# IST-2003-507581 WINNER

## D5.2

## *Determination of Propagation Scenarios*

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**Abstract:** The objective of WINNER is to develop a single new ubiquitous radio access system concept whose parameters can be scaled or adapted to a comprehensive range of mobile communication environments from short range to wide area. To contribute to this objective WP5 *Channel Modeling* will define the channel models to be used in the simulations performed in the WINNER project to select the most promising system concepts for further discussion. This deliverable determines the propagation scenarios for which the channel models will be created. The propagation scenarios are determined in detail for the initial simulations, taking into account the work specified in the previous and contemporary documents of the other Work Packages, especially the WP2, WP3 and WP7. Propagation scenarios for the coming advanced channel models have been determined more generally. In addition, the coming advanced channel models have been specified in general terms to inform other parties about the ideas and goals maintained in the WP5. The preliminary channel model selections of the WP5 described in the deliverable D5.2 has been refined and connected to the initial deployment scenarios specified in the WP7.

**Keyword list:**

**Disclaimer:**

# Executive Summary

This deliverable determines propagation scenarios based on the scenario definitions in IR5.1, D5.1, IR1.1 and IR7.1. Assumptions on the system, propagation and channel models are introduced. Classifying channel characteristics with respect to link-level and system-level simulations is described in detail. Different modeling principles, such as ray-based and stochastic modeling, are discussed. Propagation scenarios are based on test scenarios defined in IR7.1. Propagation scenarios specify environment, mobility, frequency and bandwidth for each scenario. Channel model requirements are defined for link-level and system-level models. These requirements include path loss, large-scale fading, small-scale fading, noise and interference, transitions and antenna effects. In addition, software implementation of both initial 3GPP SCM models and the models developed in this project is discussed.

# 1. Introduction

This deliverable discusses the determination of propagation scenarios for the further work in WINNER WP5 and other work packages. In addition we consider the specification of the channel models that will be prepared in this work package. The latter part of the discussion has to be performed in quite a general level, because the matter has to be investigated by conducting measurements, doing analysis and comparing the results to the existing and ongoing work in the literature and ongoing projects like COST 273, Newcom etc. However, we try to specify the guidelines and goals to allow other WINNER work packages and other interested parties to get the information they need for the cooperation within WINNER project and with other parties.

The goal in the WINNER project WP5 is to create the channel models that can be used in the link-level (LL) and system-level (SL) simulations. The dead-line for the models is in September 2005. However, the simulations will be started within other work packages much earlier, latest in September 2004. Therefore the previous deliverable of the WP5, D5.1 [2] proposed two initial models for these initial simulations.
These two models were selected among the few existing MIMO models, and they are the 3GPP/3GPP SCM model and IST-METRA-based IEEE802.11n model. Due to the time schedule of the WINNER these initial models will be used until the final models are released in the autumn 2005.

The coming channel models that are created by the WP5 are called final channel models, by which is meant that they are the final models of WP5 in the Phase I. This deliverable defines the propagation scenarios for which these coming models will be created during the WINNER Phase I, and outlines some requirements for these.

Since the coming channel models are mainly targeted for the simulation work in WINNER, the propagation scenarios have been adapted to the deployment scenarios defined by the WINNER WP7 in [9]. In that document the test scenarios were divided into two groups: 14 basic deployment scenarios out of which five are selected as prioritized deployment scenarios [9]. The prioritized scenarios are those that are used in the initial simulations, where also the initial channel models are used.

During the task 5.2 work it has been agreed in the WINNER that WP5 will provide the project for the SW implementation of the selected initial channel model 3GPP/3GPP2 SCM. This model and the other selected model METRA based IEEE802.11n have been connected to the initial test configurations, defined by the WP7 in D7.2 [9]. This refinement has been described also in this document, in the section 5.5.

Otherwise the deliverable is composed so that section 2 includes the general definitions, abbreviations and symbols used in the document. Section 3 discusses the background for the propagation scenario selection, section 4 describes the propagation scenarios, section 5 discusses the requirements for the channel models and the chapter 6 contains the conclusions.

# 2. Terminology

## 2.1 List of Abbreviations

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| 3GPP2 | 3rd Generation Partnership Project 2 |
| A1 | Test scenario for In-building Indoor |
| AoA | Angle of Arrival |
| AoD | Angle of Departure |
| AP | Access Point |
| AS | Angular Spread, Azimuth Spread |
| AVI | Actual Value Interface |
| AWGN | additive white Gaussian noise |
| B1 | Test scenario for Hot-spot Typical urban |
| B3G | Beyond Third Generation Mobile and Wireless Communications |
| BER | Bit Error Ratio |
| BLER | Block Error Ratio |
| BRAN | Broadband Radio Access Network |
| BS | Base Station |
| BW | Bandwidth |
| C2 | Test scenario for Metropol Typical urban |
| C/I | Carrier to Interference |
| CIR | Channel Impulse Response |
| COST | European Co-operation in the field of Scientific and Technical research |
| D1 | Test scenario for Rural |
| DL | Downlink |
| DMC | Diffuse multipath component(s) |
| DoA | Direction of Arrival |
| DoD | Direction of Departure |
| DoT | Direction of Travel |
| DPS | Doppler Power Spectrum |
| DS | Delay Spread |
| Dx.y | Deliverable x.y |
| EADF | Effective aperture distribution function |
| FER | Frame Error Ratio |
| FSC | Far scatterer clusters |
| HW | Hardware |
| I/C | Interferer to Carrier Ratio |
| IEEE | Institute of Electrical and Electronics Engineers, Inc. |
| IR | Interim Report |
| IST | Information Society Technologies |
| ITU | International Telecommunication Union |
| ITU-R | International Telecommunication Union, Radio Sector |
| LL | Link Level |
| LLS | Link level simulation |
| LOS | Line-of-sight |
| Matlab® | Commercial product (numerical calculation software) |
| METRA | Multi-Element Transmit and Receive Antennas (project name) |
| MISO | Multiple Input Single Output |
| MIMO | Multiple Input Multiple Output |
| MS | Mobile Station |
| NLOS | Non-Line-of-Sight |
| OLOS | Obstructed Line-of-Sight |
| PAS | Power Azimuth Spectrum |
| PCS | Personal Communication Services |
| PDF | Probability Density Function |
| PDP | Power Delay profile |
| PDS | Power Delay Spectrum |
| PL | Path Loss |
| RS | Relay station |

| | |
|---|---|
| RMS | Root Mean Square |
| RV | Random Variable |
| SCM | Joint 3GPP/3GPP2 Spatial Channel Model |
| TDL | Tapped Delay Line |
| UE | User Equipment |

## 2.2 List of Symbols

| | |
|---|---|
| $a^*$ | Complex conjugate of the scalar a |
| $a^H$ | Hermitian transpose of the vector a |
| $a_l e^{j\sigma_{li}}$ | Complex amplitude of *lth* path |
| A | Polarisation matrix |
| $A^T$ | Transpose of the matrix A |
| $c_{i,j}(\Omega)$ | Array response vector |
| $C_1$ | Tx array response matrix |
| $C_2$ | Rx array response matrix |
| det | Determinant |
| $d_{BP}$ | Break point correlation distance |
| $d_c$ | Correlation distance |
| $E[.]$ | Expected value of the argument |
| fc | Carrier frequency |
| g | Complex circularly symmetric Gaussian vector |
| $G_{i,m,j}(\Omega)$ | Antenna Radiation field pattern of Tx/Rx ($i$ = 1/2), $m$th antenna element on $j$th polarisation |
| $G_w$ | Complex circularly symmetric Gaussian matrix |
| $H(\tau, \theta, \phi, \nu)$ | Channel impulse response |
| $H(t, \tau)$ | Transfer matrix $H$ of the MIMO channel |
| H | Channel matrix for a single “delay tap” |
| Im[. ] | Imaginary component of the complex argument |
| j | Imaginary unit |
| K | Ricean K factor |
| L | Number of paths |
| $L_f$ | Attenuation per floor |
| $L_W$ | Attenuation per wall |
| n | Path loss exponent |
| $n_f$ | Number of traversed floors |
| $n_W$ | Number of traversed walls |
| PL(d,f) | Path loss |
| $PL_{FS,1}$ (f) | Free-space path loss |
| Pr[.] | Probability of the argument |
| R | Correlation matrix |
| Re[.] | Real component of the complex argument |
| $r_{i,m,j}$ | Vector to $m$th antenna element with $j$th polarisation |
| $t_c$ | Coherence time |
| vec(·) | Vectorisation operation |
| $vec^{-1}(\cdot)$ | Inverse vectorisation operation |
| v(t) | Mobile speed |
| Var(.) | Variance of the argument |
| $X_\sigma$ | Zero mean log-normally distributed random variable, standard variation $\sigma$ |
| $\alpha_{l,i,j}$ | Complex gain from Tx polarisation $i$ to Rx polarization $j$ of of *lth* path |
| $\phi_l$ | Elevation angle of *lth* path |
| $\lambda$ | Wavelength |
| $\tau_l$ | Delay of *lth* path |
| $\theta_l$ | Azimuth angle of *lth* path |
| $\Delta r$ | Distance between the two correlated positions |
| $\Delta x$ , $\Delta y$ | Displacements in coordinates x and y between the correlated positions |
| $\Omega$ | Direction |
| $\otimes$ | Kronecker product |

## 2.3 Definitions

***Antenna de-embedding*** is the method for separating antenna and propagation channel from radio channel data or radio channel model.

***Antenna embedding*** is the method where propagation channel characteristics and antenna characteristics can be combined to obtain radio channel model.

***Calibration model*** is the radio channel model with fixed parameters for calibrating simulation environment.

***Channel model*** is the model including both antennas and propagation. It can be understood to be everything between transmitter antenna connector and receiver antenna connector.

***Cluster*** is a group of scatterers located close to each other.

***Geometric model*** is the radio channel model based on geometric description of antennas and propagation environment.

***Geometric based stochastic model*** is the channel model where key parameters (delay and DoA/DoD) are obtained from the geometry but fading is stochastic.

***Kronecker model*** is the model where MIMO correlation matrix calculated by Kronecker product of Tx and Rx correlation matrices.

***Link-level channel model*** is the channel model for link-level simulations.

***Macro-cell*** is an urban, suburban, or rural cellular network deployment scenario, in which the base station antennas are located above the average rooftop level of the surrounding buildings.

***Micro-cell*** is an urban cellular network deployment scenario, in which the base station antennas are located below the average rooftop level of the surrounding buildings.

***Propagation environment*** is the physical environment of the system, but it doesn't specify any system parameters.

***Propagation model*** is the model of only propagation, excluding antennas. Propagation model is independent of antennas and it often includes definition of Delay, DoA and DoD for each path.

***Propagation scenario*** is the propagation environment where key system parameters such as mobility and center frequency have been specified.

***Realization of the channel*** is the set of impulse responses, where all random variables have been calculated.

***RMS Delay Spread*** is the power weighted standard deviation of the excess delays, i.e. square root of the second central moment of the power delay profile of the impulse response

***Scatterer*** is an object causing radio-wave scattering.

***Short-Range*** is the WINNER scenario for short-range hot-spot and WLAN applications.

***Stochastic Model*** is the radio channel models where channel realizations are based on pre-determined methods and random noise.

***System-level channel model*** is the channel model for system-level simulations.
***Test scenario*** is the simulation and test scenario specified in the IR7.1.

***Wide-Area*** is the WINNER scenario for outdoor mobile systems.

# 3. Background

## 3.1 Channel Modeling

### 3.1.1 Modeling principles

Development of new channel models requires two steps: 1) setting up a generic channel model and identifying the parameters that have to be determined for its description and 2) actually performing the measurement campaigns and extracting statistics and distributions of the parameters [1]. Principles of the first step are described in the sub sections below.

#### 3.1.1.1 Model statistics

The term Statistical Modeling is typically used to describe the modeling approach which directly models the observed channel in a communication system. In the following we will briefly present the background and the relation to Geometrical Modeling.

Under the assumption of limited signal bandwidth, limited Doppler bandwidth, finite delay-spread, and linearity of the propagation channel, a communication system observes the propagation channel as a discrete-time finite-length filter. The effective (observed) channel thus has only limited degrees of freedom.

From a propagation point of view, the channel has infinite bandwidth (and hence resolution). Because scatter contributions are often physically clustered together (e.g. imagine the leaves of a tree) and because of the limited resolution of our observation, it makes sense to define a channel model by concentrating on these clustered and dominant scattering effects. This is done by simply dropping the discrete delay-times. It is important to note that this is merely a model and the mapping of parameters from a specific propagation channel to this model is not unambiguous (depends on bandwidth etc.).

Due to the large variability in propagation environments and resulting channels, only a statistical description makes sense. With respect to the previous model, we thus get random variables for the delays, tap coefficients, and number of taps/clusters. Under a time-variant assumption these are modeled as random processes.

Assuming at least wide-sense stationarity, the model is fully described by the joint distribution of all parameters at all time differences. If it is further assumed that the variables at different delays are independent of each other, we arrive at the classic Wide-Sense Stationary Uncorrelated Scattering (WSSUS) assumption.

From the channel observations, certain properties of the physical (geometric) propagation effects can be derived if additional assumptions are employed. With the assumption of only one reflection per path for example, a path delay can be mapped to the potential locations of that scatterer, which is described by an ellipse around transmitter and receiver. On the other hand, scatterers can be distributed on such an ellipse, and the statistics of the resulting filter coefficients will match that of the observations. This is called elliptical model.

The use of multi-antenna systems adds another dimension to the channel. Individual channels as described before can now be attributed to each pair of transmit and receive antennas. Due to the close distance between antenna elements, most parameters such as number of paths and delays of the individual paths are equivalent across antenna combinations. In this case we can simply replace the tap coefficients by a vector or matrix.

Again, it is possible to map channel observations to physical propagation effects under additional assumptions. For example with the assumption of plane waves, small relative bandwidth, and the knowledge of the antenna response, the angle of an impinging wave can be estimated. This estimation process is however confined by an equivalent resolution limit to time-domain. Specifically, for each delay resolution bin, only N-1 waves can be estimated, if N is the number of antennas.

Similar to instantaneous filter coefficients, statistical parameters can be related. For a certain delay resolution bin, the correlation between two spatially separated antennas is directly dependent on the angular power spectrum (APS or PAS) of the contributions for that bin.

#### 3.1.1.2 Ray-based modeling

In radio wave propagation at high frequency, multipath propagation wireless channels can be understood and modeled by applying ray theory. A uniform plane wave can be seen as a ray. Hence, each radio path is approximated by a ray, where energy propagates between antennas of transmitter and receiver within ellipsoid shaped tubes defined by first Fresnel zone. The higher the frequency is the more accuratethe field can be approximated by the zeroth order of Luneberg-Kline expansion which are called ray fields. The interaction of radio waves (or rays) with the environment determine the characterizing parameters of each ray. Once the detailed database of the environment is known in addition to the locations of transmitter and receiver, the channel properties are derived from the positions of the scatterers by applying the fundamental laws of propagation mechanism of electromagnetic waves, i.e., rays can be traced to find the coupling paths. This is known as ray tracing, i.e., deterministic modeling.

The rays can be characterized from the propagation environment by their delay (or length), angle of arrival, angle of departure, Doppler shift, polarization, and amplitude. The ray-based modeling is also the heart of geometry-based stochastic modeling approach, which is the most commonly used approach in directional channel modeling for testing performance of adaptive antenna or MIMO systems. The approach assumes a statistical distribution of discrete scatterers around the two (or one) ends of the wireless link. With the knowledge of position of the scatterers of each channel realization, the rays can be characterized by their parameters as each scatterer usually corresponds to one ray. The positions of scatterers are drawn from the probability density functions of multipath delays and the direction of arrivals and departures by ray-based approach. Depending on the distribution of the obstacles, the interaction of the transmitted signal with the environment changes and consequently different signal components appear super-positioned at the receiver, having a multipath channel. The scatterer distributions depend on the environments. In indoor environment, the scatterers can be around both the wireless link ends, in case of highly elevated antennas (i.e., macrocells) the scatterers can be considered only around the mobile station. Each scatterer has its own direction of departure, direction of arrival, and time of arrival, which can be determined by ray-based approach. The distribution of scatterers has clear influence on the distribution of the direction of arrival and direction of departures and time of arrival. Once, the channel parameters of each ray, i.e. delay, azimuth angle, elevation angle at the MS and BS, Doppler frequency, and complex amplitudes have been characterized, the channel behavior is identified in multi-dimensions.

*Diffuse multipath components DMC*

In general the understanding of the physical propagation phenomena is based on a ray optical approach. Paths are modeled by planar, narrowband wavefronts. This is motivated by the idea of specular reflections at smooth surfaces. To model the influence of receiver noise, a white noise component is usually added. It is, however, well known that wave propagation phenomena may also comprise diffuse scattered components [56]. Its contribution varies depending on the complexity of the propagation environment. It can be almost negligible in macrocell LOS scenarios and can even dominate in complicated propagation environments such as factory halls [57]. Whereas the electromagnetic background of diffuse scattering and the importance are basically understood and there are also attempts to include diffuse scattered components into geometric channel models. Thereby a data model comprising two components can be introduced [58]. The first part is considered as deterministic and results from a limited number of specular-like reflections. This can be called the structural part of the model since it has clear geometric interpretation. The second part is observed as dense diffuse part that is stochastic in nature and cannot be resolved by the measurement device. It results from distributed diffuse scattering as it occurs in a complicated, multipath rich environment. For example, a sounder having a measurement bandwidth of 120 MHz [59] gives excellent possibilities to resolve a number of specular components. Even though, the spatial resolution is only about 2.5 m which corresponds to 43 wave lengths at 5.2 GHz. Hence, in a “microscopic” sense we can expect quite a big number of superimposed diffused components in any delay-bin. This can be called “dense multipath model”. The resulting CIR part is therefore adequately modeled by a complex circular normal distribution. It might be argued that diffuse components can be negligible in presence of specular paths. This is however not consistent with the experience. One explanation could be that specular paths can contribute to the received power only for very distinct angular constellations. On the other hand, diffused power has the chance to reach the receiver within large (almost continuous) variety of propagation angles supposed there is a big number of widely distributed scatters. Note that modeling of diffuse scattering for the purposes of parameter estimation does not need to model the individual scatterers. Rather a model is needed which describes the superimposed contributions at the receiver.

#### 3.1.1.3 Modeling based on spatial correlation matrix

With correlation-based channel models the spatial correlation is explicitly defined and generated by means of a spatial correlation matrix, whereas with the ray-based models the correlation is implicitly present in the channel matrix generation process. The generation of MIMO channel matrices based on channel correlation matrix is defined as

$$\mathrm{R=E[vec(H)vec(H)^{H}]} \qquad (1)$$

where $vec(\cdot)$ operator is the vectorisation operator which stacks all elements of a matrix in one column. The channel matrix $\mathbf{H}$ is for a single "delay tap"; in general, the correlation matrix $\mathbf{R}$ can be different for each channel tap. The matrix $\mathbf{R}$ captures the spatial correlation properties of the MIMO channel at the transmitter and receiver end. Generation of Rayleigh fading channel matrices with the correlation structure defined by $\mathbf{R}$ can be done according to

$$\mathbf{H} = \mathrm{vec}^{-1}\left(\mathbf{R}^{1/2}\mathbf{g}\right), \qquad (2)$$

where $\mathbf{g}$ is a zero-mean complex circularly symmetric Gaussian vector with independent unit-variance entries, and $\mathrm{vec}^{-1}(\cdot)$ is the inverse vectorisation operation. Note that the desired time correlation (i.e. Doppler spectrum) has to be induced into the sequence of channel matrices by filtering the elements of $\mathbf{H}$ over time. A deterministic line-of-sight signal component with a pre-defined K factor can also be added to the signal to simulate Ricean fading.

The spatial correlation matrix, which basically forms the model, can be estimated from measured channel matrices, matrices generated using a ray-based model, or (in some cases) derived from analytical calculations. The correlation matrix is antenna array dependent and hence has to be re-estimated for different arrays. To simplify analysis and the model itself, a Kronecker structure is often imposed on the correlation matrix, i.e. it is assumed that the correlation matrix can be written as a Kronecker product $\mathbf{R} = \mathbf{R}_{tx} \otimes \mathbf{R}_{rx}$. In this case the channel matrices are generated using

$$\mathbf{H} = \mathbf{R}_{rx}^{1/2}\mathbf{G}_{w}\mathbf{R}_{tx}^{1/2}, \qquad (3)$$

where $\mathbf{G}_{w}$ is a $M \times N$ matrix with zero-mean complex circularly symmetric Gaussian entries. The advantage of the Kronecker assumption is that (3) is a computationally simpler operation than (2). The underlying assumption is that the directional properties of the radio propagation channel are independent at the receiver and the transmitter. Methods for finding the "optimum" Kronecker approximation for a general correlation matrix $\mathbf{R}$ have been reported in literature [43],[46]. Often the Kronecker approximation is sufficient [45] although it has also been shown to have certain deficiencies [47].

The main advantages of the correlation-based approach are its computational and modeling simplicity; a spatial correlation matrix and a Doppler filter essentially define the model. The main drawbacks are that, since antennas affect the spatial correlation, the correlation matrix must usually be re-estimated for all array geometries, and that the model parameterization describes only the second-order statistics of the channel without any physical interpretation of the propagation medium. Also, with the Kronecker assumption, the modeling accuracy may not be enough for all channel scenarios. On the other hand, using the full correlation matrix $\mathbf{R}$ increases the computational complexity. MIMO channel models using the correlation matrix and Doppler filtering approach include METRA, I-METRA and the IEEE P802.11 model.

#### 3.1.1.4 Antenna independency of the propagation models

Radio channel model is called antenna independent if the antennas and propagation channel are separable in the model formulation (like in e.g. equation (4)). Antenna independent model supports arbitrary antenna array geometries and arbitrary radiation patterns for antenna elements. Antenna information can be embedded in the generation procedure of channel model realization. [4]

Antenna independency supports:
- arbitrary antenna array geometry
- arbitrary radiation pattern for antenna elements

## 3.2 Notation of the MIMO channel

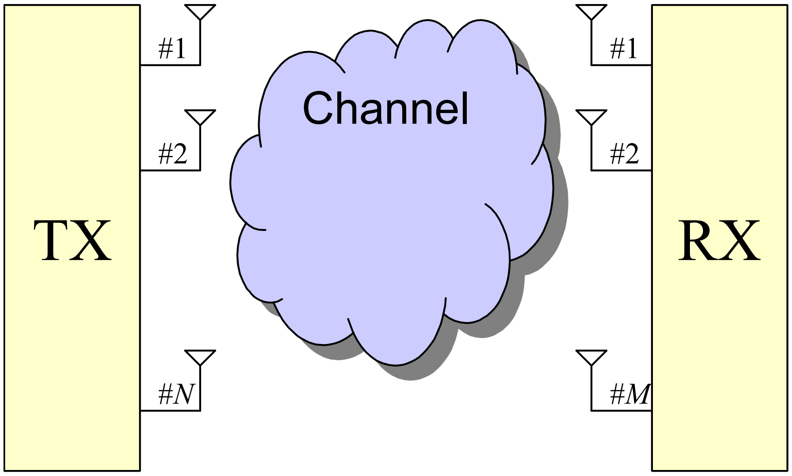

**Figure 1. MIMO System Model.**

Mathematical notation here is based on papers [4], [5], [6] and [7].

Transfer matrix $\boldsymbol{H}$ of the MIMO channel with $L$ paths is

$$\boldsymbol{H}(t,\tau)=\sum_{l=1}^{L}\boldsymbol{H}_l(t;\theta_l)=\sum_{l=1}^{L}\exp(j2\pi\upsilon_l t)\boldsymbol{C}_2(\Omega_{2,l})\boldsymbol{A}_l\boldsymbol{C}_l^T(\Omega_{1,l})\delta(t-\tau_l) \qquad (4)$$

where components included are the Doppler frequency $\upsilon$, Rx array response matrix $\boldsymbol{C}_2$, polarisation matrix $\boldsymbol{A}$, Tx array response matrix $\boldsymbol{C}_1$ and delay $\tau$. Parameter vector is

$$\theta_l=(\Omega_{1,l},\Omega_{2,l},\tau_l,\upsilon_l,\boldsymbol{A}_l). \qquad (5)$$

Polarisation matrix $\boldsymbol{A}$ of path $l$ is 2x2 matrix, which elements $\alpha_{l,i,j}$ are the complex gains from Tx polarisation $i$ to Rx polarization $j$ of path $l$, here i, j ∈ {1,2} referring to two polarisations.

$$A_l=\begin{bmatrix}\alpha_{l,1,1} & \alpha_{l,1,2}\\ \alpha_{l,2,1} & \alpha_{l,2,2}\end{bmatrix} \qquad (6)$$

Array response matrices are composed of array response vectors of two polarisations, for Tx array

$$\boldsymbol{C}_1(\Omega_{1,l})=[\boldsymbol{c}_{1,1}(\Omega_{1,l})\ \ \boldsymbol{c}_{1,2}(\Omega_{1,l})] \qquad (7)$$

and for Rx array

$$\boldsymbol{C}_2(\Omega_{2,l})=[\boldsymbol{c}_{2,1}(\Omega_{2,l})\ \ \boldsymbol{c}_{2,2}(\Omega_{2,l})]. \qquad (8)$$

Array response vector are $\boldsymbol{c}_{i,j}$ where $i$ = 1 denotes Tx and $i$ = 2 Rx, $j$ stands for $j$th polarisation. On vectors below $r_{i,m,j}$ is vector to $m$th antenna element with $j$th polarisation. For example

$$\boldsymbol{c}_{1,1}\left(\Omega_{1,l}\right)=\begin{bmatrix} G_{1,1,1}\left(\Omega_{1,l}\right)\exp\left(j2\pi\lambda_0^{-1}\left(\Omega_{1,l}\cdot r_{1,1,1}\right)\right) \\ G_{1,2,1}\left(\Omega_{1,l}\right)\exp\left(j2\pi\lambda_0^{-1}\left(\Omega_{1,l}\cdot r_{1,2,1}\right)\right) \\ \vdots \\ G_{1,M_1,1}\left(\Omega_{1,l}\right)\exp\left(j2\pi\lambda_0^{-1}\left(\Omega_{1,l}\cdot r_{1,M_1,1}\right)\right) \end{bmatrix} \tag{9}$$

where $G_{i,m,j}(\Omega)$ is antenna field pattern of Tx/Rx ($i = 1/2$) $m$th antenna element on $j$th polarisation and direction $\Omega$.

It should be mentioned that the right-hand expression in (9) is valid, if coupling is neglected. However, (4) is still valid for any arrays C1($\Omega$) and C2($\Omega$) and the array responses, e.g. obtained from calibration.

## 3.3 Simulation of radio systems

The performance of transmission techniques for new advanced multiple antennas systems requires both LL and SL simulations. The different types of simulations to be run in the WINNER project, mainly in the WP2 and WP3, have been specified in the WINNER document [10].In addition the simulations can be static, quasi-static or dynamic. The LL simulation focuses on the performance of one radio link between transmitter and receiver. If a repeater is involved, the LL simulations include the two hops and the repeater function [10]. The LL simulations may include several mobiles if a multiuser detection receiver is used and also includes several base stations if soft handover is modeled [11] The LL simulations simulate performance of a single link with a high resolution in time, i.e., work in bit rate (or chip frequency) scale, which is required for accurate receiver performance evaluation. The performance evaluation may be measured, for example, by bit error ratio (BER), frame error ratio (FER), etc. The scope of LL simulation is to model the physical layer functionalities. For example, performance of channel coding and decoding algorithms, modulation and demodulation algorithms can be compared based on LL simulation. The LL simulations include the necessary parts of transmitting and receiving structures in a system and proper fading channel model in order to compare the performance of different candidate algorithms. In WP5, we just focus on modeling the fading channel part. From channel modeling perspective, a channel model for LL simulation is the channel between two terminals with antenna arrays for MIMO case. It is well known that the performance gain achieved from a single link could not be interpreted as similar gain in system level. In System level, multi base stations communicate with multiple mobile stations. The LL simulations of all links in SL are clearly prohibitive at the time resolution scale of LL simulation. On the other hand the time resolution for the SL simulations needs to be the same order as the time constant of the fastest simulated control loop. The LL and SL simulations are linked together so that in most cases the SL simulations use results calculated in LL simulations as tabulated input parameters [10].

### 3.3.1 Channel models for Link-level simulations

Mobile radio channels can be narrowband, i.e., flat fading channels, or broadband, i.e., frequency selective fading channel. So, different channel models have to be developed. In mobile radio channels, the high mobility causes rapid variations across the time-dimension, large multi-path delay spread causes severe frequency-selective fading, and large multi-path angular spread causes significant variations in the spatial channel responses. For best performance, the transmitter and receiver algorithms must accurately track all dimensions of channel responses (space, time, and frequency). The algorithms that can be considered optimal for AWGN and flat fading channels, will neither maximize system performance nor guarantee robustness in applications to frequency selective channels. Channel models for SISO systems provide information on the distributions of envelope and Doppler shifts of the received signals [12]-[17]. The LL simulation results for SISO systems highly depend on these two parameters. Channel models of SIMO and MISO for LL simulation have been studied and different models have been proposed in [18]. The MIMO channel models which are based on the classical understanding of multi-path fading and Doppler spread, incorporate additional concepts by including spatial dimension at the transmitter and receiver ends, i.e., double directional, which is presented in terms of angular spread, angle of arrival, power azimuth spectrum, and the antenna array correlation matrices at the transmit and receiving ends. These different domains phenomena and their correlation have strong influence on the results of the LL simulations. A large body of publications in open literature deals with channel modeling for single link scenarios. The link throughput, transmitter and receiver processing have been extensively investigated for MIMO transmission on link level [19]-[24]. The used channel models initially started with uncorrelated flat fading channels and successfully take into account more effects of real environment, i.e., correlations of MIMO channel or frequency selectivity of the channel. A review of MIMO channel models that can be used with LL simulations can be traced in [25]. The review covered MIMO channels of METRA [26] and SATURN [27] projects as non-physical models, the One-ring model [28], the Two-ring models, the Von Mises angular distribution model [29], the distributed scattering model [30], the extended Saleh-Valenzuela MIMO model [31], the COST 259 directional channel model which is extended to MIMO model [32], the electromagnetic scattering model [33], and the virtual channel model [34],[35] are some examples of physical MIMO channel models. The extension of COST 259 directional model to COST 273 for MIMO channel is ongoing research under European COST project. In [36], the 3GPP/3GPP2 link level models are based on the ITU models. The IEEE802.11n [37] is based on ETSI BRAN models for indoor channels [38],[39] and extending it to include different clusters and adopting METRA principle making it applicable to MIMO systems. The final report of COST 259 contains an extensive review of papers related to channel measurements and modeling [40] for LL simulations. A space-time MIMO channel model that uses different distribution in different domains is described in [41].

### 3.3.2 Large scale parameters

The large-scale fading in a MIMO radio channel can be characterized in terms of mean amplitude and mean power variation of multipath components. Both mean amplitude and power stay approximately constant within a certain interval of time and space (i.e., few wavelengths). A local-stationary area is a sufficiently small area, within which all the positions that a MS might occupy are characterized by constant scalar measures such as path-loss, shadowing, RMS-delay-spread, RMS-azimuth-spread, antenna correlation, channel rank, mutual information, number of paths etc. The constant measures are needed in order to characterize matrix valued impulse responses for MIMO channel; they are called bulk parameters because they relate to all the scalar sub-channels and delay components of a full channel impulse response, and represent local averages over 20-100 wavelengths of movement of the mobile. These parameters are often used as inputs to the subsequent generation of the detailed impulse responses. With large-scale movements of the MS (i.e., hundreds of wavelengths), the bulk parameters are going to change considerably.

#### 3.3.2.1 Path-loss

There are many approaches for calculating path loss either for outdoor or indoor environments. The computational complexity is a very important parameter for SL simulations. So, the path loss model has to be as computational efficient as possible without degrading its reliability at the interest frequency. Therefore, the most favorable path loss models are empirical models with minimum number of parameters. The empirical models are usually single or double slope models extracted from measurements. Usually the empirical path loss formulas are defined in terms of intercept and path loss exponent. Then, the path loss can be calculated as function of distance for specific values of exponent. There many values of the exponent for either indoor or outdoor. The exponent has a value of 2 in free space. If it is less that 2, that indicates waveguiding effect may exist as in LOS of indoor environments. The intercept is determined by free space path loss to reference distance and environment dependent constant. The general formulations of empirical path loss models for outdoor environment can be given in the

$$\mathrm{PL}(d,f) = PL_{FS,1}(f) + 10n \log_{10}(d) + C, \qquad [\mathrm{dB}] \tag{10}$$

where $PL_{FS,1}(f) = 20 \log_{10}(4\pi f/c)$ is the free-space path-loss at 1m distance,
d is the distance between the transmitter and the receiver,
$f$ is the center frequency of the signal,
c is the velocity of light in vacuum,
$n$ is the path-loss exponent that depends on the environment and
$C$ is a environment dependent constant.

Later this model will be used in the simplified form

$$\mathrm{PL}(d) = A \log_{10}(d) + B \tag{11}$$

where $A = 10n$

$\mathrm{B} = PL_{FS,1}(\mathrm{f}) + C$

For indoor environments the well-known Keenan-Motley path loss model [52] describes the signal path loss as follows

$$\mathrm{PL(d,f)} = PL_{FS}\,(\mathrm{d,f}) + \mathrm{n_W\,L_W} + \mathrm{n_f\,L_f} \quad [\mathrm{dB}] \tag{12}$$

where $PL_{FS}\,(\mathrm{d,f}) = 20 \log (4\pi \mathrm{df/c})$ is the loss in free space for an isotropically radiating antenna,

$\mathrm{L_W}$ is the attenuation per wall,

$\mathrm{L_f}$ is the attenuation per floor,

$\mathrm{n_W}$ is the number of traversed walls,

$\mathrm{n_f}$ is the number of traversed floors.

This model is widely preferred since it models number of walls and floors explicitly. However, its validity to 5 GHz range is questionable and many of the published paths loss model for indoor environment at 5 GHz range is given in the form of (11) as it seems that they do not fit with (12).

A generalization to (10) is a multi-slope model, where different distances are covered with different slopes. An example of such is the two-slope formula used in a WLAN indoor model [53], which defines an abrupt transition from LOS at short range to the NLOS condition at longer range after a certain breakpoint.

### 3.3.2.2 Shadowing

Shadowing is widely accepted to be modeled by the well-known log-normal attenuation model, where the median value for the shadowing attenuation is zero, corresponding to situation where the attenuation is given by the path-loss formula used. The decibel value of the excess shadowing fading, X, has normal distribution with zero mean and standard deviation σ. The values of σ depend on the environment. Typical values e.g. in an urban environment vary from 3 to 10 dB.

Assuming stationary environment the autocorrelation of the shadowing attenuation can be described by a exponential formula defined by the correlation distance dc [60]. Then the autocorrelation can be assumed symmetric in the xy-plane (or in practice on the earth surface)

$$R_X(\Delta r) = \sigma^2 \exp(-\frac{\Delta r}{d_c}) \tag{13}$$

| | |
|---|---|
| where $\Delta r = \sqrt{\Delta x^2 + \Delta y^2}$ | is the distance between the two correlated positions, |
| $\Delta x$, $\Delta y$ | are the displacements in the geographical coordinates x and y between the correlated positions, |
| $\sigma^2$ | is the variance of the random variable X and |
| dc | is the correlation distance (where the correlation is $e^{-1}$ times the maximum one). |

## 3.3.3 Interference modeling

### 3.3.3.1 Co-channel interference

For advanced broadband MIMO system evaluation the realistic spatial as well as the temporal properties of multiple received signals, which are affected by the channel characteristics, from the desired sectors/users as well as from the interfering sectors/users are important. The accurate modeling of those inter-cell and intra-cell interferences is a crucial (e.g. for precision vs. computational complexity) and still an open point. In general for link-level simulations no interferers are taken in account. Hence this is allocated as task of the channel modeling for the system-level simulations. In 3GPP [36], see chapter 5.7, relatively weak interferers are discussed to be considered as spatially white, the accurate spatial characteristics are ignored. Whereas the strongest interferers are treated as spatially correlated based on their covariance matrixes. With this a Gaussian noise process is coloured and added. This concept has a low complexity approach, but lacks in the reflection of the realistic interference situation. Therefore it can be insufficient for sophisticated MIMO receiver testing. In particular for those who aim to suppress and cancel interferer mainly based on the spatial-temporal characteristics of all received signals.

In addition to this a straightforward approach can be applied where the spatial-temporal characteristics of the interferers influence is created based on the channel models for link-level simulations. Here the simulation tool on link-level has to generate a new channel for each single interferer. By applying superposition and relative power differences for the interferers to the desired signals the received signal can be created. But due to the multiple call of the link-level model this approach lacks one major issue: correlation (space, time and frequency) between the multiple interferers, possibly other multiple base stations and the user is not included. Furthermore it will also increase the computational complexity, at least multiplied by the number of links.

#### 3.3.3.2 Interference between different frequency channels

Interference between different frequency channels, e.g. the adjacent channel interference, may probably be simulated in WINNER. However, this is considered to be out of the scope of the propagation and channel modeling in WP5, because this would require the channel model bandwidths to be extended over 100 MHz bandwidths.

#### 3.3.3.3 Interference between different systems

Interference between WINNER systems and other systems is an important matter. However, this is considered to be out of the scope of the propagation and channel modeling in WP5.

# 4. Propagation scenarios

Propagation scenario means here the propagation environment with the following parameters defined:

-cell type: micro-cell, macro-cell, indoor, outdoor-to-indoor etc. cell types,
-BS location(s) and antenna height(s) in relation to the local roof-top heights (outdoor),
-corresponding indoor parameters in relation to the building dimensions,
-BS antenna patterns, antenna group geometries and antenna directions,
-MS antenna heights, antenna patterns and antenna group geometries,
-mobile location range(s) within the environment and
-MS velocity range(s).

The propagation scenarios defined by the WP5 to be used in connection of the WINNER channel models should comply with the deployment scenarios defined in [9]. It is also possible for WP5 to define some additional environments and propagation scenarios, if found reasonable. The deployment scenarios are discussed in the paragraph 4.1.

## 4.1 Deployment Scenarios

WP7 has defined in the IR7.1 [8] and D7.2 [9] the basic deployment scenarios (in the IR7.1 with the name “test scenarios”) that will be used in the WINNER project. It is assumed that the simulations in the WINNER project will be performed using these deployment scenarios. It is quite natural for the WP5 to define the propagation scenarios to comply with these deployment scenarios. Therefore it is assumed that WP5 will create channel models primarily for these scenarios. It should be noted that the deployment scenarios may be updated during the WINNER project Phase I. Then the propagation scenarios have to be updated accordingly, if needed. All the basic deployment scenarios can be seen in the Table 1.

From the 14 basic deployment scenarios five were selected as the prioritized deployment scenarios by the WP7 in [9]. First simulations in the WINNER will be performed using these five deployment scenarios.

The prioritized deployment scenarios and the proposed initial channel models are shown in the Table **2** in the paragraph 4.1.1.

**Table 1. Basic deployment scenarios and the corresponding measurement plans. Y, N, P mean Yes, No and Preliminary, respectively, in the measurement data availability columns.**

| Deployment scenario | Definition | LOS/ NLOS | Mobility | Measurement data | | Note |
|---|---|---|---|---|---|---|
| | | | | Existing | Planned | |
| A1 In | Indoor | LOS/ NLOS | 0–5 km/h | P | Y | To be modeled by the WP5. |
| A2 In | Indoor to outdoor | NLOS | 0–5 km/h | N | Y | AP inside and coverage outside the building.To be modeled by the WP5. |
| B1 Hot spot | Typical Urban | LOS/ NLOS | 0–70 km/h | P | Y | To be modeled by the WP5. |
| B2 Hot spot | Bad Urban | NLOS | 0–70 km/h | N | N | **Issue:** No measurements planned in WINNER by the WP5. |
| B3 Hot spot | Indoor | LOS | 0–5 km/h | N | Y | To be modeled by the WP5. |
| B4 Hot spot | Outdoor to Indoor | NLOS | 0–5 km/h | N | N | Airport-type. Coverage in shopping hall with BTS outside. |
| B5 Hot spot | LOS – Stationary Feeder | LOS | 0 km/h | N | N | AP to FRS: AWGN channel with free space path loss proposed by the WP5. No measurements planned in WINNER by the WP5. |
| C1 Metropol | Suburban | LOS/ NLOS | 0–70 km/h | N | Y | To be modeled by the WP5. |
| C2 Metropol | Typical Urban | NLOS | 0–70 km/h | P | Y | To be modeled by the WP5. |
| C3 Metropol | Bad Urban | NLOS | 0–70 km/h | N | N | **Issue:** No measurements planned in WINNER by the WP5. |
| C4 Metropol | Outdoor to Indoor | NLOS | 0–70 km/h | N | N | |
| C5 Metropol | LOS –Feeder | LOS | 0 km/h | N | N | AP to FRS: AWGN channel with free space path loss proposed by the WP5. |
| D1 Rural | Rural | LOS/ NLOS | 0–200 km/h | N | Y | No initial model. To be modeled by the WP5. |
| D2 Rural | LOS – Moving Networks (Feeder) | LOS | 0–300 km/h | N | N | No measurements planned in WINNER by the WP5. |

The measurement plans can be found in the references [61] to [64].

### 4.1.1 Prioritized deployment scenarios

The simulations with the available models will be performed in different stages. The first stage consists of the initial simulations that use the initial channel models. For this stage, the five prioritized deployment scenarios have been specified. They are shown in the Table 2 together with the information on the initial channel models.

**Table 2. Prioritized deployment scenarios and the corresponding initial channel models.**

| Deployment scenario | Definition | LOS/ NLOS | Mobility | Initial channel model | Note |
|---|---|---|---|---|---|
| A1<br>In building | Indoor | NLOS | 0–5 km/h | Initial model 1, IEEE 802.11n | SW available [37]. |
| B1<br>Hot spot | Typical Urban | LOS/ NLOS | 0–70 km/h | Initial model 2, SCM, micro-cell | SW: Extended SCM by the WP5. |
| B5<br>Hot spot | LOS – Stationary Feeder | LOS | 0 km/h | | AP to FRS: AWGN channel with free space path loss proposed by the WP5. No special initial model provided. |
| C2<br>Metropol | Typical Urban | NLOS | 0–70 km/h | Initial model 3, SCM, macro-cell | SW: Extended SCM by the WP5. |
| D1<br>Rural | Rural | LOS/ NLOS | 0–200 km/h | Initial model 4, SCM suburban, macro-cell | **ISSUE**: Rural environment not modelled by the original SCM, but is an initial test scenario. **Proposed solution: Use the modified SCM by the WP5.** |

Note that although the deployment scenario C2 is defined for the NLOS propagation conditions only in D7.2, WP5 proposes to include there also the LOS condition.

Note also that the prioritized deployment scenarios are a sub-set of all the deployment scenarios defined so far. This means that also the coming, more advanced, channel models will be used in the prioritized deployment scenarios in the later stages of the simulations.

### 4.1.2 Basic deployment scenarios

It is assumed that the basic deployment scenarios (Table 1) will be used in the WINNER simulations in a later stage. . It is also possible that some new scenarios will be specified. It is also assumed that in connection of these basic deployment scenarios the coming advanced channel models will be used. The precision of the models is assumed to be improved in the coming advanced channel models. Also the number of the final propagation scenarios will probably be greater than that of the initial propagation scenarios, as a consequence of the increased number of deployment scenarios.

For the basic deployment scenarios more propagation scenarios are needed. If only the test scenarios in the Table 1are covered, and if the feeder scenarios do not need separate channel models (except e.g. an AWGN model), eight or nine propagation scenarios would be sufficient. However, this matter needs further study, because the basic deployment scenarios are not complete yet.

## 4.2 Initial propagation scenarios

In the paragraph 4.1 five prioritized deployment scenarios were defined. It can also be seen that four propagation scenarios are needed in the initial phase.

The initial propagation scenarios are defined to comply with the initial channel models that have been proposed in the D5.1.

The initial propagation scenarios are defined for the following general conditions:

| | | |
|---|---|---|
| -center frequency: | 5 | GHz |
| -RF bandwidth | 100 | MHz |

### 4.2.1 Initial Propagation Scenario for A1 (Indoor)

The initial propagation scenario for the deployment scenario A1 is based on the IEEE802.11n model C-NLOS specified for the environment Residential/Small Office [37].

Initial propagation scenario for the deployment scenario A1 is defined with the parameters shown below.

| **Parameter** | **Value** |
|---|---|
| -environment | indoor small office / residential |
| -propagation | NLOS |
| -AP antenna height | 2 m |
| -UE antenna height | 1 m |
| -distance between AP and UE | 2 m – [30] m |
| -UE velocity range | 0 - 5 km/h |

### 4.2.2 Initial Propagation Scenario for B1 (Typical Urban Hot Spot)

Initial propagation scenario for B1 is defined with the parameters shown below.

| **Parameter** | **Value** |
|---|---|
| -environment | typical urban micro-cell |
| -propagation | LOS/NLOS |
| -BS antenna height | below roof-top, (e.g. 12 m above ground level) |
| -MS antenna height | 1,5 m |
| -distance between BS and MS | 20 m – [200] m |
| -MS speed range | 0 – 70 km/h |

### 4.2.3 Initial Propagation Scenario for C2 (Typical Urban Metropolitan)

Initial propagation scenario for C2 is defined with the parameters shown below.

| **Parameter** | **Value** |
|---|---|
| -environment | typical urban macro-cell |
| -propagation | LOS/NLOS |
| -BS antenna height | above roof-top (e.g. 32 m above ground level) |
| -MS antenna height | 1.5 m |
| -distance between BS and MS | 35 m – 3000 m |
| -MS speed range | 0 – 70 km/h |

### 4.2.4 Initial Propagation Scenario for D1 (Rural)

Initial propagation scenario for D1 is defined with the parameters shown below.

| **Parameter** | **Value** |
|---|---|
| -environment | rural macro-cell |
| -propagation | LOS/NLOS |
| -BS antenna height | above roof-top, (e.g. 32 m above ground level) |
| -MS antenna height | 1,5 m |
| -distance between BS and MS | 35 m – 3000 m |
| -MS velocity range | 0 – 70 km/h |

## 4.3 Final propagation scenarios

The term "final propagation scenario" means here the propagation scenarios defined during the WINNER Phase I with the coming (final) channel models created at the same time. After the Phase I the propagation scenarios, as well as the channel models, are supposed to be further evolved in the next Phases of the WINNER.

The final propagation scenarios should comply with the basic deployment scenarios. The final propagation scenarios should be defined in more detail than the initial ones, because the models should be more accurate with more parameters, e.g. the continuous time evolution of the channel parameters.

Final propagation scenarios will be defined by specifying the parameters shown below.

| **Parameter** | **Note** |
|---|---|
| -environment | defined in the basic deployment scenarios and/or during the Phase I |
| -propagation | NLOS and/or LOS |
| -AP antenna height | below / above roof-top |
| -UE antenna height | |
| -distance between AP and UE | |
| -UE velocity range | |

The proper values or ranges for these parameters shall be investigated during the WINNER project. It is also quite possible that the basic deployment scenarios will evolve during the WINNER Phase I. As well it is possible for the WP5 to define propagation scenarios for other deployment scenarios than defined by the WP7. However, the basic deployment scenarios are the default ones and serve as a good starting point for the determination of the coming final WP5 propagation scenarios.

# 5. Channel models

## 5.1 Assumptions on the WINNER conditions

### 5.1.1 WP5 assumptions on propagation

The assumptions have been listed in the IR7.1 [8]. The most important have been reproduced below. Some new assumptions have been added in reply to the requirements of the other WPs.

#### 5.1.1.1 General assumptions

Both computational complexity and number of parameters of the channel models should be minimized without losing accuracy and reliability.

The following facts will apply:

- Models should support both SW simulations and HW simulations. Models for link-level algorithm testing need to be defined also in HW.
- The propagation models should consist of an antenna independent part and a part that defines the antenna characteristics.
- The models should support arbitrary antenna patterns, polarizations and antenna array configurations. A set of predefined antenna arrays should also be delivered.

Four sets of channel models will be developed: two sets for LL simulations and two sets for SL simulations. The division between the LL-models and SL-models has been defined in [8]. A general definition of expected channel models for LL and SL simulations is given Section 5.6. It is assumed that both channel models for LL and SL can still be divided in different sub-classes as basic and advanced channel models. This division is intended for different applications for particular LL or SL simulations.

Channel models will be delivered as written documents. In addition the models will be implemented in Matlab. The initial channel models have been proposed in the D5.1 [2]. The final channel models will be proposed in the coming deliverable D5.4.

The proposed initial channel models are the 3GPP/3GPP2 SCM [36] and IEEE802.11n [37].
For the SCM-model a Matlab implementation will be released by the WP5 [44] with some extensions. For the IEEE802.11n an implementation is already available, free to use [37]. For the final WINNER channel models there will also be a Matlab reference implementation prepared by the WP5.

#### 5.1.1.2 Frequency related assumptions on the models

The channel models should be able to cope with the system frequency range:

- Frequencies are in the range 1 - 6 GHz 1).
- System frequency range may consist of nonadjacent bands.

The maximum bandwidth of the models should be 100 MHz.

1) Models are based on measurements at 2 GHz and 5 GHz. It is assumed that they can be interpolated and/or extrapolated to the whole frequency range given afore.

#### 5.1.1.3 Mobility

1. The correlation in time (Doppler effect) is obtained via some kind of description of the users' mobility.
2. In the case of a full geometry-based model, if adopted, the position of the UE's will change in time.
3. Different mobility schemes, i.e., with different speeds, should be adopted for the different scenarios. However, the mobility schemes is considered as input to the channel model.

#### 5.1.1.4 Antennas

In the modeling of the antennas the following facts apply:

1. The models should support arbitrary antenna geometries of different field patterns.
2. The antennas should be characterized by a precise physical description (polarization, directivity and so on)
3. The antenna arrays could also include realistic effects such as the coupling between the antenna elements.

## 5.2 Classifying channel characteristics for LL and SL simulations

The channel model for LL simulation is assumed to represent the channel for a single hop connection between two antenna arrays at the transmitter and the receiver, where the spacing between the elements of the antenna array at each side is smaller than the shadowing correlation distance. The channel model for SL simulation is assumed then to model the multi-hop, multi-receiver and multiple cell cases with antenna arrays at the two sides. In principle the LL simulation treats only location/scattering environment and continuous time. Current SL simulation, based on the 3GGP context, normally have a number of drops i.e. locations/scattering environments with some limited duration of time.
The channel characteristics are the main concern and interest to LL and SL simulations. In other words, the LL and SL simulations require channel models which generate channels that display specific characteristics that have a clear influence in a particular problem under study. Some characteristics can be classified as those are of concern to LL simulations and others are of concern to SL simulations. In dynamic SL simulation, channel parameters such as directions, delays, number of paths, shadow fading loss etc. evolve in time. However, quasi-static simulations, these parameters are fixed for each "Drop" but differ from "Drop" to "Drop". As a general level the channel characteristics that generally have clear influence in small scale fading or large scale fading are of concern and interest to LL simulation or SL simulations, respectively. Table 3 shows more in detail how different channel features are classified with respect to LL and SL simulations.

Table 3 shows a possible classification of several channel characteristics with respect to LL and SL simulations.

**Table 3. Classification of channel characteristics: LL vs. SL simulations**

| | User Side | |
|---|---|---|
| **Characteristic** | **Link-Level Simulations** | **System-Level Simulations** |
| Path Loss | Fixed value | Yes |
| Shadowing | Fixed value | Yes |
| Shadowing correlation distance | — | Yes |
| Correlation of shadow fading between MSs | — | Yes |
| Correlation of shadow fading between BSs | — | Yes |
| Small-Scale Fading | Yes | Possible |
| Evolution of large scale parameters | — | Yes |
| Cross-correlation of large scale parameters | — | Yes |
| Cross-correlation between LL parameters | Yes | — |
| Evolution of LL parameters in time (with only small movement in space), e.g. fixed-wireless and quasi-static Doppler | Yes | — |
| Distribution of SL parameters (shadowing, interference, LL parameters involving multiple users, LL parameters involving multiple BS) | — | Yes |
| Evolution of SL parameters and LL parameters in space (averaging over small movements), e.g. birth and death of paths | — | Yes |
| Coexistence interference | — | Yes |
| Non-stationary effects in LL and SL parameters, e.g. scenario transitions | — | Yes |

## 5.3 Channel models for LL simulations

Realistic LL simulations require specific information about radio channel. The channel models for LL simulations are mainly for statistical characterization of small scale fading of the mobile channels. The MIMO channel model has to describe correlation properties in the temporal, spatial and frequency domains. A full statistical description of the channel is desirable to generate the entries of the MIMO channel matrices. One approach is the joint distribution in angle, delay, and Doppler domains [42]. For MIMO channels, the distribution of angles includes both angles of arrivals and angle of departures in both azimuth and elevation. The joint angle of arrival and departure distributions requires double directional measurements. Deriving multidimensional joint distribution is intractable mathematically and is computationally intensive. One approach, described in [1] is to use a huge file for the multidimensional distribution. To overcome such problem, the commonly used assumption for MIMO link level model is the independence of spatial correlation properties at the transmitter and receiver, commonly known as the METRA principle. This assumption is based on the Kronecker product approach, which neglects the joint spatial structures at the transmitter and receiver and characterizes the MIMO channel assuming that the angles of arrival are independent from the angles of departure. This technique does not describe the general spatial mechanisms of MIMO channels. It merely provides a rough estimate of its spatial properties [43] .

WP5 has initially selected the IEEE802.11n METRA based channel model for short range scenarios and 3GPP SCM (Spatial Channel Model) for wide area scenarios. They were selected for the immediate use of WP2 and WP3 to start their simulations. However for a bandwidth of 100 MHz at 5 GHz frequency range, different link level channel models will be proposed for different scenarios. The developed MIMO channel models can be used for the single input single output (SISO) channels when only one antenna at each side is used. The following phenomena should be included in developing the channel model for LL simulations: temporal characterization, frequency characterization, spatial characterization (i.e, power azimuth spectrum, possibly also elevation angular dispersion in certain scenarios), polarization effects, correlation between various parameters. For the wideband case, the channel level for LL simulation will be based on MIMO tapped delay line concept. The fast fading of each Tap depends on the Doppler spectrum and the number of multipath components within the corresponding bin, where the bin width is directly related to the bandwidth. For 100 MHz bandwidth, there will be measurement-based investigation for fading distribution and Doppler spectra of the each Tap. For such wide bandwidth, the number of multipath components and associated directional information within each Tap will be less than that is based on 5 MHz bandwidth. The antenna independent channel models allow the testing of different antenna array configurations.

### 5.3.1 Antenna Effects

The spatial features displayed by the MIMO channel are greatly influenced by the antenna arrays, whose characteristics are determined by the positions of their elements, as well as their beam patternsand coupling. In the following paragraphs are summarized some design considerations for antenna deployment, channel measurement and identification:

- Planar antenna arrays such as uniform linear arrays (ULA) or uniform rectangular arrays (URA) always have a limited viewing angle. They are useful to represent a base station's (BS) view of the channel. Circular antennas have a full field of view. They can be conveniently used to represent the mobile station (MS).
- Double directional modeling requires antenna arrays at both ends of the link and MIMO operation of the sounder. For cellular system consideration, a combination of planar and circular arrays is adequate, whereas for ad-hoc peer-to-peer networks identical circular arrays are most preferable.
- Mainly for micro- and pico-cell scenarios, estimation of the elevation is desired in addition to the azimuth. This requires URA, cylindrical or spherical arrays. Three dimensional wave analyses (azimuth and elevation) should always include polarization resolution.
- Spherical antenna arrays may be applied for full azimuth and elevation coverage. However, there exists no geometric solution to arrange more than 20 patch antenna elements on a spherical surface with identical inter-element distances. Therefore, the design of spherical arrays will be complicated by non-uniform inter-element distances and various relative polarization orientations of adjacent elements.
- Full polarimetric analysis of the radio channel requires not only polarimetric reception but also polarimetric excitation of the channel. This is even true for omnidirectional excitation where a two-port antenna is needed to send both orthogonal polarized waves with an omnidirectional characteristics and, thus, doubling the required sounder output ports.
- High and reliable resolution in terms of separation capability of closely spaced paths and low probability of outliers, requires an antenna architecture which offers a maximum of antenna array aperture size in the respective spatial dimension, including a minimum number of antenna elements, low antenna element coupling, and precise calibration. This also has to include the antenna switches and feeder cables. The characteristics of the antenna elements depend on the basic element design (dipoles, patches, slots, etc.). It has a significant influence on high resolution performance, estimation ambiguities, probability of outliers and polarization resolution capability. Furthermore by modeling the antenna characteristic the accuracy and the computational complexity is important, therefore an efficient description of the polarimetric beam pattern can be applied, such as the effective aperture distribution function (EADF).

In order to allow antenna de-embedding/embedding in the channel model, special attention must be paid to antennas used in MIMO channel measurements. Multielement spherical, circular, linear, planar or cylindrical arrays are required in the measurements to characterize propagation effects, such as DoA and DoD in addition to delay and path gain, and to separate them from antenna effects. Therefore the antennas used in the channel measurements are often different from those used in the real radio systems.

#### 5.3.1.1 Modeling the antenna characteristics

In the antenna steering vector equation (9) for the channel transfer matrix (4) antenna locations $r_{i,m,j}$ are freely settable. Additionally, the radiation patterns $G_{i,m,j}(\Omega)$ are freely settable for each antenna element for the two polarizations. Radiation patterns can be given as a closed form function of direction or as tabulated values. If available, closed form function would be computationally effective. Table of radiation pattern values on azimuth and elevation directions is more general, but it requires interpolation. Mutual coupling of array elements can be embedded in the tables of radiation patterns.

## 5.4 System-Level Models

The system-level aspects of channel models are statistical properties and dependencies that become important in system-level simulations, i.e. where, as opposed to link-level simulations, the location of a user in space is included. Classic dependency parameters are for example propagation scenario, antenna heights, and distance between transmitter and receiver. Typical dependent parameters are path loss, shadowing, delay spread, and Ricean K-factor. Most available models to date consider the distribution of these parameters (with a deterministic dependence) only. More recent publications have examined the cross-correlation between these parameters and their autocorrelation function versus space.

With the consideration of space, not only new parameters can be studied but also previous link-level parameters can be re-examined in this context. For example the evolution of taps / clusters in delay domain has been previously rendered with a birth / death model. Now the same effect can be modeled in terms of evolution in space of the number and location of scattering clusters. This new area of spatial modeling is yet however not very well studied.

Further interest and complexity arises if the interaction between multiple users and/or multiple base stations is considered in detail. This is particularly important for handover scenarios, interference evaluation, ad-hoc networks, and networks featuring multi-hop / relaying techniques. Again the correlation and evolution in space of system-level and link-level parameters concerning these multiples links are of interest. A special emphasis is also on the interference modeling. Because modern communication systems are able to deal with interference much more intelligently, its modeling needs to be treated in more detail than previously done. Besides other base stations and users, interference also arises from other communication systems (coexistence) in case the medium is shared.

Due to the ubiquitous nature of future communication systems and the move from circuit-switched to packet-switched data transmission, the importance to model effects in a non-stationary way has risen. Examples are the modeling of scenario transitions, and allowing for abrupt changes in shadowing or K-factor.

With increasing complexity of modeling, the extraction of underlying parameters becomes more crucial as well. Emphasis thus needs to be put on establishing a solid base of different estimation techniques including the understanding of implicit assumptions and limitations.

### 5.4.1 Initial Path loss models

The initial WP5 models provide the path loss formulations in terms of distance-attenuation plus shadowing. In fact, path loss and shadowing model is proposed to be according to IEEE 802.11n PL models for short-range indoor scenarios (e.g. for deployment scenario A1), whilst it is proposed to follow the 3GPP/3GPP2 SCM PL models for outdoor scenarios (e.g. for deployment scenarios B1 and C2).

The IEEE 802.11n PL model is based on a two-slope formula, which defines an abrupt transition from LOS at short range to the NLOS condition at longer range after a certain breakpoint (typically representing the distance to the closest wall) [53]. Different break-point distances $d_{BP}$ can be selected for different scenarios. The model can be expressed as follows:

$$\mathrm{PL}(d) = \mathrm{PL}_{\mathrm{FS}}(d) \qquad d <= d_{BP}$$

$$\mathrm{PL}(d) = \mathrm{PL}_{\mathrm{FS}}(d_{BP}) + 35\log_{10}(d / d_{BP}) \qquad d > d_{BP} \qquad (13)$$

where $d$ is the transmit-receive separation distance expressed in meters. In addition a log-normal distribution is assumed for the shadowing with an environment dependent standard deviation

The initial outdoor PL models are based on 3GPP/3GPP2 SCM 2 GHz path loss models [36]. For suburban macrocell and urban macrocell environments, the modified COST 231 Hata urban propagation model is used in the calculations. For microcell environment, the COST 231 Walfisch-Ikegami model is used for path loss calculations.

**Table 4. 3GPP/3GPP2 SCM 2 GHz path loss models for outdoor [36]**

| *Model* | *PL formulation (dB)*<br>*Note: d(m)* | *Shadow fading std. dev. (dB)* | *Comments* |
|---|---|---|---|
| *Urban micro* | LOS: PL(d)=34.53+38*log10(d)<br>NLOS: PL(d)=30.18+26*log10(d) | 10<br>4 | BS antenna height = 12m<br>MS antenna height = 1.5m<br>… |
| *Urban macro* | NLOS: PL(d)=34.5+35*log10(d) | 8 | BS antenna height = 32m<br>MS antenna height = 1.5m |
| *Suburban macro* | NLOS: PL(d)=31.5+35*log10(d) | 8 | |

In addition to these default models empirical path loss formulations, based on Nokia measurements in urban macro- and micro-cells at 5.25 GHz are considered in order to accommodate a more accurate model for the 5 GHz center frequency [54].

**Table 5. Nokia empirical 5 GHz path loss models for outdoor environments. Antenna gains excluded.**

| Model | PL formulation (dB)<br>Note: d(m) | Shadow fading std. dev. (dB) | Comments |
|---|---|---|---|
| Urban micro NLOS | PL(*d*)=33.7*log10(*d*)+54.7 | 4.7 | BS antenna height < 10m (below roof-tops) |
| Urban micro LOS | PL(*d*)=23.4*log10(*d*)+43.3 | 3.0 | BS antenna height < 10m (below roof-tops) |
| Urban macro NLOS | PL(*d*)=28.3*log10(*d*)+61.5 | 5.7 | BS antenna height 30 – 35 m (above roof-tops) |

The initial large-scale models will be updated after the analysis and the investigations of the measurements to be carried out T5.3. The WP5 approach to yield more refined large-scale models is proposed in the next paragraph.

### 5.4.2 Proposals for the refined large-scale models

We propose to use an extended set of bulk parameters within the propagation models. Such an idea is backward compatible to previous work as 3GPP SCM model, where shadowing, RMS-delay-spread, and RMS-azimuth-spread are randomly generated. Besides this, the use of sets of bulk parameters and the analysis of their different types of correlations is an important way to guarantee a channel model with a realistic dynamics behavior in all dimensions.

Of potentially greater importance is the modeling of the joint distribution of the bulk-parameters [48], [49]. This also includes the joint distribution of bulk-parameters in two or more links [50], for instance the correlation of the bulk parameters in the links between two base-stations and one mobile-station. To exemplify the importance of such a propagation model we may think of a beam steering transmitter/receiver. This approach can deliver an array gain when the azimuth spread is small. However, if the azimuth-spread is small only when the signal is not shadowed, the gain will never be realized when it actually is needed. Some of these particular phenomena are seen in the paper [51]. One particular form of joint distributions between the bulk parameters is the distribution of the channels of mobiles some hundreds of wavelengths apart. When a mobile moves these joint distributions can be interpreted as the time evolution of bulk-parameters. In reality there can never be a strict division between areas of local stationarity. A reasonable approach to model the transition between areas of assumed local stationarity would be to simply apply some form of thresholding. The threshold should be optimised to yield results as close as possible to reality.

Another dimension of this issue is considering the different propagation environments such as indoor, rural, urban, outdoor-to-indoor etc. A starting point is that these environments should have different joint distributions of bulk-parameters.

Note that all of this scope represents a vast research area - the realistic target for WINNER WP5 shall be to analyse the measurement data collected within the project and incorporate the correlations that are observed to the proposed channel models.

### 5.4.3 Antenna Effects

The channel modeling for system-level simulations assumes in principle the same requirements as for link-level simulations, see 5.3.1. In extension to these issues the cell structure and topology have to be carefully considered. Different BS sides could have different antenna designs/characteristics as well as the MS antennas. Furthermore e.g. for pathloss modeling issues the specific different antenna gains will play a role.

## 5.5 Initial channel models

The initial channel models were proposed by the WP5 in [2]. During the task 5.2 work it has been agreed in the WINNER that WP5 will provide the project for the SW implementation of the selected initial channel model 3GPP/3GPP2 SCM and at the same time extend the model for 5 GHz carrier frequency and 100 MHz bandwidth. This model and the other selected model METRA based IEEE802.11n have been connected to the initial test configurations, defined by the WP7 in D7.2 [9]. This refinement has been described below in the paragraphs 5.5.1 to 5.5.4.

For the IEEE802.11n model used in the deployment scenario A1 the environment parameters that specify the simulation have been defined in [37], Table 1. For the SCM extended model the environment parameters that specify the simulation have been defined in [36], Table 5.1, with the following exceptions:

1. The lognormal shadowing standard deviations for the different scenarios have been specified in the paragraphs 5.5.2 to 5.5.4 of this document.
2. The pathloss models used in the different scenarios have been specified in the paragraphs 5.5.2 to 5.5.4 of this document.
3. The extended model includes both the LOS and NLOS propagation conditions in the Urban macro environment.

Initial channel models have been listed below. The constants A and B below (with or without subscripts) refer to the coefficients in the path loss model described in the paragraph 3.3.2.1.

### 5.5.1 Initial Channel model for the scenario A1 (Model 1)

Initial Channel model for the scenario A1 is defined below:

IEEE802.11n C-NLOS

| | |
|---|---|
| -path-loss | two slope [37], table 1:<br>$A_1 = 20$ dB, $B_1 = 46.42$ dB, for distances < 5 m<br>$A_2 = 35$ dB, $B_2 = 21.96$ dB, for distances > 5 m |
| -shadowing | log-normal, standard deviation<br>3 dB, for distances < 5 m<br>5 dB, for distances > 5 m |

Model based restrictions:

| | |
|---|---|
| -AP antenna type | vertically polarized |
| -UE antenna type | vertically polarized |

### 5.5.2 Initial Channel model for the scenario B1 (Model 2)

Initial Channel model for the scenario B1 is defined below:

SCM extended by WP5, urban micro-cell

Propagation condition NLOS:

| | |
|---|---|
| -path-loss | A = 33.7 dB, B = 54.7 dB |
| -shadowing | log-normal, standard deviation 4.7 dB |

Propagation condition LOS:

| | |
|---|---|
| -path-loss | A = 23.4 dB, B = 43.3 dB |
| -shadowing | log-normal, standard deviation 3 dB |

The selection between the propagation conditions LOS and NLOS is specified in the original SCM specification [36].

### 5.5.3 Initial Channel model for the scenario C2 (Model 3)

Initial Channel model for the scenario C2 is defined below:

SCM extended by WP5, urban macro-cell

Propagation condition NLOS:

| | |
|---|---|
| -path-loss | A = 28.3 dB, B = 61.5 dB |
| -shadowing | log-normal, standard deviation 5.7 dB |

Propagation condition LOS:

| | |
|---|---|
| - path-loss | A = 23.4 dB, B = 43.3 dB |
| -shadowing | log-normal, standard deviation 3 dB |

The selection between the propagation conditions LOS and NLOS is specified as in the paragraph 5.5.2.

### 5.5.4 Initial Channel model for the scenario D1 (Model 4)

Initial Channel model for the scenario D1 is defined below:

SCM extended by WP5, rural macro-cell

TBD.

### 5.5.5 Initial Channel model for the scenario C5

Not defined at the moment. The need for the model to be discussed between WP5 and other WPs.

## 5.6 Calibration models

The purpose of these calibration models is to create baselines for comparison/calibration of simulation software created/used from different partners – to ensure the comparability of the different simulators and to support the clarification of possible errors in the simulation methods implemented. Following the 3GPP SCM model [36] the calibration procedure basically belongs to the link-level, but within WINNER the calibration is considered on link-level and system-level base for simulation calibration [55], this belongs to WP2 and WP3. The definition of calibration scenarios is urgent for WP2. Furthermore the calibration of the simulators within WP2 and WP3 should be based on a common calibration setup; further additional simulation parameters are allowed. To optimize the effort and the complexity one common calibration setup is approached. For this one scenario one traffic model and one propagation model should be considered. This is not necessarily a test scenario as stated in WP7 T7.4, but overlapping between the calibration and test scenarios are likely. Probably a suburban/urban micro cell propagation scenario (see C2 from the deployment scenarios – typical urban) is the preferred channel model for the calibration. Within this the path loss and shadowing modeling are considered based on [36] (see table 5.1) and further extended according to WINNER requirements, see D5.2.

## 5.7 General description of expected channel models

The influence of physical mobile radio channels has to be considered carefully within both LL and SL simulations. During transmission in mobile channels some phenomena can not be neglected, e.g., changing delays, changing direction of arrivals, availability of multipath components, etc. These will affect in varying bit error rate as well as burst error structures. To evaluate performance of MIMO algorithms, the emulation of the variation of the channel in LL and SL are required. The test of only fixed channel parameters are not adequate as they only represent snapshots of the channel, which are isolated cases that do not tell the whole scenario and propagation conditions. With these physical channel features and their influence on channel properties which affect transmitted data, a channel model has to be as accurate as possible. On the other hand, it has to be as computationally efficient as possible. Since the required details of channel model for LL and SL simulations depend on the application, we define four sets of channel models, two sets for each of LL and SL simulations. They are named as: 1) basic channel model for LL simulations, 2) advanced channel model for LL simulations, 3) basic channel model for SL simulations, and 4) advanced channel model for SL simulations. Each set has different models for different scenarios defined in Section 4. As different problems will be investigated in LL and SL simulations, the complexity of the channel model will depend on the problem understudy. The channel models will be scalable and organized in components. So the user can add up or reduce the complexity of the channel model based on the specific simulation of a certain problem for the application of interest. It is assumed that the channel models are antenna independents, so different antennas configurations with different field patterns can be embedded and de-embedded. The general definition of the four sets of channel models is given below.

1) Basic channel model for LL simulations

This model represents the physical channel variations for small scale movements (i.e., a few λs). ). In small scale movement, the basic channel model may be sufficient but only a small set of the infinite number of possible channels is covered, since e.g. there are only a small number of PDPs defined. The basic channel model for LL simulation offers characterization of the small-scale fading considering a double directional, geometry-based, and dispersion on different domains. Small-scale fading is the effect that is visible over short distances whereas most other parameters tend to change rather slowly. The path loss and the shadowing have constant values since the basic model neglects a detailed characterization of large-scale fading and characteristics for small-scale MS movements. The model will be MIMO tapped delay line (TDL) model which will degenerate into SISO TDL model when single antennas are used at both ends and can also be used for SIMO or MISO simulations when one antenna is used at one end and multiple antennas at the other end.

2) Advanced channel model for LL simulations

This model represents the physical channel variations for large scale movements of the MS for one link. In such scale of movements the large scale channel parameters (i.e., mean direction of arrival, mean direction of departure, number of paths, angular spread, delay spread, path loss, shadowing parameters, and relative mean power of multipath components, etc) changes considerably, so the assumption of having them fixed does not hold any more. In order, to model the radio channel accurately its dynamic has to be modeled carefully. This model can be thought as a sequence of local stationary channels that the MS crosses along some trajectory for large scale movements while keeping large-scale parameters change continuously between the local areas. Such model might be useful to for investigate subspace tracking algorithms in detail and/or for example to exploit long-term effects in channel estimation or to improve RX operation. This model may have limited applications in LL simulations.

3) Basic channel model for SL simulations

In this model multi-cell and multiple MS are considered. The basic channel for SL simulations is based on the "Drop" concept in the context of 3GPP, normally in quasi-static system simulations. In this concept the successive channel responses and their parameters are independent. There is no time evolution of large scale parameters within each "Drop". Parameters generated in each "Drop" are independent from the previous one. In this model set, the correlation of shadow fading is modeled for different base station but not between different users. Path parameters of each ray (i.e., delay and angles) are fixed during each "Drop" but small scale fading is generated via Doppler effect by selecting the velocity vector of the MS and update the channel assuming that the delay, angles, etc are not changing. For each MS the delay spread and angular spread in addition to the shadow fading are correlated but there exist no correlation between different MS. The channels of the interferers will also be modeled. The basic channel for SL simulations that will be provided by WP5 is based on the SCM model and extended for 100 MHz bandwidth at 5 GHz frequency range with proper path loss and shadowing models.

4) Advanced channel model for SL simulations

This model is intended to be adopted for dynamic system simulations. The main feature of this channel model is to model the dynamic features of the channel. In this model successive channel realizations or impulse response are dependent. Features presented in Section 5.4.2 are used in this set of channel models. Hence, time evolution of large scale parameters will be modeled. Correlation of shadow fading between different MSs as well as between BS/AP are modeled. Shadow fading correlation distance is also to be modeled. This model considers some cases of transition scenarios where large scale parameters change abruptly after some movements, i.e., LOS to NLOS, outdoor to indoor, etc. Some of the system level simulations will need small scale fading, so modeling of small scale fading will also be possible but in a simple fashion. So, this set of models will be for the dynamic evolution of the channel, as function of time and distance to describe the time/space evolution of the large scale channel parameters to take into account that parameters such as mean direction of arrival, mean direction of departure, mean number of paths, birth and death of paths, angular spread, delay spread, path loss, shadowing parameters, and relative mean power of multipath components, etc., change significantly during a transmission in a mobile channel for a large-scale MS movements. Channels of interferers will also be modeled.

## 5.8 Validation

Validation within the channel modeling effort occurs on two levels, specifically the verification of the model description in the model documentation, and the verification of the software reference implementation.

With respect to the model description we aim to verify that

- The models accurately reproduce effects modeled earlier (backward compatibility). For example MIMO models should retain SISO model characteristics when setting antenna configuration to 1x1. Similarly, they should match statistics of parameters in classic narrowband models.
- The models accurately reproduce a newly included propagation effect
- The models show increased accuracy for a certain parameter or parameter extension to justify the increased complexity.

Validation is based on comparing model output channel realizations with that of measured channels. Independent parameters can be used to show improvement, e.g. eigenvalue statistics which are typically modeled only indirectly.

A third level of validation is connected with the channel measurements and parameter extraction. Here, care has to be taken to verify the applicability and accuracy of parameter estimation and extraction algorithms.

## 5.9 Limitations of the initial channel models

Limitations of the initial channel models are listed in the D5.1 [2].

## 5.10 Channel model SW implementation

This subsection gives a brief overview of the SW implementation principles for the channel model. However, detailed SW implementation will have to be done at a later stage as it heavily depends on the model specification itself. Therefore, the SW implementation framework described in the following is subject change.

### 5.10.1 Interface between the channel model and simulation program(s)

The input/output arguments of the channel model program will most likely follow the framework given in [44]. The main output is a multidimensional array whose dimensions are: links, path/subpath delays, receiver antennas, transmit antennas and time samples. It is possible to generate matrices for several links with a single function call. Optional outputs include e.g. the delay values, DoA/DoDs, path loss, shadowing, final phases of the complex sinusoids (for the ray-based model).

Input parameters include the MIMO system size, antenna patterns, and link- specific parameters, such as MS-BS distance, array orientations, BS/MS array heights. The link-specific parameters are generated by the user of the model using his/her network geometry and mobility model. The model is also likely to include several switch-selectable options that are configurable by the model user. For example, the user may supply his own path loss model in an external function and/or configure the antenna field pattern interpolation parameters to increase computational efficiency.

Note that, compared to [44], the number of user-configurable parameters is likely to increase. External helper functions will be supplied to assist in model configuration. For example, WINNER-specific propagation scenarios and the associated input parameter settings can be set easily using the helper functions.

### 5.10.2 Channel model SW architecture

The channel model SW architecture will be designed to be as modular and scalable as possible. This allows the user to select a complexity level meeting his/her requirements for model accuracy and computation time. The detailed model SW architecture is TBD upon model specification. Initial channel model SW implementation has been specified in [44].

# 6. Conclusions

In the previous sections the propagation scenarios for the coming WINNER channel models, the so called final channel models, have been proposed. In addition, some requirements for the coming channel models have been stated in the document, partly to give some guidance for the WP5 future work, partly to inform the other work packages about our goals and views in this modeling effort.

In the previous deliverable of the WP5, D5.1 [2], two initial channel models were defined. Those models will be used in the initial simulations in the WINNER project. Later, when the coming (final) channel models have been created in the WP5, these should be taken into use in the simulations. (The term final channel model means here only that the models are the final ones in WINNER Phase I. It is foreseen that the modeling work will continue intensively also in the later Phases of the WINNER project, and outside WINNER also, of course.)

The propagation scenarios have been adapted to the deployment scenarios defined by the WINNER WP7 in [9]. In that document the deployment scenarios were divided into two groups: 14 basic deployment scenarios out of which five are selected as prioritized deployment scenarios. The prioritized scenarios are those that are used in the initial simulations, where also the initial channel models are used.

In this deliverable the propagation scenarios have been defined, for which these coming models will be created during the WINNER Phase I. Some requirements for these models have also been outlined, as indicated in the Annex I of the WINNER contract agreement.

The propagation scenarios have been defined in detail for the so called prioritized deployment scenarios [9], because they will be used in the initial simulations of the other work packages of WINNER. On the other hand the previous deliverable of the WP5, D5.1, defined the initial channel models, which in turn determine the initial propagation scenarios to certain extent. In this document the proposal for the use of the initial channel models has been refined, fixing at the same time the propagation scenarios for the initial simulations and linking them to the prioritized deployment scenarios. One purpose of this document is to state the proposal of the WP5 for the other WP:s, how the initial channel models are linked to the prioritized deployment scenarios. It may happen that this proposal has to be revised in cooperation with the other WP:s to create a working simulation environment.

The propagation scenarios for the coming final channel models, linked to all the 14 basic deployment scenarios, have been defined in less detail. This is due to the fact that the coming channel models are still subject of ongoing research work, performed in the WINNER WP5 and many parallel research projects in Europe and throughout the world. It should also be pointed out that during the WINNER Phase I the definitions for the basic deployment scenarios may change in some extent, creating the need for later updates for the propagation scenarios.

One point of view is also that WP5 does not need to restrict to the 14 basic deployment scenarios. It may, and perhaps should, define other propagation scenarios as well. They might have more general goals than just to support the simulations of the other work packages in the WINNER. However, the 14 basic deployment scenarios, and more specifically the five prioritized deployment scenarios are a good starting point, and this is the point of view WP5 has used in its definition work in this deliverable. The widening the scope of the propagation scenarios and the coming channel models should then be performed during the modeling effort in the succeeding WP5 tasks T5.4 and T5.5.

During the WP5 task T5.2, the SW implementation of the SCM model has been specified. Although the implementation is performed by all partners and also in the tasks T5.4 and T5.5, the effort and its goals have been described in this document. The specification of this SW, including the definition of the interface, has been created elsewhere, but the SW has been shortly described in the section 5 of this document. During the dead-line of this deliverable the implementation work is ongoing.

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