ISSN 2319-8885,Volume01,Issue No. 02

International Journal of Scientific Engineering and Technology Research

www.semargroups.org

Jul-Dec 2012, P.P. 162-168

High Data Rate Operation and BER Performance of OFDM System

YOUSIF JAWAD KADHIM NUKHAILAWI[1], T.MADHAVI KUMARI[2]

[1]M.Tech Student of JNTU-HYD, Hyderabad, AP-India,y.alkafaji@yahoo.com

[2]Associate Prof, Coordinator Academic and Planning,ECE Dept, JNTU-HYD, Hyderabad, AP-India.

Abstract: One of the main challenges of the 4th Generation wireless systems is to provide high data rates in mobile environments. In these 4G products, WiMax (worldwide interoperability for microwave access) and LTE (Long Term Evolution) will be the platform technologies. The rapid development of the Internet with new services and applications has created new challenges for the development of mobile communications systems. Many wireless systems offer high data rate services (IEEE 802.11n, IEEE 802.15.3 and IEEE 802.16). Possible migration of 3G to 4G (LTE) will increase data rates throughput in the range of 100Mbps. These high data rate applications may be difficult to support with the required quality-of-services (QoS) in high mobility environment. the mobile WiMax can be used at mobile speeds of 60 km/h to 120 km/h sufficient for car applications but not for high speed trains. One possible solution is to use a main router for each coach connected with a single antenna to the external broadband network and to distribute the signal inside the coaches thanks to a repeater. An other architecture consider direct transmission to mobile cellular telephone networks using the 3G technology such as the HSDPA (High Speed Downlink Packet Access) and HSUPA (High Speed Uplink Packet Access) allow high-speed data rates, opening the door to a range of mobile usage. All these future and advanced systems are mainly based on orthogonal frequency division multiplexing (OFDM) known to be resistant to various impairments in the mobile channels. In this paper, a transmission system based on OFDM technique and a solution for channel estimation is proposed. The main results will be presented in the case of high mobility context.

Keywords- WiMax, LTE, OFDM, MMSE, QOS, HSDPA.

1. INTRODUCTION

The practice of constraining the data stream in order to mitigate the effects of the communication channel on the received signal, commonly referred to as channel coding, is a fundamental technique in digital communications that is responsible for some of the most dramatic improvements in the modern communication standards. While channel coding is employed in most of today's communication systems, both wireless and wireline, in order to improve on the speed/reliability/ energy efficiency of the system, the technique remains unexploited in a ubiquitous class of communication systems, namely the high-speed backplane and chip-to-chip interconnects. More than just a question of unharvested potential, the increasing network speeds place a large burden on high-speed links, which fail to keep up with the scaling trends. The underlying problem is the bandwidth-limited nature of the backplane communication channel, exacerbated by severe complexity and power constraints.

Despite several recent efforts [1], [2], the topic of channel coding for high-speed links remains largely unexplored due to a lack of suitable analysis and simulation frameworks. The residual intersymbol interference (ISI), coupled with noise and other circuit impairments, significantly obscures the performance picture and renders both the theoretical and computational approaches more arduous. Specifically, the channel memory introduces error correlation in the received symbol stream, regardless of whether the latter is constrained or unconstrained. The code performance is determined by the joint symbol error statistics and, as the task of accurately accounting for the error correlation due to channel memory is combinatorial in nature, exact expressions are computationally intractable.

The problem of estimating the performance of a coded high-speed link is further exacerbated by the low error rates of interest , which render direct Monte Carlo simulation prohibitive and strain the accuracy of common approximations. This paper provides a more systematic look at the potential of bringing energy-efficient channel coding to high-speed links. the systems's error region and the channel's sign signature. The error region corresponds to the set of values in the ISI distribution that are responsible for the majority of errors. While the error region is determined by the combined noise and the magnitude of the coefficients forming the channel's pulse response, the channel signature is specified by the signs of those coefficients. It relies on accurately capturing the short-term error correlation within nonoverlapping blocks of symbols and assumes independence in the error behavior across distinct blocks, rather than individual symbols. The computational mechanics are Transmit/receive equalization is reflected on the symbol-spaced pulse response. those of integer partitions and the approach is computationally efficient for high-speed link channels. The proposed analysis and simulation frameworks also present a realistic case cautioning against the use of biased Monte Carlo methods in the performance estimation of coded high-speed links.

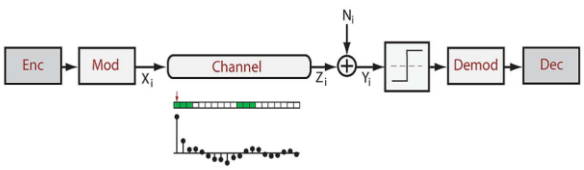

Fig. 1. Simplified model of a high-speed link.

II. SYSTEM MODEL

A simplified model of a high-speed link is shown in Fig. 1. The bitstream, which can be coded or uncoded (unconstrained), is modulated to produce the equivalent symbol stream and transmitted over a communication channel. The system employs PAM2 modulation with detection performed on a symbol-by-symbol basis with the decision threshold at the origin. The transmitter and receiver may contain equalizers, in which case the channel's impulse response may contain residual ISI. The two main mechanisms that account for the most significant portion of the residual ISI in high-speed links are dispersion and reflection. In addition, residual interference may also include co-channel interference, caused, for instance, by electro-magnetic coupling (crosstalk) [3], [4]. As accounting for co-channel interference involves the same set of mathematical tools as accounting for the ISI, the remainder of the paper focuses on the effects of the ISI.

The quantity of interest is the received signal at the input to the decision circuit at time *i*, denoted Y_i and expressed as

$$Y_i = Z_i + N_i \tag{1}$$

where Z_i denotes the received signal in the absence of noise and N_i is the noise term. Specifically, denoting the channel's pulse response by $h_{-k}, \ldots, h_{-1}, h_0, \ldots, h_m$, where $l = k + m + 1$ represents the length of the pulse response and is associated with the principal signal component, and letting $\{X_i\}$ denote a sequence of transmitted symbols, then

$$Z_i = \sum_{j=-k}^{m} X_{i-j} h_j. \tag{2}$$

The noise term, representing the combined thermal noise and timing jitter, is assumed to be Gaussian with the standard deviation of relative to the peak values of 1 V [5].

III. ERROR BEHAVIOR IN SYSTEMS WITH NOISE AND ISI

In the system of Fig. 1, an error at the receiver occurs if the noise and ISI couple to bring the received signal over the decision threshold. It follows that the marginal symbol error probability for the i^{th} symbol is given by

$$p_i = \mathrm{P}(\{Y_i < 0 | X_i = 1\} \cup \{Y_i > 0 | X_i = -1\}) \tag{3}$$

Assuming an unconstrained symbol stream, the marginal symbol error probabilities are equal, that is for all symbols i,j . The quantity *p*, which becomes the relevant figure of merit, is entirely determined by two factors, namely the channel pulse response $h_{-k}, \ldots, h_{-1}, h_0, \ldots, h_m$, and the probability distribution of the noise. Efficient methods of computing the marginal error probability *p* are described in [6], [7] among others.

In a coded system with ISI, this picture changes in two important ways. Due to constraints on the symbol stream, the marginal error probabilities are no longer equal across different symbols. An efficient method of computing for different symbol locations in a codeword is described in [8], which focuses on systematic binary linear block codes. However, the performance of a coded system cannot be expressed through marginal error statistics alone, but is instead dependent on the joint error behavior. For instance, the performance of a -error correcting linear block code is typically expressed through the word error rate (WER), given by the probability of observing at least errors in a codeword.

The following development shows that the complex relation between the ISI and the joint error behavior can be greatly elucidated by decoupling the effects of the magnitude and the signs of the channel's pulse response. Understanding the effect of system's error region and channel's sign signature on error correlation lends a deeper insight into the behavior of codes and the shortcomings of common simulation techniques in high-speed links. Further, an analysis of correlation distance in high-speed links paves the way for a more reliable simulation approach.

A. Error Region, Channel Signature and Error Correlation

The error region for a particular system should be thought of as the set of ISI values that are responsible for the majority of errors at the receiver. More formally, letting $0 < f \leq 1$ denote a lower bound on the proportion of symbol errors ascribed to the error region (e.g., 99% of all errors), the error region is the smallest possible interval of the form such that $\mathcal{E}_f = (-\infty, v]$

$$\mathrm{P}(Z_i \in \mathcal{E}_f | E_i, X_i = 1) \geq f \qquad (4)$$

where denotes the error event on the th symbol. The concept of error region is primarily useful when it is possible to pick large enough so that the ISI events $\mathcal{E}_f$ in are responsible for the majority of the errors, and at the same time small enough so that every event in $\mathcal{E}_f$ is likely to cause an error. For the system of Fig. 1 and some given , the error region is entirely determined by the decision threshold, the noise standard deviation and thechannel pulse response $h_{-k}, \ldots, h_{-1}, h_0, \ldots, h_m$, where $k+m+1=l$. Note that for an unconstrained symbol stream, only the magnitudes of the pulse response coefficients are needed.

The signs of the coefficients are captured by the channel signature $\mathbf{s} = (s_{-k}, \ldots, s_0, \ldots, s_m)$, which takes values from the set $\{-1, 0, 1\}^l$ and is defined as

$$\mathbf{s} = (\mathrm{sign}(h_{-k}), \ldots, \mathrm{sign}(h_{-1}), \mathrm{sign}(h_0), \ldots, \mathrm{sign}(h_m)) \qquad (5)$$

To elucidate the link between the error region, channel signature and error correlation, first consider the case where the error region is limited to the worst-case ISI only, that is, where other ISI events cause error with negligible probability. The corresponding regime is referred to as worst-case-dominant in [9]. Symbol $X_i = 1$ is affected by worst-case ISI when

$$(X_{i+k}, \ldots, X_i, \ldots, X_{i-m}) = \mathbf{p} \qquad (6)$$

where

$$\mathbf{p} = (-s_{-k}, \ldots, -s_{-1}, 1, -s_1, \ldots, -s_m)$$

is referred to as the channel's worst-case pattern.2 It follows that the joint error statistics are entirely determined by the "nesting" properties of the channel'sworst-case patterns, which are in turn determined by the channel's signature. The pattern nests if p and some shifted versions of $\pm\mathbf{p}$, each shifted by at most $l-1$ symbols relative to the first pattern, align exactly on the overlapping symbols. For instance, the pattern $\mathbf{p} = 1\,1\text{-}1\text{-}1\,1\,1$ nests simultaneously in three locations, as shown below

$$\begin{array}{lll} 1\ 1\text{-}1\text{-}1\ 1\ 1 & & = \mathbf{p} \\ \quad \text{-}1\text{-}1\ 1\ 1\text{-}1\text{-}1 & & = -\mathbf{p} \\ \qquad\quad 1\ 1\text{-}1\text{-}1\ 1\ 1 & & = \mathbf{p} \end{array} \qquad (7)$$

Suppose that the channel is such that the worst-case sequences $\pm\mathbf{p}$ nest simultaneously at several locations. Then, among the symbol sequences that are likely to cause an error on at least one symbol, that is, sequences containing $\pm\mathbf{p}$, a relatively large proportion will also contain additional nestings of $\pm\mathbf{p}$. It follows that the error-prone sequences likely cause errors on more than one symbol and the result is generally an increase in the frequency of certain higher-order error events compared to the assumption that errors occur independently across distinct symbols.

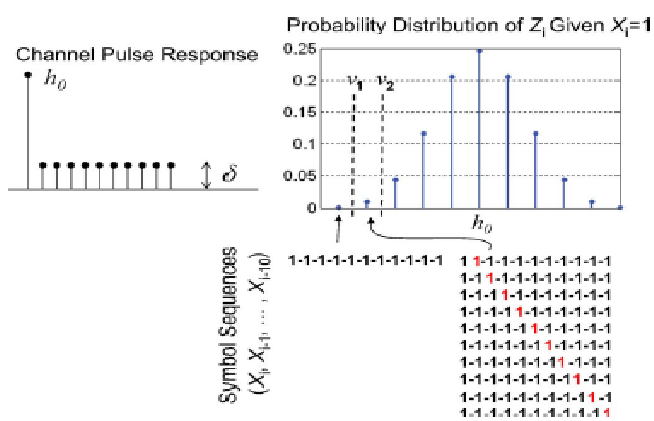

Fig.2. Simplified pulse response [left] and the corresponding ISI distribution [right].

B. Error Correlation in High-Speed Links

In practical channels, the direct link between the channel signature, error region and joint error behavior holds only asymptotically. For instance, in the worst-case-dominant conditions, the problem reduces to the nesting properties of p, while in the limit of large noise, the effect of any channel correlation vanishes as errors become independent. However, both the channel signature and the error region play an important role in determining the joint error statistics. An illustration of the effect of channel signature on error correlation in a realistic high-speed link is shown in Figs. 3 and 4.

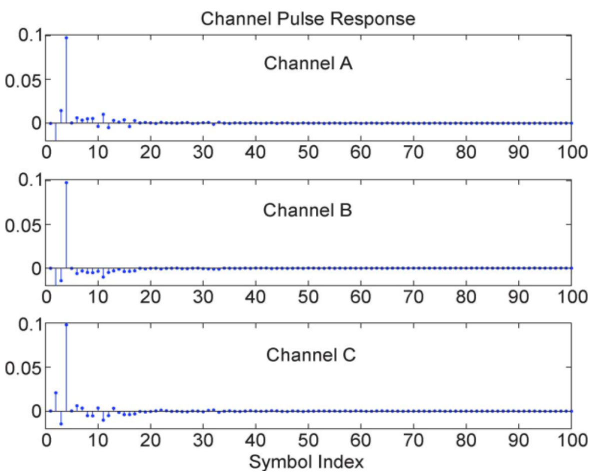

Fig. 3. Equalized pulse response of the standard 802.3ap B32 [10] channel operating at 10 Gb/s. Channel A: Actual channel. Channel B: All-positive signature. Channel C: Randomly generated signature.

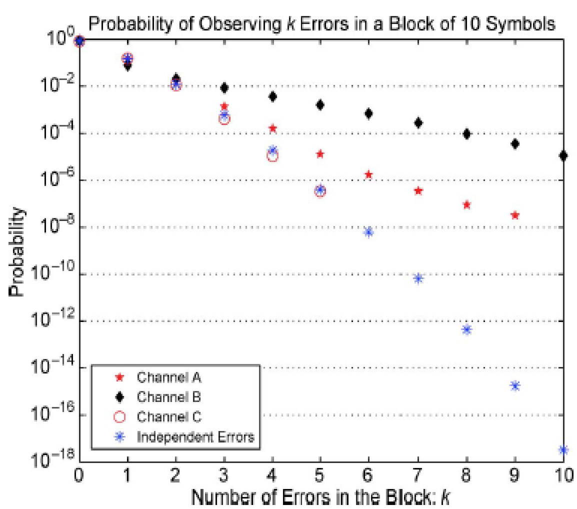

Fig. 4. Joint error statistics for the channels

Unlike the maximally-correlated channel (Channel B), the original channel (Channel A) does not nest in the sense described in the previous section, neither considering the worstcase patterns formed by the entire channel pulse response, nor those formed by the dominant interference coefficients only. However, both channels show a significant increase in the frequency of the higher-order error events compared to the independent-errors assumption. This behavior is analogous to the example of Fig. 2 and is due to the size of the error region, which is made sufficiently large to generate Monte Carlo estimates.

Due to the limitations of the Monte Carlo method, it is difficult to infer the degree and type of error correlation associated with the randomly generated signature (Channel C). The presence of a handful of strong interference coefficients in the previous example is due to the dispersive nature of the high-speed link channel and the presence of signal reflections. In general, the pulse response of a typical high-speed link can contain several clusters of strong interference coefficients, separated by coefficients of significantly weaker magnitudes. This suggests that a viable method of deriving intuition about the error behavior from the channel pulse response consists of considering the error correlation caused by these dominant interference coefficients separately from that caused by the rest of the channel.

IV. Channel estimation of OFDM system for high data rate communications

Mobile communication systems have become one of the most recent areas in the field of telecommunications [1]. In the next ten years, it is predicted that considerable number of connections will become partially or completely wireless. Rapid development of the Internet with new services and applications, like video-on-demand (VoD) over internet and mobile Internet has created new challenges for the further development of mobile communication systems to be connected everywhere. Many wireless systems propose very interesting services at high data rate (IEEE 802.11n, IEEE 802.15.3 and IEEE 802.16) [1, 5] but generally for a non moving user and mainly in the downlink direction. All these new systems are based on OFDM technique. In this context, this paper evaluates the high mobility effect on the coded OFDM system (COFDM) [6, 9] for the return link.

V. OFDM SYSTEM MODEL

The multipath effect introduced by the propagation channel causes interferences between symbols when using a transmission type series. A good solution to overcome the effects of the channel is to use a parallel or multicarrier transmission. The OFDM concept consist to convert the serial coded data stream on parallel blocks and to transmit simultaneously these blocks on several orthogonal carriers by means of the inverse fast Fourier transform (IFFT). Time domain OFDM symbol can be written as (8):

$$x(n) = ifft(X(k)) = \sum_{n=1}^{N} X(k).e^{j2\pi nk/N)} \qquad (8)$$

Where N is the IFFT/FFT size and X(k) is a frequency domain complex coded data symbol at kth subcarrier in OFDM symbol. This data is throughput of either PSK or QAM modulation. The channel code used is concatenated codes with an outer code (RS code) and an inner code (Convolutional code). After the passage in the channel and performing the FFT transform in reception, the frequency domain data symbol at kth subcarrier is given by (9):

$$\mathrm{Y(k) = X(k).H(k) + V(k).} \qquad (9)$$

Where H(k) and V(k) are respectively the channel transfer function and the white Gaussian noise sample. The data sample will be recovered with the well known zero forcing equalization. Thus, the data will be demodulated and decoded in order to reconstruct the transmitted stream. Figure 5 illustrates a synoptic block scheme of the transmission link.

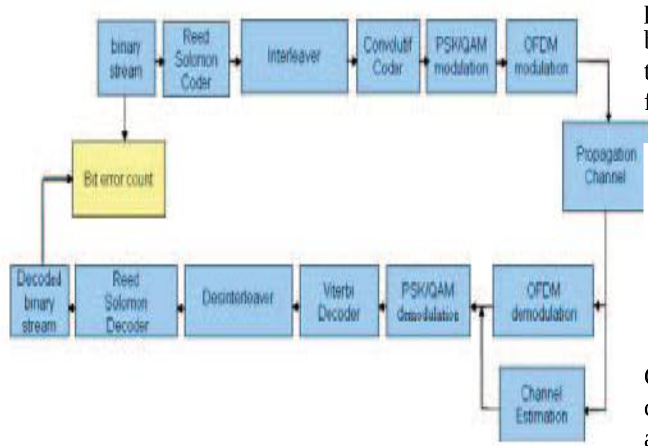

Fig.5. Synoptic block scheme of the transmission link.

VI. CONCATENATED CHANNEL CODE

Convolutional encoding with Viterbi decoding has been used in many digital communications systems, extensively in the satellite communications, in the purpose to increase significantly their performances. A characteristic of the Viterbi decoding process is that errors, that Viterbi decoder can't repair, appear at the decoder output in bursts. A class of codes that are well known to correct bursty errors is the Reed- Solomon code. Then the concatenatatioin of the Viterbi and Reed Solomon codes allows to achieve better decoding results The Reed Solomon codes are part the of block codes family. They are a subset of powerful cyclic BCH codes (Bose Chaudhuri Hocquenghem) based on the coding block and are used in a wide range of applications in wireless digital communications, and data storage. Reed-Solomon codes are cyclic codes with symbols made of m bit sequences, where m is any positive integer having a value greater than 2. RS (n, k) codes on m bit symbols exist for all n and k for which $0 < k < n < 2^m+2$, where k is the number of data symbols being encoded and n is the total number of code symbols in the encoded block (figure 2). For the most usual RS (n, k) code, $(n, k) = (2^m -1, 2^m -1-2t)$ Where t is the symbol error correcting capability of the code, and n - k = 2t is the number of parity symbols.

At the reception, the decoder of Reed-Solomon treats each block and attempts to correct errors and recover the original data. A decoder of Reed-Solomon can correct up to t symbols that contain errors in a code word, where t = (n-k)/2. Code Reed Solomon has a good efficient of error correction since it can correct both a symbol where a single wrong bit or where all the bits are wrong. If the bursts of errors are larger than the possibility of correction of the code, interleaving must be introduce to limit the size of packet of errors. This technique makes this type of coding especially effective for correcting bursts of errors.

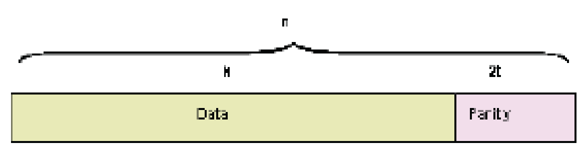

Fig. 6. RS (n, k) package format.

Convolutional codes have rather good correction capability and perform well on very bad channels. Like any error correcting code, a convolutional code works by adding some structured redundant information to the user's data. It associates a bit to send to multiple bits previously transmitted.

A binary convolutional encoder can be represented as a shift register. The outputs of the encoder are modulo 2 sums of the values in certain register cells. A combination of register cells that forms one of the output streams is defined by a polynomial. Let m be the maximum degree of the polynomials constituting a code, then K=m+1 is a constraint length of the code. Encoder polynomials are usually denoted in the octal notation. At reception side, Viterbi algorithm reconstructs ideally the maximum likelihood path given the input sequence. The branch metric is a distance between the received codeword of bits and one of the ideal codeword. A path metric is a sum of metrics of all branches in the path. A meaning of distance depends on the type of the decoder: Hamming distance (i.e. a number of differing bits) with hard decision decoder and Euclidean distance with soft decision decoder. In these terms, the maximum likelihood path is a path with the minimal path metric.

VII. CHANNEL ESTIMATION

Before performing the equalization, the channel transfer function must be estimated. The propagation channel can vary not only from an OFDM symbol to another, but also within the same OFDM symbol. This variation is mainly due to changes in propagation conditions between the transmitter and receiver while the vehicle is moving. The variations in the channel are characterized by the Doppler Effect. The higher the Doppler spread; the faster the time variations of the channel. Since the radio channel is frequency-selective and time-varying, then appropriate channel estimation techniques are necessary for proper detection of OFDM signals. A classical approach for the channel estimation is made through pilots transmission (training sequence). However, these techniques require the channel variations to be slow compare to the transmitted data rate (channel invariant over several OFDM symbols or a block of symbols). Another type of channel estimation is through comb-type pilot (pilot subcarriers over several OFDM symbols) which could require channel equalization if the channel is fast fading. Simple, yet practical, channel estimation technique is based on the least squares (LS) criteria [10].

VIII. SIMULATIONS

In order to obtain simulation results, we have used a COFDM (Coded OFDM) system simulated with a 2 MHz bandwidth. The total number of subcarriers is 512 in which 360 subcarriers are deployed for data transmission and 60 subcarriers are used like pilots. We set to zero the middle DC carrier and the lateral 91 subcarriers placed on left and on right of the OFDM symbol spectrum. A cyclic prefix (CP) with 64 samples is used [4] Two modulations are used (QPSK, and 16QAM).

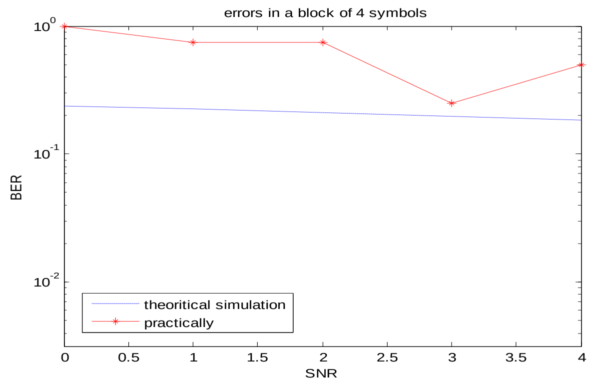

Fig7. Performance of SNR Vs BER at 4-symbols

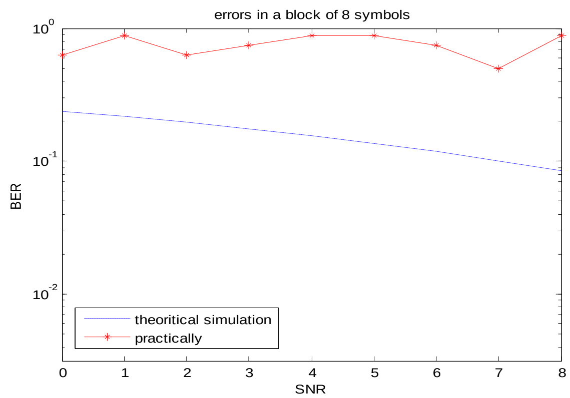

Fig8. Comparison of SNR Vs BER at 8-symbols

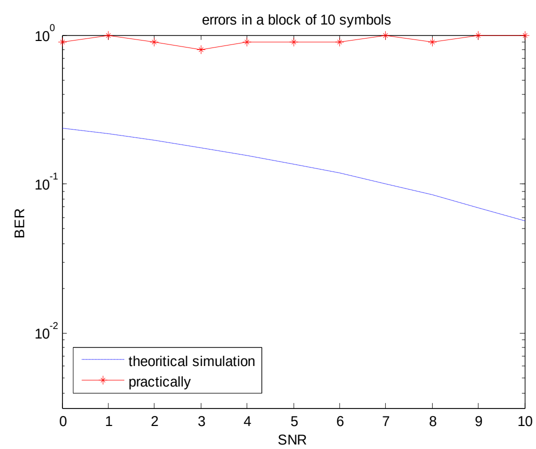

Fig9.Comparison of SNR Vs BER at 10-symbols

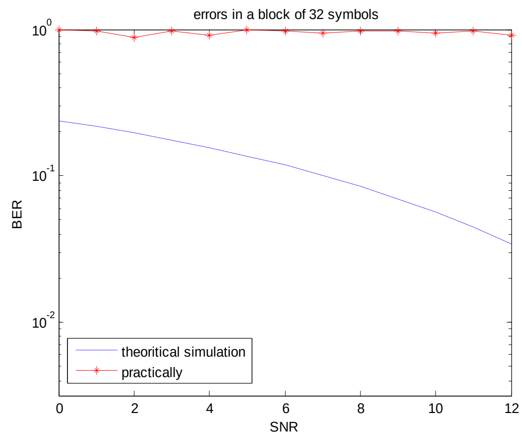

Fig10. Performance of SNR Vs BER at 32-symbols

IX. CONCLUSION

In this paper, we highlight the consequences of the OFDM system performances. In this purpose, the bit error rate performances of COFDM link over mobile channel model are examined. Channel estimation results for different modulations (QPSK and 16QAM) are given at medium and high mobile speed. Likewise, the MSE channel estimation behavior of a QPSK for different mobile velocities is treated, Decoupling the effect on the joint error behavior of the magnitudes of the pulse response coefficients from the corresponding sign signature yields a deeper insight into the nature of error correlation in high-speed links. It shows that error correlation is not to be ignored when evaluating the performance of coded high-speed links and, through the concept of correlation distance, yields a simple statistical method that takes into account varying degrees of short-term correlation, predominant in highspeed links.

X. REFERENCES

[1] A. Dowler, A. Doufexi and A. Nix, "Performance Evaluation of Channel Estimation Techniques for a Mobile Fourth Generation Wide Area OFDM System," Vehicular Technology Conference, 2009. Proceedings. VTC 2002 Fall, 2002 IEEE 56th, vol.4, pp. 2036 – 2040, 2008.

[2] C. Xiao, Y. R. Zheng, and N. C. Beaulieu, "Novel Sum of Sinusoids Simulation Models for Rayleigh and Rician Fading Channels," IEEE transaction on wireless communications, vol. 5, N°. 12, Dec 2009.

[3] E.A.Ratzer, "Convolutional code performance as a function of decoding delay," Cavendish Laboratory, Cambridge CB3 0HE, 2008.[4] F. Hsieh, F. Wang and A. Ghosh, "Link Performance of WiMAX PUSC," Wireless Communications and Networking Conference, 2008. WCNC 2008. IEEE, pp. 1143 – 1148, Apr 2008.

[5] IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1, 2008.

[6] J.C. Rault, D. Castelain and B.L Le Floch, "The coded orthogonal frequency division multiplexing (COFDM) technique, and its application to digital radio broadcasting towards mobile receivers," Global Telecommunications Conference 1989 and Exhibition. GLOBECOM, IEEE, vol.1, pp: 428 – 432, Nov 1999.

[7] M. Chennaoui, M. Berbineau, A. Rivenq and J. Assad, "Performance of turbo coded OFDM for communication in railways environment," Proceedings of the 6th World Wireless Congress, WWC'2005, San Francisco, CA, USA, may 24-27, 2008.

[8] V. Ponnampalam, A. Grant, "An efficient SISO algorithm for reed-solomon codes," Information Theory, 2003. Proceedings. IEEE International Symposium on. Volume , Issue , pp : 204 –20429, Jul 2003.

[9] Y. Yu, H. Zhijian , Z. Chengxue, Z. Qiang and Z. Haibin, "Realization of High Speed Digital Carrier Communication Module Using COFDM," IEEE International Conference on Electric Utility Deregulation, Restructuring and Power Technologies (DRPT2004), Hong Kong, Apr 2004.

[10] L. Wookwon, "On channel estimation for OFDM systems in multipath environments with relatively large delay spread," Vehicular Technology Conference, 2003. VTC 2003-Spring. The 57th IEEE Semiannual, Volume 2, 22-25 April 2003 Page(s):1303 - 1307 vol.2. 2003.

[11] L. Deneire, P. Vandenameele, L. van der Perre, Bert Gyselinckx, and M. Engels, "A Low-Complexity ML Channel Estimator for OFDM," IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 51, NO. 2, FEBRUARY 2003.

[12] P. Chen H. and Kobayashi , "Maximum likelihood channel estimation and signal detection for OFDM systems," Communications, 2002. ICC 2002. IEEE International Conference on, Volume: 3, On page(s): 1640- 1645 vol.3, Aug 2002.