Performance of MIMO Systems over Rayleigh Channels

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Abstract— The aim of this study is to study the architecture of MIMO systems, MIMO technology, with the different types of space-time codes, and spatial multiplexing, combined with the OFDM technique to solve the problem of flow and time. The simulation of the capacity of the various SISO, SIMO, MISO and MIMO channels will highlight the influence of the number of antennas and also the importance of the spatial diversity in the minimization of the error rate in order to obtain better qualities of the signal at the reception.

Keywords— AWGN; MIMO; OFDM; OSTBC; Rayleigh channel

I. INTRODUCTION

With the great growth of wireless communication systems use and the rapid expansion of mobile internet in the four corners of the globe (3G / 4G networks), the majority of research in this area focuses on deployment New technologies to make wireless networks more and more efficient.

The design of new generations of wireless networks is still confronted with the problem of capacity limitation posed by a very narrow bandwidth and often limited transmission power.

In order to overcome these disadvantages, a new technology commonly called MIMO (multiple inputs, multiple outputs) attempts to take advantage of the spatial dimension by installing several antennas at the transmitters and / or receivers [1,2]. Thus, the use of such a technology provides a considerable increase in transmission link rates (keeping the same bandwidth and power).

MIMO technology is considered one of the most innovative technologies in the world of wireless communication and also a strong candidate for the physical layer of the next generation of wireless networks (4G networks and more) [3,4].

MIMO systems introduce a new form of diversity known as spatial diversity. This technique seeks to exploit the phenomena of fading and multi-paths, long considered as handicaps. Indeed, the receiver receives and combines several copies of the same signal sent from several antennas and undergoing independent fading. Therefore, the receiver takes the correct decision to reconstruct the original message without error. In summary, the use of multiple antennas in MIMO systems can be used to improve transmission reliability by reducing the error probability (diversity gain) and increasing the transmission rate (multiplexing gain) [4,5].

The basic idea of MIMO systems is relatively simple: in a given frequency band, the information is transmitted by simultaneously using several antennas for transmission and reception. In a first approximation, the rate transmitted in this frequency band is multiplied by the number of transmitting antennas. Concrete implementation, on the other hand, raises complex problems: indeed, all the signals

transmitted are mixed, and it is necessary to be able to separate the elements from the mixture. Receptor-based methods of signal processing should then be used.
The use of transmitting and receiving antenna arrays thus improves the spectral efficiency and / or the reliability of digital transmissions in an environment rich in diffusers [1-2, 4].

II. GENERAL HYPOTHESIS

The channel under consideration is characterized by:

- Narrowband, non-selective in frequency, and is such that the complex gains h_{ij} follow a Rayleigh distribution.
- The Doppler effect is not taken into account in the channel modeling.
- The additive noise is considered Gaussian white (AWGN).

III. PRESENTATION OF MIMO TECHNOLOGY

The applications envisaged by these MIMO techniques are the wireless local area networks which are probably the first to benefit from technological innovations. The two main reasons are, firstly, that the interior environment is a medium rich in diffusers enabling us to exploit the spatial dimension of the system and, secondly, that the channel coherence time is typically large before a Significant number of symbol periods permitting feedback.
For an SISO system the capacity is given by the well-known Shannon formula:

$$C_{SISO} = \log_2(1+\rho|h|2) \quad b/s/Hz \tag{1}$$

Where h is the complex coefficient of the channel (assumed to be non-dispersive here). This coefficient can be fixed (deterministic channel) or random. ρ represents the receiving SNR. If M antennas are deployed on reception, a SIMO system is obtained with a capacity given by:

$$C_{SIMO} = \log_2(1+\rho\sum_{i=1}^{M}|h_i|2) \quad b/s/Hz \tag{2}$$

Where h_i is the gain for antenna i. The peculiarity of this equation is that a linear growth of M brings only a log growth of the capacity on an AWGN channel. Note that this result is the optimal capacity of any system exploiting diversity in reception. If all the channels h_i are of constant amplitude we find a classic result: the resulting SNR is equal to the product of the single-channel SNR and the number of elements.
If N antennas are now deployed in transmission with only one reception, a MISO system with a capacity given by:

$$C_{MISO} = \log_2(1+\frac{\rho}{N}\sum_{i=1}^{N}|h_i|^2) \text{ b/s/Hz} \tag{3}$$

Where the division by N serves to fix the total power in transmission. In this case, we also observe a logarithmic dependence of the number of antennas N. If now we want to take advantage of the diversity in transmission and reception at the same time, N antennas are deployed and M antennas are received to obtain a MIMO system with A capacity given by the formula:

$$C_{MIMO} = \log_2[\det(I_M+\frac{\rho}{N}HH^{\rightarrow})] \text{ b/s/Hz} \tag{4}$$

Where (→) represents the conjugate transpose and H and an MxN matrix which characterizes the channel. The given capacity increases linearly with m = min (M, N) contrary to a logarithmic growth of the MISO and SIMO system. This is the fundamental result regarding the capacity of MIMO systems, which have become ubiquitous (future WiFi standard, WiMAX, 4G).

This part of simulation studies the impact of the number of antennas on the flow curves. This is to observe the interest of spatial diversity. The sub-channels considered are totally decorrelated, while reducing the power levels; the gains in terms of useful bit rates are very significant.

IV. PERFORMANCE ANALYSIS

We notice a marked increase in capacity for MIMO configuration compared to SISO, SIMO, MISO and MIMO.

The capacity advantage of MIMO systems is mainly due to the use of multiple paths. First, they allow the receiver to differentiate between

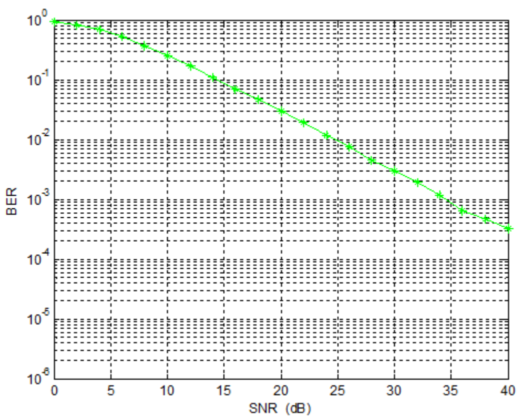

Fig. 1. BER versus SNR for SISO-OFDM.

The simulated channel is a Rayleigh channel, that is, the transmitted signal is affected by fading and white Gaussian additive noise (AWGN).

For weak SNRs, AWGN and fading are the main signal perturbations which give high BER values.

On the other hand, when Eb / N0 (SNR) is larger, the BER falls according to the Rayleigh parameter (the variance of the noise denoted σ^2 the probability of error is minimal for increasing variances).

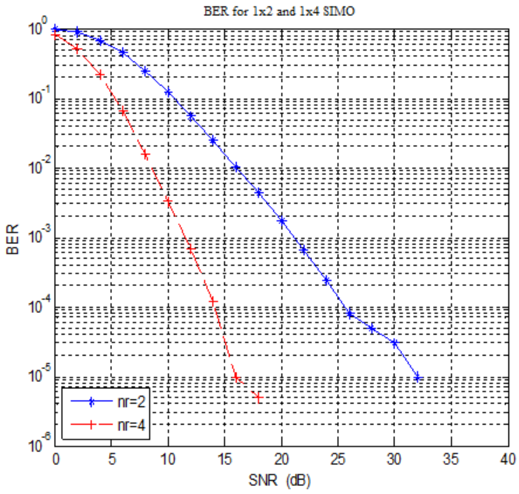

Fig.2. BER for SIMO-OFDM.

The multiplicity of antennas at the reception allows the use of the techniques of combining the replicas to combat distortions and fades undergone by the signal during the transmission. The BER decreases with the increase in the number of antennas for increasing SNRs. The BER decreases with the increase of the number of antennas and the association of the OFDM technique for increasing SNRs [6, 7].

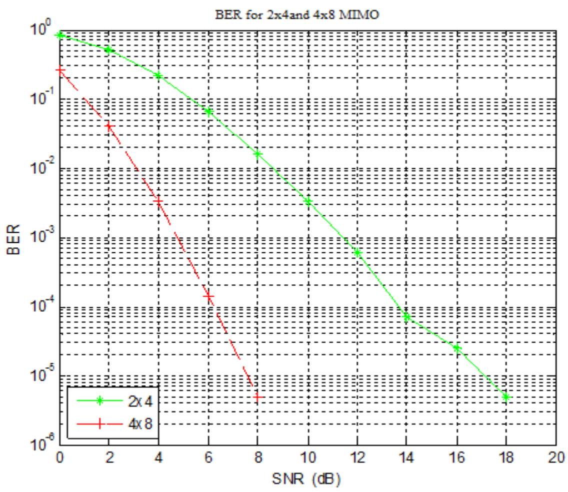

Fig.3. BER with MIMO-OFDM

The use of spatial diversity in transmission and reception leads to the application of reception algorithms. In our simulation it is assumed that the number of receivers is at least as large as the number of transmitters to have a low BER and therefore an optimal signal on reception.

In summary, we can say that the greater the order of diversity, the greater the number of sub-carriers in such a way as to eliminate the phenomenon of interference between symbols, the error rate will be decreasing with the growth of the SNR .

A Comparison between the SIMO-OFDM BER and MIMO-OFDM

In Fig.4 we present a comparison between a SIMO system and MIMO. For an SNR equal to 1 dB the BER is about: $10^{-0.15}$ for a SIMO channel, 10^{-1} for a MIMO channel.

For an SNR equal to 5dB the BER is approximately:

$10^{-0.9}$ for a SIMO channel and $10^{-3.2}$ for a MIMO channel.

Thus we note that the BER reaches the value of 10^{-5} for a SNR of 7.5dB (MIMO) and $10^{-4.5}$ for a SNR of 16 dB for SIMO, which shows well the utility of the multiplicity of antennas in emission and Thus receiving the association of the OFDM.

B Space-time codes

MIMO techniques jointly use two types of diversity: emission diversity that uses multiple transmit antennas and reception diversity that uses multiple receiving antennas.
The diversity of reception is perhaps the most obvious solution since it consists in recombining the spatial replicas of the same signal (the channel is supposed known by the receiver).
The emission diversity was gradually imposed by the idea of deploying antenna arrays on the base-station side rather than on the terminal side. The constraints are then smaller (congestion, spacing, topology of the antennas).

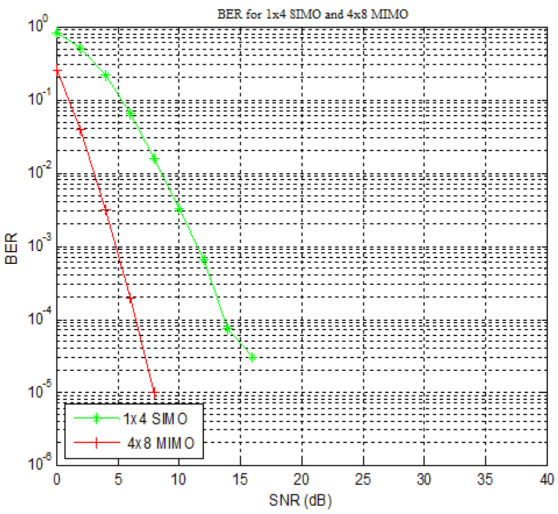

Fig.4. Comparison between SIMO-OFDM and MIMO-OFDM.

Nevertheless, the problem posed by the diversity of emission is to send the signal in parallel on Nt. Nr subchannels with a superposition of waves to the interference-generating receiver, that is: each receive antenna receives a weighted combination of transmitted signals. The decoder is then more complex in the case of MISO than in the case of SIMO.

The capacity of the channel is also decreasing according to Nt. The distribution of power on Nt antennas at transmission is also detrimental. However, the order of diversity with equal number of antennas is exactly the same [2-6].
Space-time coding (STC) has emerged to improve the reliability of transmission in a context of emission diversity. The following figure shows the different families of codes. Two approaches derived from SISO codes exist:
Space-time block coding (STBC) and lattice code (STTC: space-time trellis coding).
The former are simple to implement and the latter offer the best performance. Note that in the context of implementation and even more of prototyping, block codes are almost always preferred to their lattice counterpart.
The block codes split into several groups, playing on the orthogonality of the data transmitted by the antennas, because the superposition of the data on each receiving antenna corrupts the original data. A

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particular coding allowing the receiver to separate them easily is called orthogonal. This qualifier gives its name to one of the groups of the STBC codes:

The OSTBC (Orthogonal STBC). The other groups are then called quasi-orthogonal STBC codes or simply STBC if there is no orthogonality. From the system point of view, the STCs insert redundancy into the symbol flow and thus reduce the useful flow rate. This is referred to as the efficiency of the R code to quantify the useful rate loss.

The yield is always less than or equal to one. The performance, in addition to its performance in terms of reliability of the link is also to be taken into account in the choice of the code.

C Alamouti code:

In order to solve the problem of the decoding complexity for STTC, Alamouti discovered a transmission technique using two antennas at transmission and allowing decoding in the sense of maximum linear likelihood. The following figure shows the operating principle of this transmission technique [8-10]:

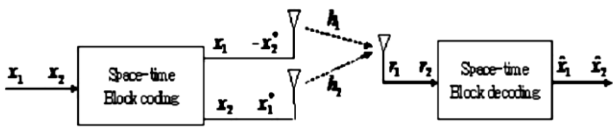

Fig.5Alamouti Scheme

The estimation of the code words x1 and x2 and easy since:

$$[h_2 h_1^{\rightarrow}] \begin{bmatrix} r_1^{\rightarrow} \\ r_2 \end{bmatrix} = (|h_2|^2+|h_1|^2)\, x_1+n_1 \rightarrow \hat{x}_1 \quad (6)$$

$$[-h_1 h_2^{\rightarrow}] \begin{bmatrix} r_1^{\rightarrow} \\ r_2 \end{bmatrix} = (|h_2|^2+|h_1|^2)\, x_2+n_2 \rightarrow \hat{x}_2 \quad (7)$$

Or $r_1 = h_1 x_1 + h_2 x_2$ et $r_2 = h_1(-\hat{x}_2^{\rightarrow}) + h_2 \hat{x}_1^{\rightarrow}$ (8)

The orthogonal coded modulations maximize the gain of spatial diversity (hence of robustness) but do not offer any coding gain. They are perfectly suited for applications where robustness is sought at the expense of flow.

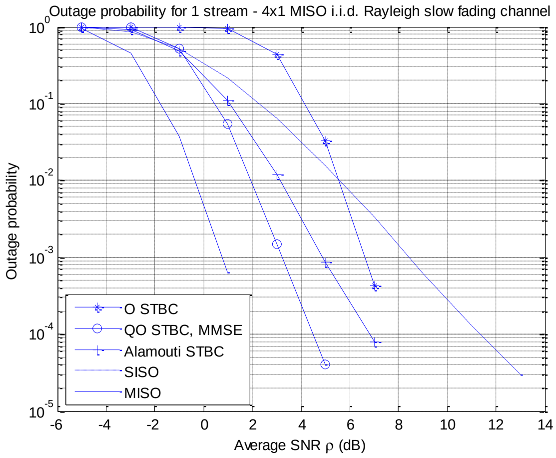

Fig.6 Outage probability versus average SNR

Diversity techniques, and in particular the spatial diversity inherent in MIMOs, are very effective in reducing the impact of various problems such as limitation of the frequency band of the channel, fading and multipath systems. MIMO systems generate diversity gain, which can be used to improve system performance in terms of QoS and transmission throughput.

V. CONCLUSION

This paper is based on the study of the propagation channel capacity, and the minimization of the bit error rate (or symbols). From our results, we can see that capacity grows indefinitely with the number of transmitters and receivers. Moreover, the MIMO-OFDM association makes it possible to obtain better qualities of the signal at reception by eliminating the selectivity of the channel and by reducing the phenomenon of interference between symbols and thus the more the order of diversity increases the higher the rate of The error decreases and the more the signal at reception is optimal (high SNR).

REFERENCES

[1] A. Bouacha, F. Debbat and F.T. Bendimerad, ” Modified blind beamforming algorithm for smart antenna”, Journal of Radio Electronics, N° 1, 2008.
[2] B. Benadda, and F.T. Bendimerad, “Quadratic error optimization algorithm applied to 3D space distributed array sensors”, Journal of Applied Sciences Research, 5(10) pp.1320-1324, 2009.
[3] Kaïs Mabrouk, ” Conception et réalisation d‘un système de Télécommunications MIMO avec formation numérique de Faisceaux en réception ; Calibrage aveugle du Démodulateur triphasé Zéro IF et comparaison au démodulateur classique à 2 voies I et Q ”, Ecole nationale supérieur des télécommunications, 12 Décembre 2008.
[4] I.Ouachani,” Performance analysis of communication systems wireless operator Micro and Macro Diversity”, University of Paris XI Rosary, Discipline: Automatic and Signal Processing, June 28, 2005.
[5] J.Yang and K.Cheun, ” Low Complexity implementation of Alamouti Space-time coded OFDM transmitters “, IEEE Communications letter, vol.8,pp.229-231, April 2004.

[6] N. Bikas Sinha and R. Bera," Investigating the Impact of Hybrid/SPREAD MIMO-OFDM System for Spectral-Efficient Wireless Networks", Research Journal of Applied Sciences, Engineering and Technology 2(3): 289-294, 2010.

[7] T.C.W. Schenk," Performance Analysis of Zero-IF MIMO OFDM Transceivers with IQ Imbalance‖, Journal of communications", Vol. 2, No. 7, December 2007

[8] R. Böhnke, V. Kühn and K.-D. Kammeyer," Adaptive MIMO-OFDM for Future Mobile Radio Communications", IEE International Conference on 3G & Beyond London, GB, 7. - 9. November 2005.

[9] J.Yang and K.Cheun, "Low Complexity Implementation of Alamouti Space- Time Coded OFDM Transmitters", Communications Letters, IEEE, vol. 8, no4, pages 229–231, April 2004.

[10] P.-J. Bouvet and M. Hálard," Near Optimal Performance for High Data Rate MIMO, MC-CDMA Scheme", Multi-Carrier Spread-Spectrum 2006, pp. 303-310