Paper

PHY Abstraction Methods for OFDM and NOFDM Systems

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Abstract— In the paper various PHY abstraction methods for both orthogonal and non-orthogonal systems are presented, which allow to predict the coded block error rate (BLER) across the subcarriers transmitting this FEC-coded block for any given channel realization. First the efficiency of the selected methods is investigated and proved by the means of computer simulations carried out in orthogonal muticarrier scenario. Presented results are followed by the generalization and theoretical extension of these methods for non-orthogonal systems.

Keywords— orthogonal and non-orthogonal multicarrier systems, PHY abstraction methods.

1. Introduction

In the past where multi-modal operation was not an option, the role of performance evaluation (analytically or by simulation) was to simply check whether a given signal design met the pre-specified performance requirements. The average performance of a system was quantified by using the topology and the channel macro-characteristics in order to compute a geometric (or average) signal-to-interference plus noise ratio (SINR) distribution across the cell. If there were degrees of freedom either for transmitter-based signal design or for receiver-based algorithmic choice, then the role of performance evaluation was to pick the right set of parameter values so as to optimize a performance metric. In that sense, performance evaluation started becoming an integral part of the system design process itself, and the motivation thus arose to have simple analytic forms for these performance results which would make them amenable to easy parametric optimization.

Once the design aspect advances to become multi-modal and multi-parametric at both sides of the transmission link (e.g., current orthogonal frequency division multiplexing (OFDM) based systems: 3rd generation partnership project-long term evolution (3GPP-LTE), worldwide interoperability for microwave access (WiMAX)), the task of link-performance evaluation becomes not only germane to the design procedure itself, but the effective and efficient representation of this parameterized performance in ways that are compact (parsimonious) yet accurate comprises a main challenge of the optimization task.

Compact-description models are also of great interest in the context of evaluation methodologies (EVM's) which are currently being developed for various systems in the respective standardization bodies (e.g., IEEE 802.16m Task Group [1]). The goal of this type of physical-layer (PHY) abstraction is to determine the performance of a given link and thus avoid the need for extensive simulation. This "simulation-shortcut" accelerates the corresponding system-level simulations where a large number of physical-layer-related links need to be taken into account. The abstraction should be accurate, computationally simple, relatively independent of channel models, and extensible to interference models and multi-antenna processing.

A very novel and challenging task is to define the proper (PHY) abstraction methods for the non-orthogonal mutlicarrier (NOMC) systems, which are gaining the interest in the area of considered future wireless communication techniques. In the case of non-orthogonal frequency division multiplexing (NOFDM) signals, the impulses used at the transmitter overlap each other both in time and in frequency domain, thus they are not orthogonal. The shape and the signaling time of the applied impulses can be chosen without any restrictions besides ensuring that the pulses used at the receiver are biorthogonal to pulses used on the transmitter side. The (NOFDM) systems are the part of the larger set of generalized mutlicarrier (GMC) systems, where all of the transmit parameters can be in general chosen without any specified restriction. Thus a GMC signal set includes the orthogonal multicarrier signals as well.

The remainder of the paper is organized as follows: first the idea of (PHY) abstraction methodology is described and some possible abstraction methods are presented. These are followed by some results obtained for (OFDM) scenario. Finally, the main features of (NOFDM) systems are presented and the proposals for modification of some abstraction methods for (NOFDM) case are described. The whole paper is summarized in the last section.

2. PHY Abstraction Methodology

Physical-layer abstraction methodology for predicting instantaneous link performance for OFDM systems has been an active area of research and has received considerable attention in the literature [2]–[11]. The content in this section is based on the evaluation methodology document [1] of the ongoing work in IEEE 802.16m Task.

In a coded OFDM system, the coded block is transmitted over many subcarriers usually over a frequency selective channel, resulting in unequal channel gains for the subcarriers, and thus non-uniform and time-varying post-processing SINR values just prior to decoding. The task of the PHY abstraction methodology is to predict the coded block error rate (BLER) across the OFDM subcarriers transmitting this forward error correction (FEC) coded block for any given channel realization (not averaged over the channel statistics). To do that, the vector of post-processing SINR values at the input to the FEC decoder are also considered as the input to the PHY abstraction methodology. As the link-level BLER curves are always generated based on a frequency-flat channel for various SINR's, an effective SINR (ESINR) is required to map the system-level SINR vector on these link-level BLER curves to determine the resulting BLER. This mapping is termed effective SINR mapping (ESM). The PHY abstraction is thus tantamount to compressing the vector of received SINR values to a single ESINR value, which can then be further mapped to a BLER number.

Several ESM approaches for predicting the instantaneous link performance have been proposed in the literature, including: mean instantaneous capacity [2]–[4], exponential-effective SINR mapping (EESM) [5]–[8] and mutual information effective SINR mapping (MIESM) [9], [10]. Each of these approaches uses a different function to map the vector of SINR values to a single number. In general, any ESM PHY abstraction method can be described via the following equation:

$$SINR_{eff} = \Phi^{-1}\left(\frac{1}{N}\sum_{n=1}^{N}\Phi(SINR_n)\right), \tag{1}$$

where: $SINR_{eff}$ is the effective SINR, $SINR_n$ is the SINR in the nth subcarrier, N is the number of symbols in a coded block, or the number of subcarriers used in an OFDM system, and Φ is the invertible function that defines the specific ESM.

Another important abstraction step is the per-tone SINR computation. All PHY abstraction metrics are computed as a function of post-processing per-tone SINR values across the coded block at the input to the decoder. The post-processing per-tone SINR is therefore dependent on the transmitter/receiver multiple input multiple output-space time coding (MIMO-STC) structure used to modulate/demodulate the symbols.

2.1. PHY Abstraction Methods for OFDM Systems

2.1.1. Mutual Information Based Effective SINR Mapping – Received Bit Mutual Information Rate (RBIR)

The computation of the mutual information per coded bit can be derived from the received symbol-level mutual information; this approach is termed received bit mutual information rate (RBIR). For a soft-input/soft-output (SISO)/soft-input/soft-output (SIMO) system the symbol mutual information (SI) is given by [1]

$$SI(SINR_n, m(n)) = \log_2 M - \frac{1}{M}\sum_{m=1}^{M} E_U\Big\{\log_2\Big(1 + \sum_{k=1,k\neq m}^{M} e^{-\frac{|X_k - X_m + U|^2 - |U|^2}{1/SINR_n}}\Big)\Big\}, \tag{2}$$

where: U is zero mean complex Gaussian with variance $\frac{1}{2SINR_n}$ per component, $SINR_n$ is the post-equalizer (SINR) at the nth symbol or subcarrier and $m(n)$ is the number of bits at the nth symbol (or subcarrier).

Assuming N subcarriers are used to transmit a coded block, the normalized mutual information per received bit (RBIR) is given by

$$RBIR = \frac{\sum_{n=1}^{N} SI(SINR_n, m(n))}{\sum_{n=1}^{N} m(n)}. \tag{3}$$

2.1.2. Mutual Information Based Effective SINR Mapping – Mean Mutual Information per Bit (MMIB)

The mutual information can be defined on the bit channel, which is referred as the mutual information per coded bit. The bit channel is obtained by defining the mutual information between bit input into the quadrature amplitude modulation (QAM) mapping and log-likelihood ratio (LLR) output at the receiver. The concept of "bit channel" encompasses SIMO/MIMO channels and receivers. The main difference between the bit and symbol level mutual information (MI) definitions is that the bit LLR reflects the demodulation process to compute LLR, which was not reflected in the symbol-level. The MMIB can be expressed as [1]

$$MI = \frac{1}{mN}\sum_{n=1}^{N}\sum_{i=1}^{m} I_{m,b_i(n)}(SINR_n) = \frac{1}{N}\sum_{n=1}^{N} I_m(SINR_n). \tag{4}$$

The mean mutual information is dependent on the SINR on each modulation symbol (index n) and the code bit index i (or ith bit channel), and varies with the constellation order m. In order to construct a numerical approximation can be used, for details refer to [1].

2.1.3. Exponential-Effective SINR Mapping (EESM)

The EESM abstraction method is given by [1]

$$SINR_{eff} = -\beta \ln\left(\frac{1}{N}\sum_{n=1}^{N} e^{-\frac{SINR_n}{\beta}}\right), \tag{5}$$

where: β is a value for optimization/adjustment that depends on the modulation and coding scheme (MCS) and the encoding block length.

2.2. Evaluation of Selected ESM Methods

In this section a preliminary assessment of the abovementioned ESM methods for the SISO case are presented. The simulation parameters are chosen based on the WiMAX standard, as a typical example of OFDM system with a variety of operational modes (modulation, coding rate, number of subchannels). For the selected schemes, 100 different channel realizations with normalized total power (over the used subchannels) were produced.

The simulation parameters are:

– channel type: scenario definition in the timing definition language (TDL), pederastian B for 100 different channel realizations;

- subcarrier allocation method: full usage of subchannels (FUSC);
- code type: convolutional turbo code;
- chosen modulation/coding schemes: 4QAM with rate 0.75 for 1 subchannel per coded block (12 bytes); 4QAM with rate 0.75 for 6 subchannels per coded block (72 bytes); 64QAM with rate 0.5 for 3 subchannels per coded block (108 bytes).

In Figs. 1–4 with points are the additive white Gaussian noise (AWGN) link performance curves, while with solid line are the different realizations of the frequency selective case. The figures display the BLER based on the chosen ESNR metric per different channel realization.

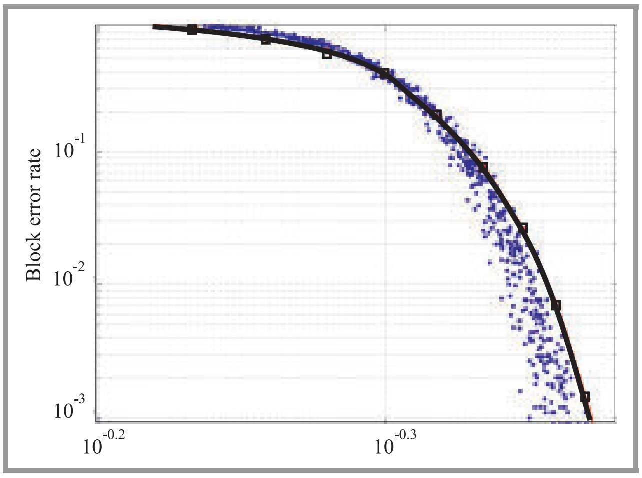

Fig. 1. The BLER based on the RBIR metric, 4-QAM, rate = 0.75, per 1 subchannel.

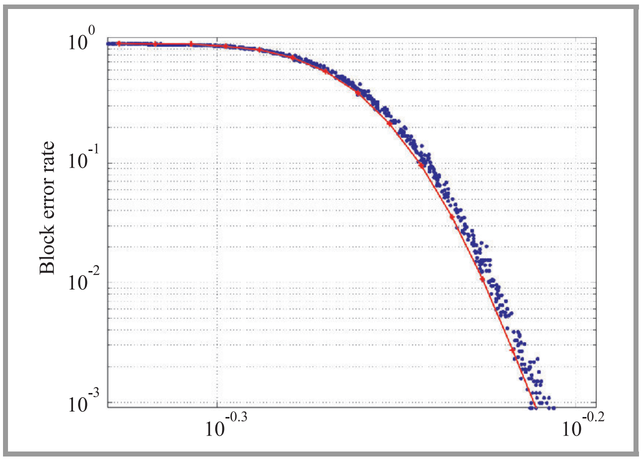

Fig. 2. The BLER based on the MMIB metric, 64-QAM, rate = 0.5, per 3 subchannels.

From the system level simulation perspective, the performance curves for all the methods exhibits low dispersion and good prediction since they are close to the AWGN reference curves. In the EESM case a calibration factor is used (β) for each MCS. The performance is plotted for two

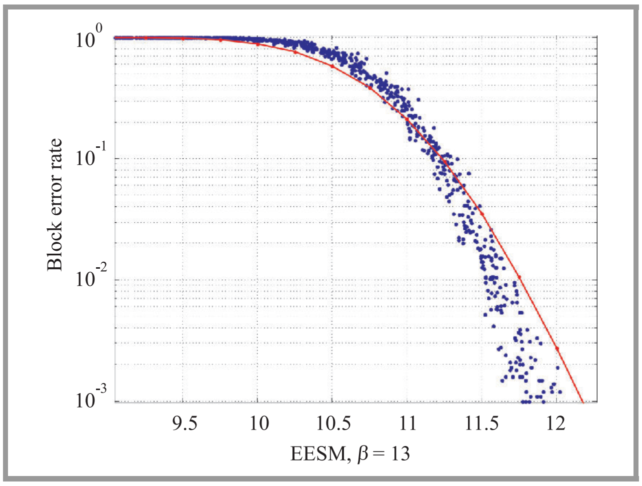

Fig. 3. The BLER based on the EESM metric, 64-QAM, rate = 0.5, per 3 subchannels, $\beta = 13$.

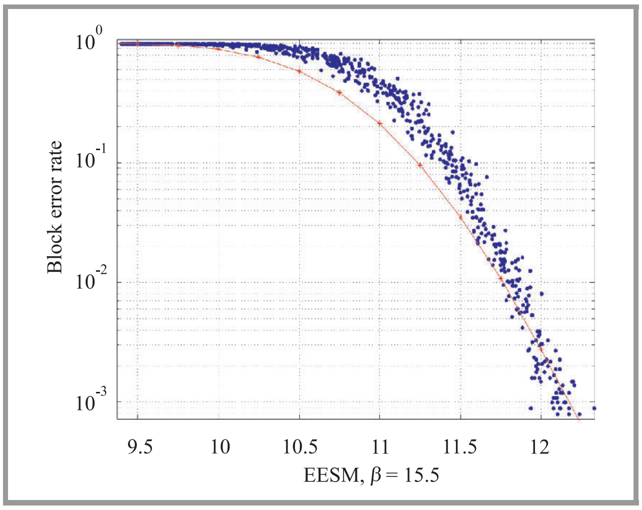

Fig. 4. The BLER based on the EESM metric, 64-QAM, rate = 0.5, per 3 subchannels, $\beta = 15.5$.

different selections of β. This demonstrates that the prediction accuracy in different BLER areas can be controlled via proper calibration, and this property can be exploited in the design of adaptive modulation and coding (AMC) algorithms.

3. PHY Abstraction Proposal for NOFDM Systems – Theoretical Analysis

In this section the main features of NOFDM systems are presented, which are followed by the preliminary modification proposals of PHY abstraction methods for NOFDM systems. Let us stress that the presented proposals need to be intensively tested by the means of computer simulation, which will be the next step of common investigation in this area.

3.1. NOFDM Signal Description

The non-orthogonal multicarrier signal belongs to particular subclass of all multicarrier signals (known as GMC signals) for which the neighboring information-bearing-pulses are not orthogonal. Such approach is in opposition to the well-known OFDM signals, where the pulses transmitted on adjacent subcarriers are mutually orthogonal. From the mathematical point of view, the transmit signal $s(t)$ (one NOFDM frame of N subcarriers and L time slots) is represented as the superposition of the translated and modulated elementary functions $g(t)$ multiplied by the weighting coefficients $c_{l,n}$:

$$s(t) = \sum_{l=0}^{L-1} \sum_{n=0}^{N-1} c_{l,n} g(t - lT) \mathrm{e}^{2\pi jnFt} = \sum_{l=0}^{L-1} \sum_{n=0}^{N-1} c_{l,n} \cdot g_{l,n}(t). \tag{6}$$

The above equation describes the inverse Gabor transform, and the weighting coefficients $c_{l,n}$ are the so-called Gabor coefficients, which are obtained by the means of Gabor transform [12]–[14]:

$$c_{l,n} = \int_{-\infty}^{\infty} s(t) \cdot \gamma_{l,n}^{*}(t) dt, \tag{7}$$

where: $\gamma_{l,n}(t)$ represents the window function (localized at time-frequency point (l,n) on time-frequency grid and dual to $g_{l,n}(t)$) used at the receiver to recover the transmit data and $(^{*})$ denotes conjugation.

One can observe, that each coefficient $c_{l,n}$ can be treated as the transmit data symbol located at the nth subcarrier in lth time period carried by the pulse $g_{l,n}(t)$. It is worth mentioning that in order to represent any signal by the means of the sum of the elementary pulses $g_{l,n}(t)$ (called also atoms), these pulses have to create the basis (denoted hereafter as $\boldsymbol{G}$) which spans the considered signal space. In other words, the forward and inverse Gabor transform switch the spaces from one-dimensional (time domain) to two-dimensional (time-frequency plane) and backwards, respectively. At the receiver, the dual set of elementary functions $\gamma_{l,n}(t)$ has to be applied, which constitute the basis $\boldsymbol{\Gamma}$. In order to ensure the perfect reconstruction requirement, the biorthogonality condition between the elementary pulses used on the transmitter and on the receiver side has to be fulfilled [15]. The two abovementioned sets of pulses will be biorthogonal, only if the following relation is true:

$$\sum_{l,n} g_{l,n}(t) \gamma_{l,n}(t') = \delta(t - t'), \tag{8}$$

where $\delta(x)$ is the well-know Dirac delta function, which is non-zero only for $x = 0$. Let us stress, that the set of elementary functions constitutes also the so-called "frame" [13], [14] – in such a case, there exist real numbers A and B, $0 \le A \le B < \infty$, for which the following relation holds:

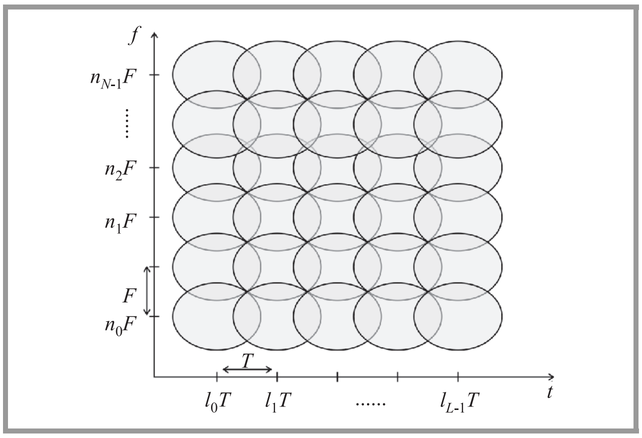

Fig. 5. Time-frequency representation of one GMC frame.

$$A \|s(t)\|^2 \le \sum_{l,n} |\langle s(t), g_{l,n}(t) \rangle| \le B \|s(t)\|^2, \tag{9}$$

where $\|\cdot\|$ and $\langle\cdot\rangle$ are the norm and the inner product, respectively, and $s(t)$ is the data signal.

The exemplary GMC signal frame is depicted in Fig. 5, where one circle represents one waveform. One can observe, that in general the neighboring pulses can overlap each other both in time and in frequency domain.

3.2. Proposals of Modification of PHY Abstraction Methods for NOFDM Systems

When referring to the NOFDM systems, the following aspects have to be considered: first, the NOFDM signal (frame) is represented on time-frequency plane, thus the algorithms shall be two-dimensional, second – the neighboring atoms overlap each other in both domains. These two phenomena have a significant impact on the definition of PHY abstraction methods. In the following the proposals of modification of selected PHY abstraction methods for NOFDM systems will be shortly presented and explained.

3.3. General Considerations

As highlighted in the previous section, besides the straightforward change from one-dimensional to two-dimensional processing, the overlapping between neighboring pulses has to be considered. Thus, in the first step, let take into account all separated values of $SINR_{l,n}$ (related to one atom on time-frequency plane) in the calculation of the effective $SINR_{eff}$:

$$SINR_{eff} = \Phi^{-1} \left(\frac{1}{LN} \sum_{n=0}^{N-1} \sum_{l=0}^{L-1} \Phi\left(SINR_{l,n}\right) \right). \tag{10}$$

Obviously, the definition of the $SINR_{l,n}$ has to be adjusted to NOFDM case, since the power of residual interferences (i.e., the total amount of power coming from the adjacent atoms and affecting the considered pulse at time-frequency point (l,n)) has to be considered. Let us start from deriving the expression of SINR value for orthogonal systems, in which the cyclic prefix is added at the beginning of every OFDM transmit symbol. Based on [8], one can define the SINR value for nth subcarrier as

$$SINR_n = P_n\overline{G}\left(\frac{N}{N+N_P}\right)\left(\frac{R_D}{N_{sd}/N_{st}}\right), \quad (11)$$

where: P_n is the frequency-selective fading power value for nth subcarrier, N_p is the length of the cyclic prefix, R_D denotes the power allocated to the data subcarriers, N_{sd} is the number of data subcarriers and N_{st} is the number of total useful subcarriers.

In other words, the factor within the first brackets describes the power loss due to the cyclic prefix removal at the receiver, whereas the term in second brackets indicates the pilots/signaling overhead (the percentage of power allocated to data subchannels referred to the relative numbers of data subcarriers to total useful subcarriers). The so-called geometry $\overline{G}$ (which includes all other factors that affect the received SINR, such path loss, shadowing, interference form base stations, etc.) can be defined as

$$\overline{G} = \frac{I_{or}}{I_{oc}+N_0}, \quad (12)$$

where: I_{or} is the total received signal power prior to any receiver processing, I_{oc} denotes the total interference power and N_0 is the thermal noise power measured across the noise bandwidth.

In order to adjust the SINR definition to the NOFDM case, the above equations have to be rewritten as follows. First, let define the SINR value related to one waveform localized at (l,n) point on time-frequency grid as

$$SINR_{l,n} = P_{l,n}\overline{G_{ln}}\left(\frac{N_s}{N_s+N_P}\right)\left(\frac{R_D}{N_{sd}/N_{st}}\right), \quad (13)$$

where all of the parameters should be interpreted on time-frequency (two-dimension) plane. That is, N_s denotes the number of samples of transmit signal (one NOFDM frame) in time-domain without the cyclic prefix of the length of N_P samples, R_D is the total power allocated to data pulses, whereas N_{sd} denotes the number of data-bearing pulses and N_{st} is the total number of useful waveforms on time and frequency (TF) plane. Moreover, one of the reasons for applying of NOFDM is to remove the cyclic prefix used in OFDM to mitigate the effect of inter-symbol interference (ISI). In such a case, above relation can be simplified:

$$SINR_{l,n} = P_{l,n}\overline{G_{ln}}\left(\frac{R_D}{N_{sd}/N_{st}}\right). \quad (14)$$

Moreover, the geometry $\overline{G_{l,n}}$ can be defined as

$$\overline{G_{l,n}} = \frac{I_{or}}{I_{oc}+I_{int}^{(l,n)}+N_0}, \quad (15)$$

where $I_{int}^{(l,n)}$ describes the amount of power that comes from the neighboring pulses and affect the transmit data atom at (l,n) point of TF grid.

3.4. Received Bit Mutual Information Rate (RBIR) ESM

In Subsection 2.1, the RBIR ESM method has been introduced. For NOFDM case the RBIR metric definition has to be adjusted to two-dimensional signal representation. Thus, instead of one sum operation over N subcarriers, two sum operations over whole time-frequency plane have to be calculated. In such a case, the values of $SINR_{l,n}$ (see Eq. (14)) and number of bits m assigned to each pulse on time-frequency plane have to be computed. The RBIR metric in NOFDM scenario can be expressed as

$$RBIR = \frac{\sum_{n=0}^{N-1}\sum_{l=0}^{L-1} SI\left(SINR_{l,n}, m(l,n)\right)}{\sum_{n=0}^{N-1}\sum_{l=0}^{L-1} m(l,n)}. \quad (16)$$

In the above equation, the number of bits carried by the pulse localized at the (l,n) point on time-frequency grid is denoted by $m(l,n)$.

3.5. Exponential-Effective SINR Mapping (ESM)

Similar conclusions as for RBIR ESM method can be drawn for EESM PHY abstraction method. In such a case, the effective SINR can be computed as

$$SINR_{eff} = -\beta \ln\left(\frac{1}{LN}\sum_{n=0}^{N-1}\sum_{l-0}^{L-1} \mathrm{e}^{-\frac{SINR_{l,n}}{\beta}}\right). \quad (17)$$

The simulation have to be carried out to define the values of the unknown parameter β.

3.6. Mean Mutual Information per Bit (MMIB) ESM

In Subsection 2.1, the metric called mean mutual information per bit ESM has been also defined and shortly described. In such a case, the definition of mean mutual information MI should be modified for NOFDM systems as follows:

$$MI = \frac{1}{mLN}\sum_{n=0}^{N-1}\sum_{l=0}^{L-1}\sum_{i=1}^{m} I\left(b_i^{(l,n)}, LLR\left(b_i^{(l,n)}\right)\right), \quad (18)$$

where $b_i^{(l,n)}$ and $LLR(b_i^{(l,n)})$ denote the ith bit in one tuple (block of m bits mapped to one constellation point) carried on the nth subcarrier and lth time slot in one NOFDM frame and the log-likelihood ratio computed for this particular bit, respectively. The mutual information function is assumed to be a function of the QAM symbol SINR, thus the mean mutual information MI may be alternatively written as

$$MI = \frac{1}{mLN}\sum_{n=0}^{N-1}\sum_{l=0}^{L-1}\sum_{m=1}^{m} I\left(SINR_i^{(l,n)}\right). \quad (19)$$

However, the definition of LLR for NOFDM case has to be derived, which takes into account the overlapping phenomenon of neighboring pulses in time and frequency domain. These derivations are out of scope of this paper.

4. Conclusions

In this paper new efficient PHY abstraction methodologies were described, which allow the system designers to reduce the amount of information sent in the reverse channel from the receiver to the transmitter in order to select the appropriate (in terms of error probability) modulation and coding scheme. On the other side, these signal-to-noise ratio (SNR) mapping techniques give the possibility of proper prediction of the BLER value (needed for system-level simulation) without implementing the particular decoding stages. Provided simulation results show the correctness of such approach, and confirm that SNR mapping is the promising technique for carrying out the system-level simulations. Moreover, it is shown, that these methods, originally proposed for OFDM case, can be also adjusted, extended or even generalized for non-orthogonal multicarrier systems. In order to do this, the overlapping phenomena between neighboring pulses has to be taken into account.

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References

[1] IEEE 802.16m-08/004r1, "Evaluation methodology document", http://ieee802.org/16/tgm/

[2] Sony, Intel, "TGn Sync TGn proposal MAC simulation methodology", IEEE 802.11.

[3] ST Micro-Electronics "Time correlated packet errors in MAC simulations", IEEE Contribution, 802.11-04-0064-00-000n, Jan. 2004.

[4] Atheros, Mitsubishi, ST Micro-Electronics and Marvell Semiconductors, "Unified black box PHY abstraction methodology", IEEE Contribution, 802.11-04/0218r1, March 2004.

[5] 3GPP TR 25.892, "Feasibility study for OFDM for UTRAN enhancement (release 6)", ver. 1.1.0, March 2004.

[6] WG5 Evaluation Ad-Hoc Group, "1x EV-DV evaluation methodology – addendum (V6)", July 2001.

[7] Ericsson, "System level evaluation of OFDM – further considerations", TSGRAN WG1, no. 35, R1-03-1303, Nov. 2003.

[8] Nortel, "Effective SIR computation for OFDM system-level simulations", TSG-RAN WG1, no. 35, R03-1370, Nov. 2003.

[9] K. Brueninghaus *et al.*, "Link performance models for system level simulations of broadband radio access systems", in *IEEE 16th Int. Symp. Pers. Indoor Mob. Radio Commun. PIMRC*, Berlin, Germany, 2005.

[10] L. Wan *et al.*, "A fading insensitive performance metric for a unified link quality model", in *Proc. IEEE WCNC'06 Conf.*, Las Vegas, USA, 2006.

[11] I. Dagres and A. Polydoros, "Dynamic transceivers: adaptivity and reconfigurability at the signal-design level", in *SDR Forum Tech. Conf.*, Orlando, USA, 2003.

[12] W. Kozek and A. F. Molisch, "Nonorthogonal pulseshapes for multicarrier communications in doubly dispersive channels", *IEEE J. Selec. Areas Commun.*, vol. 16, no. 8, pp. 1579–1589, 1998.

[13] H. Feichtinger and T. Strohmer, *Gabor Analysis and Algorithms. Theory and Applications*. Berlin: Birkhäuser, 1998.

[14] S. Qian and D. Chen, "Understanding the nature of signals whose power spectrum change with time. Joint analysis", *IEEE Sig. Proc. Mag.*, vol. 16, iss. 2, pp. 52–67, March 1999.

[15] P. P. Vaidyanathan, *Multirate Systems and Filter Banks*. Englewood: Prentice Hall, 1993.

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