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Performance evaluation of adaptive bit interleaved coded modulation in OFDM with various fading channels

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Abstract: Bit-interleaved coded modulation (BICM) is a flexible modulation/coding scheme which allows the designer to choose a modulation constellation independently of the coding rate. This is because the output of the channel encoder and the input to the modulator are separated by a bit-level interleaver. In order to increase spectral efficiency, BICM can be combined with high-order modulation schemes such as quadrature amplitude modulation (QAM) or phase shift keying techniques. BICM is particularly well suited for fading channels, and it only introduces a small penalty in terms of channel capacity when compared to the coded modulation capacity for both additive white Gaussian noise and fading channels. In this paper an adaptive BICM technique is proposed and modelled with one of the modulation schemes in OFDM and verified with various channel models. The results pertaining to these studies are mentioned. It is evident that the proposed ABICM is validated for the channel models.

Keywords: Bit-interleaved coded modulation (BICM), OFDM, QAM.

I. INTRODUCTION

The increasing interest and importance of wireless communications over the past couple of decades have led the consideration of coded modulation [1] for fading channels. It is known that, even for fading channels, the probability of error can be decreased exponentially with average signal to noise ratio using optimal diversity. Naturally, at first, several approaches using Ungerboeck's method of keeping coding combined with modulation are applied over fading channels, as summarized in [2]. These approaches considered the performance of a trellis coded system that is based on a symbol-by-symbol interleaver with a trellis code. The order of diversity for any coded system with a symbol interleaver is the minimum number of distinct symbols between codewords. Thus, diversity can only be increased by preventing parallel transitions and increasing the constraint length of the code. In 1989 Viterbi et al [3] introduced a different approach. They designed schemes to keep their basic engine an off the-shelf Viterbi decoder. This resulted in leaving the joint decoder/demodulator for two joint entities.

Zehavi [4] later realized that the code diversity, and there-fore the reliability of coded modulation over a Rayleigh channel, could be improved. Using bit-wise interleaving and an appropriate soft-decision bit metric1at a Viterbi decoder, Zehavi achieved to make the code diversity equal to the smallest number of distinct bits, rather than channel symbols, along any error event. This leads to a better coding gain over a fading channel when compared to TCM, [4]. Following Zehavi's paper, Caire et al [5] presented the the- ory behind BICM. Their work illustrated tools to evaluate the performance of BICM with tight error probability bounds, and design guidelines. In Section II we present a brief overview of BICM, and refer the reader to [5] for details.

In QAM systems, the ML detector for BICM uses the minimum distance between the received symbol and M/2 constellation points on the complex plane as soft-decision metrics. It is evident that soft-decision bit metrics for the ML decoder can be further simplified to the minimum distance between the received symbol and $\sqrt{M/2}$ constellation points on the real line R1. This reduces the number of calculations needed for each bit metric substantially, and therefore reduces the complexity of the decoder without compromising the performance.

II. BIT INTERLEAVED AND ADAPTIVE BIT INTERLEAVED CODED MODULATION

Bit-interleaved coded modulation (BICM) was first introduced by Zehavi in [4], and later analyzed from an information theory point of view in the landmark paper of Caire et al. [5]. BICM owes its popularity to the fact that the channel encoder and the modulator separated by a bit-level interleaver may be chosen independently allowing for a simple and flexible design [2]. BICM is considered the dominant technique for coded modulation in fading channels [3], and it only introduces a small penalty when compared to the coded modulation capacity [2, 4]. BICM schemes have been proposed in the IEEE wireless standards such as IEEE 802.11a/g [5] (wireless local area network) and IEEE 802.16 [6] (broadband wireless access). Other examples include the low complexity receivers proposed by the IEEE for the multiband orthogonal frequency-division multiplexing (OFDM) ultra wide band (UWB) transceivers [7], and the wireless world initiative new radio (WINNER) consortium [8]. BICM-OFDM is also considered as a good candidate for power line communication systems [9]. An additional advantage

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of BICM compared to other schemes such as trellis coded modulation is that due to the flexibility imposed by the bit-level interleaver, the implementation of adaptive modulation and coding schemes is straightforward [10]. In order to increase the spectral efficiency, BICM can be combined with high-order modulation schemes. The most common modulation schemes used in practice are phase shift keying (PSK) and quadrature amplitude modulation (QAM). This thesis focuses on the latter. Borrowing from the idea of iterative processing, the performance of BICM can be further increased by exchanging information between the demapper and the decoder. This scheme called BICM with iterative decoding (BICM-ID) was proposed in [12] and further studied in [13–14]. In Fig. 1 a general discrete baseband BICM transmission model is shown. The vector of coded bits y generated by the binary channel encoder (ENC) is interleaved (π) generating y′= π(y). These coded and interleaved bits are then gathered in length–n codewords ctsuch that y′= [c0,...,cN−1], where N is the symbol block length.

At any time instant t, the codeword ct is mapped to a complex symbol $x_t \in$ X using a binary memoryless mapping

$$M : \{0,1\}n \rightarrow X,$$

where X is the constellation alphabet.
The symbols

$$x = [x0,...,xN-1] = [M\{c0\},...,M\{cN-1\}]$$

are sent through the channel whose output is given by $r_t = h_t \cdot x_t + \eta_t$, where h_t is a complex channel gain and η_t is a zero- mean, real, white Gaussian noise sample with varianceN0. Since the mapping is memoryless and both the noise and the complex channel gain samples are independent and identically distributed, from now on we drop the time index t. The magnitude of the complex channel gain samples follow a Nakagami-m distribution, which allows us to consider a wide range of channels ranging from a Rayleigh fading channel (m = 1) to an additive white Gaussian noise (AWGN) channel (m → ∞). The instantaneous signal to noise ratio (SNR) is given by $\gamma = |h|2/N0$. The probability density function (PDF) of the instantaneous SNR is then given by

$$p_\gamma(\gamma;\overline{\gamma},m) = \frac{\gamma^{m-1}}{\Gamma(m)}\left(\frac{m}{\overline{\gamma}}\right)^m \exp\left(-\frac{m\gamma}{\overline{\gamma}}\right), \qquad (1)$$

The adaptive bit-interleaved coded modulation (ABICM) was proposed in [1] to improve robustness of adaptive coded modulation to unreliable channel state information (CSI). In the original ABICM method [1], the Bhattacharyya bound based on the minimum distance of the constellation and a nominal non-adaptive BICM scheme were employed to determine the constellation size and the transmission power. The actual BER of this method significantly deviates from the specified target BER [1], [2]. Hence, additional experimental energy adaptation is required to maintain the BER. ABICM was also investigated in [3], [4] under the assumption of perfect CSI at the transmitter, which is reasonable for static fading channels such as indoor wireless systems, but not for outdoor mobile radio channels. Moreover, due to the difficulty of evaluating the exact BER, simulations were used in [3], [4] to obtain the thresholds that determine the transmission constellation as well as power.

III. IMPLEMENTATION OF THE SYSTEM

Implementation part involves in framing the BICM channel in the conventional OFDM system and then implementing the Adaptive nature of the proposed system in order to fulfil the requirements. Fig.1 shows the block diagram of the BICM channel in the conventional system. Fig.2 shows the representation of the adaptive BICM for the proposed model.

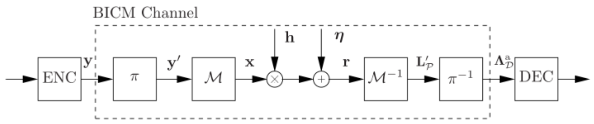

Fig.1: BICM channel block diagram

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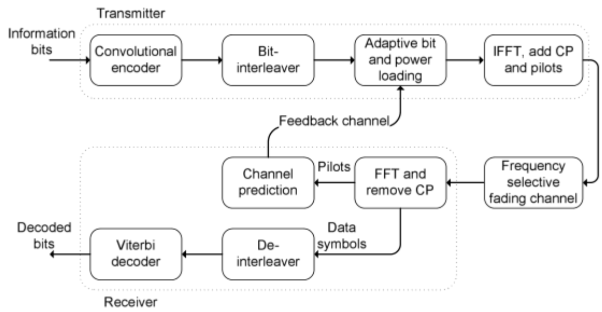

Fig.2: LRP based ABICM

IV. RESULTS

Results pertaining to the proposed ABICM model in OFDM with QPSK and QAM are presented in this section withh the following figures.

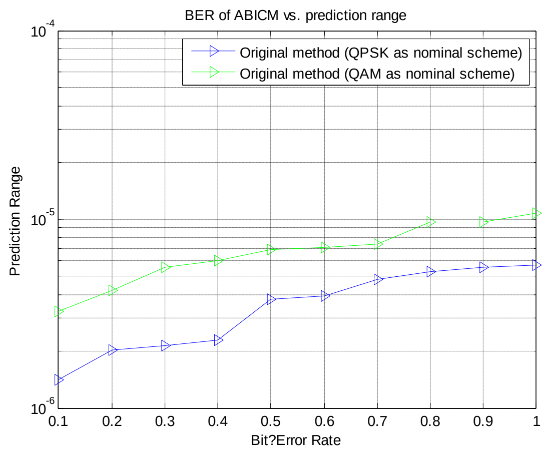

Fig.3: BER vs prediction range

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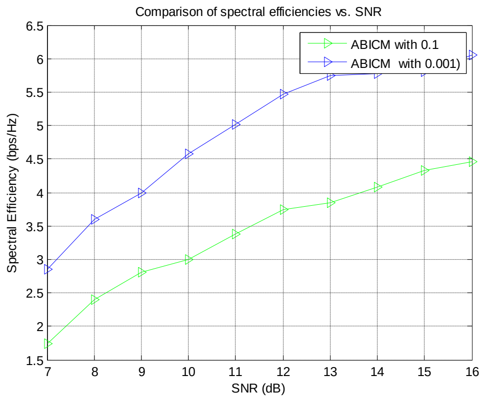

Fig.4: SNR vs Spectral efficiency

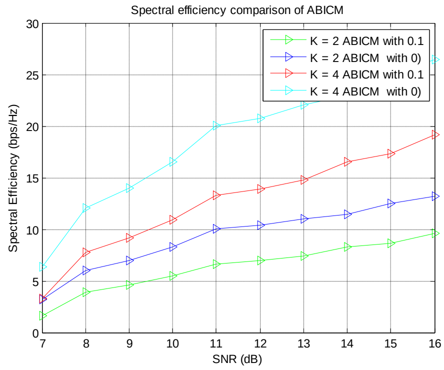

Fig.8: ABICM with different k values

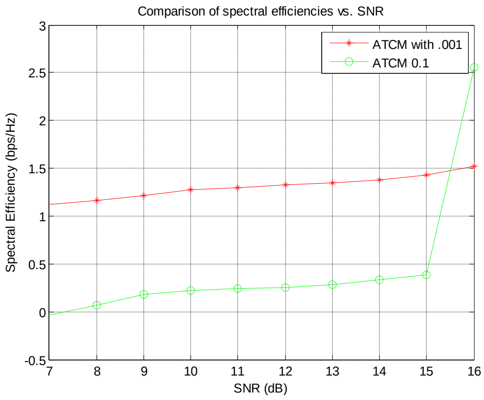

Fig.5: SNR vs Spectral efficiency with ATCM

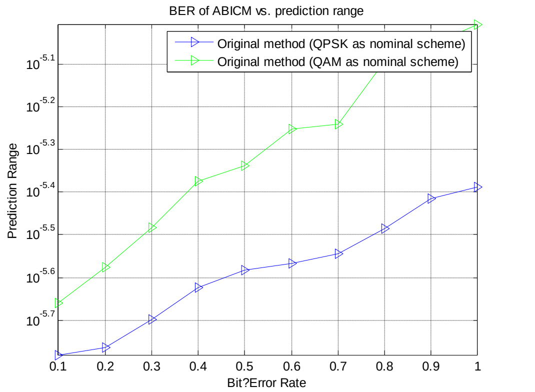

Fig.9: Rayleigh channel implementation of ABICM

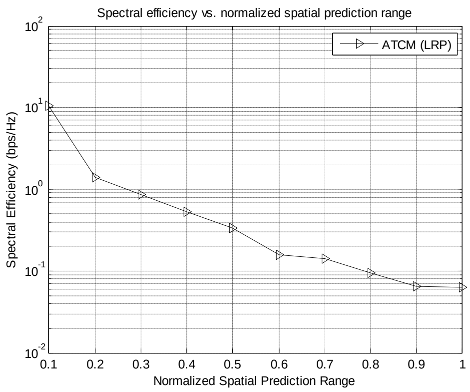

Fig.6: Spectral prediction range vs Spectral efficiency

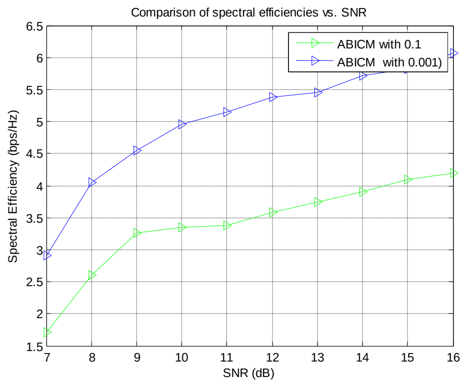

Fig.10(a)

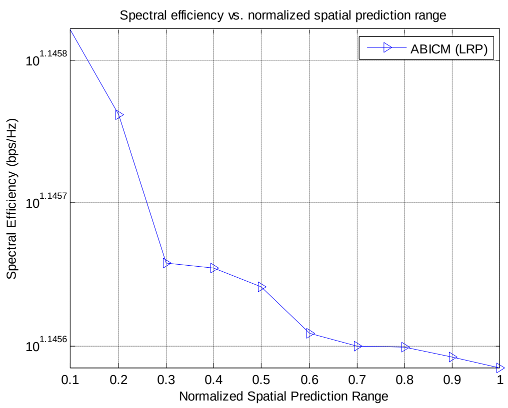

Fig.7: ABICM with LRP (existing)

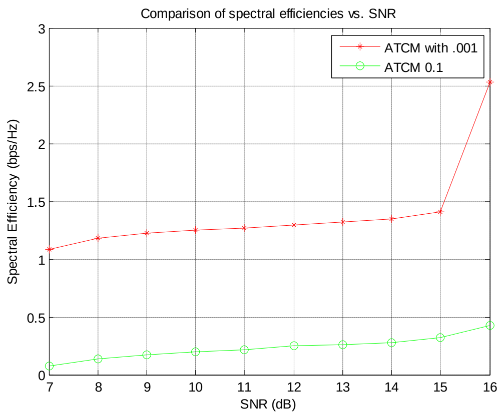

Fig.10(b)

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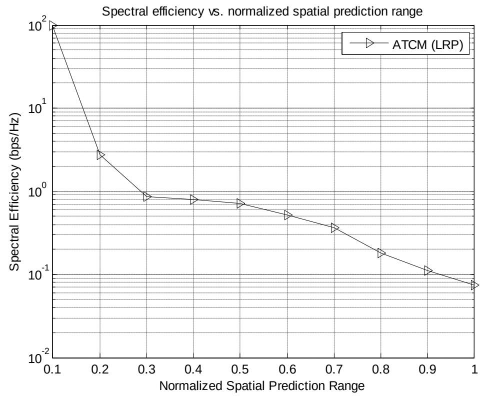

Fig.10(c)

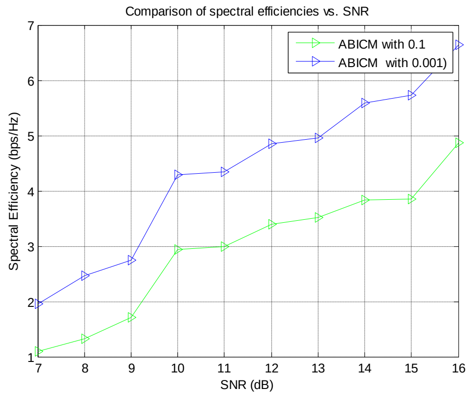

Fig.11(b)

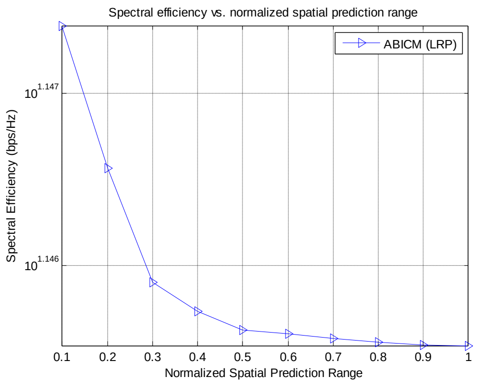

Fig.10(d)

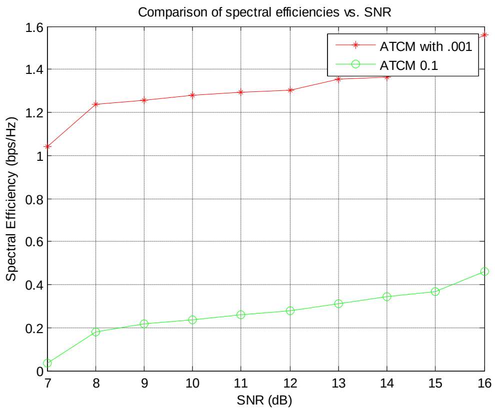

Fig.11(c)

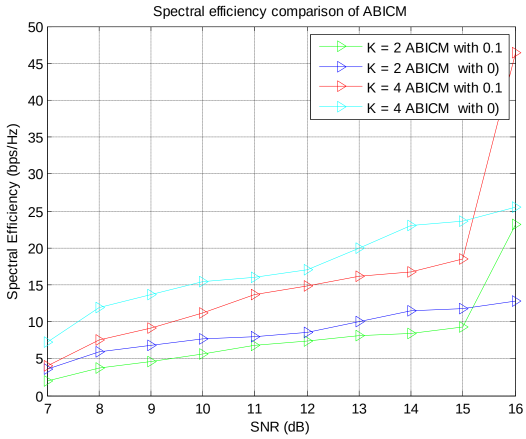

Fig.10(e)

Fig.10: Analysis plots for the proposed ABICM in Rayleigh Channel

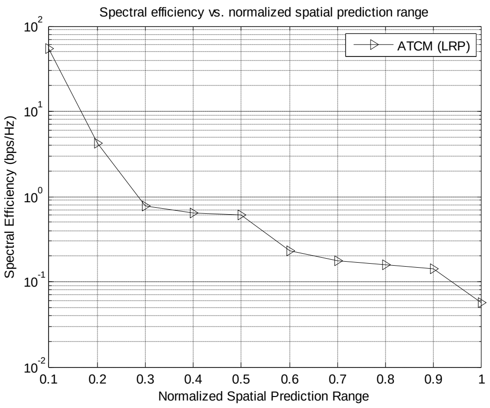

Fig.11(d)

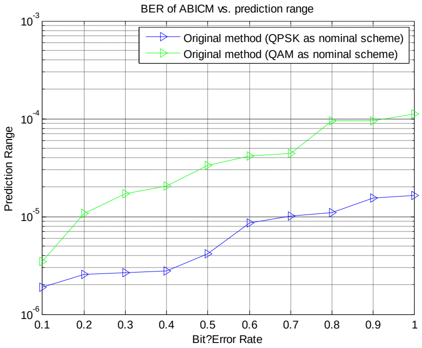

Fig.11 (a)

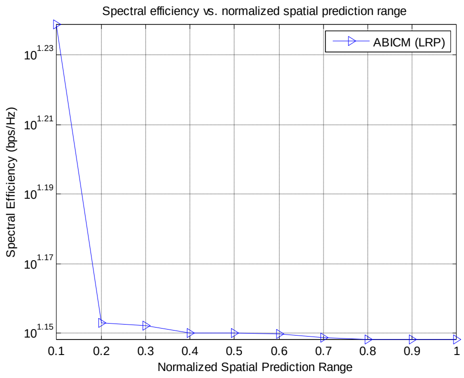

Fig.11(e)

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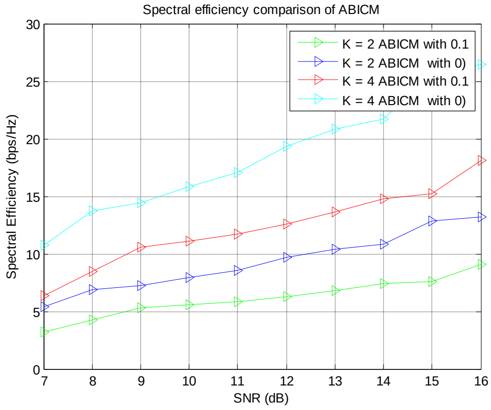

Fig.11(f)

Fig.11: Implementation of ABICM in recian channel

V. CONCLUSION

Simulation of ABICM in guassian, rayleigh and rician channels are presented in the last section. The effective implementation resolves many issues related to power handling capabilities which are formulated in the references. The effective implementation is justified with comparative and thorough analysis of the proposed model with the analysis of the results.

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