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OPTIMAL CODING PERFORMANCE FOR MIMO SYSTEM

K. Prabhakara Rao[1] and P. V. Sridevi[2]
[1]Department of Electronics and Communication Engineering, B.V. Raju Institute of Technology, Narsapur, Telangana, India
[2]Department of Electronics and Communication Engineering, A.U. College of Engineering,Visakhapatnam, Andhrapradesh, India
E-Mail: prabhakar.kapula@gmail.com

ABSTRACT

Estimation of the channel and its performance under dynamic conditions have always remained a challenge for wireless communication domain. New techniques were developed for channel diversity and spectrum utilization. In this paper a new interference management with resource control is proposed, to achieve the objective of higher performance in MIMO systems, using interference conditions. A generic approach for both coordinated and randomized multi-user access strategies for interference mitigation is investigated. The suggested analytical framework develops the correlation of fading channel over the space-frequency domain and non-stationary features of the multipath interference to allocate resources for minimizing interference.

Keywords: MIMO system, coding performance, resource diversity, error estimation.

1. INTRODUCTION

Wireless channels are getting diverse in nature. The uncertainty in channel conditions has degraded the estimation performance of conventional channel estimator logic and needs an updating. The feedback estimators are hence developed to achieve the estimation performance under variant channel condition. Among the various approaches of channel estimation logic, feedback based estimators are used as a feedback estimator, which works with the objective of channel tracking. The estimation process is governed by a state transition logic, where the process of estimation and updating is carried out to obtain a estimate. In the process of MIMO-OFDM channel estimation, the application of feedback filters is made for its simpler coding and estimation performance. However, with the increase in communication approaches and offered services, the conventional model of feedback filtration isneeded to be improved. To derive better performance for such system, different methods were developed in recent past. In [1] frequency selective fading channel estimation is proposed. The issue of channel imperfection is analyzed. A novel method of pilot expansion is proposed to capture the multipath signal arise in the MIMO system. A Decision feedback filter is proposed for channel tracking in the communication system. The approach of flexible pilot flexible coding is being presented. A joint estimation of channel gain and phase noise in MIMO system is analyzed in [2]. A decision directed extended feedback filter for phase noise tracking is developed. The approach of extended feedback filter is observed to be more stable in tracking phase noise estimation. A similar approach of channel estimation in semi-blind approach is proposed in [3]. A recursive estimation updating in feedback based estimation logic using blocks for MIMO system is employed. A dynamic block processing expansion model is presented to channel estimation for fast fading channel. The issue of diversity in MIMO-OFDM system is being analyzed in recent time. In [4] to achieve a faster divergence solution, a channel estimation algorithm based on feedback filter is developed. A state transfer coefficient (STC) is derived with a threshold correction logic for the time varying environment. Towards the issue of user mobility, in [5,6] new scheme of mobility concern in MIMO-OFDM system is suggested. An intelligence logic using fuzzification was developed for variant format of slow, fast and medium speed mobility. The feedback filter is designed to perform the channel estimation for the signal received under mobility condition.The operational efficiency of a channel estimator is dependent on the channel impulse response estimation in MIMO-OFDM system. In [7] a channel impulse response estimation based on the correlation of transmits or receive antennas. An approach of concatenated wiener filters for the optimization of channel estimation by optimizing the channel characteristic in time and frequency domain. In [8], to estimates channels in different high speed mobile environments, a wiener filter based approach with basis expansion model (BEM) is presented. The suggested approach provides a better estimation under time variant channel condition. Towards effective estimation, in [9] a novel a symmetric extension method was suggested for OFDM system to reduce the MSE, leakage power and noise of conventional DFT. The estimation of partial frequency response is symmetrically extended as well as reduced MSE and noise eliminated with the very small power loss. In [10] an SCM based blind channel estimation method for zero padding MIMO-OFDM systems have the distinctive features. The identifiability condition is very simple and is more relaxed than the irreducible or column reduced condition. It can apply to the more transmit antennae case under a certain condition. Through numerical simulation, it yields improved BER performance in the low-to-moderate SNR region. In [11] a first order approximation method as well as a second order approximation method for joint CFO and CIR estimated in OFDM systems. In first order approximation method provides an adaptive iteration algorithm with excellent estimation and tracking range compare to the conventional. The Second order approximation method will improve frequency tracking range and channel estimation compared to the first order method. In [12] a channel estimator computes the long-

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term features through a subspace tracking algorithm by identifying the invariant (over multiple OFDM symbols) space–time modes of the channel. On the other side, the fast-varying fading amplitudes are possibly tracked by using LS techniques that exploit temporal correlation of the fading process. In particular, MIMO-OFDM with BICM and MIMO-turbo equalization has been selected as a benchmark for performance evaluation in terms of BER. In [13] a semi-blind timing synchronization and channel estimation scheme for OFDM systems was developed based on unit vectors. Semi blind approach having three stages, (i) coarse timing offset with maximum gain is obtained in multipath fading channels, (ii) a fine time adjustment algorithm to find an actual time position in channels, (iii) based on final timing estimation obtained the frequency domain in channel response. In this paper, we propose a new methodology to assess the performance of MIMO-OFDMA systems over space frequencies elective channels and non-stationary interference. The performance is evaluated in terms of average bit error probability at the output of the forward error correction (FEC) decoder. We concentrate on convolution coding for this is the mandatory FEC scheme for the majority of the commercial standards based on OFDM with BICM technology. Nevertheless, the analysis based on the union bound approach is general and can be extended to either convolution or block codes. To provide a brief insight in the proposed methodology, let us consider the transmission of a codeword over a set of parallel sub-channels i.e., the OFDM subcarriers.

2. MIMO SYSTEM

Future wireless systems demand for high data rate offering so as to achieve the demanded objective. In conventional systems the available approaches are limited by inter-symbol-interference (ISI) due to the frequency selectivity of the wireless channel. To achieve a high throughput communication with minimum interference OFDM systems was proposed. By sending information in parallel with larger symbol durations, OFDM systems avoid the ISI significantly. To achieve high data rate the OFDM systems are enhanced via the exploitation of the MIMO technique. MIMO offers additional parallel channels in spatial domain to boost the data rate. Hence, MIMO-OFDM is a promising combination for the high data requirement of future wireless systems. Multiple input multiple output (MIMO) antenna systems with orthogonal frequency division multiple access (OFDMA) is the most promising combination of technologies for high data-rate services in next generation wireless networks. Performance assessment of multi-cell systems based on these technologies is of crucial importance in the deployment of broadband wireless standards such as WiMAX and 3GPP LTE.

A. System outline

In MIMO-OFDMA systems, the side information can be the correlation due to the time evolution of the channel, the correlation between channel taps and OFDM subcarriers. Many studies exploited time and frequency domain correlation to get the advantages of both domains. With MIMO, correlation from the spatial domain exists. Spatial correlation arises due to close antenna spacing's and poor scattering environments. Coherent demodulation of the transmitted symbols requires accurate channel estimation. MIMO-OFDM channel estimation can perform in frequency and/or time domains. In frequency domain, channels at each OFDM sub-carrier are estimated. In time domain estimation, the unknowns are the channel length, tap delays, and their corresponding coefficients. Channel estimation methods can be improved by using the side information. In every cell the base station (BS) is equipped with $N_R \geq 1$antennas and each of thesubscriber stations (SSs) has an antenna array of $N_T \geq 1$elements. The transmission is organized according to the logical frame, with $K_T$adjacent sub-carriers observed over Zconsecutive OFDM symbols. Within each cell, multiple accesses are handled by dividing the logical frame into frequency-time units (data regions) of $K \times Z$subcarriers each. The BS can assign one or more data regions to each SS. The multi-user scheduling strategy provides the mapping rule from the logical frame onto the physical resource to form the time-frequency physical frame. Since some of the sub-carriers might remain unassigned, the traffic load $\eta \leq 1$ is introduced to denote the number of active sub-carriers out of the total number. Depending on the degree of cooperation among BSs and on the traffic loadη, every data region can experience up to N_I interferes with constant power over the whole data region. Differently from coordinated approach, the interference randomization policy employs a cell-specific permutation of the sub-carriers over the OFDMA bandwidth before mapping the logical sub-carriers onto the physical resources, for the purpose of randomizing the interference within each data region. In this paper, we consider both the coordinated and the randomized scheduling policy for the uplink case. Notice that for the former policy the scheduler of each BS could dynamically optimize the assignment of a certain data region to minimize the cross interference. However, since the optimization of the scheduler is beyond the scope of this paper, the assignments of the data regions are here assumed to be random and independent from cell to cell as for a non-optimized scheduler.

B. Channel model

In frequency-selective multipath environment, the NR×NT channel response$H_k$on the i_{th} subcarrier can be modeled as the sum of W path contributions:

$$H_k = G_k \sum_{r=1}^{W} \sqrt{P_r}\, A_r \exp\left(-j2\pi \frac{k}{N}\right) \quad (1)$$

Where each path is characterized by mean power P_r, the NR × NTfading amplitudes. The complex term $G_k$denotes the frequencyresponse of the cascade connection of the transmitterand receiver filters on the ith sub-carrier, The fading amplitudes(are assumed to be Rayleigh distributedand uncorrelated from path to path, according to the widesense stationary uncorrelated scattering model:

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$$R_{S,r} = R_{Tx,r} \otimes R_{RX,r} \quad (2)$$

Accounts for the spatial correlation of the fading channel, denoting the Kronecker product and withR_{Tx}, andR_{Rx},being the spatial covariance's among the transmitting and receivingantennas respectively. Following the same reasoning's, we consider two different models correspondingto different assumptions about the correlation (2) and geometryof the antenna arrays: a beamforming model is adopted forantenna arrays with closely spaced apart elements and adiversity model for array elements that are sufficiently farapart.In this section we define two specific scenarios for performanceassessment. If interference is spatially correlated, the covariance matrix (1) is structured and thus themulti-antenna combiner can exploit this knowledge to mitigatethe inter-cell interference by an appropriate beamforming strategy.Inter-cell interference filtering by beam forming is herepaired with coordinate scheduling policy as in this case thespatial structure of the interference remains the same over thedata region with many practical benefits (e.g., the interferencecovariance can be estimated with a high degree of accuracy). Onthe other hand, uncorrelated interference, as for the diversitymodel, is coupled with randomized schedulingpolicy to maximally exploit the space/time/interference diversity.Even if the noise power is changing sub-carrier-bysub-carrieraccording to (2), the receiver could realisticallyestimate the average interference power within the data region $\mathcal{K}, \sigma^2 = \frac{1}{KZ}\sum_{k\in\mathcal{K}} \sigma_k^2$which is the interference level usedin soft decoding. Based on these considerations, we define thefollowing two typical scenarios:

C. Coordinated interference scenario

In the coordinatedstrategy, the data regions in all cells are mapped overadjacent, or piecewise-adjacent, sub-carriers, which makethe interference pattern to be constant over the whole data region and thus $Q_k = Q$, for$k \in \mathcal{K}$.The stationary of the interference configuration allowsfor an accurate estimate of the impairment covarianceQwhich can be efficiently exploited for interference mitigation. The MIMO-OFDMA system provides two dimensions that can be employed for interference reduction:the frequency domain of the OFDM signaling and the spatial domain offered by the array processing. To enhance the interference rejection capability, weadopt a uniform linear antenna array (ULA) with closely spaced apart antennas and a beamforming processingover each sub-carrier. The SINR variate $\gamma_k = \gamma(H_k.ℸ)$depends only on the channel variations over k, whereasthe interference pattern ℸdoes not vary along the dataregion. Assuming the perfect knowledge of$\{H_k, Q\}$,the minimum variance distortionless receiver (MVDR) issued to combine the signals received at different antennas,yielding at the output of the combiner the following SINR,

$$\gamma_k = \frac{p_o}{N_T} tr\{H_k^H Q^{-1} H_k\} \quad (3)$$

to be exploited when establishing the branch metric ofthe Viterbi decoder.

D.Randomized interference scenario

This scenario ismodeled to exploit the maximum diversityprovided by thefluctuations of both channel and impairments. Diversity isartificially introduced through the randomized multi-useraccess approach which provides interference fluctuationsover the codeword. In this case, any interference mitigationtechniques are unfeasible due to the unpredictabilityof the impairments configuration (i.e., the highly varyingcovariance $Q_k$cannot be reliably estimated). To exploitthe diversity provided by the MIMO channel we adoptan OSTBC with antennas sufficiently spaced apart. Thereceiver is based on coherent maximum likelihood (ML) OSTBC detector, where the Viterbidecoder exploits the knowledge of the average noisepower σ^{-2} over the whole data region (conventional decoder).In this case, the SINR to be used for decodingis

$$\gamma_k = \frac{p_o}{N_T} \frac{tr\{H_k^H Q^{-1} H_k\}}{\sigma^2} \quad (4)$$

As lower-bound performance reference, we also considerthe optimal decoding based on the knowledge of theinstantaneous interference power σk^2on each subcarrierfor this genie decoderthe instantaneous SINR at thedecision variable is

$$\gamma_k = \frac{p_o}{N_T} \frac{tr\{H_k^H Q^{-1} H_k\}}{\sigma k^2} \quad (5)$$

The channel and the interference are modeled for analytical purposes, it is convenient to rewrite the SINRas a function of the $N_T N_R \times 1$ normalized space-frequencychannel vector

$$\acute{h}_k = \sqrt{\frac{p_o}{N_T}}.vec(Q_k^{-H/2} H_k) \quad (6)$$

Where the interference covariance is$Q_K = Q$ defined as in (1)for the coordinated scenario, $Q_K = \sigma^2 I_{NR}$for the randomizedone with conventional decoder and for the geniedecoder. The SINR reduces to:

$$\gamma_k = \| \acute{h}_k \|^2 \quad (7)$$

Properties of this equivalent space-frequency channel$\tilde{h}_K$forperformance analysis depend on the spatial-temporal dispersionof the multi-path propagation for the MIMO channel H_k,the spatial configuration of the inter-cell interference from thecovariance $Q_k$and the fluctuations of the interference power induced by the multiple access policy (i.e., the variations ofℸk), according to the models in the previous sections.

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3. PROPOSED BIT SPARSE CODING

In the sequel we extend the performance evaluation tohigher order modulations. Without loss ofgenerality, we consider a fixed interference scenario, droppingthe symbol ר in the notation. We focus on a MQAMmodulation, with a modulation set ofdimension defining the transmittedsymbols as,

$$s_k = (s_k^Q + js_k^I)\sqrt{E_g}\text{with}s_k^Q, s_k^I \in \{\pm 1, \pm 3, \ldots . \pm\sqrt{M} - 1\}$$

Where$E_g = \frac{3}{2(M-1)}$

is the transmittedwaveform energy. We restrict the analysis to BICM withMax-Log-Map demodulation.Compared to the error probability derivation, herethe average PEP for an error event of Hamming distance depends not only on the subcarriers, but alsoon the symbols of the M-QAM constellation and the positionsin the *bit* labels that are associated with the erroneousbits. More specifically, let us consider the h bit the interleaver maps such a bit to a constellationsymbol on the sub-carrier and to a position in the modulation label set. We can express theinterleaver effect by writing the sets, $L = \{l_1, \ldots, l_d\}$and$\chi = \{x_1, \ldots, x_d\}$. We point out that thetransmitted symbol $xk \in S$depends not only on the bit inl_k but also on the remaining $m-$ 1 bits of the label. Theyare selected (by the interleaver) from different positions of thesame coded block, thus we can consider the other m−1 bitsas independent variables. We further suppose that each bit ofthe error event is assigned to a different frequency:$f_i \neq f_j$ for$i \neq j$where {i,j}= 1, ..., *d*. This is a simplification asan interleaver (acting on a finite length coded sequence) canassociate to the same frequency two or more erroneous bitsof the same error event.The average PEP can be obtained as,

$$\text{P(c)} \leq \sum_L P(\chi)P(c|L,\chi) \tag{8}$$

Where$P(c|L,\chi)$is the PEP conditioned to the set $(L,\chi,)$,while $P(L) = 1/m^d$Pis the probability of each label set. Notice that for any coded bit sequence to be modulated and any given label set L, there are $2^{(m-1)d}$possible symbol sequences $\chi$with equal probability $P(\chi) = 1/2^{(m-1)d}$. As in the BPSK case, the conditioned PEP $P(c|L,\chi)$depends on the effective SINR γeff that is a linear combinationof the SINR values$\gamma_f = \{\gamma_{f_1}, \ldots, \gamma_{f_d}\}$. Here, however, eachSINR value γkhas to be scaled by a factor to account forthe Euclidean distance between the transmitted symbol andits nearest concurrent in the considered symbol constellation,hereinafter denoted as Δ^2_k. This factor can vary with $x_k$andl_k. More specifically, for a QAM modulation, let $S_0^1$and S_1^1)be the subset of all symbolsx_k whose label has the value 0(and 1) in positionl_k, for $l_k = 1$. The subset $S2^1$focusing on thed^{th}bit of the receivedcode word, accounting for M=16 with Gray's mapping. If thetransmitted bit is equal to 1 and it is mapped onto the *l*th labelposition, the transmitted symbol $x_k$belongs to the subset S_1^1.The Max-Log-Map demodulator decision is erroneous whenthe received symbol lies in S_0^1. Thereby, the probability oferror can be upper bounded by using the Euclidean distancebetween *xk*and the boundary of the area associated to thenearest neighbor in S_0^1. For the 16-QAM example (l_d= 2), this distance is$\sqrt{E_g}\Delta_k$, with Δ_k= 1 for ever. The*k*th coded bit is mapped over the frequency in the QAM symbol andin the label position. The plot below shows the areas of correct decisionfor the kth bit.Symbolsx_k, therefore this value does not depend on the other$m-1$ bits. The same holds for label position *l*= 4. On theother hand, for label positions *l*= 1 and *l*= 3 the value ofthe scaled distance is Δ_k= 1 for half symbols and Δ_k= 2for the other half symbols.It follows that the k_{th} bit experiences the SINR:

$$\gamma_k = \frac{P_0}{N_T}\frac{3}{2(M-1)}\Delta_k^2 \| \hat{h}_k \|^2 \tag{9}$$

The modified expression is used to rewrite the effectiveSINR (16) as a function of the set of *d*Euclidean distances {Δ1, . . . ,Δk*}*. Thereby the corresponding PEP becomes:

$$P(c|L,\chi) = P(c|D) = E_\gamma\left[Q\left(\sqrt{2\gamma\text{eff}(\gamma, \text{D})}\right)\right] \tag{10}$$

It is worth noticing that each distance $\Delta_k$can assume onlyfew values. As a matter of fact, for the 16-QAM constellationit is $\Delta_k = 1$for three quarters of the sets and $\Delta_k = 3$for the remainder, i.e.: $(\Delta_k = 1) = {}^3/_4$and $(\Delta_k = 3) = {}^1/_4$. Similar considerations hold for64-QAM whereas it can be easily observed that for QPSK (n= 4) it is $\Delta_k = 1$and the effective SINR simplified. For BPSK modulation it is$\Delta_k = 1/2$. Since onlyfew distance values are observed, it is convenient to gather all the configurations that correspond to thesame distance set c, yielding:

$$\text{P(c)}=E_\gamma[P(c|D1)] \tag{11}$$

Where(p(D)) is the probability of the distance set *c*.However, in order to avoid the expensive EVD for eachconfiguration of we propose to approximate the expectationby means of a sample average: we simulate some valuesas the outcomes of i.i.d. random variables, havingknown distribution (see the probabilities above for 16-QAM);for each value, the effective SINR is obtained and its pdfis calculated.Theestimate of the average bit error probability is then obtainedby averaging over some realizations.

4. SIMULATION RESULTS

This section gives the performance evaluation of the proposed method under various regards.

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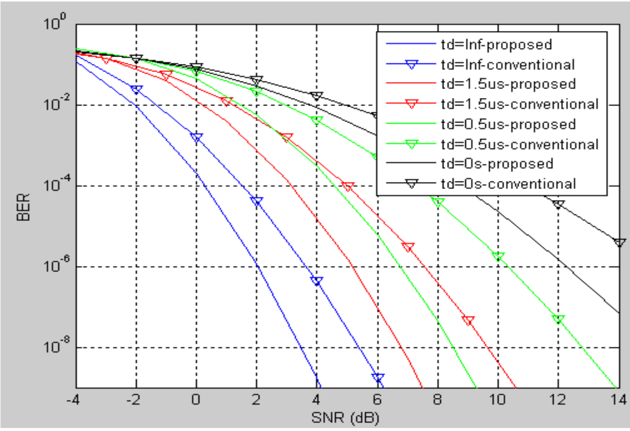

Figure-1. Performance of the proposed method at various Doppler frequencies.

The above figure represents the Bit error rate versus Signal to noise ratio plot. From the above figure it is clear that the performance of the proposed method for various Doppler effects (1ns, 1.5us, 5us, 0us) is efficient. It also denotes that with an increase in SNR value at there is a nominal decrease in the BER of the proposed method is decreasing due to the availability of multiple channels, thus the total SINR is going to be decreased. Thus, this decreased value provides the optimum power allocation for users.

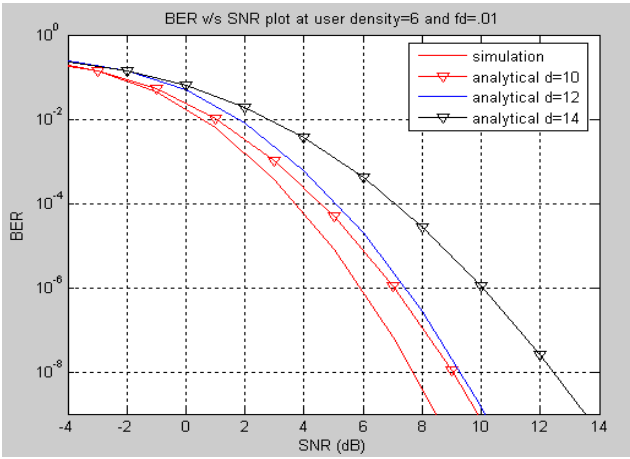

Figure-2. Analytic and simulated BER Vs traffic load ηin randomized 3interference scenario with an ideal genie decoder.

Performance of a SISO IEEE802.16-e system with QPSK, convolution code WiMAXcc1, Interferencerandomization with PUSC strategy and fixed delay spread σ_{τ}= 1μs.

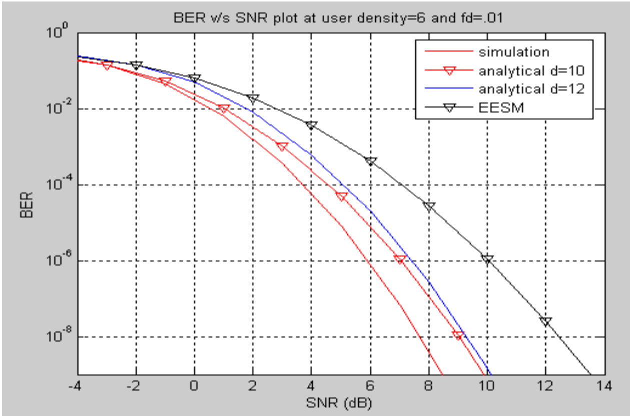

Figure-3. BER Vs SINR in coordinated interference scenario for the proposed.

Above Figure-3 shows thecomparison between the two methods for the IEEE 802.16-d beam forming scenario with QPSK modulation and codeWiMAXcc1. Conclusions are described in the next section.

5. CONCLUSION

An estimation logic in MIMO system following OFDM approach is developed. The Error performance of the developed approach is observed to be minimized under the coordinated interference scenario and randomize interference scenario. The signal estimation is improved using bit spring logic. The overall performance was proved to be optimal under channel diversity condition, for random as well as a coordinated interference model.

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