LTE Optimal Transmission Mode Selection Guidelines over MIMO Channels

ILLA KOLANI
Laboratory of Network, Architecture and Convergence, BUPT
China.
ilabbeni@gmail.com.

JIE ZHANG
State Key Laboratory Information Photonics and Optical Communications, BUPT, China.
lgr24@bupt.edu.cn

RODRIGUE GERMANY
Research Laboratory of Alsett, Toulouse
Alsett
France.
rgermany@alsett.net

Abstract: - In LTE /LTE -advanced standards, the physical layer is mapped into multiple transmission modes(TM) and each TM should be dynamically selected depending on the time-varying MIMO channel. Besides the single antenna SISO transmission (TM1), multielement antenna (MIMO) technology such as Open Loop Spatial Multiplexing (OLSM) and Close Loop Spatial Multiplexing (CLSM) transmission are also specified by the 3GPP standard for LTE downlink transmission. In this paper, on the basis of study upon interaction between MIMO channel correlations through the correlation metric in terms of the amount of correlation with MIMO Diversity-Multiplexing Trade-off (DMT), we propose an optimal transmission mode switching method by delimiting wisely guards intervals of different correlation environment levels.

Key-Words: - **LTE, MIMO, Spatial Multiplexing, OLSM, DMT, Amount of Correlation, Transmission Mode, OSTBC.**

1 Introduction

Long Term Evolution (LTE) network downlink transmission system differently from others wireless network, is mandated to operate in multiple transmission modes related to MIMO systems[1].Each transmission mode may be consisted of transmitting one or two independent data streams (code words) assisted respectively by precoding matrix (phase matrix indicator), transmit diversity and by a cyclic delay prefix .All of those MIMO transmission techniques can be grouped into transmission modes (TM) 1,2,3,4,5,6,7 and 8 However it should be noted the transmission modes are extended to TM9 and TM10 specifying multiple layers transmission up to 8 layers in LTE-Advanced Release 10. Beyond, it should be noted also that the major and important transmission modes systems that have attracted the major research and operators recently are CLSM (close loop spatial multiplexing) and OLSM (open loop spatial multiplexing) systems. Having their strength and weakness [2][3]in regard with the variation of the MIMO channel state information, the two groups of transmission modes can be then seen complementary to implement a complete transmission system that takes into account the frequency, time and spatial selectivity of MIMO channel.

The strategy of adapting LTE downlink transmission mode is advantageous and well thought as wireless MIMO channel is known to be varying not only time and frequency domain but also in spatial domain. This means that sometimes, the MIMO channel state or variation can be suitable for a given transmission mode and prejudicial to another [2][3][4]. In other words, we may smartly define and delimit environments favorable or unfavorable to a given TM. However, many authors [2][3][4] have often limited themselves by only describing those environments conditions without delimiting or defining properly those conditions. For instance, TM1 can only be enabled in case of MIMO bad channel or one rink matrix case. When the Channel State Information (CSI) or phase matrix indicator (PMI) is not known (resp. is known), the eNode B (base station of the LTE network) can only transmit in OLSM (resp.CLSM) manner. However the transmission mode selection can only be optimal if the spatial correlations environments are perfectly known at the base station .Hence it is well known vaguely that OLSM (resp.CLSM) rank 1or TM2 performance is more robust in high correlated

MIMO channel while OLSM (resp.CLSM) rank2 or TM3 transmission performance is only guarantied in low correlation environments, without however being able to specify properly and numerically those correlation levels.

In this paper, by taking into account the diversity multiplexing tradeoff [5] aspect resulting from MIMO channel space-time coding and the effective diversity that can be offered by a MIMO spatially-correlated channel, our study demonstrates the possibility to define rigorously a set of correlation environments through the amount of correlation metric [6][7].We show later that these set of correlation environments can be used to perform an optimal transmission mode selection at the eNode B.

2 Spatial Correlations Environments

The assumption of identical and independent distributed (i.i.d) MIMO cchannel is a utopia due to the fact spatial correlations are not only generated by small spacing of antennas but also scattering objects surrounding the multielement antenna communication systems.

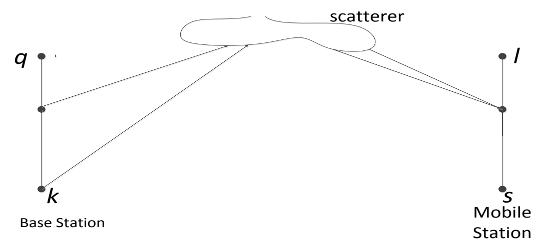

Fig.1 Typical MIMO channel

Indeed, let's consider a MIMO channel H with n_t transmit and n_r received antennas, we can define the correlation between channel H random entries by the space-time correlation matrix R as:

$$\mathrm{R} = \varepsilon\left\{\mathrm{vec(H)}\,\mathrm{vec(H)}^H\right\} \quad (1)$$

ε denotes the expectation and $(.)^H$ the conjugate transpose .

R can explicitly be written as in (2) where $r_{kl,qs}$ is the correlation between two arbitraries sub channels defined by antennas k, q at the receiver side and antennas l, s at the transmitter.

Generally, we can distinguish low, medium from high correlation environments, however difficulties remain when it is necessary to define them. A significant drawback remains the huge size of the full correlation matrix R and its high number of elements to be estimated as shown in (2).

$$\mathrm{R} = \begin{pmatrix} 1 & r_{11,21} & r_{11,12} & r_{11,qs} & \cdots & r_{11,n_tn_r} \\ r_{11,21}^{\,*} & 1 & r_{21,12} & r_{21,qs} & \cdots & r_{21,n_tn_r} \\ r_{11,12}^{\,*} & r_{12,21} & 1 & r_{12,qs} & \cdots & r_{12,n_tn_r} \\ r_{11,qs}^{\,*} & r_{kl,21} & r_{kl,12} & 1 & \cdots & r_{kl,n_tn_r} \\ \vdots & \ddots & \ddots & \ddots & \ddots & \vdots \\ r_{11,n_tn_r}^{\,*} & r_{21,n_tn_r} & r_{12,n_tn_r}^{\,*} & r_{kl,n_tn_r}^{\,*} & \cdots & 1 \end{pmatrix} \quad (2)$$

Other obviousness is the fact the impact of spatial correlations on both capacity and error rate performances of different MIMO transmission modes is not the same; therefore what can be seen, for instance low level of correlation environments for 4x2 MIMO-OLSM rank 2 should not directly be the same for 2x2 MIMO-OLSM rank 2.Hence, it is necessary to lean on a set of fundamental characteristics related to MIMO signal processing to define correlation levels of environments according to each transmission mode. In the following, we discuss the feasibility of delimiting correlation levels on the basis of the diversity-multiplexing curve in MIMO systems.

3 MIMO Diversity Gain

The effective diversity gain is one of the fundamental concepts when designing MIMO systems. It is intuitively related to the number of degree of freedom of a spatial correlated MIMO channel.

The effective diversity gain g_d offered by a MIMO channel can be defined [8] as a function of channel correlation:

$$g_d = \frac{\left(n_t n_r\right)^2}{n_t n_r + \sum_{k,q=1}^{n_t} \sum_{l,s=1}^{n_r} r_{kl,qs} r^*{}_{kl,qs}} \quad (3)$$

It should be noted that g_d to be specified requires

$$\psi_{n_t n_r} = \sqrt{\frac{1}{n_t n_r (n_t n_r - 1)} \left(\sum_{\substack{k,q=1 \\ k \neq q}}^{n_t} r_{kl,ql} r^*_{kl,ql} + \sum_{\substack{l,s=1 \\ l \neq s}}^{n_r} r_{kl,ks} r^*_{kl,ks} + \sum_{\substack{k,q=1 \\ k \neq q}}^{n_t} \sum_{\substack{l,s=1 \\ l \neq s}}^{n_r} r_{kl,qs} r^*_{kl,qs} \right)} \qquad (5)$$

$n_t n_r (n_r n_t - 1)$ number of elements $r_{kl,qs}$ of the correlation matrix R . Hence, to dispense with the study of the effect each element on g_d , we adopt the correlation measure metric of the amount correlation $\psi_{n_t n_r}$ [7][6]:

$$\psi_{n_t n_r} = \sqrt{\frac{1}{n_t n_r (n_t n_r - 1)} \sum_{k,q=1}^{n_t} \sum_{l,s=1}^{n_r} r_{kl,qs} r^*_{kl,qs}} \qquad (4)$$

However in MIMO channel correlations representation, it is often distinguished transmit correlations from receive correlations and cross-correlations. Hence transmit correlations $r_{kl,ql}$, receive correlations $r_{kl,ks}$ and cross correlations $r_{kl,qs}$ can be obtained by setting respectively $l = s, q \neq k$; $l \neq s, q = k$ and $l \neq s, q \neq k$. In this case, the amount of correlation is can be written (5).

This metric can be seen as the average on the overall element $r_{kl,qs}$. It measures the state correlation in MIMO channel. High (resp.low) amount of correlation implies high (resp. low) correlated and its value extends from 0 to 1.
The effective diversity gain from the combination of (2) and (3) is simplified:

$$g_d = \frac{g_{d\,max}}{1 + (n_t n_r - 1)\psi^2_{n_t n_r}} \qquad (5)$$

Clearly, it appears that the effective diversity gain decreases following the increase of $\psi_{n_t n_r}$ and vice versa. Figure 2 depicts the effective diversity gain offered by MIMO channels in the presence of correlations. $\psi_{n_t n_r}$ =0 corresponds to the utopia assumption of the uncorrelated channel. At this state, the MIMO channel is capable to offer the full diversity gain i.e. $g_{d\,max} = n_t n_r$. In contrast, $\psi_{n_t n_r}$ =1 corresponds to the rank one situation which is similar to the SISO channel. It can be analyzed that high number of antenna MIMO system offer high diversity gain. However, from the value $\psi_{n_t n_r}$ =0.9, diversity gains of MIMO systems approximately tend to be the same. Note also that from Figure 2**,** the possibility to define and delimit a set of correlation environments from low level, moderate level to high level through the impact of the amount of correlation on the diversity. Similar approach has been processed in [6] [7]resulting in establishment of *equivalence class* of MIMO systems.

However, it is also obvious that, for MIMO systems with different number of antenna, in terms of effective diversity gain, the correlation level that can be seen as low correlation for a given system ,cannot be seen immediately as the same for other system. Therefore, In addition, it advisable to define correlation levels for a specific MIMO system by taking into account the overall interaction between MIMO signal processing fundamental parameters.

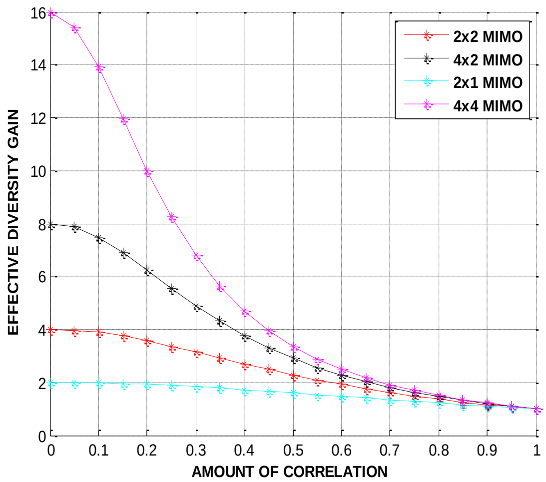

Fig.2 Effective Diversity Gain versus MIMO Channel Amount of Correlation.

4 Diversity-Multiplexing Tradeoff

It would be incomplete to state that the degree of diversity $g_{d\,max}$ that can offer any MIMO channel is only limited by correlations (Amount of correlation). Indeed, we can learn from MIMO channel space-time coding that, the capacity motivation based MIMO design is generally achieved at the cost of the diversity: this is known as diversity-multiplexing tradeoff (DMT). In general the maximum capacity achievable in MIMO systems can take form in the maximum spatial multiplexing rate $n = Q/T$ where Q denotes the number of symbols and T the symbol period duration. In LTE, n is also referred to as the maximum of transmissible layers or Ranks. In LTE downlink, both Rank 1 and Rank 2 can be used for data transmission. Rank1 transmission mode often referred to as diversity motivation-based MIMO design can be processed from transmit diversity (LTE TM2) and Beamforming techniques (LTE TM6). However while transmitting in Rank 2 mode, a temptation to increase diversity can be done by adding Cyclic Delay Diversity (CDD).This is the case of OLSM Rank 2(LTE TM3).

The DMT tradeoff curve for a MIMO transmission mode may allow writing the diversity gain as a function of n. However, since Spatial Multiplexing(SM) transmission modes and Orthogonal Space-Time Block Codes (OSTBC) transmission modes are used in LTE, we will focus on their respective DMT curves. We will assume also a high Signal to Noise (SNR) scenario and in this case, the DMT curve [9] coincides with the DMT derived assuming i.id channels [10].

Considering MIMO-OSTBC transmission, the DMT curve is given[9]:

$$g_{d_{max}} = n_t n_r \left(1 - g_s/n\right) \quad \text{with} \quad g_s = [0, n] \tag{6}$$

$$n \leq 1$$

$$n = \text{minimum}\,(n_t, n_r)$$

where g_s denotes the spatial multiplexing gain. From the combination of (5) and (6), we derive the DMT of spatial multiplexing in correlation environments as:

$$g_{dostbc} = \frac{n_t n_r}{1 + (n_t n_r - 1)\psi^2_{n_t n_r}} \left(1 - g_s/n\right) \tag{7}$$

Let's now consider MIMO-SM transmissions, the DMT curve can be rewritten [8][5]:

$$g_{d_{max}} = n_r (1 - g_s/n) \quad \text{with} \quad g_s = [0, n] \tag{8}$$

From (5) and (8), we derive the DMT of the OSTBC in correlation environments as:

$$g_{dsm} = \frac{n_r}{1 + (n_t n_r - 1)\psi^2_{n_t n_r}} \left(1 - g_s/n\right) \tag{9}$$

It should be noted both (7) and (9) relationship connects three fundamental parameters inherent of MIMO systems: the diversity, the spatial multiplexing gain and the correlation parameter. Figures 3.4 depict the DMT in different correlation environments with antenna number n_t =2, n_r =2

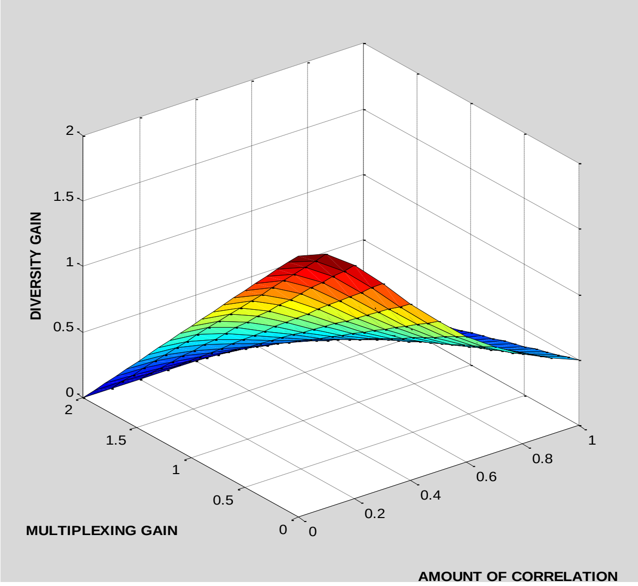

Fig 3 SM: Diversity-multiplexing tradeoff versus channel correlation

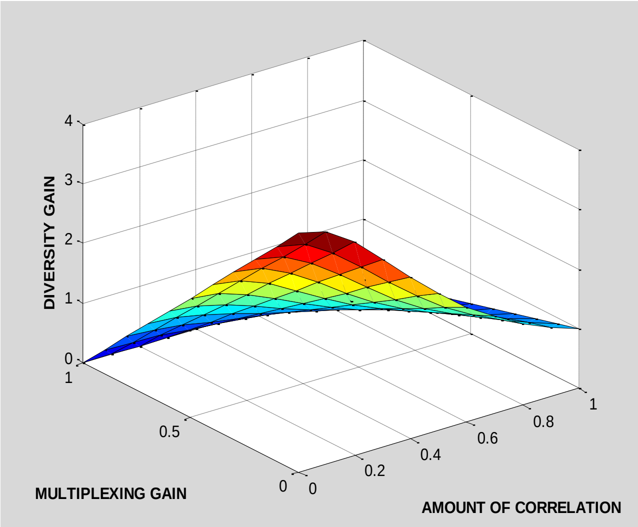

Fig.4 OSTBC Diversity-multiplexing tradeoff versus channel correlation

Although both diversity and multiplexing gain performances targets are searched, it can be seen there is hard tradeoff between them. Moreover this tradeoff is highly impacted in correlation environments. We note also, as expected, although OSTBC may offer the full effective gain $n_t n_r$, it is limited in offering the highest multiplexing gain as in case of spatial multiplexing code .

5. Correlation Levels Delimitation

In this section, we focus on the delimitation of correlations levels for MIMO systems. Those correlation levels can be seen as guard intervals for different transmission mode performances. We will only assume a LTE system using 2x2 MIMO and 4x2 MIMO systems.

1. Firstly, since rank 2 TM_s are expected to work in low correlation intervals, the spatial multiplexing diversity-multiplexing tradeoff function $g_{d_{sm}}\left(g_s, \psi_{n_t n_r}\right)$ should be used to delimit low correlation level as follows:

$$\left\{\begin{matrix} g_{d_{sm}}\left(g_s, \psi_{n_t n_r}\right) \le \mu_o \\ \psi_{n_t n_r} \to \psi^{o}{}_{n_t n_r} \end{matrix}\right\} \qquad (10)$$

Where μ_o denotes the minimum diversity gain required to ensure a given performance of spatial multiplexing transmission mode at the bound position $\psi^{o}{}_{n_t n_r}$ of the amount of correlation $\psi_{n_t n_r}$ .Hence, it should be noted that (9) delimits the interval $0 \le \psi_{n_t n_r} \le \psi^{o}{}_{n_t n_r}$ as low correlation level.

2. Secondly, we assume that rank 2 TM can be used for data transmission in medium correlations interval, therefore the diversity-multiplexing tradeoff function $g_{d_{sm}}\left(g_s, \psi_{n_t n_r}\right)$ should be used to delimit medium correlation level as follows:

$$\left\{\begin{matrix} g_{d_s}\left(g_s, \psi_{n_t n_r}\right) \le \mu_1 \\ \psi_{n_t n_r} \to \psi^{1}{}_{n_t n_r} \end{matrix}\right\} \qquad (11)$$

Where μ_1 denotes the minimum diversity gain specified in medium correlation level. Taking $\mu_1 = g_{d_{sm}}\left(g_s, \psi^{1}{}_{n_t n_r}\right)$, medium correlations level is then delimited by $\psi^{o}{}_{n_t n_r} \le \psi_{n_t n_r} \le \psi^{1}{}_{n_t n_r}$.

3. Thirdly, although rank 1 transmission modes are robust in high correlation level, their performances, however are always limited in extremely high correlations. Therefore, the DMT of the OSTBC should be used to delimit the upper-bound of high correlations level:

$$\left\{\begin{matrix} g_{d_{ostbc}}\left(g_s, \psi_{n_t n_r}\right) \le \mu_2 \\ \psi_{n_t n_r} \to \psi^{2}{}_{n_t n_r} \end{matrix}\right\} \qquad (12)$$

Hence, the interval $\psi^{1}{}_{n_t n_r} \le \psi_{n_t n_r} \le \psi^{2}{}_{n_t n_r}$ is referred to as high correlations level.

4. Finally, beyond $\psi^{2}{}_{n_t n_r}$ i.e. within the interval $\psi^{2}{}_{n_t n_r} \le \psi_{n_t n_r} \le 1$, the eNode B should enable a SISO transmission.

Propositions of MIMO correlations environments delimitation

In order to compute numerically those correlations levels as specified from (9)-(11), we adopt a fixed (g_s=0) data rate-DMT of both rank 1(OSTBC) and rank2 (SM) transmission modes (see figure 5). A set of propositions should be done:

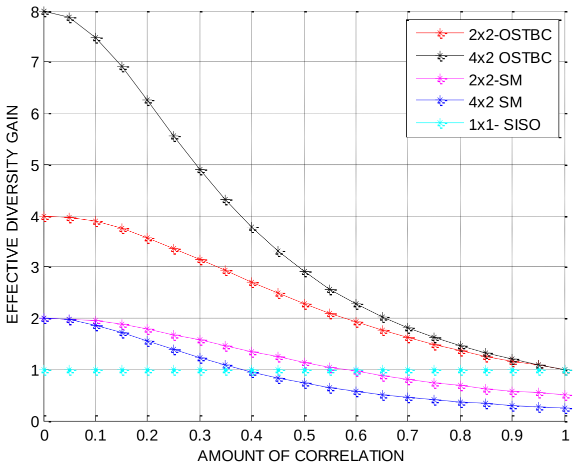

Fig.5 Effective Diversity Gain versus MIMO Channel Amount of Correlation , g_s=0

Proposition1

We define the *low correlation level*, the bound of the interval of the amount of correlation $\psi_{n_t n_r}$ from which the impact of correlation on the diversity gain of the MIMO-SM (see figure 5) starts decreasing beyond a factor of 1/2 of the diversity gain corresponding that of the i.i.d channel. As illustrate in figure 5**,** this interval corresponds to $0 \le \psi_{n_t n_r} \le 0.2$ for 4x2 MIMO-SM and $0 \le \psi_{n_t n_r} \le 0.3$ for the 2x2 MIMO-SM.

Proposition 2

We define the *moderate correlation level*, the bound of the interval of the amount of correlation $\psi_{n_t n_r}$ from which the impact of correlation on the diversity gain of MIMO-SM (see figure 5) starts decreasing beyond the diversity gain(*gs*=1) of SISO channel. As illustrated in figure 5**,** this interval corresponds to $0 \le \psi_{n_t n_r} \le 0.4$ for 2x2 MIMO-SM and $0 \le \psi_{n_t n_r} \le 0.6$ for 4x2 MIMO-TM4.

Proposition3

We define the upper bound of the *high correlation level*, the position of the amount of correlation from which the diversity gains of both 2x2 MIMO-OSTBC and 4x2MIMO-OSTBC start to coincide nearly that of the SISO channel. From figure 5, this position starts approximately from 0.95 of the amount of correlation. Therefore, the intervals $0.4 \le \psi_{n_t n_r} \le 0.95$ and $0.6 \le \psi_{n_t n_r} \le 0.95$ should be considered as high correlation levels.
Note that the above delimitation of correlation levels, reasonably can found similarities in *equivalence class* of MIMO systems in [7] [8].

6. LTE Downlink TM Selection

In this section, we focus on the implementing of a LTE adaptive MIMO TM selection . In order to set up a framework of an adaptive MIMO TM switching two factors should be considered also: The availability or not of the CSI referred here as the PMI and the Adaptive Modulation and coding(AMC) scheme.

From the above positions, we can resume correlation environments as follows:

- For the 4x2MIMO system

$0 \le \psi_{n_t n_r} \le 0.3$, *low correlation level* environments that we name C1

$0.3 < \psi_{n_t n_r} \le 0.6$, *moderate correlation level* environments, C2

$0.6 < \psi_{n_t n_r} \le 0.95$, *high correlation level* environments, C3

$0.95 < \psi_{n_t n_r} \le 1$, *bad MIMO channel (rank one),* C4

- For the 2x2 MIMO system

$0 \le \psi_{n_t n_r} \le 0.2$, *low correlation level* environments, C1

$0.2 < \psi_{n_t n_r} \le 0.4$ *moderate correlation level* environments, C2

$0.4 < \psi_{n_t n_r} \le 0.95$, *high correlation level* environments, C3

$0.95 < \psi_{n_t n_r} \le 1$, *bad MIMO channel (rank one),* C4

The Adaptive Modulation and coding (AMC) Scheme is an adaptive scheme which combines the modulation and the channel coding rate with the aim to enhance both capacity and error rate performances. The scheme dynamically should perform on the basis of the Signal to Noise Ratio (SNR) the instant choice of the CQI_index extending from 0 to 15.Similarly, the adaptive scheme involving PMI should perform the choice of the appropriate PMI_index extending from 1 to 2.

Since OLSM consists of two transmission modes, it will refer to as a Group of Transmission (GT) mode in the following. We assume also that rank 2 in *low correlation level* as well as in *moderate correlation level* , can be used for data transmission; hence in case of the rapidly-time varying MIMO channel(the eNode B has no CSI),the skeleton of the adaptive TM switching is as follows:

GT=OLSM [TM2 TM3]
For Channel state *case*= 1:4
case =1,2; Channel state *case* = C1,C2
RI=2
TM= TM3
CQI=CQI_index [1, 2…15]
case = 3; channel state *case* = C3
RI=1
TM=TM2
CQI=CQI_index [1, 2…15]
case = 4; channel state *case* =C4
Rank one case (bad channel)
TM= TM1
CQI=CQI_index [1, 2…15]

End

7. Practical Optimal TM Selection

In this section, we will provide simulation results for LTE downlink OLSM performances over correlation environments. Those correlation environments can be investigated through MIMO channels [11]-[19]. However we will adopt the Rayleigh channel model developed in [11] by assuming multiple scattering rings (MRSC) environments in the cell.

7.1 MIMO Multi Ring Scattering Channel Model

In this sub section, we will briefly recall the principle of MRSC channel model [11] .It is based on the assumption that the cell environment can be divided in multiple scattering rings with different sizes or beamwidth α_n seen at the base station. Strictly, each scattering ring is corresponding to the well-known MIMO one-ring scattering channel.
For a typical arbitrary MIMO one-ring scattering with size α_n , the general form of the spatial-temporal correlation $r^n{}_{kl,qs}(\Delta t)$ between two arbitrary MIMO sub channels $h_{k,l}(t)$ and $h_{q,s}(t+\Delta t)$ with a time lag Δt=0, are given respectively as [11][12][20]:

$$r^{n}{}_{lk,qs}\left(0\right)=J_0\left(\frac{2\Pi}{\lambda}\alpha_n d.i+\frac{2\Pi}{\lambda}D.j\right) \quad (13)$$

With

$$i=\begin{Bmatrix} k-q \\ with\ k-q=0,1,2...n_r-1 \end{Bmatrix}$$

And

$$j=\begin{Bmatrix} s-l \\ with\ s-l=0,1,2...n_t-1 \end{Bmatrix}$$

It should be noted that k and q define the positions of a pair of antenna in the Uniform Linear Antenna (ULA) array at the receiver mounted with n_r antennas whereas s and l determine the positions of antennas at the transmit array with n_t antenna.

d and D denote respectively the spacing between two antennas at the receive array and at the transmit array. α_n denote the beamwidth seen at the base station and is given as :

$$\alpha_n=\text{tang}\left(\frac{r_n}{L_n}\right) \quad (14)$$

Where r_n is the scattering ring and L_n is the distance between the base station and the mobile station.

Since r_n and L_n are subject to vary in the environment cell with time, the mobile station is assumed moving through multiple scattering rings with different size α_n. As previously mentioned, it should be noted (13) describes the correlation between two arbitrary MIMO sub channel in an arbitrary scattering ring with size α_n. Therefore, (13) can be seen as a channel realization whereas the principle of MRSC performs an averaging on the overall channel realizations.

Let us now consider $\overline{r_{kl,qs}}(0)$ as the average on the overall channel realization $r^{n}{}_{lk,qs}\left(0\right)$, we may write:

$$\overline{r_{kl,qs}}(0)=\frac{1}{N}\sum_{n=1}^{N}d_n\, r^{n}{}_{lk,qs}\left(0\right) \quad (15)$$

Where d_n/N is the probability $p(\alpha_n)$ for a given channel realization to be occurred. Within a given section of the cell, N can be assumed tending infinite such as in this case, a Gaussian probability Density Function (PDF) is suitable to describe the statistical process and (15) can be written in the integral form. Hence $p(\alpha_n)$ can be written:

$$p\left(\alpha_n\right)=\frac{2.c}{\sqrt{\pi}}e^{-c^2\left(\alpha_n-\alpha_0\right)^2} \quad (16)$$

α_o denote the beamwidth for which $p(\alpha_n)$ reaches the peak; c is a parameter controlling the spread of the beamwidth $\alpha_{n.}$ .For more information about the MRSC, see [11].

From the combination of equations (16) and (13) the transmit correlations, receive correlations and cross-correlations are given respectively:

$$\overline{r_{kl,ql}}\left(0\right)=\frac{1}{\sqrt{\pi}}J_0\left(\frac{2\pi}{\lambda}d.i.\alpha_0\right)\sum_{m=0}^{\infty}\frac{\left(-1\right)^m}{\left(2.c\right)^{2m}}\frac{\Gamma\left(m+\frac{1}{2}\right)}{\left(m!\right)^2} \quad (17)$$

$$\overline{r_{kl,ks}}\left(0\right)=J_0\left(2\pi\left(\frac{D.j}{\lambda}\right)\right) \quad (18)$$

Where $J_0(.)$ is the zero order Bessel function of the first kind. Γ(x) denotes the gamma function and $J_p(.)$ the p order Bessel function of the first kind.

7.2 Kronecker's Model Validity

This model leads to a simplification in the analysis of correlations behavior separately at both transmitter side and receiver side following the formulation:

$$\text{H} = \text{R}_\text{r}.G.\text{R}_\text{t} \quad (21)$$

Where R_r and R_t are respectively the receive correlation matrix and the transmit correlation matrix. The vector G is populated by i.i.d. complex random.

In practice, the model is often used for wireless networks performance analysis, however the limitations of this model has been pointed in [21][22].The requirement to be fulfilled by any MIMO channel model in order to be seen as Kronecker's is given in[23] as:

$$\overline{r_{kl,qs}}\left(0\right)=\overline{r_{kl,ql}}\left(0\right).\overline{r_{kl,ks}}\left(0\right) \quad (22)$$

It can be observed that (17), (18) and (19) does not fulfill (22) a priori. However, it can be assumed that the second part of the cross-correlation (19) can be neglected due the fact high orders Bessel function of the first kind decreases rapidly as well as the multiplication between them. Therefore the cross-correlation $\overline{r_{kl,qs}}(0)$ can be simplified as (20):

$$\overline{r_{kl,qs}}(0) = J_0\left(2\pi\left(\frac{D.j}{\lambda}\right)\right).\frac{1}{\sqrt{\pi}}J_0\left(\frac{2\pi}{\lambda}d.i.\alpha_0\right)\sum_{m=0}^{\infty}\frac{(-1)^m}{(2.c)^{2m}}\frac{\Gamma\left(m+\frac{1}{2}\right)}{(m!)^2}+\frac{1}{\sqrt{\pi}}\sum_{p=1}^{\infty}J_p\left(2\pi\left(\frac{D.j}{\lambda}\right)\right)J_p\left(\frac{2\pi}{\lambda}d.i.\alpha_0\right)\sum_{m=0}^{\infty}\frac{(-1)^m}{(2.c)^{2m+p}}\frac{\Gamma\left(m+\frac{p}{2}+\frac{1}{2}\right)}{m!(m+p)!} \tag{19}$$

$$\overline{r_{kl,qs}}(0) = J_0\left(2\pi\left(\frac{D.j}{\lambda}\right)\right).\frac{1}{\sqrt{\pi}}J_0\left(\frac{2\pi}{\lambda}d.i.\alpha_0\right)\mathbf{X}\sum_{m=0}^{\infty}\frac{(-1)^m}{(2.c)^{2m}}\frac{\Gamma\left(m+\frac{1}{2}\right)}{(m!)^2} \tag{20}$$

In this case, (17), (18) and (20) respect relationship in (22).

7.2 Amount of Correlation

Since the metric of the amount correlation has been used to delimit correlation environments; it can be computed in (5) by using (17), (18) and (19).

Taking a working frequency of 2GHz, the antenna spacing used is that specified by the standard i.e. d=4λ at the eNode B and D=0.2 λ at the UE when considering the 3-sector cell configuration in Urban macro propagation environment. The channel has been considered fulfilling Kronecker requirement. The corresponding amount of correlation (figure 6) of the channel is plotted following the beamwidth α_0 (tangent value of angle) seen at the eNode B. From this result a set of correlation environments are drawn (see table 1).Both 2x2 MIMO and 4x2 MIMO capacity and error rate performances in comparison with that of the single SISO transmission in the region α_0 = 0.1(moderate correlation level) and the region α_0 =0.025(high correlation level).

7.3 Error and Capacity Analysis

In order to foresee the error rate and capacity performances for those TM, we adopt the 10MHz bandwidth as specified by the 3GPP LTE standard. We also assume that the eNode B requests a 4 CQI_ index .This CQI index correspond to a Quadrature Phase Shift Keying (QPSK) and a channel coding rate of 0.3.

Clearly from fig.7 and 8 depicting the Block error rate and capacity performances. It can be seen that while achieving its highest capacity in acceptable SNR, TM3 BLER remains reasonably performing in terms of BLER. In contrast, TM2 being an error-rate motivation based design, achieves a lowest error rate while not being able to offer a high capacity. In this case of moderate correlation level, the eNode B can only choose to optimize the capacity and thus enable the TM3 mode. Similar analysis for the BLER and capacity performances can be done in high correlation level. As depicted in fig.9 and fig.10.It can be seen that the error–rate for TM3 becomes catastrophic while its capacity also may take slightly an increase. In this case, the eNode B can optimally choose to maximize the spatial diversity by enabling TM2 mode which remains more robust and performing. The Results of this analysis are then satisfactory and in agreement in regard with the proposed adaptive MIMO TM.

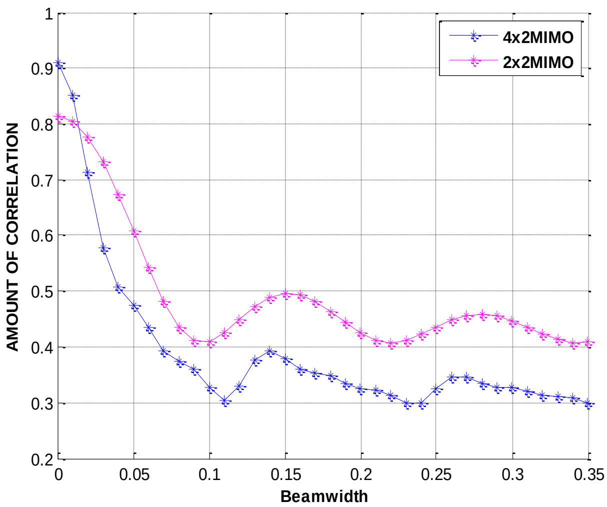

Figure 6 Amount of correlation versus Beamwidth.

8. Conclusion

LTE system is specified transmit in multiple modes depending on MIMO correlation environments. In This paper, we have delimited numerically a set of guard intervals of correlation levels to ensure the good performance for LTE OLSM (TM2, TM3) by studying the interaction between the diversity multiplexing of MIMO correlated channels. An adaptive MIMO switching has been proposed to perform optimally the selection process between TM1, TM2 and TM3 in spatial correlation environments. Beyond, any operator can delimit its own correlation levels by using formulas (10), (11) and (12) in order to specify a given level of TM performance, however we suggest also taking care about the delimitation of MIMO channel correlation levels since the impact of the same value of the amount of correlation on the performances of 2x2 MIMO TMs and 4x2 MIMO TMs cannot be the same. Equivalence class of MIMO channel cannot be used.

Table1. Correlation levels of different scattering environments

α_0	0.025	0.1	0.15
2x2 MIMO(Amount of correlation)	Ψ=0.64: State C3 (high correlation level)	Ψ=0.3283: State C2 (moderate correlation level)	Ψ=0.3782: State C2 (moderate correlation level)
4x2 MIMO(Amount of correlation)	Ψ=0.7558: State C3 (high correlation level)	Ψ=0.4094: State C1 (moderate correlation level)	Ψ=0.4963: State C2 (moderate level of correlation)

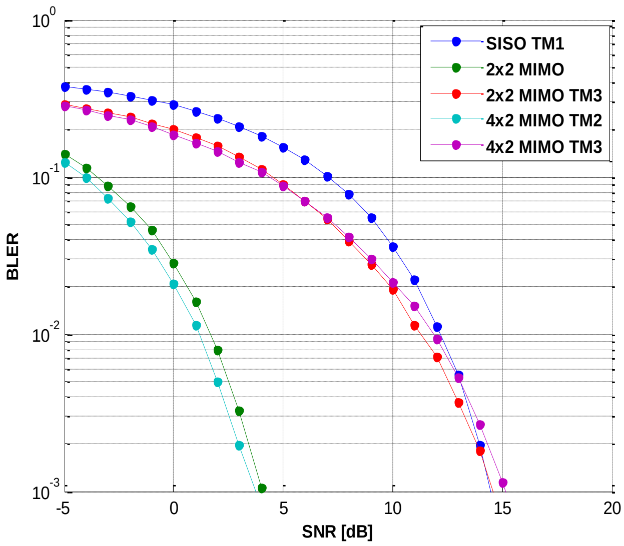

Figure.7 Block error rate performance in the region α_0 =0.1(moderate correlation level environment)

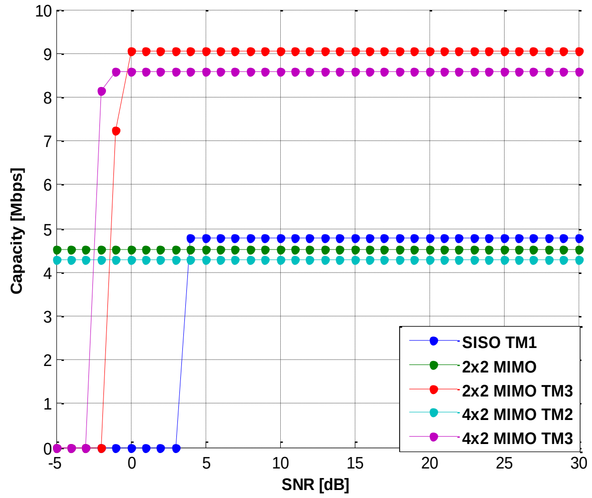

Fig.8 Capacity performance in the region α_0 =0.1(moderate correlation level environment).

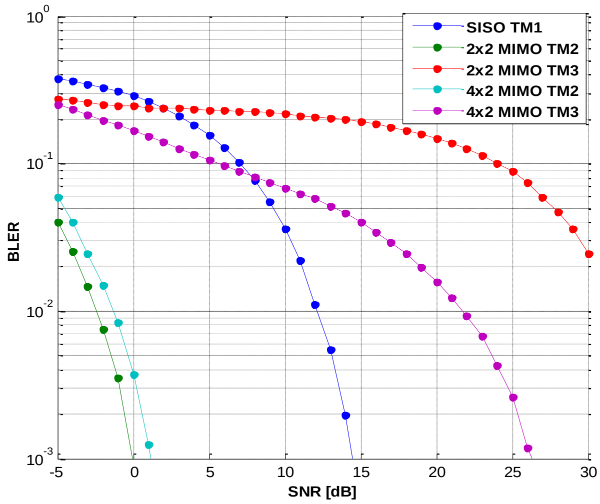

Figure .9 Capacity performance in the region α_0 =0.025(high correlation level).

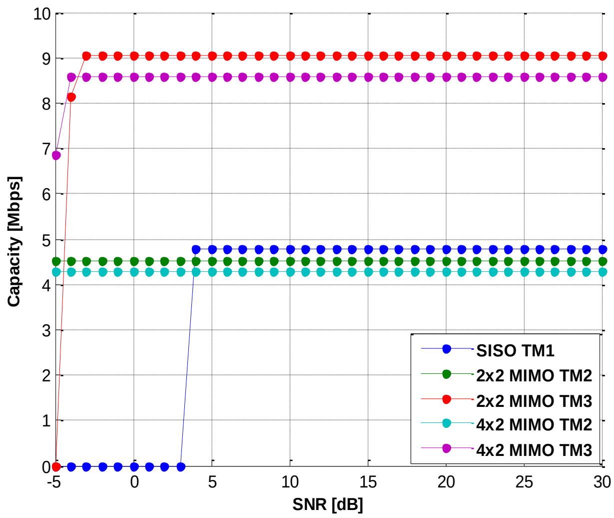

Fig.10 Capacity performance in the region α_0 =0.025(high correlation level).

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