WiMAX Forum® Mobile Release 1.0 Channel Model

Copyright Notice, Use Restrictions, Disclaimer, and Limitation of Liability.

Copyright 2008 WiMAX Forum. All rights reserved.

The WiMAX Forum® owns the copyright in this document and reserves all rights herein. This document is available for download from the WiMAX Forum and may be duplicated for internal use, provided that all copies contain all proprietary notices and disclaimers included herein. Except for the foregoing, this document may not be duplicated, in whole or in part, or distributed without the express written authorization of the WiMAX Forum.

Use of this document is subject to the disclaimers and limitations described below. Use of this document constitutes acceptance of the following terms and conditions:

THIS DOCUMENT IS PROVIDED "AS IS" AND WITHOUT WARRANTY OF ANY KIND. TO THE GREATEST EXTENT PERMITTED BY LAW, THE WiMAX FORUM DISCLAIMS ALL EXPRESS, IMPLIED AND STATUTORY WARRANTIES, INCLUDING, WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF TITLE, NONINFRINGEMENT, MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE WiMAX FORUM DOES NOT WARRANT THAT THIS DOCUMENT IS COMPLETE OR WITHOUT ERROR AND DISCLAIMS ANY WARRANTIES TO THE CONTRARY.

Any products or services provided using technology described in or implemented in connection with this document may be subject to various regulatory controls under the laws and regulations of various governments worldwide. The user is solely responsible for the compliance of its products and/or services with any such laws and regulations and for obtaining any and all required authorizations, permits, or licenses for its products and/or services as a result of such regulations within the applicable jurisdiction.

NOTHING IN THIS DOCUMENT CREATES ANY WARRANTIES WHATSOEVER REGARDING THE APPLICABILITY OR NON-APPLICABILITY OF ANY SUCH LAWS OR REGULATIONS OR THE SUITABILITY OR NON-SUITABILITY OF ANY SUCH PRODUCT OR SERVICE FOR USE IN ANY JURISDICTION.

NOTHING IN THIS DOCUMENT CREATES ANY WARRANTIES WHATSOEVER REGARDING THE SUITABILITY OR NON-SUITABILITY OF A PRODUCT OR A SERVICE FOR CERTIFICATION UNDER ANY CERTIFICATION PROGRAM OF THE WiMAX FORUM OR ANY THIRD PARTY.

The WiMAX Forum has not investigated or made an independent determination regarding title or noninfringement of any technologies that may be incorporated, described or referenced in this document. Use of this document or implementation of any technologies described or referenced herein may therefore infringe undisclosed third-party patent rights or other intellectual property rights. The user is solely responsible for making all assessments relating to title and noninfringement of any technology, standard, or specification referenced in this document and for obtaining appropriate authorization to use such technologies, technologies, standards, and specifications, including through the payment of any required license fees.

NOTHING IN THIS DOCUMENT CREATES ANY WARRANTIES OF TITLE OR NONINFRINGEMENT WITH RESPECT TO ANY TECHNOLOGIES, STANDARDS OR SPECIFICATIONS REFERENCED OR INCORPORATED INTO THIS DOCUMENT.

IN NO EVENT SHALL THE WiMAX FORUM OR ANY MEMBER BE LIABLE TO THE USER OR TO A THIRD PARTY FOR ANY CLAIM ARISING FROM OR RELATING TO THE USE OF THIS DOCUMENT, INCLUDING, WITHOUT LIMITATION, A CLAIM THAT SUCH USE INFRINGES A THIRD PARTY'S INTELLECTUAL PROPERTY RIGHTS OR THAT IT FAILS TO COMPLY WITH APPLICABLE LAWS OR REGULATIONS. BY USE OF THIS DOCUMENT, THE USER WAIVES ANY SUCH CLAIM AGAINST THE WiMAX FORUM AND ITS MEMBERS RELATING TO THE USE OF THIS DOCUMENT.

The WiMAX Forum reserves the right to modify or amend this document without notice and in its sole discretion. The user is solely responsible for determining whether this document has been superseded by a later version or a different document.

"WiMAX," "Mobile WiMAX," "Fixed WiMAX," "WiMAX Forum," "WiMAX Certified," "WiMAX Forum Certified," the WiMAX Forum logo and the WiMAX Forum Certified logo are trademarks of the WiMAX Forum. Third-party trademarks contained in this document are the property of their respective owners.

TABLE OF CONTENTS

ABSTRACT 5

1. SCOPE 5

2. DEFINITIONS 7
  2.1 ABBREVIATIONS 7
  2.2 DEFINITIONS 7

3. SISO CHANNEL MODEL 8
  3.1 Model Description 8
  3.2 Channel Parameters 8

4. MIMO CHANNEL MODEL 9
  4.1 Introduction 9
  4.2 ITU Tapped-Delay-Line (TDL) Based Channel Model 9
  4.3 Definition of Correlated MIMO Channel Model 10
  4.4 MIMO Channel Model Generation 11
  4.5 Long channel and high speed mobility 13
  4.6 Derivation of the correlation matrices 13
  4.7 Reference antenna configuration 17
  4.8 Channel model for Dedication Pilot in STC Zone in DL (informative example) 18

LIST OF TABLES

TABLE 1. PDP AND SPATIAL CHANNEL MODEL PARAMETERS 10
TABLE 2. MIMO CORRELATION PARAMETERS..11
TABLE 3. PDP AND SPATIAL CHANNEL MODEL PARAMETERS FOR LARGE DELAY SPREAD.............13
TABLE 4. RAY OFFSET ANGLES WITHIN A TAP, GIVEN FOR 1° RMS ANGLE SPREAD...........................13
TABLE 5. PER TAP PARAMETERS FOR PED B CHANNEL USING $\beta's$ FROM TABLE 2 20

Abstract

The purpose of this document is to specify Channel Model for WiMAX Forum Mobile Release 1.0.

1. Scope

The scope of this document is to specify the SISO and MIMO Channel Model requirements used for certification of WiMAX Forum Mobile R1.0 products. The purpose of channel modeling is to provide a realistic and standard setting for the performance testing of mobile fading environment. In particular, the setting covers the frequency-time variation characteristics of both SISO and MIMO systems.

References

[1] RECOMMENDATION ITU-R M.1225, GUIDELINES FOR EVALUATION OF RADIO TRANSMISSION, TECHNOLOGIES FOR IMT-2000, 1997

2. Definitions

For the purposes of the present document, the following terms and definitions apply.

2.1 *Abbreviations*

2.2 *Definitions*

3. SISO Channel Model

Compliance to the following three channel models as specified in [1] is required.

- AWGN
- ITU Pedestrian B 3 km/h
- ITU Vehicular A 60 km/h

3.1 Model Description

Refer to [1].

3.2 Channel Parameters

Refer to [1].

4. MIMO Channel Model

4.1 Introduction

Mobile WiMAX™ RCT requires the use of MIMO channel models. ITU models (Ped-B & Veh-A: 6-tap TDL) were chosen for SISO RCT test. This model was extended to 2x2 MIMO channel models with the definition of a per-tap spatial correlation. Three levels of channel correlation have been defined, to serve as three options for the RCTs. Note that the content of this appendix is relevant to downlink.

4.2 ITU Tapped-Delay-Line (TDL) Based Channel Model

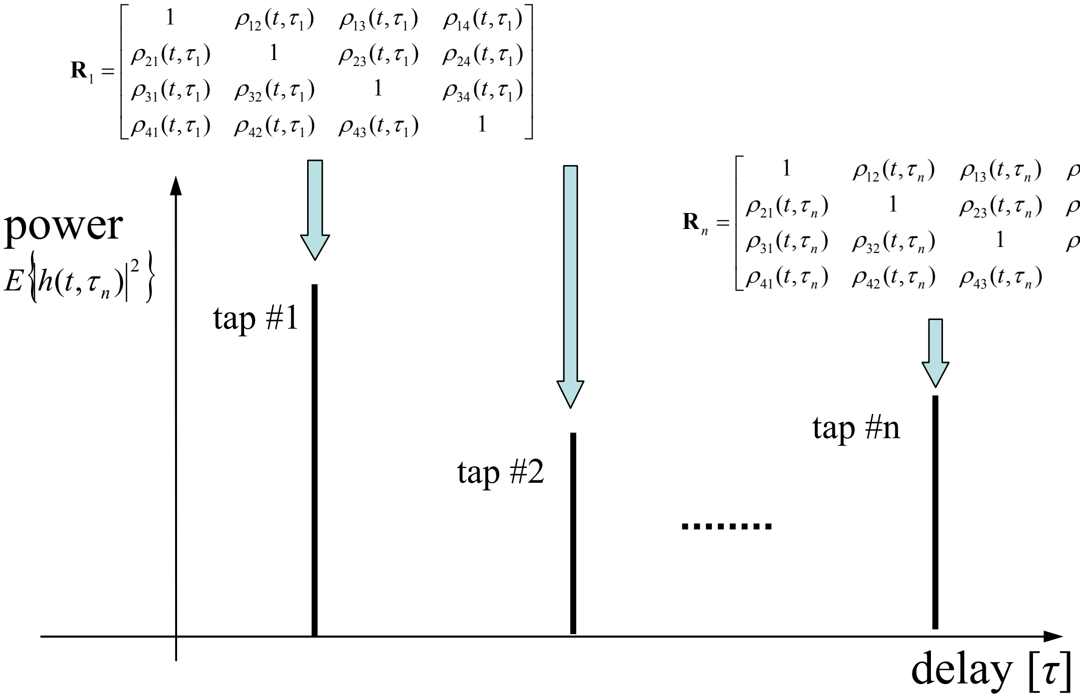

Figure 1. Per tap MIMO correlation matrices

ITU propagation scenarios are extended to spatial dimension by defining mean azimuth angle, azimuth spread and Laplacian shaped power azimuth spectrum for each tap. Tap-wise MIMO correlation matrices can be calculated based on the spatial information combined with specific antenna configuration. Per tap azimuth spread in both scenarios and with all taps is 2° on BS side (AoD) and 35° on MS side (AoA).

Propagation scenarios are based on ITU Pedestrian B and Vehicular A power delay profiles PDP. The Doppler spectra and amplitude distributions are in all the cases Classical and Rayleigh, respectively. The Classical Doppler spectrum is defined as $S(f) \propto 1/(1-(f/f_D)^2)^{0.5}$ for $f \in [-f_D, f_D]$. The channel model parameters (PDP, AoA, AoD) are shown in Table 1.

Table 1. PDP and Spatial Channel Model Parameters

Path	ITU Pedestrian B, 3 km/h				ITU Vehicular A, 60 km/h			
	Relative Delay [ns]	**Relative Mean Power [dB]**	**Mean AoA**	**Mean AoD**	**Relative Delay [ns]**	**Relative Mean Power [dB]**	**Mean AoA**	**Mean AoD**
1	0	0	147.34	18.11	0	0	142.22	165.11
2	200	-0.9	50.84	24.48	310	-1.0	13.92	170.43
3	800	-4.9	139.08	21.11	710	-9.0	110.94	182.2
4	1200	-8.0	49.50	6.47	1090	-10.0	45.25	162.44
5	2300	-7.8	260.03	23.85	1730	-15.0	98.38	170.6
6	3700	-23.9	128.93	24.24	2510	-20.0	50.41	155.68
Total AS			67.91	4.99			69.9	4.99

4.3 Definition of Correlated MIMO Channel Model

The MIMO correlation matrices of the three 2x2 antenna configurations – obtaining high, medium, and low correlation – are defined by (1)-(3). Extremely high correlation can be considered later. In the equations below $(\cdot)^*$ denotes complex conjugate. Parameters for the matrices are given in Table 2. Derivation of the correlation matrices is described in details in the Appendix A, the associated reference antenna configurations is shown in Appendix B

High correlation:

$$\mathbf{R}_{MIMO} = \begin{bmatrix} 1 & \beta & \alpha & \alpha\beta \\ \beta^* & 1 & \alpha\beta^* & \alpha \\ \alpha^* & \alpha^*\beta & 1 & \beta \\ \alpha^*\beta^* & \alpha^* & \beta^* & 1 \end{bmatrix} \quad (1)$$

Medium correlation:

$$\mathbf{R}_{MIMO} = \begin{bmatrix} 1 & 0 & \gamma & 0 \\ 0 & 1 & 0 & -\gamma \\ \gamma & 0 & 1 & 0 \\ 0 & -\gamma & 0 & 1 \end{bmatrix} \quad (2)$$

Low correlation:

$$\mathbf{R}_{MIMO} = \begin{bmatrix} 1 & 0 & \gamma\alpha & 0 \\ 0 & 1 & 0 & -\gamma\alpha \\ \gamma\alpha^* & 0 & 1 & 0 \\ 0 & -\gamma\alpha^* & 0 & 1 \end{bmatrix} \qquad (3)$$

Where,

$$\mathbf{R}_{BS} = \begin{bmatrix} 1 & \alpha \\ \alpha^* & 1 \end{bmatrix}$$

$$\mathbf{R}_{MS} = \begin{bmatrix} 1 & \beta \\ \beta^* & 1 \end{bmatrix}$$

Table 2. MIMO correlation parameters

	Pedestrian B			Vehicular A		
Tap	β	α	γ	β	α	γ
1	-0.1468 + 0.4156i	0.0303 + 0.7064i	0.7264	-0.2366 + 0.4312i	0.6883 + 0.1211i	0.7264
2	-0.4467 + 0.4227i	-0.4007 - 0.6073i		0.1388 + 0.2343i	-0.3508 - 0.5926i	
3	-0.2906 + 0.4347i	-0.6664 + 0.2620i		-0.6443 + 0.3650i	0.3884 - 0.5604i	
4	-0.4273 + 0.4259i	-0.6522 + 0.2088i		-0.3620 + 0.4331i	0.1899 + 0.6795i	
5	-0.7026 - 0.3395i	-0.5378 - 0.4866i		-0.7074 + 0.3372i	-0.3933 - 0.5650i	
6	-0.4500 + 0.4222i	-0.4564 - 0.5655i		-0.4405 + 0.4238i	-0.4383 - 0.5800i	

4.4 MIMO Channel Model Generation

There are different ways in generating the correlative channel coefficients. For example, the generation of both temporal and antenna correlation can be done as shown in Figure 2 below.

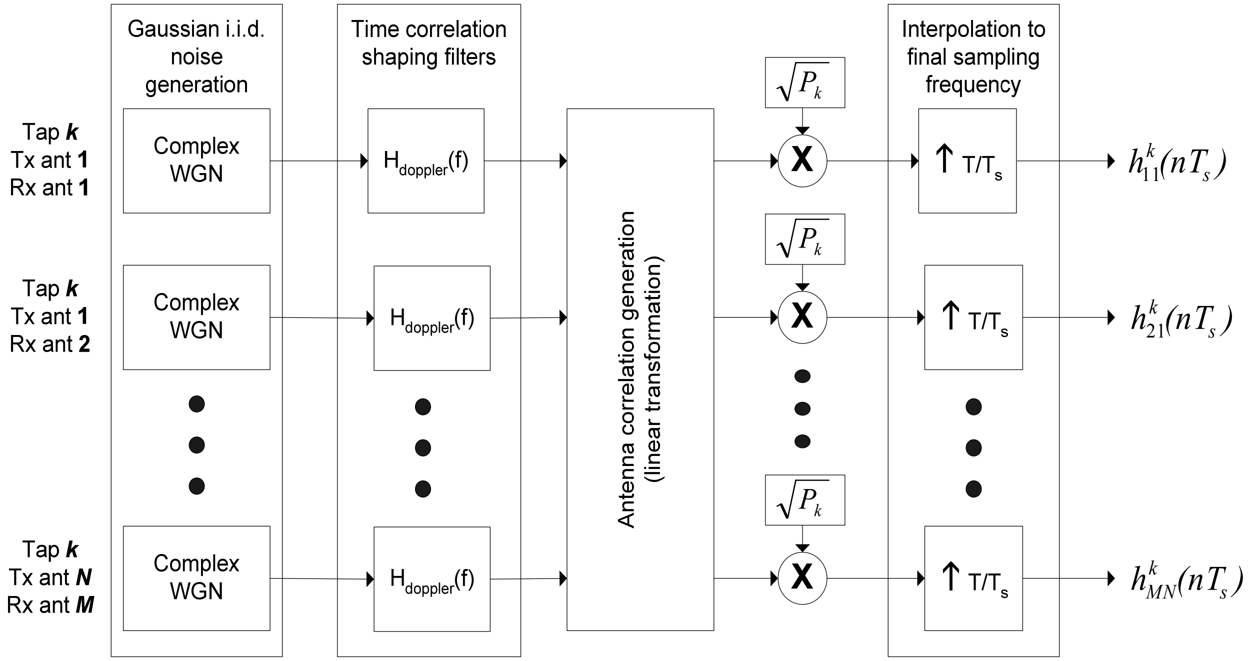

Figure 2. Block diagram of correlated channel coefficient generation.

Above P_k is the power of tap k in the power delay profile. Gaussian random numbers are generated with sample interval T, which has to satisfy Nyquist criterion with maximum Doppler frequency f_{max} ($1/T > 2f_{max}$). Antenna correlation generation is a matrix multiplication $\mathbf{C} = \mathbf{M}\mathbf{H}_d$, where $\mathbf{M} = \mathbf{R}$^(1/2) or $\mathbf{M} = \text{chol}(\mathbf{R})$, $\mathbf{H}_d$ is a MN x K matrix with uncorrelated rows and (Doppler) correlated columns, K is the number of time samples (columns). After antenna correlation generation the channel coefficients fulfil correlation matrix $\mathbf{R}$.

1. Take an Hermitian 'square-root' (e.g. Cholesky) of the correlation matrix ($R_{MIMO}^{1/2}$) and multiply the vectorized form of $\mathbf{H}_{\mathbf{iid}}$,
$$vec(\mathbf{H}) = \mathbf{R}_{MIMO}^{1/2} \cdot vec(\mathbf{H}_{iid})$$
2. For each pair of MS-BS antennas and for each subcarrier, the signal, Y, at the output of MIMO channel is the result of multiplication of the matrix $\mathbf{H}$ with the transmitted signal, S, i.e. $Y = \mathbf{H} \cdot S$.
3. **H** structure is – $\mathbf{H}_{\mathbf{R,T}}$ where MS (Rx) elements are on rows and BS (Tx) elements on columns. For the sake of clarification, for BS antennas 1 and 2 and for MS antennas 1 and 2, the channel H is according to the following:

$$\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} = \begin{bmatrix} BS_1 \to MS_1 & BS_2 \to MS_1 \\ BS_1 \to MS_2 & BS_2 \to MS_2 \end{bmatrix},$$

and correlation between MIMO channels is defined by

$$\mathbf{R}_{MIMO} = E\left[\mathrm{vec}(\mathbf{H})\mathrm{vec}(\mathbf{H})^H\right] = E\begin{bmatrix} h_{11}h_{11}^* & h_{11}h_{21}^* & h_{11}h_{12}^* & h_{11}h_{22}^* \\ h_{21}h_{11}^* & h_{21}h_{21}^* & h_{21}h_{12}^* & h_{21}h_{22}^* \\ h_{12}h_{11}^* & h_{12}h_{21}^* & h_{12}h_{12}^* & h_{12}h_{22}^* \\ h_{22}h_{11}^* & h_{221}h_{21}^* & h_{22}h_{12}^* & h_{22}h_{22}^* \end{bmatrix}.$$

4.5 Long channel and high speed mobility

In order to entertain the requirement of supporting long channel impulse response (10 µs) and high mobility (120 km/h), the following channel will be used (Table 3):

- ITU Veh. A channel (Table 1) with the alteration that the last tap will be moved from 2510 ns to 10,000 ns where its magnitude will remain the same (-20dB)
- Associated speed will be doubled from 60km/h to 120km/h
- Correlation matrices for all taps would include the exact same values as for the non-modified Veh. A (Table 2).

Table 3. PDP and Spatial Channel Model Parameters for Large Delay Spread

Path	Large delay spread channel, 120 km/h			
	Relative Delay [ns]	Relative Mean Power [dB]	Mean AoA	Mean AoD
1	0	0	142.22	165.11
2	310	-1.0	13.92	170.43
3	710	-9.0	110.94	182.2
4	1090	-10.0	45.25	162.44
5	1730	-15.0	98.38	170.6
6	10000	-20.0	50.41	155.68
Total AS			69.9	4.99

4.6 Derivation of the correlation matrices

Spatial correlation

Spatial correlation can be calculated based on antenna geometry and the power azimuth spectrum (PAS). Per tap azimuth spread in both scenarios and with all taps is assumed 2° on BS side and 35° on MS side. Power azimuth spectrum with all taps is assumed Laplacian shaped. Mean AoA and AoD angles for each tap were taken to be the ones tabulated in Table 1. Laplacian PAS with 1° rms azimuth spread is modeled by 20 offset angles of Table 4. Finally offset angles $\Delta\theta_k$ with rms azimuth spread Y are calculated by $\Delta\theta_k = Y\omega_k$.

Table 4. Ray offset angles within a tap, given for 1° rms angle spread

Ray	Basis vector of offset

number k	angles ω_k
1,2	± 0.0447°
3,4	± 0.1413°
5,6	± 0.2492°
7,8	± 0.3715°
9,10	± 0.5129°
11,12	± 0.6797°
13,14	± 0.8844°
15,16	± 1.1481°
17,18	± 1.5195°
19,20	± 2.1551°

Spatial correlation between two antenna elements is calculated by

$$\rho(D)=\frac{1}{K}\sum_{k=1}^{K}\exp\left(-j2\pi D\sin\left(\theta_0+\Delta\theta_k\right)\right), \tag{4}$$

where D is separation of antenna elements in wave lengths, $K = 20$, θ_0 is mean AoA (AoD) and $\Delta\theta_k$ is the kth offset angle in radians.

Spatial correlation is the only source of correlation with reference antenna configuration "high correlation". For the "high correlation" case the MIMO correlation matrix is derived with the following procedure:

As an example, spatial correlation between BS antenna elements is

$$\alpha=\rho(4)=\frac{1}{20}\sum_{k=1}^{20}\exp\left(-j2\pi\cdot 4\cdot\sin\left(\theta_0+\Delta\theta_k\right)\right), \tag{5}$$

where e.g. for the first tap of Pedestrian A scenario $\theta_0 = 18.11°$ and $\Delta\theta_k = 2°\cdot\omega_k$. Angles must be converted to radians before substituting to eq. (5). Derivation of spatial correlation β between MS antenna elements is analogous.

Now correlation matrix of BS antenna array is

$$\mathbf{R}_{BS}=\begin{bmatrix}1 & \alpha\\ \alpha^* & 1\end{bmatrix} \tag{6}$$

and correlation matrix of MS antenna array is

$$\mathbf{R}_{MS}=\begin{bmatrix}1 & \beta^*\\ \beta^* & 1\end{bmatrix}. \tag{7}$$

Finally the MIMO correlation matrix for reference antenna configuration "high correlation" is

$$\mathbf{R}_{MIMO} = \mathbf{R}_{BS} \otimes \mathbf{R}_{MS} = \begin{bmatrix} \mathbf{R}_{MS} & \alpha\mathbf{R}_{MS} \\ \alpha^* \mathbf{R}_{MS} & \mathbf{R}_{MS} \end{bmatrix} = \begin{bmatrix} 1 & \beta & \alpha & \alpha\beta \\ \beta^* & 1 & \alpha\beta^* & \alpha \\ \alpha^* & \alpha^*\beta & 1 & \beta \\ \alpha^*\beta^* & \alpha^* & \beta^* & 1 \end{bmatrix}. \qquad (8)$$

Polarization correlation

Correlation between polarized antennas results from the cross polarization power ratio (XPR). The polarization matrix is given by:

$$\mathbf{S} = \begin{bmatrix} s_{vv} & s_{vh} \\ s_{hv} & s_{hh} \end{bmatrix}, \qquad (9)$$

where v denotes vertical and h horizontal polarization, the first index denoting the polarization at BS and the second the polarization at MS. In the ITU scenarios we assume -8 dB per-tap power ratio between vertical-to-horizontal and vertical-to-vertical polarisations (also P_{hv}/P_{hh} = -8dB). This results to mean power per polarization component

$$\begin{aligned} p_{vv} &= E\left\{\left|s_{vv}\right|^2\right\} = 0\text{ dB} = 1 \\ p_{vh} &= E\left\{\left|s_{vh}\right|^2\right\} = -8\text{ dB} = 0.1585 \\ p_{hv} &= E\left\{\left|s_{hv}\right|^2\right\} = -8\text{ dB} = 0.1585 \\ p_{hh} &= E\left\{\left|s_{hh}\right|^2\right\} = 0\text{ dB} = 1 \end{aligned} \qquad (10)$$

For the “medium correlation” case the MIMO correlation matrix is derived with the following procedure:

The MS polarizations are vertical and horizontal, but the BS polarizations are slant +45° and -45°. The MS and BS polarization matrices $\mathbf{P}_{MS}$ and $\mathbf{P}_{BS}$ respectively are rotation matrices, which map vertical and horizontal polarizations to MS and BS antenna polarizations.

$$\mathbf{P}_{MS} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad (11)$$

$$\mathbf{P}_{BS} = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \qquad (12)$$

The total channel is the matrix product of the BS polarization, the channel polarization, and the MS polarization:

$$\mathbf{Q} = \mathbf{P}_{BS}\,\mathbf{S}\,\mathbf{P}_{MS} = \frac{1}{\sqrt{2}}\begin{bmatrix} s_{vv}+s_{hv} & s_{vh}+s_{hh} \\ s_{vv}-s_{hv} & s_{vh}-s_{hh} \end{bmatrix} \tag{13}$$

The covariance matrix of the channel is

$$\begin{aligned}
\mathbf{\Gamma} &= E\left\{vec(\mathbf{Q})\cdot vec(\mathbf{Q})^H\right\} \\
&= E\left\{\frac{1}{2}\begin{bmatrix}
(s_{vv}+s_{hv})(s_{vv}+s_{hv})^* & (s_{vv}+s_{hv})(s_{vv}-s_{hv})^* & (s_{vv}+s_{hv})(s_{vh}+s_{hh})^* & (s_{vv}+s_{hv})(s_{vh}-s_{hh})^* \\
(s_{vv}-s_{hv})(s_{vv}+s_{hv})^* & (s_{vv}-s_{hv})(s_{vv}-s_{hv})^* & (s_{vv}-s_{hv})(s_{vh}+s_{hh})^* & (s_{vv}-s_{hv})(s_{vh}-s_{hh})^* \\
(s_{vh}+s_{hh})(s_{vv}+s_{hv})^* & (s_{vh}+s_{hh})(s_{vv}-s_{hv})^* & (s_{vh}+s_{hh})(s_{vh}+s_{hh})^* & (s_{vh}+s_{hh})(s_{vh}-s_{hh})^* \\
(s_{vh}-s_{hh})(s_{vv}+s_{hv})^* & (s_{vh}-s_{hh})(s_{vv}-s_{hv})^* & (s_{vh}-s_{hh})(s_{vh}+s_{hh})^* & (s_{vh}-s_{hh})(s_{vh}-s_{hh})^*
\end{bmatrix}\right\} \\
&= \frac{1}{2}\begin{bmatrix}
p_{vv}+p_{hv} & p_{vv}-p_{hv} & 0 & 0 \\
p_{vv}-p_{hv} & p_{vv}+p_{hv} & 0 & 0 \\
0 & 0 & p_{vh}+p_{hh} & p_{vh}-p_{hh} \\
0 & 0 & p_{vh}-p_{hh} & p_{vh}+p_{hh}
\end{bmatrix}
\end{aligned}$$

Above the property of uncorrelated fading between different elements in **S** (i.e. $E\left\{s_{ij}s_{kl}^*\right\}=0, \quad i \neq k, j \neq l$) has been used to simplify the expressions. When all of the diagonal elements are equal, the covariance matrix can be further normalised to correlation matrix:

$$\mathbf{R}_{MIMO} = \begin{bmatrix} 1 & \gamma & 0 & 0 \\ \gamma & 1 & 0 & 0 \\ 0 & 0 & 1 & -\gamma \\ 0 & 0 & -\gamma & 1 \end{bmatrix} \tag{14}$$

Value of γ depends only on XPR. With different orientations of MS and BS antenna polarizations, also the covariance matrix structure will be different.

Note, this correlation matrix derivation is actually done for the H_{TR} case. Transforming it into an H_{RT} form the channel elements $h_{1,2}$ and $h_{2,1}$ are switched and thus the 2nd and 3rd rows and columns should be switched as well, resulting in the form:

$$\mathbf{R}_{MIMO} = \begin{bmatrix} 1 & 0 & \gamma & 0 \\ 0 & 1 & 0 & -\gamma \\ \gamma & 0 & 1 & 0 \\ 0 & -\gamma & 0 & 1 \end{bmatrix}$$

Spatial plus polarization correlation

With the antenna configurations resulting to both spatial and polarization correlation, the two MIMO correlation (or covariance) matrices can be derived separately and combined by element-wise matrix product $\times$.

The reference antenna configuration "low correlation" is combination of spatial and polarization correlation.

4.7 Reference antenna configuration

Three different antenna configurations are defined for three different levels of MIMO correlation:

High correlation: may be obtained from an MS ULA with a half-wavelength spacing and BS ULA with four wavelength spacing.

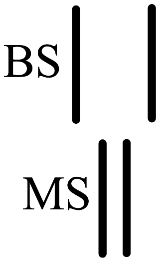

Figure 3. High correlation antennas configuration

Medium correlation: may be obtained from a cross polarized MS antenna and a slant cross-polarized BS antenna, "\" is TX antenna number 1, "/" is TX antenna number 2, "|" is RX antenna number 1, and "–" is RX antenna number 2.

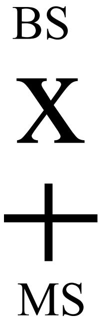

Figure 4. Medium correlation antennas configuration

Low correlation: May be obtained with the same spatial parameters as in the high configuration but with cross-polarized antennas

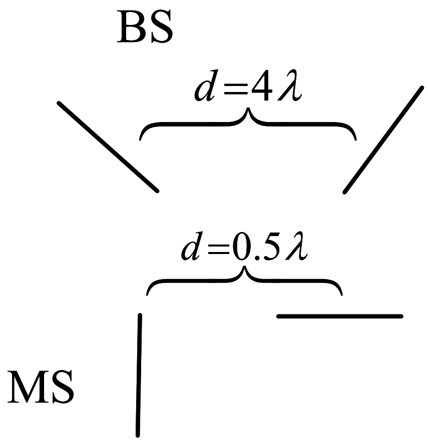

Figure 5. Low correlation antennas configuration

4.8 Channel model for Dedication Pilot in STC Zone in DL (informative example)

Channel Model for Dedicated Pilot in STC Zone can be a natural extension of the MIMO channel model, based on the folowing:

1. Generating an i.i.d. channel, $\mathbf{H}_{\mathbf{iid}}$ - For a 4x2 and a 8x2 antenna configuration selecting respectively a 4x2 and a 8x2 i.i.d fading matrices based on Ped. B or Veh. A channel
2. Correlation:
    1. The 2x2 received correlation matrix, $\mathbf{R}_{\mathbf{MS}}$, is the one used in the regular 2x2 MIMO case
    2. The Tx correlation matrix $\mathbf{R}_{\mathbf{BS}}$ is now a 4x4 or 8x8 matrix (for the 4x2 and 8x2 configuration respectively). The calculation of these matrices follow the procedure described in the MIMO channel model (above) but using the different distances between each pair of antennas for calculating the related matrices elements.
    3. For a linear array, the overall correlation matrix is $\mathbf{R} = \mathbf{R}_{BS} \otimes \mathbf{R}_{MS}$
3. The effective channel is then (in vector form): $vect(\mathbf{H})=\mathrm{sqrt}(\mathbf{R})\cdot vect(\mathbf{H}_{\mathbf{iid}})$

Choosing antenna configuration as follows:

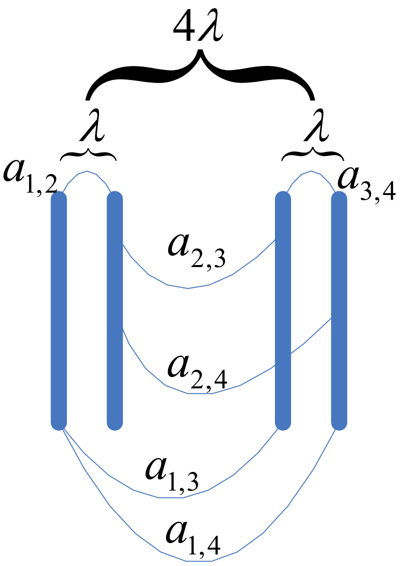

Figure 6. Antenna Configuration for Dedicated Pilot in STC Zone

For this configuration the spacing between antennas are:

$$D_{1,2} = D_{3,4} = \lambda$$
$$D_{2,3} = 3\lambda$$
$$D_{1,3} = D_{2,4,} = 4\lambda$$
$$D_{1,4} = 5\lambda$$

The correlation matrix is:

$$\mathbf{R}_{MIMO} = \mathbf{R}_{BS} \otimes \mathbf{R}_{MS} = \begin{bmatrix} 1 & \alpha_{1,2} & \alpha_{1,3} & \alpha_{1,4} \\ \alpha_{1,2}^{\ *} & 1 & \alpha_{2,3} & \alpha_{2,4} \\ \alpha_{1,3}^{\ *} & \alpha_{2,3}^{\ *} & 1 & \alpha_{3,4} \\ \alpha_{1,4}^{\ *} & \alpha_{2,4}^{\ *} & \alpha_{3,4}^{\ *} & 1 \end{bmatrix} \otimes \begin{bmatrix} 1 & \beta \\ \beta^{*} & 1 \end{bmatrix}$$

Using the equalities between the different $\alpha's$ (see below) the correlation matrix is then expressed in Eq. 18

$$\alpha_{1,2} = \alpha_{3,4} = a_1$$
$$a_{2,3} = a_2$$
$$\alpha_{1,3} = \alpha_{2,4} = a_3$$
$$\alpha_{1,4} = a_4$$

$$\mathbf{R}_{MIMO}=\begin{bmatrix} 1 & \beta & a_1 & a_1\beta & a_3 & a_3\beta & a_4 & a_4\beta \\ \beta^* & 1 & a_1\beta^* & a_1 & a_3\beta^* & a_3 & a_4\beta^* & a_4 \\ a_1^* & a_1^*\beta & 1 & \beta & a_2 & a_2\beta & a_3 & a_3\beta \\ a_1^*\beta^* & a_1^* & \beta^* & 1 & a_2\beta^* & a_2 & a_3\beta^* & a_3 \\ a_3^* & a_3^*\beta & a_2^* & a_2^*\beta & 1 & \beta & a_1 & a_1\beta \\ a_3^*\beta^* & a_3^* & a_2^*\beta^* & a_2^* & \beta^* & 1 & a_1\beta^* & a_1 \\ a_4^* & a_4^*\beta & a_3^* & a_3^*\beta & a_1^* & a_1^*\beta & 1 & \beta \\ a_4^*\beta^* & a_4^* & a_3^*\beta^* & a_3^* & a_1^*\beta^* & a_1^* & \beta^* & 1 \end{bmatrix}$$

The values of the per-tap parameters for Ped. B channel are listed in Table 5.

Table 5. Per tap parameters for Ped B channel using β's from Table 2

Tap	a_1	a_2	a_3	a_4	β
1	-0.364 - 0.90831i	0.74898 + 0.33995i	0.030322 - 0.70636i	-0.54975 + 0.1956i	-0.1468 + 0.4156i
2	-0.84105 - 0.5036i	0.038607 - 0.83508i	-0.4007 + 0.60728i	0.54842 - 0.26651i	-0.4467 + 0.4227i
3	-0.62399 - 0.75477i	0.72576 - 0.39943i	-0.66635 - 0.26197i	0.18727 + 0.56467i	-0.2906 + 0.4347i
4	0.74211 - 0.63477i	-0.42392 - 0.68757i	-0.65216 - 0.20882i	-0.51201 + 0.21596i	-0.4273 + 0.4259i
5	-0.80752 - 0.55544i	0.19447 - 0.81151i	-0.53779 + 0.48664i	0.6011 - 0.083037i	-0.7026 - 0.3395i
6	-0.82868 - 0.52356i	0.098425 - 0.82958i	-0.45644 + 0.56546i	0.57528 - 0.19866i	-0.4500 + 0.4222i