCM with speed up to 2mph for all paths
2. SCM with the fourth path assigned a speed of 40mph (rest of the paths are assigned 0mph).

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**Example Usage of SCM**

1. Download Matlab code from [4]. Main function is scm.m
2. Define some parameters
   1. scmpar.CenterFrequency=0.9e9;
   2. scmpar.Scenario='urban\_macro';
   3. scmpar.BsUrbanMacroAS='eight';
   4. scmpar.NumBsElements=4; (number of BS antennas)
   5. antpar.BsElementPosition=0.5; (antenna spacing)
   6. scmpar.NumMsElements=1;
   7. Call main function [H delays out]=scm(scmpar,linkpar,antpar); H is a time domain MIMO channel between all Tx and Rx antennas
3. Calculate frequency response

3.2.1 Modeling intercell interference

Sophisticated MIMO receivers account for the spatial characteristics of the signals from the desired sector as well as

from the interfering sectors. The spatial characteristics of these signals can be modeled according to the channel matrix generated. However, it may be prohibitively complex to explicitly model the spatial characteristics of all interfering sectors, especially those whose received powers are relatively weak. It has been shown that by modelling the signals of relatively weak interferers as spatially white (and thereby ignoring their spatial characteristics), the resulting performance difference is negligible. The following four steps outline the procedure for modelling intercell interference.

- Determine the pathloss and shadowing of all sectors. (Note that "pathloss" implicitly includes antenna patterns as

well.)

- Rank the sectors in order of received power (based on pathloss and shadowing). The base with the strongest

received power is the serving base, and the others are interfering bases.

- Model the strongest *B* interfering sectors as spatially correlated processes whose covariances are determined by

their channel matrices. These channel matrices are generated from above and account for the pathloss, shadowing, and fast fading variations. The way in which the channel realizations are employed depends on the receiver algorithm and simulation methodology. For example, if only the statistics of the interfering sectors are required, their signals can be modeled as spatially correlated additive Gaussian noise processes with covariances determined by the channel matrices.

- Model the remaining sectors as spatially white Gaussian noise processes whose variances are based on a flat Rayleigh fading process. Hence the variances are varying over the duration of a simulation drop. To model the remaining "weak" sectors, we assume that the mean power of the flat Rayleigh fading process is equal to the effects of pathloss and shadowing from each sector. Therefore if the received power from the *b-*th sector due to pathloss and shadowing is *Pb* , then the Rayleigh fading process for the *m-*th receive antenna (*m* = 1,…, *M*) as a function of time is given by *rb*,*m*(*t* ) where the mean of *rb*,*m*(*t* ) over time is *Pb* . The fading processes for each sector and receive antenna are independent, and the doppler rate is determined by the speed of the mobile. We assume that the

fading is equivalent for each mobile receive antenna. The total received noise power per receive antenna due to all

"weak" sectors at the *m-*th antenna is



where *F* is the set of indices for the "weak" sectors.

For 3-sector systems, we model the *B* = 8 strongest sectors. For 6-sector systems, we model *B* = 12 strongest sectors.

The values for *B* are based on simulation results for the typical cell layout with a single hexagonal cell surrounded by two rings of cells (a total of 19 cells) and with users placed in the center cell. For other layouts, different values of *B* or an entirely different technique may be required to properly account for the intercell interference.

**References**

[1] 3GPP TR 25.996 - Technical Specification Group Radio Access Network; Spatial channel model for Multiple Input Multiple Output (MIMO) simulations

[2] Link to Matlab implementation of [3]

<http://radio.tkk.fi/en/research/rf_applications_in_mobile_communication/radio_channel/scm-05-07-2006.zip>

[3] 11-03-0940-04-000n-tgn-channel-models.doc – channel model F

[4] 15-09-0742-01-004g-fading-in-900mhz-smart-utility-radio-channels.pdf – Steve Shearer