Measurement based parameter extraction for WINNER radio channel model

Lassi Hentilä [1], Milan Narandžić [2] and Juha Meinilä [1]

[1]Elektrobit, Tutkijantie 7, FI-90570, Oulu, Finland
E-mail: firstname.lastname@elektrobit.com

[2]TU-Ilmenau, FG EMT, PSF 100 565, D-98684 Ilmenau, Germany
E-mail: milan.narandzic@tu-ilmenau.de

Abstract

This paper describes the overall procedure of radio channel model parameterization – from channel measurements to the environment dependent model parameters. The process contains following steps: measurement campaign, data conversion stages, data post-processing, use of super-resolution algorithms, and parameterization of the channel model according to a set of analysis items. Each of the steps is described briefly and some issues of the parameter analysis stages are discussed.

1. Introduction

Radio channel measurements have traditionally been considered as a basis for the research work of the wireless propagation characterization. In order to achieve as realistic as possible insight into the propagation environment, the modeling should be based on a large variety of measurement campaigns and data. Even though we carried out over a dozen large measurement campaigns during the four-year IST-WINNER (Wireless World Initiative New Radio) project, we can say that there is still need for new campaigns. The MIMO technology, which is envisioned for future wireless systems, also leads to challenges for the measurement equipment and post-processing tools. Super-resolution algorithms such as Space-Alternating Generalized Expectation maximization (SAGE) or RIMAX (Maximum likelihood parameter estimation framework for joint super-resolution estimation of both specular and dense multipath components) have been used for the joint multi-dimensional parameter extraction from the MIMO measurements. Due to the computational complexity of these algorithms, super-resolution analysis is one of the most time-consuming phases in the modeling work. The used algorithms provide the following characteristics of the propagation paths: their number, propagation delays, angle-of-departure (AoD), angle-of-arrival (AoA) for azimuth and elevation, Doppler frequency, polarization dependent powers and cluster structure information. We have developed a systematic description of channel parameter analysis items with corresponding methods and formulas [1], that should enable simple and transparent generation of channel model parameters for e.g. a WINNER-type ITU-R channel model.

2. Measurements

In IST-WINNER project wideband MIMO measurements were carried out is 2 and 5 GHz frequency ranges. The propagation scenarios measured in the WINNER were indoor office, indoor-to-outdoor, typical urban micro- and macro-cell, bad urban micro- and macro-cell, large indoor hall, outdoor-to-indoor micro- and macro-cell, different feeder links, suburban, rural macro-cell, and high speed moving network for rural areas. The word “typical” means here the environments that are found in European and North-American countries. Most of the measurements were done using Elektrobit’s Propsound [2] and Medav’s RUSK [3] channel sounders. Papers [4] – [7] present a few of the WINNER measurement campaigns and some results extracted from the data.

3. Data conversion and post-processing

The measurement data was at first converted to the internal Matlab® representation. The post-processing tools e.g. ISIS™ (Initialization and Search Improved SAGE) software is based on a super-resolution SAGE algorithm employing maximum likelihood techniques. The super-resolution algorithm is based on multi-parameter estimation of resolvable propagation paths using a double-directional signal model. Another algorithm, called RIMAX, was employed for super-resolution parameter estimation, as well. This algorithm is trying to increase reliability of determined parameters by introducing concept of Dense-Multipath-Components (DMC): only limited number of specular components is resolved as such, while the rest of the observed energy is jointly characterized as DMC. Additionally, RIMAX reduces processing time by employing joint optimization of propagation path parameters.

Since WINNER partners have used different measurement equipment/setups, it was necessary to establish the common signal processing assumptions in order to get comparable results. In addition to a usage of equivalent equations for each analysis item, the following assumptions should be fulfilled:
1. Processing bandwidth has to be equalized by decimation.
2. Analyzed dynamic range was kept constant to avoid e.g. dependence of delay spread from thresholding level.
3. Space-time averaging window has to be equivalent with the stationary interval of the channel.

The WINNER channel model [8] is a geometry-based stochastic model in which propagation paths appear in clusters. Its structure requires characterization on several levels: i) global, ii) cluster, and iii) ray level, however, this paper covers only global characterization levels.

The established analysis items are aiming to describe distribution of total channel power between clusters, and channel cross-polarization properties. In order to describe distribution of total channel power between clusters, it is necessary to determine: a) received power b) effective number of clusters c) power of the each cluster, and d) delay-directional distribution of the clusters. The clustering algorithm and the definition of a cluster are presented in [9]. The outputs of the clustering algorithm are the identified and tracked clusters with their parameters over the cluster lifetime periods.

The analysis items to be discussed below are: transmission loss, shadow fading standard deviation (SF), number of clusters, power delay profile (PDP), per-cluster shadowing standard deviation, narrowband K-factor, delay spread (DS), angular spread (AS), cross-polarization ratio (XPR). The group of the Large-Scale-Parameters (LSP): SF, DS, azimuth and elevation AS both at Tx and Rx, K-factor under LoS conditions and XPR are characterized stochastically and described by appropriate log-normal probability density functions (PDFs). Cross-correlations between LSPs (excluding XPR) are introduced to reflect interdependence observed in measurements.

4. Analysis items – global characterization level

Transmission loss is normally presented in decibels as a function of distance and calculated by summing the taps in delay domain and averaging over the measurement snapshots along the measurement run. The WINNER model uses explicit transmission loss formulas that are independent from other parameters. As an example, the path loss results for a rural scenario are given in Figure 1.a) with a curve fitting of the data and the free space loss as a reference.

Power delay profile has been obtained from the measurement by averaging instantaneous PDP's from all spatial sub-channels within a local stationary interval. If any of the resulting averaged PDP did not fulfill the dynamic range requirement i.e. 20 dB from the peak to the noise floor, that snapshot was eliminated from the further analysis. In Figure 1.b) an example PDP with the threshold is illustrated. In WINNER model, PDP is used to assign cluster power according to cluster delay.

Delay spread expresses the delay dispersion of the channel and is probably the most important metric describing a radio channel characteristics. When considering delay spread extracted from the channel impulse response data, the receiver sensitivity and noise cut threshold have to be mentioned. Since the delay spread is a function of the noise cut threshold, results of different measurement campaigns in literature are not always comparable. Figure 1.c) shows a result of delay spread analysis from a high speed network scenario. The above-mentioned 20 dB noise threshold criterion has been utilized here.

Shadow fading describes the large scale variation of the power level of radio channel. In decibels, it is calculated by subtracting the measured received power from the path loss model (fitted line) and modeled with a zero mean Gaussian distribution with a standard deviation of a few decibels, typically. Figure 2.a) presents the PDF of the shadow fading for indoor-to-outdoor scenario.

K-factor analysis is strongly dependent on the selected stationary interval of the channel. In our analyses, it has been calculated using the Greenstein's moment's method [10]. One could claim that every data analyzer is able to find as pleasing K-factor as liked by picking on a suitable data interval for the analysis. In addition, if the measurements are carried on a MIMO-mode, new problem emerges: How to get K-factor for the whole system out of the hundreds of measured sub-channels? The K-factor empirical CDFs are determined in several ways are compared with reference SISO data being generated by dipole antennas (Figure 2b). It is found that the vertical component of the ISIS results best reflects the reference data. Randomly generated K-factor values are used to introduce appropriate scaling coefficients for LoS component and sum of all other components.

Angle spread is not too widely presented in the literature of radio channel propagation. There are many methods to obtain angular information of transmitted and received signals: 1. the use of a directional antenna with a narrow beam width and high gain and scan the whole 360 degrees of azimuth angles, 2. the use of the beam-forming algorithms or 3. super-resolution algorithms e.g. ESPRIT, SAGE, RIMAX and MUSIC. In this study we utilized SAGE and RIMAX for the angle information extraction and calculated the angle spread for each time instant by using the 3GPP SCM specification [11]. Averaging in angular domain was also calculated over the stationary interval, with a sliding window. Angle spreads are controlling wrapped Gaussian PAS of cluster centroids. Figure 2.c) presents the angle spread cumulative density functions (CDF) of the indoor scenario.

Cross-polarization ratio is defined as a power ratio between the co- and cross-polarized components of the received signal. In decibels the ratio is typically between 0 and 20 dB, when the propagation conditions are NLOS and LOS, respectively. However, there are many situations e.g. a rich scattering environment and some indoor halls when the XPR is quite low even in a LOS case. Figure 3.b) shows a situation of a low XPR in LOS propagation.

Number of clusters is determined as median of the experimental CDF. We extract the cluster number CDF by using the algorithm presented in [9]: “The optimum number of clusters is defined by the lowest number of clusters for which it is possible to reflect the given scenario with a certain error threshold.” The threshold is found empirically. Figure 3.c) presents an example CDF of the number of clusters in indoor-to-outdoor scenario.

5. Conclusion

Since the radio channel measurements are the basis for the research of the wireless propagation phenomena, it is important to consider the whole procedure from measurements to channel models. The overall procedure was described by emphasizing the most important analysis items. The same procedure developed in WINNER can be used for development or parameterization of other channel models as well.

6. Acknowledgments

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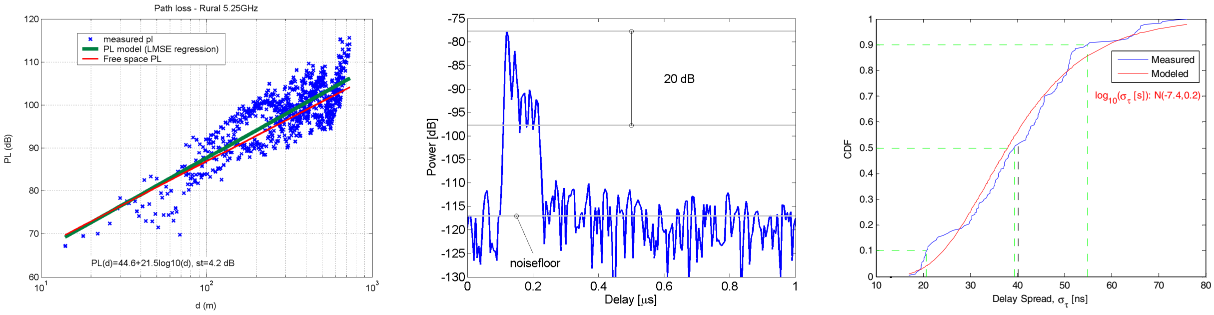
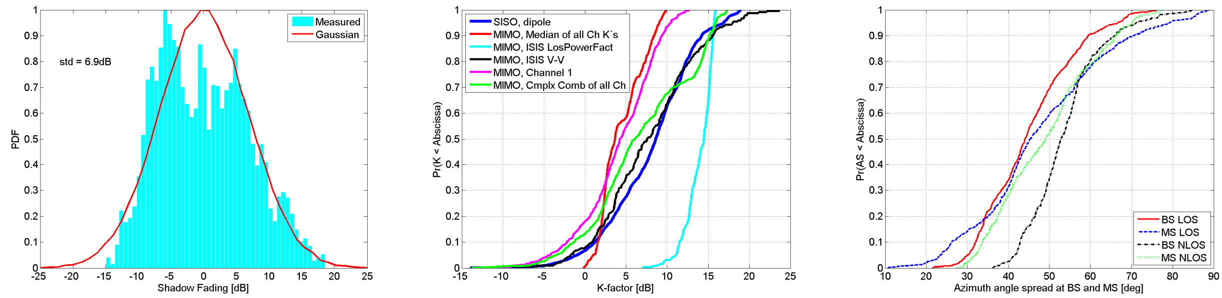


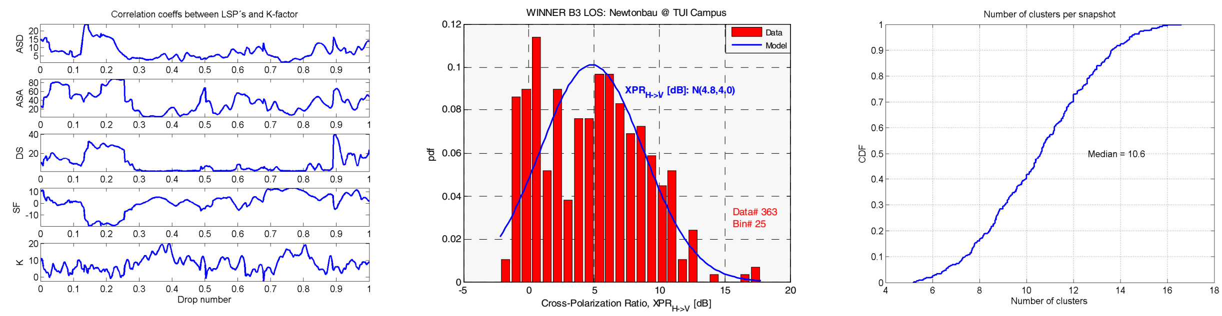
(a) (b) (c)

Figure 1. a) Path loss for rural scenario. b) Example PDP with cut threshold. c) Delay spread for high speed networks.



(a) (b) (c)

Figure 2. a) Shadow fading standard deviation for indoor-to-outdoor scenario. b) Rician K-factor: MIMO method comparison. c) Azimuth angle spread for indoor scenario.



(a) (b) (c)

Figure 3. a) Cross-correlation between LSP's for indoor office scenario. b) XPR_H for large indoor hall. c) Number of clusters per snapshot for indoor-to-outdoor scenario.