ADAPTIVE BIT INTERLEAVED CODED MODULATION FOR MOBILE RADIO OFDM SYSTEMS BY USING RICIAN FADING CHANNEL

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ABSTRACT

NOW a day's industries require some special techniques due to increase in wireless communications. These techniques should solve the communication related problems and challenges and improves the quality of service. When the signal propagates from transmitter to receiver it undergoes to some random fluctuations called Noise. This will happened in both time and frequency domain. We need to predict such noise and eliminate it. The need of predicting noise and measure of it is referred as Channel state information simply CSI. This is the measurement of noise prediction. But, here the measurement will be observed after some time units. The transmitter selects appropriate modulation technique depending on the Channel state information. This process is called as Adoption. In this process transmitter and receiver both need to send acknowledgement to each other to confirm whether it received or not. This method is referred as Channel state information feedback. These techniques combined together is referred as the adaptive bit interleaved coded modulation simply ABICM. There are so many other techniques are there like UAM, ATCM and BICM. Previous method called BICM was based on Bhattacharya bound. This method was works based on minimum distance of constellation and a nominal non-adaptive BICM. It works by determine the Constellation size and transmission power. ATCM method or adaptive trellis coded modulation gives better performance but outdated. So, Proposing ABICM was based on expurgation bounded aided by fading prediction. This ABICM method improves the accuracy of bit error rate (BER). This method also gives better spectral efficiency and performance.

Keywords: *Adaptive modulation, fading channels, interleaved coding, frequency division multiplexing and resource management.*

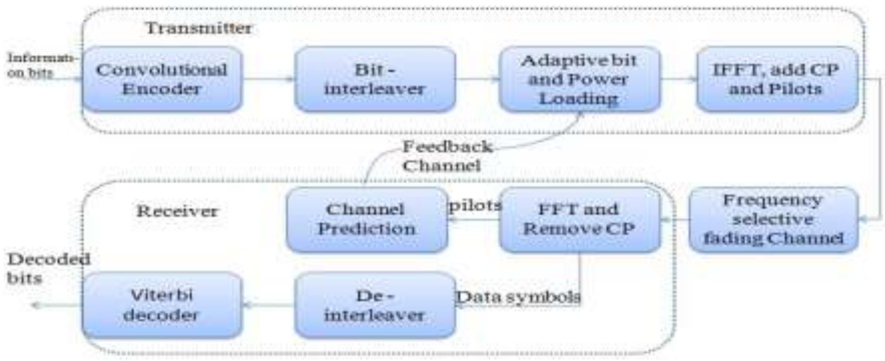

Fig.1 System diagram of LRP-enabled adaptive OFDM system with ABICM using Rician Channel.

I. INTRODUCTION

THE adaptive bit-interleaved coded modulation (ABICM) was projected in [1] to enhance lustiness of adaptive coded modulation to unreliable channel state info (CSI). Within the original ABICM technique [1], the Bhattacharyya certain supported the minimum distance of the constellation and a nominal non-adaptive BICM theme were utilized to work out the constellation size and therefore the transmission power. The particular BER of this technique significantly deviates from the specified target BER [1], [2]. Hence, extra experimental energy adaptation is needed to keep up the BER. ABICM was additionally investigated in [3], [4] below the idea of excellent CSI at the transmitter, that is affordable for static attenuation channels like indoor wireless systems, however not for out of doors mobile radio channels. Moreover, because of the issue of evaluating the precise BER, simulations were utilized in [3], [4] to get the thresholds that confirm the transmission constellation similarly as power.

The censored certain provide correct BER estimates for non-adaptive BICM in additive white mathematician noise (AWGN) and attenuation channels [5].

Rician fading is a stochastic model for radio propagation anomaly caused by partial cancellation of a radio signal by itself — the signal arrives at the receiver by several different paths (hence exhibiting multipath interference), and at least one of the paths, typically a line of sight signal, is much stronger than the others. In Rician fading, the amplitude gain is characterized by a Rician distribution.

A Rician fading channel can be described by two parameters: K and Ω. K is the ratio between the power in the direct path and the power in the other, scattered, paths. Ωis the total power from both paths ($\Omega = V^2 + 2\sigma^2$), and acts as a scaling factor to the distribution.

The received signal amplitude (not the received signal power) R is then Rice distributed with parameters

$$v^2 = \frac{K\ \Omega}{(K+1)}$$

And $\sigma^2 = \frac{\Omega}{2(K+1)}$

The resulting PDF then is:

$$f(x) = \frac{2(K+1)x}{\Omega} \, exp\left(-K - \frac{(K+1)x^2}{\Omega}\right) I_o\left(2\sqrt{\frac{K(K+1)x}{\Omega}}\right)$$

Where $I_o(0)$ the 0th order is modified Bessel function of the first kind.

During this letter we have a tendency to style associate degree ABICM system power-assisted by imperfect CSI by using the censored certain. The power to keep up the target BER exploitation this technique is incontestable exploitation simulations for associate degree adaptive orthogonal frequency division-multiplex (OFDM) system. In [1] the performance of ABICM was evaluated exploitation the CSI sample calculable at the receiver and fed back to the transmitter. Because of speedy attenuation variation, this CSI becomes noncurrent, and attenuation prediction is important to keep up re-liable performance [6], [7]. during this letter, we have a tendency to use associate degree autoregressive model-based four-dimensional long vary attenuation predictor (LRP) technique [6] for associate degree OFDM system in numerical comparisons of ABICM, uncoded adaptive modulation, and adaptive trellis coded modulation (ATCM)

[8].In this comparison, we have a tendency to show the prevalence of ABICM for sensible mobile radio systems with feedback delays.

In Section II, the adaptive OFDM channel model, the prediction method, and the bit and power loading algorithm are summarized. Section III discusses the original method in [1] and our ABICM method based on the expurgated bound. Numerical results are presented in Section IV, and conclusions are contained in Section V.

II. ADAPTIVE OFDM AIDED BY LONG-RANG EPREDICTION

II. (i) Channel Model and Long-Range Prediction

The system of block diagram of the adaptive OFDM system under investigation is shown in Fig.1. We tend to assume the frequency-selective wide-sense stationary (WSS) Rician fading channel as in [1]. The received signal for the l^{th} subcarrier (l=1…..L) of the n^{th} OFDM symbol is

$$Y(n,l)=H(n,l)X(n,l)+W(n,l) \qquad (1)$$

Where H(n,l) are the complex Gaussian channel response $H(n,l) \sim CN(0,1)$, the transmitted signal, and the complex additive white Gaussian noise with variance N_0, respectively. It is assumed the inter-symbol interference (ISI) is removed using appropriate cyclic prefix. Without loss of generality, we set H (n,l) $=E_p$ for pilot symbols, where E_p is the pilot symbol energy. To facilitate the LRP, pilot symbols are inserted in both frequency and time domains. Past pilot observations with in a rectangular area that includes $[2p_f+1]$ pilot tones and P_t past pilot OFDM symbols are employed to predict the current channel coefficient H (n,l) [2,Fig.4.2]. In this letter, we assume that channel statistics are known and construct a linear minimum mean square error (MMSE) predictor of order $(2p_f+1)\ p_t$ [2]. In practice, similar prediction accuracy can be achieved by the auto-regressive (AR) model based predictors that track fading channel variations. The performance of this predictor can be improved at low and medium SNR by employing noise reduction [2], [9], [10]. However, we do not utilize noise reduction since we focus on robustness of adaptive coding methods to imperfect predictions. The channel coefficient H (n,l) and its linear MMSE prediction $H^{\wedge}(n,l)$ are jointly Gaussian distributed [1], [7]. The quality of prediction is usually measured by the prediction MMSE

$$\sigma^2 = E\left[|H(n,l) - \hat{H}(n,l)|^2\right]$$

Suppose the maximum Doppler frequency of the channel is f_{dm}, and we need to predict τ second ahead of the most recently observed OFDM symbol. Then the corresponding normalized spatial prediction range is, which is usually expressed in the unit of carrier wavelength λ [7].

II. (ii) Adaptive Bit and Power Loading

At the transmitter, the data bits are encoded employing a fixed rate convolution encoder, followed by bit-interleaving (Fig. 1). To facilitate analysis, we tend to assume that this interleaver is good as in [1], [5]. As a result of frequency diversity in OFDM systems, this assumption is realistic even for brief interleaving depth in time. After interleaving, the adaptive bit and loading rule maps the coded bits into M-Quadrature receiver. While not loss of generality, we tend to contemplate the allocation for one OFDM symbol X (n,l). Given foreseen channel coefficient $H^{\wedge}(n, l), l \in [1, L]$, suppose the minimum average image energy needed to transmit mil coded bits/symbol whereas maintaining the target BER is $E_{H^{\wedge}(n,l)}(ml)$. Our objective is to maximize the spectral efficiency below the energy constraint E_T, i.e., amplitude modulation (MQAM) symbols for all subcarriers. The constellation sizes and energies of those symbols are determined exploitation the CSI fed back from the

$$max\{\sum_{l=1}^{L} m_l\} \; subject \; to \; \sum_{l=1}^{L} E_{\hat{H}(n,l)} \qquad (2)$$

If $E_{H^\wedge(n,l)}(ml)$ is Known, the distinct water filling algorithmic rule supported the greedy principle achieves the optimum answer of (2) [11]. However, it's difficult to see the perform $E_{H^\wedge(n,l)}(ml)$ for given H^(n,*l*). This downside needs a good analytical estimate of the common BER for every modulation level as a function of the expected CSI. For totally studied un coded adaptive modulation [12] and ATCM [8], the function $E_{H^\wedge(n,l)}(ml)$ may be derived from the BER analysis of MQAM and trellis-coded modulation (TCM) in AWGN channel (see, e.g., [13], [14], [15]). However, for ABICM, antecedently projected techniques don't give correct BER estimates as mentioned earlier. Within the following section we have a tendency to review the initial ABICM technique in [1] and propose a unique technique supported the censored sure.

III. ABICM WITH IMPERFECT CSI

III. (i) ABICM technique

In ABICM, the candidate Gray-labeled MQAM constellations are $\{\chi_m\}$of sizes $|\chi_m| = 2m, m \in M,$ wherever M is that the set of attainable bits per image utilized by the adaptive modulator. Let $d_{min,m}$ and E_m denote the minimum Euclidian distance and average symbol energy of constellation χ_m Respectively. The error Probability of choosing the symbol X $\in\chi$m at the receiver when $X \in \chi_m$ is transmitted (the single image error probability) is taken into account in [1]. Given the expected channel coefficient $H^\wedge$(n,*l*), the Bhattacharyya sure of this error likelihood is [1], [2]

$$P[X \to \hat{X}|\hat{H}(n,l)] \le \frac{1+K}{1+K+C} \; exp\left(-\frac{KC}{1+K+C}\right) \qquad (3)$$

Where, K= $|\hat{H}(n,l)|^2 / \sigma^2$ and

$C = d^2_{min,m}(K+1)\sigma^2/4\,N_0$.

To relate this sure to the target BER, a non-adaptive BICM theme referred to as the nominal theme that uses fixed MQAM modulation, is utilized in [1]. The nominal theme and also the ABICM theme underneath investigation use a similar convolution encoder. For the nominal theme, the SNR needed to realize the target BER is set by simulation, and also the corresponding Bhattacharyya sure on the one image error likelihood is denoted D0 (This sure is computed from (3) by setting $H^\wedge$(n,*l*)=0 since the nominal theme isn't adaptive). as an example, a nominal theme that uses QPSK constellation and rate 2/3, 4-state convolution encoder achieves the target BER=$10^\wedge 5$ at 17.2 dB, and also the ensuing D0 = 0.0367 [1]. it's argued in [1] that the BER of ABICM is maintained just about at the target BER if the Bhattacharyya sure (3) for ABICM is equal to or smaller than D0. Hence, to take care of the target BER, the energy needed to use the constellation for the l^{th} subcarrier is

$$E_{\hat{H}(n,l)}(m_l) = arg\;min_{E_{m_l}}\left\{\frac{1+K}{1+K+C}\; exp\left(-\frac{KC}{1+K+C}\right) \le D_0\right\} \qquad (4)$$

There are potential problems with this approach, which we refer to as the original ABICM method. First, single symbol error probability is considered in (3), while the performance is usually measured by the BER.

Second, the Bhattacharyya bound in (3) is inaccurate. Finally, the utilization of the nominal scheme is not justified, and the guidelines for selecting the nominal scheme are not provided. As a result, the simulated BER can deviate significantly from the target BER, and the actual transmit power has to be adjusted by simulations to meet the desired BER.

III. (ii) ABICM method based on the Expurgated Bound

The expurgated bound proposed in [5] provides an accurate BER estimate for non-adaptive BICM, which does not require the CSI knowledge. We develop a method based on the expurgated bound for ABICM systems with predicted CSI. Suppose the transmitted coded bit sequence and their estimates are c and c^, respectively. These sequences originate and terminate at the same state and differ by d bits. The channel predictions and constellations associated with these d error bits are $\widehat{H} = [\widehat{H}^1 \widehat{H}^2 \widehat{H}^3 \ \ldots\ldots \widehat{H}^d]$ and $X = [X^1 X^2 \ \ldots\ldots X^d]$, respectively. For the i^{th} error, the constellation size $|X^i| = 2^{m^i}, i \in [1, d]$. Due to the assumption of ideal interleave, the corresponding channel coefficients $H = [H^1 H^2 H^3 \ \ldots\ldots H^d]$ are independent random variables and the conditional probability density function (PDF) is $p(H|\widehat{H}) = p(H^1|\widehat{H}^1) \ldots p(H^d|\widehat{H}^d)$ Knowledge of $\widehat{H}$ and X, the pair-wise error probability (PEP) is bounded by eq (5)

$$p(\bar{c} \to \hat{c}|\aleph, \widehat{H}) \le f_{ex}(d, \mu, \aleph, \widehat{H}) \cong \frac{1}{2\pi j}\int_{\varepsilon - j\infty}^{\varepsilon + j\infty} \prod_{i=1}^{d} \varphi_{ex}^{i}(s)\frac{ds}{s}, \qquad (5)$$

Where μ is the labeling rule, ε is a small
Positive number [16], and

$$\varphi_{ex}^{i}(s) = E\left[e^{-s\Delta(X,\hat{Z})}\right] = \frac{1}{m^i 2^{m^i}} \sum_{p=1}^{m^i} \sum_{c=0}^{1} \sum_{X \in X_{\varepsilon,p}^{i}} \emptyset_{\Delta(X,\hat{Z})}^{H^i}(s) \qquad (6)$$

From above equation, m^i is the size of constellation χ^i, $X_{\varepsilon,p}^{i}$ is the subset of χ^i where the p^{th} bit takes on the value, Δ(X, $\hat{Z}$) is the metric difference between two symbols X and $\hat{Z}$, where $\hat{Z}$ is the unique nearest neighbor of X in χ^i that satisfies $\hat{Z} \in X_{\bar{\varepsilon},p}^{i}$. We use $\bar{c}$ to denote the complement of bit c. Finally, $\emptyset_{\Delta(X,\hat{Z})}^{H^i}(s)$ is the Laplace transform of the PDF of Δ (X , $\hat{Z}$)

$$\emptyset_{\Delta(X,\hat{Z})}^{H^i} \triangleq E[e^{-s\Delta(X,\hat{Z})} | \widehat{H^i}, X, \hat{Z}] \qquad (7)$$

To calculate $P(X \to \hat{Z}|\widehat{H}^i)$, the maximum likelihood (ML) detection with the knowledge of perfect CSI H^i at the time of detection is assumed. Denote the received symbol as Y. The conditional probability of Y is

$$p_{H^i}(Y|X) = \frac{1}{\pi N_o} \exp\left(-|Y - H^i X|/N_o\right) \qquad (8)$$

Then the metric difference between X and $\hat{Z}$ at the decoder is

$$\Delta(X, \hat{Z}) = \log p_{H^i}(Y|X) - p_{H^i}(Y|\hat{Z}) \qquad (9)$$

Using $p_{H^i}(Y|X)$ and $\Delta(X, \hat{Z})$ these equations, substitute in $\emptyset_{\Delta(X,\hat{Z})}^{H^i}$ now we can get

$$\emptyset_{\Delta(X,\hat{Z})}^{H^i} \triangleq \frac{\exp\left(-\dfrac{\frac{s(1-sN_o)K|X-Z|^2}{K+1}}{1+\frac{s(1-sN_o)K|X-Z|^2}{K+1}}\right)}{1+\frac{s(1-sN_o)K|X-Z|^2}{K+1}} \qquad (10)$$

As stated earlier, for each bit rate m, our goal is to determine the symbol energy that satisfies the target BER given predicted channel coefficient H^. Although the analytical BER needed to achieve this goal can be derived from PEP, the calculation of PEP in (5) requires the knowledge of channel predictions, transmission energies, and constellation sizes for all d errors. Due to random interleaving, this knowledge is not available in practical systems. Therefore, we simplify (5) by assuming $\varphi_{ex}^{i}(s) = \varphi_{ex}^{io}(s)$ for all $i\epsilon[1, d]$where io is one of the d indices with given $H^{\wedge}i0 = \widehat{H}$ and $\chi_{io} = \chi_m$. This assumption is justified by the observation that the bit-loading algorithm selects the symbol energy and the constellation to maintain the same performance for all symbols, and$\varphi_{ex}^{io}(s)$determines the error probability of each symbol. Thus, a simplified expurgated bound on PEP, which employs $\widehat{H}$ and χ_m instead of vectors $\widehat{H}$ and χ, is defined as

$$\hat{f}_{ex}(d, \mu, \aleph_m, \widehat{H}) = \hat{f}_{ex}(d, \mu, \chi^{i_o}, \widehat{H}^{io}) = \triangleq \frac{1}{2\pi j}\int_{\varepsilon-j\infty}^{\varepsilon+j\infty}[\varphi_{ex}^{io}(s)]^d\frac{ds}{s} \qquad (11)$$

The above equation is exactly the expurgated bound on PEP for non-adaptive BICM that uses constellation χ_{min} the Rician fading channel with K factor $|\widehat{H}|^2/\sigma^2$. It can be solved numerically using the method proposed in [16].

For a rate k_c/n_c convolution encoder with the free Hamming distance d_{free}, the union bound on the BER is

$$p_b \leq \frac{1}{k_c}\sum_{d=d_{free}}^{\infty} W_I(d)\, \hat{f}_{ex}(d, \mu, \aleph_m, \widehat{H}) \qquad (12)$$

Where $W_I(d)$ are the weights of the error events at the Hamming distance Using (9), the average symbol energy that satisfies the BER constraint is derived:

$$E_{\widehat{H}(m)} = arg\ min_{E_m}\left\{\frac{1}{k_c}\sum_{d=d_{free}}^{\infty} W_I(d)\hat{f}_{ex}(d, \mu, \aleph_m, \widehat{H}) \leq BER_{tg}\right\} \qquad (13)$$

Where BER_{tg} is the target BER. The result of above eq (13) can be evaluated numerically given the predicted channel coefficient $\widehat{H}$, the MMSE of prediction σ^2, the constellation, the noise power, and the free Hamming distance of convolution encoder. We refer to this method as an ABICM scheme based on the Expurgated bound. Above Equation (13) is used to compute the thresholds for adaptive modulation. Note that it is too complex to be computed in real time due to the rapidly-varying channel conditions. However, it is possible to compute the thresholds offline and to employ a look-up table in mobile communication equipment in practice. The computational speed of $E_{\widehat{H}(m)}$ is much higher than for simulations-based methods, which are often used to determine the thresholds in complex adaptive modulation systems and need to run millions of bits to obtain reliable results.

IV. Numerical Results

IV. (i) BER Comparison

First, we investigate the BER achieved by the original method and our ABICM method for the original ABICM method, two nominal schemes that employ quadrature phase shift keying (QPSK) and 64QAM in Rician fading channel are used, and the resulting D_0 values are 0.0367 and 0.0624, respectively. Fig: 1 show the simulated BER vs. prediction range for the two ABICM methods. In practical mobile communication systems, the prediction range is usually 0.1 − 0.5λ. Within this prediction range, the BER of the original ABICM method is either significantly greater or lower than the target BER depending on the choice of the nominal scheme. Moreover, the resulting BER of the original BICM method with AWGN, ABICM method based on Expurgated

Bound with Perfect CSI conditions, ABICM method based on Expurgated Bound with Rayleigh Channel varies dramatically as the prediction range changes. On the other hand, the method based on the Expurgated Bound with Rician Fading Channel maintains the target or Better BER. Results in confirm this conclusion for other SNR values. In wireless communication system design, it is desirable to obtain as accurate estimate of the BER as possible. While the original ABICM method sometimes achieves a lower BER than the target BER, a system designer would prefer to save the transmission power by maintaining the BER at a higher but acceptable rate. Therefore, we employ our ABICM method in the simulations.

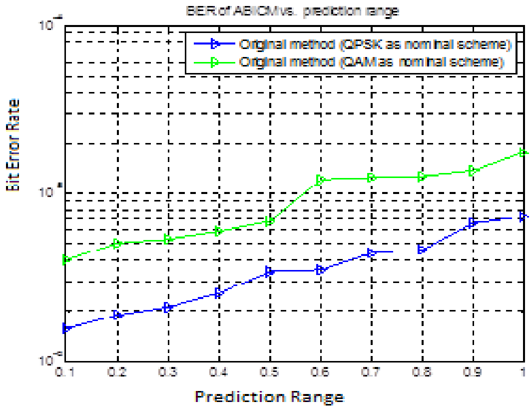

Fig: 1 BER of ABICM vs. prediction range For the Rician Fading Channel

IV.(ii) Spectral Efficiency Comparison

Fig: 2(i) and (ii) Compares the spectral efficiency of several methods for different SNR values and CSI reliability. Two prediction MMSE values are considered, σ2 = 0.1 and 0.001, which for fdm = 200 Hz correspond to 2ms (0.4λ) and 0.1ms (0.2λ) prediction ranges at 30dB SNR .When CSI is reliable (σ2 = 0.001), ATCM achieves the highest spectral efficiency for medium to high SNR since its minimum Euclidean distance is larger. On the other hand, the spectral efficiency of ATCM is significantly degraded by imperfect CSI, while ABICM still maintains high spectral efficiency for σ2 = 0.1, a typical MMSE for realistic mobile radio conditions. Both ABICM and ATCM outperform uncoded adaptive modulation, although the coding gain of ATCM is small when the CSI is not reliable. Note that ABICM significantly outperforms these non-adaptive schemes. This comparison demonstrates that in the slow fading channel adaptive modulation methods that do not require interleaving, e.g., ATCM, achieve the best spectral efficiency. On the other hand, ABICM is the best choice for practical mobile wireless channels.

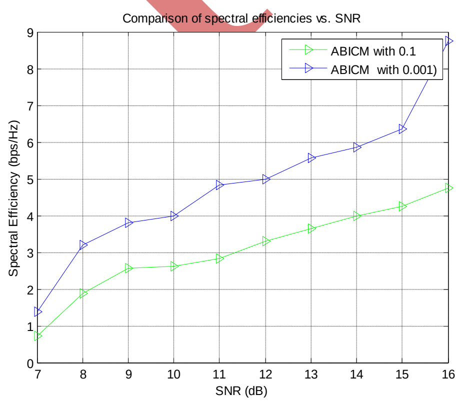

Fig: 2(i)

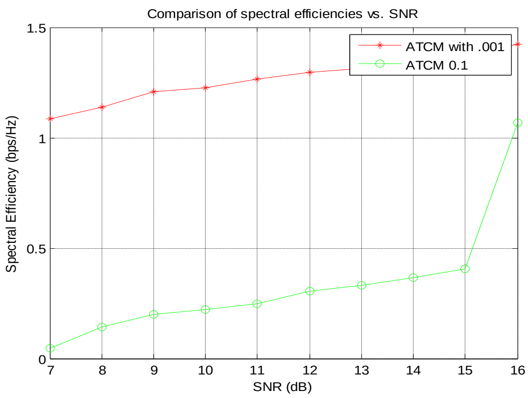

Fig: 2(ii)

Fig: 2(i), (ii) Comparison of spectral efficiencies vs. SNR for prediction accuracies σ^2 = 0.001 and σ^2 = 0.1 for ABICM, ATCM for Rician Fading Channel

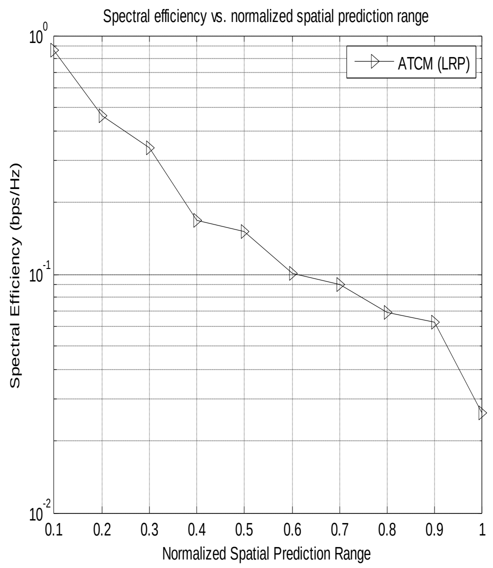

Fig:3 (i)

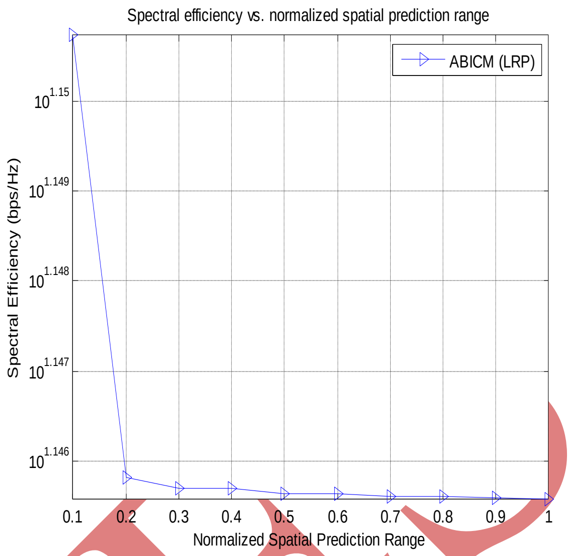

Fig: 3(ii)

Fig: 3(i), (ii) Spectral Efficiency vs. Normalized Spatial Prediction Range for ATCM and ABICM for Rician Fading Channel

Fig: 3 (i), (ii) illustrates the dependency of the spectral efficiency on the normalized spatial prediction range $f_{dm}\tau$. Fig: 4 Compares the performance of rate R = 2/3 convolution codes with different constraint lengths K. Increasing K from 2 to 4 results in spectral efficiency improvement of 0.3-0.6 bps/Hz. The spectral efficiency loss due to imperfect CSI (σ^2 = 0.1) relative to σ^2 = 0 is smaller for K = 4 than for K = 2. Thus in addition to higher coding gain, longer constraint length K provides better protection against prediction errors by spreading the bits associated with the poor channel predictions. This figure also shows that even for imperfect CSI ABICM outperforms the non-adaptive BICM scheme with the same convolution encoder.

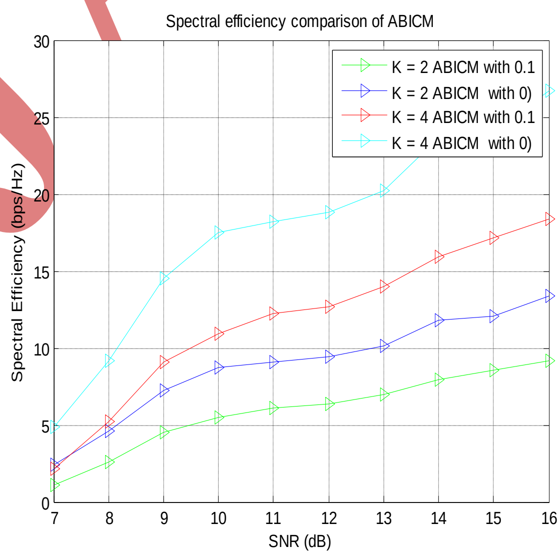

Fig: 4 Spectral efficiency comparision of ABICM : rate 2/3 Convolution Code with Different Constraint lengths K=2,4 corresponding to SNR for Rician Fading Channel

V. CONCLUSION

In this paper, we investigated ABICM aided by fading prediction for OFDM systems. New ABICM method based on the expurgated bound was developed and shown to achieve much better BER accuracy relative to the method originally proposed for ABICM with imperfect CSI. It was demonstrated that ABICM is much less sensitive to CSI errors than ATCM and un coded adaptive modulation, but reliable fading prediction is required to enable ABICM for realistic mobile radio systems. A possible future extension of this work is to investigate utilization of the variable-rate Turbo BICM [19] in the rapidly fading environment.

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