Journal of Theoretical and Applied Information Technology
20th September 2014. Vol. 67 No.2

ISSN: **1992-8645** www.jatit.org E-ISSN: **1817-3195**

PERFORMANCE ANALYSIS OF ADAPTIVE MODULATION FOR HIGH MOBILITY FOR LTE

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ABSTRACT

The demand of high data rate and affirmation to the real-time communications (network). LTE is well placed to fulfill the demands of next generation mobile networks. It delivers beneficial features such as high mobility transmission and scalability of bandwidth using both TDD and FDD duplexing methods, for the time varying and frequency selective wireless channel within one OFDM sub-carrier. For the exact estimation of wireless channel, some of OFDM subcarrier used as a reference signal while other subcarrier are either used to transmit data symbols are set as unused. The weighted time-domain interpolation computed from the channel based on the Doppler spread information and Parallel Interference Cancellation scheme jointly with Decision Statistical Combining (PIC-DSC) technique is used to reduce the ICI and to improve the data symbol detection. Here the adaptive modulation technique is used additionally to adopt the channel condition that maximizes the spectral efficiency and to meet higher throughput instead of retransmission, the transition rate can be cut down, when the channel condition is miserable. So the Quality of Service (QOS) in the time varying wireless channel is maintained.

Keywords: *Adaptive Modulation, ICI, MIMO-OFDM, PIC, DSC*

1. INTRODUCTION

This LTE (Long Term Evolution) and (WiMAX) [1] are involved in 4G family, to provide higher data rate from 100Mbps - 200Mbps, to support applications such as Mobile TV, Video conferencing, Tele-medicine, online gambling, etc. LTE is based on criteria developed by the 3rd Generation Partnership Project (3GPP) [1]. The 3rd Generation Partnership Project (3GPP) is an organization that defining a mobile system that achieves the IMT-2000 standard. LTE may also be referred as Evolved UMTS Terrestrial Radio Access (E-UTRA) and Evolved UMTS Terrestrial Radio Access Network (E-UTRAN). It provides scalable bandwidth stats from 1.25MHz up to 20+ MHz. LTE infrastructures are planned to be as simple through flexible technology with a broad diversity of frequency bands. The technology used for Downlink is OFDMA to attain the peak data rate of 100Mbit/s and Uplink is based on Single Carrier FDMA (SC-FDMA) to attain a peak data rate of 50Mbit/s. LTE provide connected automobiles, which produce a broad reach of broadband services and also facilitate better speed on current as well as new mobile applications

The main methodology in LTE to achieve high data rate, high QOS and bandwidth efficiency is using MIMO [2]. The OFDM is a multicarrier transmission scheme which provides several advantages like eliminating the ISI using CP, efficient use of spectrum by overlapping the subcarriers using the orthogonality principle and provides robustness against Co channel interference. The existing channel estimation methods [2-6], assume an invariant wireless channel within one OFDM symbol which leads to ICI (Inter Carrier Interference) problem in high mobility LTE system by losing the orthogonality between the subcarriers due to the Doppler spread. To suppress the ICI, between OFDM subcarriers, iterative Doppler assisted channel estimation with the PIC-DSC interference cancellation scheme is used [3-6]. The wireless channel is evaluated by the Doppler spread information, pilot symbols, and estimates of the data symbols at the recipient. Each channel coefficient is estimated by using time domain marker, which is expressed as a weighted interpolation between two selected time-domain markers which has maximum correlation. The detected data symbols together with the pilot symbols are used to improve the channel estimation in the next iterations. This existing method of estimation produces low SNR, leading to increased BER and decreased throughput.

In frequency domain estimation of wireless channel the color noise has been determined when there is a variation in the power spectral density. This spectral content variation affects some of the subcarriers of OFDM channel. By regular transmission of training sequences or pilot data the SNR can be estimated and using intermediate signals in channel estimation the color noise variance is calculated. 2-D minimum mean square error (MMSE) is used for noise variance at each subcarrier is estimated. By using statistics, the coefficient of noise can be calculated [7]. These estimates are very useful on adaptive modulation. To measure the average spectral efficiency in imperfect channel estimation, the system performance in the presence of color noise was provided in [8]. Adaptive modulation and coding (AMC) used for the efficient resource allocation technique by changing the system among various modulation coding schemes. By setting the modulation order depending on the quality of fading channel adaptive modulation scheme aims to improve link spectral efficiency, i.e. when the channel quality is good more bits are sent and based on the measured channel conditions additional subcarriers are allocated the different modulation scheme. The spectral efficiency is maximized even though the channel conditions are time variant and to achieve higher throughput additionally, adaptive modulation technique has been embraced. At the receiver a prediction of the future CSNR is obtained and transmitted to the transmitter via a feedback channel. To satisfy the BER demand the transmitter obtains this information to pick out the codec with the highest spectral efficiency, among the available codec's.

The rest of the paper is organized as follows; system model is described in section 2, the interference cancellation is in section 3, the estimation of channel with color noise is in section 4, Adaptive modulation is in section 5, the simulation result and the discussion is in section 6 and the conclusion is in section 7.

2. SYSTEM MODEL

The block diagram of adaptive modulation MIMO-OFDM is shown in the fig. 1, first the serial bit is modulated by using adaptive modulation. So, the series symbol stream is converted into parallel sub streams by using serial to parallel converter. Later on, this conversion, pilot symbols are inserted into the parallel sub streams. After the insertion of pilot symbols in frequency domain, OFDM modulation and demodulations are implemented by performing the Fast Fourier Transform and inverse Fast Fourier Transform (IFFT). On the receiver side the threshold values are selected depending upon the channel estimated parameters [9]. The receiver calculates the channel-quality indicator (CQI) and run it to the link adaptation, where the modulation order is taken based on CQI and eventually went to the sender.

Consider there are MT transmitter antennas and MR receiver antennas. The OFDM symbol transmitted by MT antennas can be interpreted by,

$$X = \left[X_1,\ldots\ldots,X_p,\ldots,X_{M_T}\right]^T \tag{1}$$

X_p Denotes the OFDM symbol transmitted by the antenna at kth subcarrier. Where N is the number of subcarriers for one OFDM symbol. The inverse Fast Fourier Transform (IFFT) is performed on each transmitting antenna, the time - domain modulated signal on the pth transmits antenna can be indicated $X_p = F^H X_p = \left[x_p(0),\ldots.,x_p(N-1)\right]^T$, Where F is the N×N FFT matrix. Due to multipath delay spread, Inter Symbol Interference (ISI) is occurring between the OFDM symbols. To avoid this ISI, a cyclic prefix (CP) is introduced in each OFDM symbol after IFFT. This prefix helps as a guard interval (GI) between OFDM symbols which is removed at the receiver. In,k is the color Noise and $h_{p,q}(l,n)$ is the impulse response the lth channel taps between the pth transmit antenna and the qth receive antenna at time n, L is the number of fading taps. Let L = [(max/TS] where (max is the maximum delay and TS is the duration of the OFDM symbol. Rq(k) as a sum of the desired signal and the ICI component as

$$R_q(k) = \underbrace{\sum_{p=1}^{M_T}\sum_{l=0}^{L-1} H_l^{p,q}(0) w_{l,q} X_p(k)}_{\text{desired signal}}$$

$$+ \underbrace{\sum_{p=1}^{M_T}\sum_{m=0,m\neq k}^{N-1}\sum_{l=0}^{L-1} H_l^{p,q}(k-m) w_{l,m} X_p(m)}_{\text{ICI component}} \tag{2}$$

$$+ I_{n,k}$$

3. INTERFERENCE CANCELLATION

In each iteration of the channel estimation, the ICI caused by the Doppler spread is suppressed by a PIC-DSC module. The decision statistics are brought forth by the DSC module as a weighted summation of the current PIC output and the DSC output of the former iteration. Thus, the yield of the DSC in previous iteration $\mathrm{Y}_{\mathrm{DSC},p}^{(t-1)}$ is given by

$$Y_{DSC,p}^{(\mathrm{t})}=\frac{\left(\sigma_{DSC,P}^{t-1}\right)^2}{Z}Y_p^{(\mathrm{t})}+\frac{\left(\sigma_p^t\right)^2}{Z}Y_{DSC,p}^{(\mathrm{t}-1)} \tag{3}$$

Where $Z=(\sigma_{\mathrm{DSC},p}^{t-1})^2+(\sigma_p^t)^2.(\sigma_{\mathrm{DSC},p}^{t-1})^2$ and $(\sigma_p^t)^2$ are the variances of DSC estimate $\mathrm{Y}_{\mathrm{DSC},p}^{(t-1)}$ and PIC output $\mathrm{Y}_p^{(t)}$. Then, $\mathrm{Y}_{\mathrm{DSC},p}^{(t)}$ is passed to the detector. The detected data symbols are transmitted backwards to the channel estimator. Yet, in later iterations, the interference estimates become more reliable, and a reduced interference level is likely to push the detection convergence. The ZF estimator that forces the interference to zero is given by

$$X^{(i)}=H^{(i)^H}(H^{(i)}H^{(i)^H})^{-1}R \tag{4}$$

4. ESTIMATION OF CHANNEL WITH COLOR NOISE

Here modification is needed to calculate the perfect channel in the presence of color noise signals using the transmission parameters such as coding rate and modulation scheme. It has been taken for granted that, in the looping, the transmitted data symbol vector X (t−1), which is found in the (t-1) the iteration, is available at the receiver. Rq (k) can be expressed as

$$R_q\left(k\right)=$$

$$\sum_{p=1}^{M_T}\sum_{s=0}^{N-1}\sum_{l=0}^{L-1}\sum_{i=1}^{M}b_{m(i),p,q}^{k,s}\left(l\right)h_{p,q}(l,m\left(i\right)X_p^{(t-1)}\left(s\right). \tag{5}$$

$$+I_q\left(k\right)$$

Iq(k) denotes the sum of the estimation error at subcarrier k and color noise at the qth receive antenna, and hp,q(l,n) is represents by an interpolation of the selected time-domain markers hp,q(l,m(k)) and hp,q(l,m(k)). Therefore, by defining a 1 × LM vector as $\mathbf{b}_{m(i),p,q}^{m,s}:=\left[b_{m(1),p,q}^{m,s},\ldots\ldots\ldots\ldots,b_{m(M),p,q}^{m,s}\right]$, it can further simplify Rq(k) to become

$$R_q(k)=\sum_{p=1}^{M_T}\underbrace{\sum_{s=0}^{N-1}X_p^{(t-1)}(s)b_{p,q}^{k,s}\bar{\mathbf{h}}^{p,q}}_{g_k^{p,(t-1)}}+e_q(k) \tag{6}$$

Where $\bar{\mathrm{h}}^{p,q}=\left[\mathrm{h}_{m(1)}^{p,q^T},\ldots\ldots,\mathrm{h}_{m(M)}^{p,q^T}\right]^T$ By defining $\mathrm{G}_k^{(t-1)}=\left[g_k^{1,(t-1)},\ldots\ldots\ldots\ldots,g_k^{M_T,(t-1)}\right]$ and, LS can be expressed as

$$h^{q,(t)}=(G^{(t-1)})^{\dagger}R_q \tag{7}$$

Because of large bandwidth this colored noise is preferred in the arrangement. The received signal of nth OFDM symbol at the kth subcarrier can be written as

$$Y_{n,k}=S_{n,k}H_{n,k}+I_{n,k} \tag{8}$$

$H_{n,k}$ is the value of the channel frequency response, and $I_{n,k}$ is the colored noise caused by interference. A zero-mean Gaussian variable is modeled as the interference term whose variance is a function of subcarrier and the symbol $I_{n,k}=N\left(0,\sigma_{n,k}^2\right)$ where $\sigma_{n,k}$ is the local standard deviation. The autocorrelation of the effective noise power is defined as

$$R_{\sigma'^2}(\tau,\Delta)=E_{(n,k)}[\sigma_{n,k}^{'2}\,\sigma_{n+\tau,k+\Delta}^{'2}] \tag{9}$$

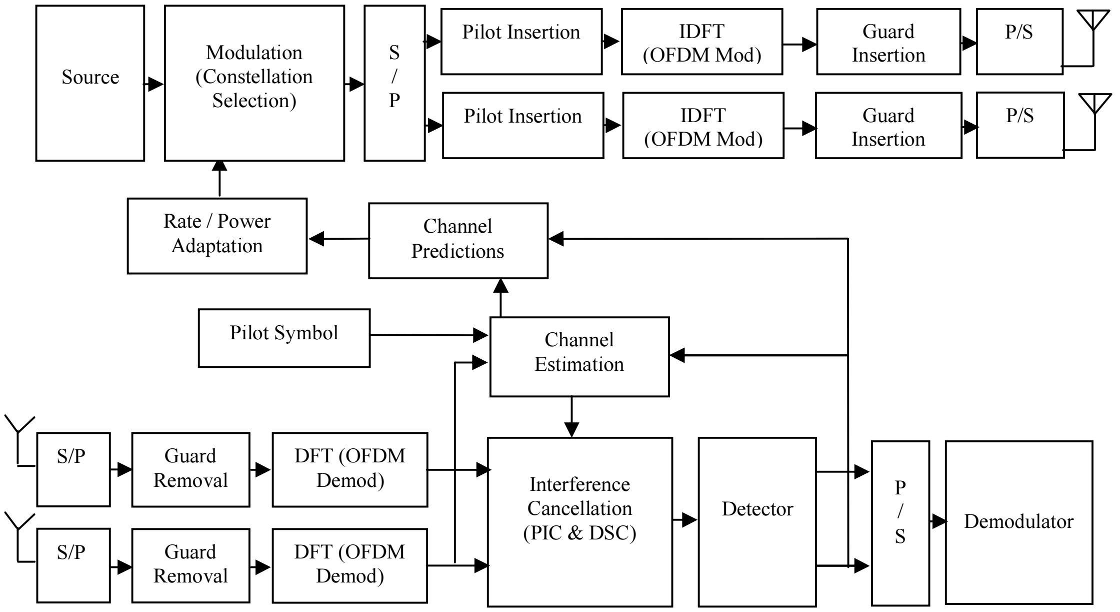

Figure 1 Block Diagram For Adaptive Modulation Transceiver

En, k [.] represents expectation over subcarriers and OFDM symbols. In the frequency domain, the basic approach for noise power estimation in OFDM systems is based on finding the difference between the noisy received samples and noiseless received sample can be expressed as

$$\hat{I}_{n,k} = \hat{Y}_{n,k} - \hat{S}_{n,k}\hat{H}_{n,k} \qquad (10)$$

The received symbol $\hat{S}_{n,k}$ is noiseless sample, $\hat{H}_{n,k}$ is the channel estimate of the nth subcarrier for the kth subcarrier. The estimation of the color noise power of the net OFDM symbol at the kth subcarrier is represented as

$$\hat{\sigma}'^{2}_{n,k} = \sum_{u=-U}^{U}\sum_{l=-L}^{L} w_{u,l}\left|\hat{I}_{n+u,k+l}\right|^{2} \qquad (11)$$

The color noise estimates calculated at each subcarrier $|\hat{I}_{n,k}|^2$ using a 2D filter. The dimensions in time and frequency directions of the filter are 2U+1 and 2L+1. The frequency domain estimator can be represented as

$$\hat{\sigma}'^{2}_{k} = \sum_{l=-L}^{L} w_{l}\left|\hat{I}_{k+l}\right|^{2} \qquad (12)$$

The MMSE estimation error at the kth subcarrier can be written as

$$\varepsilon(k) = \sum_{l=-L}^{L} w_{l}\left|\hat{I}_{k+l}\right|^{2} - \sigma'^{2}_{k} \qquad (13)$$

5. ADAPTIVE MODULATION

5.1. Adaptive Rate and Maximum BER

When the channel power gain changes the transmission rate $R = R(\gamma[l])$ is also changed. To increase the spectral efficiency the channel can be applied at the lower channel power without giving out the BER requirement. Under the certain maximum BER a communication link should usually work.

$$BER_i(\gamma_i S/S') \le BER_{max};\quad 0 \le i \le N-1 \qquad (14)$$

Where the BER (.) is a mapping of the modulation scheme relating the BER to the instantaneous SNR is considered. At received SNR, the BER for modulation i is equal to $\gamma_i S/S'$. In time varying channel the relative motion between transmitter and receiver which give rise to this channel variation of Doppler frequency [11] and are given by

$$f_d = \frac{1}{2\pi}\frac{\Delta\varphi}{\Delta t} = \frac{v}{\lambda}cos\theta \qquad (15)$$

Where v is the velocity and Δφ is the phase change

$$\Delta\varphi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi v\Delta t}{\lambda}\cos(\theta) \qquad (16)$$

5.2. Spectral Efficiency and Average BER

For the given value N the performance measures of adaptive modulation are the average BER and spectral efficiency. To evaluate the execution and to deduce the optimal SNR threshold the spectral efficiency can be computed as

$$SE' = \sum_{i=1}^{N_s}\sum_{k=1}^{K} d_k \int_{T_k}^{T_{k+1}} p_{\gamma_i}(\gamma_i)\, d\gamma_i \qquad (17)$$

Where $d_k = log_2 M_k$ is the number of bits per symbol on the ith sub-channel the probability density function is referred as $P\gamma_i(\gamma_i)$. For adaptive modulation schemes the average BER can be specified in two different ways, in

$$BER' = \frac{E[number\ of\ error\ bits\ per\ transmission]}{E[number\ of\ bits\ per\ transmission]}$$

5.3. Codec Switching Strategies

The switching threshold is defined by codec selection strategy (CSS) for the predicted CSNR (channel signal-to-noise ratio)

$$\{S_n\}_{n=0}^{N+1} = \{S_0, S_1, S_2, \ldots, S_N, S_{N+1}\} \qquad (18)$$

The CSNR threshold level (region) can be used as switching thresholds $s_n = \gamma_n, n \in \{0,1,\ldots,N+1\}$ and the codec n is selected when $\hat{\gamma} \in [s_n, s_{n+1}]$ and $\hat{\gamma}\, \varepsilon [s_0, s_1]$. The system obtained an outage only the pilot data is transmitted. The switching thresholds were then just increased by a constant (in dB), resulting in improved BER performance [12]. Due to increasing the BER there is an increased probability of mismatch between the predicted and actual CSNR when the normalized correlation is reduced.

$$P(\gamma > \gamma_n / \hat{\gamma} = s_n) = 1 - \grave{o} \qquad (19)$$

The probability of a codec mismatch can be reduced by increasing the switching thresholds, $\{S_n\}_{n=1}^{N}$, to get a certain desired ϵ (sufficiently small) constant value. To avert the problem of BER always stays below BER of with the certain (sufficiently high) probability the conditional probability density functions should be counted. Then, it can be obtained that the probability using the conditional pdf.

$$1 - \grave{o} = P(\gamma > \gamma_n / \hat{\gamma} = s_n) \qquad (20)$$

$$= \int_{\gamma_n}^{\infty} p_{\gamma/\hat{\gamma}}(\gamma / \hat{\gamma} = s_n)\, d\gamma \qquad (21)$$

The new switching thresholds can be expressed a

$$Q\left(\sqrt{\frac{2 s_n}{\hat{\gamma}(1-p)}}, \sqrt{\frac{2\gamma_n}{\hat{\gamma}(1-p)}}\right) = 1 - \grave{o} \qquad (22)$$

With respect to every $s_n, n\grave{o}\{1,2,\ldots,N\}$ forgiven values of $\hat{\gamma}, p$ and $\{\gamma_n\}_{n=1}^{N}$

6. RESULT AND DISCUSSION

This analysis shows that the performance of the system with adaptive modulation performs better than the system only with fixed modulation under the Rayleigh fading channel.

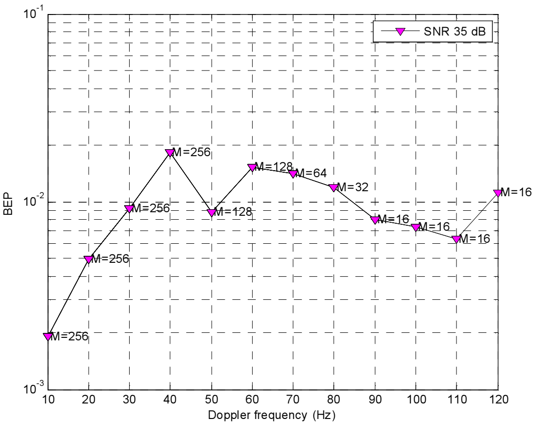

Figure 2 BEP Versus Doppler Frequency Comparisons With Different Modulation Changes From M=256 To 16 For Fixed SNR Is 35db.

The above result indicates that the performance of the system improves and reduces in terms of BEP. The analysis was tested with different modulations with fixed SNR 35dB. From the result, it is observed that when the Doppler frequency is reduced, then the modulation rate of the system gets increased. Doppler frequency from 10 to 40 Hz it works with 256 and 40 to 60 Hz is 128 and rest up to 120 Hz is with the modulation rate is changed 64, 32 and 16 respectively. Fig. 2 in the above and fig. 3 in the below shows the BEP performance of MIMO with Adaptive Modulation for different Doppler frequency.

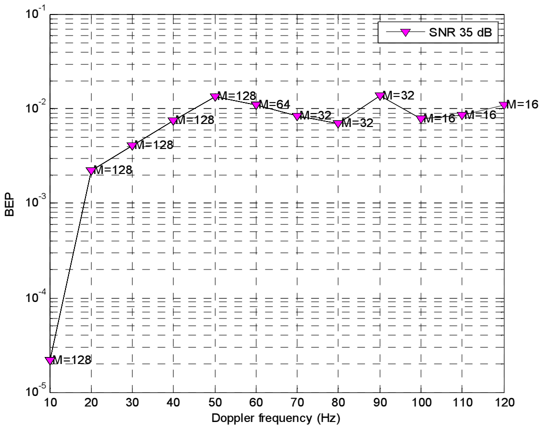

Figure 3 BEP Versus Doppler Frequency Comparisons With Different Modulation Changes From M=128 To 8 For Fixed SNR Is 35db.

From the above figure it is apparent that the system with adaptive modulation performs better than the system only with fixed modulation.

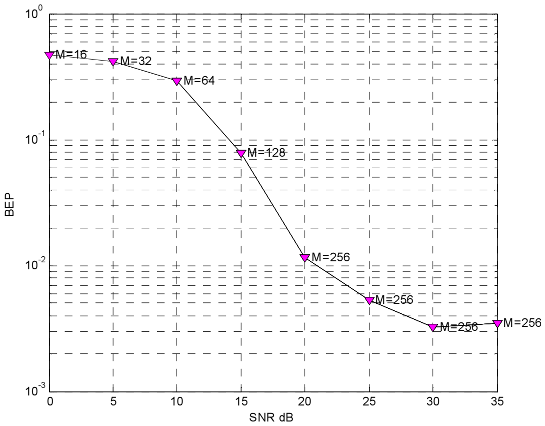

Figure 4 BEP Versus SNR Comparisons With Different Modulation Changes From M=16 To 256 For Fixed Doppler Frequency Is 20Hz.

In fig. 4 shows the BEP performances of the adaptive modulation by keeping DF kept constant at 20. It is found out clearly that there will be a substantial improvement in BEP performance for M = 256 are also accomplished. For the different SNR values BEP performance is successfully decreased to meet the BEP target 10-2.8. So it also achieves that system performance and obtaining high data rate

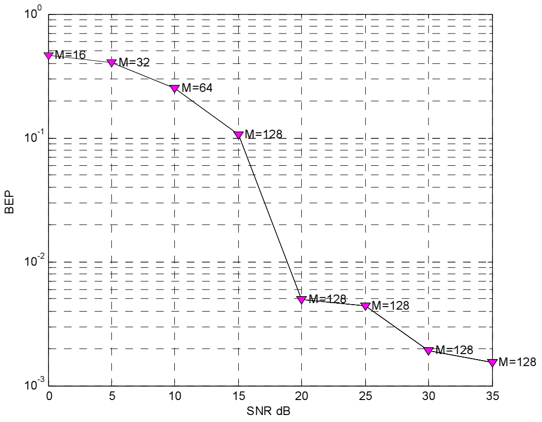

Figure 5 BEP Versus SNR Comparisons With Different Modulation Changes From M=16 To 128 For Fixed Doppler Frequency Is 20Hz.

Similarly In fig. 5 shows the BEP performances of the adaptive modulation by keeping DF kept constant at 20. It is shows the better BEP performance for M=128. For the different SNR values the BEP performance is successfully decreased to meet the BEP target up to 10-3. So it also achieves that system performance and obtaining high data rate.

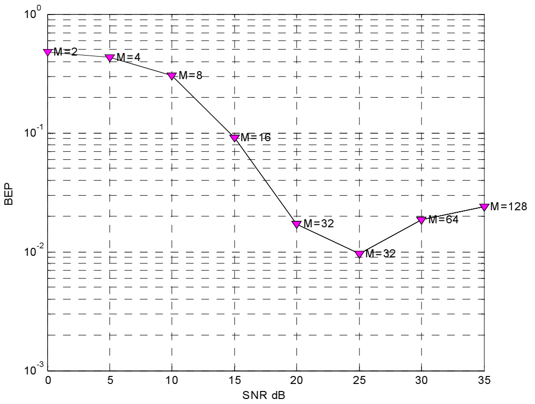

Figure 6 BEP Versus SNR Comparisons With Different Modulation Changes From M=16 To 256 For Fixed Doppler Frequency Is 80Hz.

In the fig. 6 represents BEP performances of Doppler frequency is high. Even though DF is high (fd = 80) for Initial Modulation = 128 there will be decreased BEP = 10-2 and so increasing the spectral efficiency. It is likewise observed that adaptive modulation achieves higher throughput compared to constant modulation technique. In fig. 7 below shows the performances for Doppler frequencies for the value of 12 the BEP will be equal 10-2 with an SNR of 35dB.

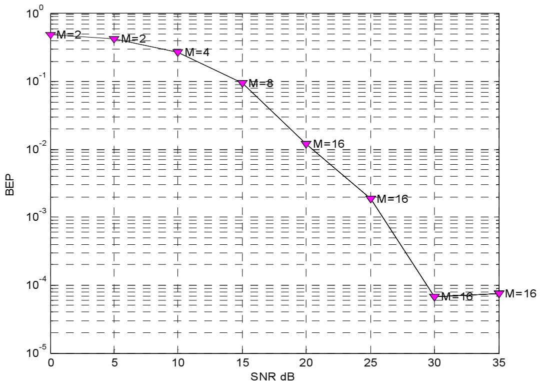

Figure 7 BER Versus SNR Comparisons With Different Modulation Changes From M=2 To 16 For Fixed Doppler Frequency Is 12Hz.

The scheme is tested for different transitions with different Doppler frequency also which is evinced in the Fig 4, Fig 5, Fig 6 and Fig 7. From Fig 4, Fig 5, Fig 6 and Fig 7 it is mentioned that the functioning of the system gradually increases due to the gain in SNR i.e. as Bit Error Probability increases. Comparing Fig. 2, Fig. 3 with Fig. 4, Fig. 5, Fig. 6 and Fig. 7, the figures show improved performance, because when the number of Doppler frequency and the SNR is increased, the carrying out of the organization is increased due to the exploitation of Bit Error Probability. From the simulation results it is clear that in all cases of the system with channel estimation with adaptive modulations performs better.

7. CONCLUSION

Normally, wireless channels are fading in both time and frequency, which results in low BEP in the received signal. The use of Doppler assisted channel estimation mitigates dispersion, but not in the sufficient level. So it is necessary to improve the system performance for achieving high data rate by combining BEP and color noise estimation. The combining technique such as PIC-DSC scheme has been used in Doppler assisted channel estimation for the interference cancellation scheme. In this paper to counteract BEP, the MIMO-OFDM system with adaptive modulation is discussed with varying different channel conditions. From the simulation result it is referred that the MIMO-OFDM system with adaptive modulation performs better in the Rayleigh fading channel as BEP is increased tremendously.

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