ESTIMATION OF CARRIER FREQUENCY OFFSET IN OFDM SYSTEM BY USING ADPATIVE MODULATION TECHNIQUES

[1]Ankita Yadav
Research Scholar, M. Tech.
Digital Communication, GGCT, Jabalpur

[2] Mrs. Papiya Dutta
Assistant Professor,
Dept. of ECE, GGCT, Jabalpur

ABSTRACT:In this paper we have implemented CFO correction under the influence of the CFO on OFDM transmission over AWGN channels. OFDM is very much sensitive to carrier frequency offset, which attenuates the desired signal & causes inter carrier interference, thus reducing the SNR. In this paper we have analyzed the Adaptive modulation with CFO and compared the average spectral efficiency with non-adaptive modulation methods. proposed adaptive modulation algorithm with CFO=0.05 achieves average spectral efficiency of that the proposed adaptive modulation algorithmgives optimum average spectral efficiency up to 5-6 bps/Hz for the target BER of 10^{-3}& up to 8-9 bps/Hz for the target BER of 10^{-6}. The proposed modulation technique is tested by MATLAB computer simulations and the simulation results exhibits better performance than the conventional adaptive modulation techniques.

Keywords: Orthogonal Frequency Division Multiplexing, Carrier Frequency Offset, Inter Carrier Interference, Channel State Information, Bit Error Rate.

1. INTRODUCTION

Orthogonal frequency division multiple access (OFDMA) is an extremely popular multiple access scheme that can support high data rate [1]. As OFDMA inherits many advantages of orthogonal frequency division multiplexing (OFDM), such as high spectral efficiency, robustness against multipath effects and flexible quality of service support (QoS), it is widely deployed in wireless communication systems. Using the multiple input multiple output (MIMO) techniques, spectral efficiency of OFDMA can be further enhanced by assuming that the channel across each transmit-receive antenna pair undergoes independent fading. However, OFDMA inherits many drawbacks of OFDM also. In a MIMOOFDMA uplink with high mobility users, the transmitted signal undergoes both time and frequency selective (doubly selective) fading due to higher Doppler spread and multipath effects, respectively. The time variations of the channel impulse response within the OFDMA symbol duration will cause frequency dispersion that may destroy the orthogonality among the subcarriers. This results in multiple access interference (MAI) which may significantly degrade the overall system performance. The carrier frequency offset (CFO) caused by the local oscillator mismatches or instabilities also cause the loss of orthogonality among the subcarriers and resulting in MAI. [1].

Carrier frequency offset (CFO), resulting from oscillators instabilities, is a common impairment in many communications systems. CFO estimation is therefore an essential component in the design of communications systems [3]. The performance of communication system with one bit per subcarrier CSI feedback is analyzed. A large class of CFO estimation schemes is the class of pilot-aided schemes, which is based on an a-priori known synchronization sequence, incorporated into the transmitted signal, and on modeling the CFO as an unknown deterministic parameter [3]. The work [17] designed a maximum likelihood (ML) scheme for the joint estimation of the CFO and of the channel transfer function (CTF) for unknown linear time-invariant (LTI) channels with additive white Gaussian noise (AWGN), without assuming a specific modulation scheme. Many suboptimal low-complexity approximations of the ML estimator (MLE) of [17] were proposed, especially for orthogonal frequency division multiplexing modulated signals and multiple antenna channels. Bit error rate (BER) is used for evaluation of the system performance. Assuming that the feedback channel is perfect, adaptive modulation selection (AMS) is used to exploit the CSI feedback and compared the results with non-adaptive modulation (fixed modulations) systems [8]-[10]. Most algorithms on CFO estimation in OFDM systems are based on the auto-correlation based method [6, 9], which uses cyclic prefix (CP) or pilots signals. However, this method is based on the assumption that during the time interval of two pilots, the channel is time-invariant. The assumption is violated for channel with large Doppler spread [4]. Adaptive technique can be applied to mitigate the deep fading effect if the channel state information (CSI) is available at the transmitter. To achieve the performance advantages of adaptive modulation,however, accurate receiver CSI is required at the transmitter. But in wireless communications, the channel is noisy and affected by CFO, the estimated CSI may be invalid. This is the fact behind the need for CFO correction in adaptive modulation.

2. ADAPTIVE MODULATION SELECTION

Adaptive modulation is a powerful technique for maximizing the data throughput of subcarriers allocated to a user. Adaptive modulation involves measuring the SNR of each subcarrier in the transmission, then selecting a modulation scheme that will maximize the spectral efficiency, while maintaining an acceptable BER [7]-[10].

The AMS scheme is based on the following idea. When a certain subcarrier is corrupted by fading channels, a constellation with smaller dimension and higher transmitted power can be assigned to this particular carrier, while constellation of large dimensions and less transmitted power can be assigned to the subcarriers whose channel gain is high. A low rate one bit per subcarrier feedback can be used to divide the subcarriers into two groups that use different constellations and transmitted powers. This adaptive modulation has well performed than conventional non-adaptive modulation techniques. The modulation scheme was chosen from the set of Binary Phase Shift Keying (BPSK),

Quadrature Phase Shift Keying (QPSK), 16-level Quadrature Amplitude Modulation (16-QAM), 64-level Quadrature Amplitude Modulation (64-QAM), as well as "No
Transmission," for which no signal was transmitted. Each scheme provides a tradeoff between spectral efficiency and the bit error rate.

The spectral efficiency can be maximized by choosing the highest modulation scheme that will give an acceptable Bit Error Rate (BER). In systems that use a fixed modulation scheme the subcarrier modulation must be designed to provide an acceptable BER under the worst channel conditions. This results in most systems using BPSK or QPSK. However these modulation schemes give a poor spectral efficiency (1-2 b/s/Hz) and results in an excess link margin most of the time. Using adaptive modulation, the remote stations can use a much higher modulation scheme when the radio channel is good. Thus as a remote station approaches the base station, the modulation can be increased from 1 b/s/Hz (BPSK) up to 4-8 b/s/Hz (16-QAM – 256-QAM), significantly increasing the spectral efficiency of the overall system. Using adaptive modulation can effectively control the BER of the transmission, as subcarriers that have a poor SNR can be allocated a low modulation scheme such as BPSK or none at all, rather than causing large amounts of errors with a fixed modulation scheme. This significantly reduces the need for Forward Error Correction.

In order to keep the system complexity low, the modulation scheme is not varied on a subcarrier-by subcarrier basis, but instead the total OFDM bandwidth of total subcarriers is split into blocks of adjacent subcarriers, referred to as subbands, and the same modulation scheme is employed for all subcarriers of the same subband. This substantially simplifies the task of modem mode signaling.

Frequency errors in the transmission due to synchronization errors and Doppler shift result in a loss of orthogonality between the subcarriers. A frequency offset of only 1-2% of the subcarrier spacing results in the effective SNR being limited to 20 dB.

3. OFDM SYSTEM MODEL WITH CARRIER FREQUENCY OFFSET ESTIMATION AND CORRECTION

OFDM partitions the incoming data stream into N low rate parallel sub streams, as is shown in the baseband equivalent model of fig.1, which modulate a set of subcarriers using Inverse Discrete Fourier Transform (IDFT) so as to obtain the time domain signals. A cyclic prefix is then added to the time domain signal to eliminate inter symbol interference (ISI) caused by channel multipath fading and enables simple channel equalization at the receiver. The inverse fast Fourier transform (IFFT) is performed on the transmit symbol $X_m(k)$, $k = 0, 1 \ldots, N-1$, to produce the time domain samples $x_m(n)$ of the m-th OFDM symbol [7]:

$$x_m(n) = \begin{cases} \dfrac{1}{N}\displaystyle\sum_{k=0}^{N-1} X_m(k) e^{j2\pi k(n-N_g)/N}, & for\ 0 \le n \le N+N_g-1 \\ 0 & otherwise \end{cases} \quad (1)$$

where N and N_g are the number of data samples and cyclic prefix samples, respectively.

The OFDM symbol $x_m(n)$ is passed through a channel $h_m(n)$ and is affected by Additive white Gaussian noise $W(n)$. When the oscillator of the receiver is perfectly matched to the carrier of the received signal, a carrier frequency offset and a phase offset will not appear. Then the received signal can be represented as follows:

$$\tilde{y}_m[n] = h_m[n] * x_m[n] + w(n) \quad (2)$$

where * is the convolution operator.

The insertion of guard intervals renders the received carriers orthogonal on the N point symbol interval. However the demodulation process, which is implemented with a DFT, is affected by carrier frequency offset. The CFO will appear when the oscillator of the receiver is not perfectly matched to the carrier of the received signal. After removing the cyclic prefix and taking the N point DFT at the receiver, $(k + r)^{th}$ subcarrier signal of the m^{th}symbol can be expressed as [2]

$$Y_m(k+r) = X_m(k)H_m(k)C_m(0) + \sum_{\substack{l=1 \\ l\neq 0}}^{N-1} X_m(k-l)H_m(k-l)C_m(l) + Z_m(k+r) \quad (3)$$

Where

$$C_m(l) = \left\{\frac{\sin \pi\varepsilon}{N\sin(\pi(l-r+\varepsilon)/N)}\right\} e^{j\varepsilon(N-1)/N} e^{-j\pi(l-r)/N}$$

From equation (3), it can be seen that the received signal is attenuated by the factor $C_m(0) = \dfrac{\sin \pi\varepsilon}{N\sin(\pi\varepsilon/N)}$,
where is normalized frequency offset which is defined as = fNT. In equation (3) the second term is the ICI caused by the frequency offset. Third term $Z_m(k+r)$ denotes the AWGN noise with zero mean and variance σ^2.

One of the ways of canceling the effect of ICI in OFDM systems is statistically estimating the frequency offset and canceling this offset at the receiver. In this technique, an OFDM symbol stream of N symbols is replicated. These symbols are then modulated using a 2N-point inverse discrete Fourier transform (IDFT). At the receiver, to get the sequence Y_{1k} the first set of N symbols are demodulated using an N-point discrete Fourier transform (DFT), and the second set is demodulated with another N-point DFT to yield the sequence Y_{2k}. The frequency offset is the phase difference between Y_{1k} and Y_{2k}, that is, $Y_{2k} = Y_{1k}\, e^{j2\pi\varepsilon}$. The maximum likelihood estimate of the normalized frequency offset is given by:

$$\hat{\varepsilon} = (1/2\pi)\tan^{-1}\{(\sum_{k=-K}^{K} \mathrm{Im}[Y_{2k}Y_{1k}^{*}])/(\sum_{k=-K}^{K} \mathrm{Re}[Y_{2k}Y_{1k}^{*}])\} \quad (4)$$

This maximum likelihood estimate is a conditionally unbiased estimate of the frequency offset and will be computed using the received data [2].

Once the frequency offset is known, the ICI distortion in the data symbols can be reduced by multiplying received symbols with a complex conjugate of the frequency shift.

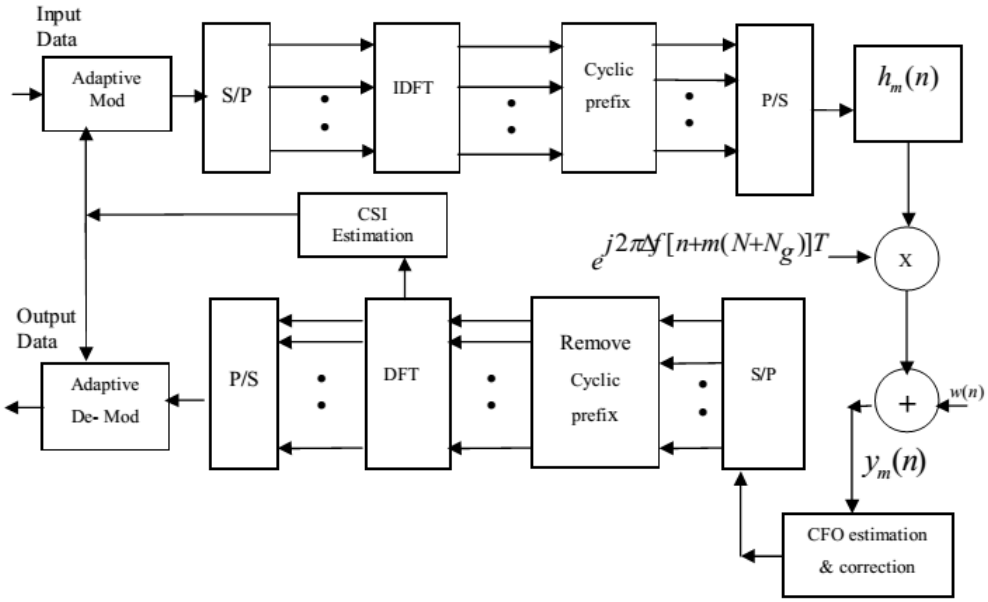

Figure 1: Block diagram of Proposed System Model for CFO correction by Adaptive Modulation

4. SPECTRAL EFFICIENCY OF ADAPTIVE OFDM

The spectral efficiency is defined as the average data rate per unit bandwidth. When we send $k() = \log_2 [M()]$ (bits/symbol), the instantaneous data rate is $k() / T_S$ (bps), where T_s is the symbol period. Assuming Nyquist data pulse $B = 1/T_s$, for the discrete rate adaptation the spectral efficiency is given by [9]

$$\frac{R}{B} = \sum_{i=0}^{N-1} k_i \int_{\gamma_i}^{\gamma_i+1} p(\gamma)\,d\gamma \qquad (b/s/Hz)$$

For the Discrete Rate case, the rate region boundaries $\{\gamma_i\}_{i=0}^{N-1}$ define the range of values over which different constellations are transmitted. More clearly, the different constellation sizes correspond to a set of discrete rates $\{k_i\}_{i=0}^{N-1}$ which are allocated respectively to each fading region $[\gamma_i, \gamma_{i+1}]\ (0 \le i \le N-1)$. When the instantaneous SNR falls within a given fading region, the associated signal constellation is transmitted.

Assume M-QAM is employed for each sub channel, and $[n, k]$ bits/symbol are sent for the kth tone in the nth block. We investigate the spectral efficiency under a constrained average BER requirement. According to [9], given the channel frequency response $H\,[n, k]$, the instantaneous BER for the k th tone in the n th block can be approximated by

$$P_e[n,k] = 0.2 \exp\left\{ -\frac{1.6 \frac{E_S}{N_O} |H[n.k]|^2}{2^{\beta[n.k]} - 1} \right\} \qquad (6)$$

Where E_S is the symbol energy at the transmitter, and $N_0/2$ is the variance of the real/imaginary part of the Gaussian noise $W\,[n, k]$.

4.1 *Non Adaptive Modulation*

Consider first the case of non adaptive modulation, where $[n, k] =$ is a constant for all n and k. Since $H[n, k]$ is a complex Gaussian random variable and all $H[n, k]$ have identical distributions, the overall average BER become

$$\overline{P_e} = E_{H[n.k]}\left\{P_e[n.k]\right\} = \frac{1.6}{\frac{0.2\, E_s / N_0}{2^{\beta} - 1} + 1} \qquad (7)$$

Assume P target is the target average BER. Then by inverting, the maximum number of bits that can be transmitted given the average BER constraint is

$$\beta = \log_2 \left[\frac{1.6 \frac{E_s}{N_0}}{\frac{0.2}{P_{target}} - 1} + 1 \right] \quad (8)$$

The spectral efficiency (number of bits per second per Hz) is equal to β, under the assumption that the symbol interval is the reciprocal of the sub channel and bandwidth.

4.2 Ideal adaptive OFDM

For adaptive OFDM, different modulation schemes are used for different subchannels. In this section we assume that perfect knowledge of the receiver information channel is available at the transmitter.To achieve the acceptable target BER (P_{target}), the number of bits transmitted in each sub channel can be derived from (6) as

$$\beta[n,k] = \log_2 \left[\frac{1.6 \frac{E_s}{N_0} |H[n,k]|^2}{\ln \frac{0.2}{P_{target}}} + 1 \right] \quad (9)$$

Therefore, the average spectral efficiency R is

$$R = E_{H[n.k]} \{\beta[n.k]\} \quad (10)$$

The average spectral efficiency of adaptive OFDM for target BER of 10^{-3} is obtained through a Monte Carlo simulation is shown in Fig 3. Inter carrier interference and the overhead due to the Guard interval is not considered. The result indicate that a significant improvement in spectral efficiency or bit rate than the non adaptive modulation techniques.

4.3 Adaptive Modulation with CFO Correction

The spectral efficiency of the proposed adaptive modulation with CFO has been derived theoretically and it is expressed as follows.

$$\beta[n,k] = \log_2 \left[\frac{1.6\gamma(\varepsilon) |H[n,k]|^2}{\ln \frac{0.2}{P_{target}}} + 1 \right] \quad (11)$$

Therefore, the average spectral efficiency R is;

$$R = E_{H[n.k]} \{\beta[n.k]\} \quad (12)$$

The average SNR in the presence of CFO for AWGN channel is

$$\gamma(\varepsilon) = \frac{C_m(0)^2 \gamma}{(1 - C_m(0)^2)\gamma + 1} \quad (13)$$

where $C_m(0) = \frac{\sin \pi\varepsilon}{N \sin(\pi\varepsilon / N)}$ and γ is the average SNRin the absence of CFO for AWGN channel. Thus by introducing the CFO correction in adaptive modulation, the attenuation of SNR is reduced and hence the spectral efficiency is improved.

5. PROPOSED ALGORITHM

The CFO will directly affect the received average SNR. This attenuation is more noticeable when SNR is large. Due to this the adaptive modulation without CFO correction will not maximize the spectral efficiency. The proposed method corrects the CFO before the estimation of CSI that is threshold is measured after the CFO correction. Thus, by introducing the CFO correction in adaptive modulation, the attenuation of SNR is compensated and hence the spectral efficiency is improved.For implementation of the proposed algorithm following steps have been adopted;

Step 1: Estimate the threshold SNR (i.e. region boundaries) for the given target BER using the following equations:

$$Y_m(k+r) = X_m(k) H_m(k) C_m(0) + \sum_{l=1, l \neq 0}^{N-1} X_m(k-1) H_m(k-1) C_m(l) + Z_m(k+r)$$

Where;

$\sum_{l=1,l\neq 0}^{N-1} X_m(k-1)H_m(k-1)C_m(l) + Z_m(k+r)$ is error function.

$$C_m(l) = \left\{\frac{\sin \pi\varepsilon}{N \sin(\pi(l-r+\varepsilon)/N)}\right\} e^{\frac{j\varepsilon(N-1)}{N}} e^{\frac{-j\pi(l-r)}{N}}$$

Where;

$$C_m(0) = \frac{\sin \pi\varepsilon}{N \sin(\pi\varepsilon/N)}$$

Step 2: Estimate the CFO (ε) using ML estimate technique.

$$\varepsilon = \frac{1}{2\pi}\tan^{-1}\left[\frac{\sum_{k=-K}^{K} Im[Y_{2k}Y^*{}_{1k}]}{\sum_{k=-K}^{K} Re[Y_{2k}Y^*{}_{1k}]}\right]$$

At the receiver, to get the sequence Y1k the first set of N symbols are demodulated using an N-point FFT, and the second set is demodulated with another N-point FFT to yield the sequence Y2k. The frequency offset is the phase difference between $Y_{1k}$and Y_{2k} that is,

$$Y_{2k} = Y_{1k}e^{j2\pi\varepsilon}$$

Step 3: Determine the average SNR $\gamma\ (\varepsilon)$ i.e. threshold SNR in the presence of CFO for AWGN channel expressed as:

$$\gamma(\varepsilon) = \frac{C_m(0)^2\gamma}{(1-C_m(0)^2)\gamma + 1}$$

Step 4: Finally determine the average SNR of the received signal using;

$$\gamma = \frac{\gamma(\varepsilon)}{C_m(0)^2 - (1-C_m(0)^2)\gamma(\varepsilon)}$$

Step 5: Compare this received average SNR with threshold SNR and select the constellation size M.

If $\gamma < \gamma_1$ then no transmission
If $\gamma_1 \leq \gamma < \gamma_2$ then M = 2 (BPSK or 2QAM)
If $\gamma_2 \leq \gamma < \gamma_3$then M = 4 (QPSK or 4QAM)
If $\gamma_3 \leq \gamma < \gamma_4$then M = 16 (16QAM) and so on.

Step 6: Perform the adaptive modulation with respect to the size M.
Step 7: Plot the graph between BER for different values of SNR for different modulation i.e. distinguish values of M.
Step 8: Plot the graph between BER for different values of SNR for distinguish values of CFO.

6. SIMULATION RESULTS

For simulation of this proposed CFO estimation algorithm using adaptive modulation technique, the implementation has been performed using MATLAB 2012. The simulation has been done with following specification mentioned in table 1.

Parameters	Values
Bandwidth for each user	20 MHz
Number of subcarriers	64,128,256,512
Cyclic Prefix Length	16
Number of pilots	4
Subcarrier frequency spacing	0.3125 MHz
IFFT/FFT period	3.2 µs
Guard interval duration	0.8 µs
Modulation method	BPSK, QPSK, 16QAM, 64QAM

Table 1: The Simulation Parameters

6.1 SNR Performance vs BER Sensitivity under AWGN with Proposed Technique

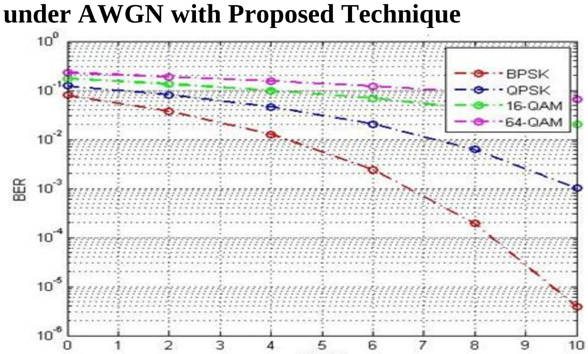

Figure 2: BER sensitivity vs SNR under AWGN with proposed adaptive modulation technique

Figure 2 shows the comparison of SNR vs BER for different modulation techniques. It shows that the BER rate mainly depends on the constellation size M. BPSK provides good BER performance, but its spectral efficiency is low for lower SBR, which is very low compared to other modulation schemes. At the same time 64-QAM will able to provide better spectral efficiency that is high, but it fails to maintain good BER performance and thus low QoS. Hence to achieve maximum spectral efficiency with achieving target BER, adaptive modulation technique is used.

The range of average SNR for the various modulation schemes have been derived from step 1 of the proposed algorithm or the threshold SNR (i.e. region boundaries) have been measured using Figure 2. These boundary values are tabulated in Table 2.

Target BER	M=2 (BPSK)	M=4 (QPSK)	M=8 (16-QAM)	M=16 (64-QAM)
10^{-2}	4 dB	7 dB	20-21 dB	27 dB
10^{-3}	6-7 dB	10 dB	25 dB	30 dB
10^{-4}	8-9 dB	13-14 dB	28 dB	32 dB
10^{-5}	9 dB	17-18 dB	30 dB	35 dB
10^{-6}	10 dB	18-19 dB	32 dB	37 dB

Table 2: BER vs SNR for Proposed Techniques of Figure 2

6.2 SNR Performance vs BER Sensitivity under AWGN with BPSK Modulation Techniquefor Different Values of CFO by Proposed Algorithm

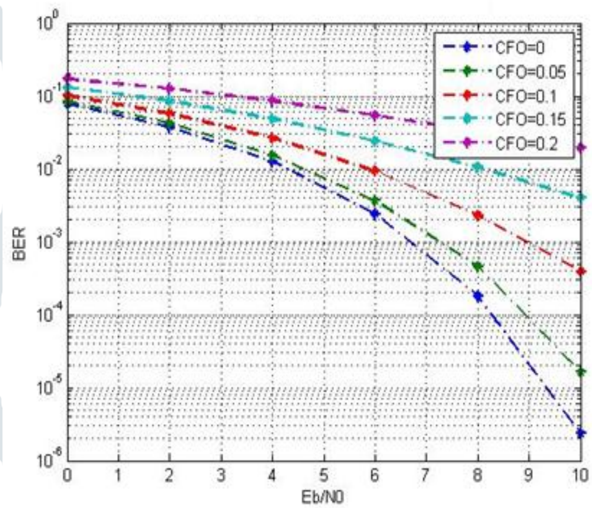

Figure 3: BER sensitivity vs CFO under AWGN with BPSK technique by proposed algorithm

Figure 3 shows that SNR degradation is more when CFO is higher. Also the result shows that SNR degradation is more for the higher values of actual SNRs than for the lower values of actual SNRs. These SNR degradations for different CFO are tabulated in Table 3.

Target BER	Bit to Noise Ratio (dB) for Different Values of CFO				
	CFO=0	CFO=0.05	CFO=0.1	CFO=0.15	CFO=0.2
10^{-2}	4 dB	4-5 dB	6 dB	8 dB	12 dB
10^{-3}	6-7 dB	7 dB	8 dB	15 dB	20 dB
10^{-4}	8-9 dB	9 dB	12 dB	20 dB	24 dB
10^{-5}	9 dB	10 dB	16 dB	22 dB	28 dB
10^{-6}	10 dB	11-12 dB	18 dB	28 dB	32 dB

Table 3: SNR degradations for different CFO for BPSK of Figure 3

It can be observed from table 3 that for CFO=0.05 SNR is 7 dB for target BER of 10-3. For this values the average spectral efficiency of 6 bps/Hz, which is better as well good BER performance.

6.3 Spectral Efficiency vs SNR for BPSK

Figure 4 shows the relation between Spectral Efficiency vs Signal to Noise Ratio for BPSK. This shows the capacity of Adaptive modulation with CFO = 0.05 has a better spectral efficiency. The proposed adaptive modulation with CFO correction technique gives better performance. This means that the adaptive modulation with CFO=0.05 achieves average spectral efficiency of 6 bps/Hz, which is better as well good BER performance.

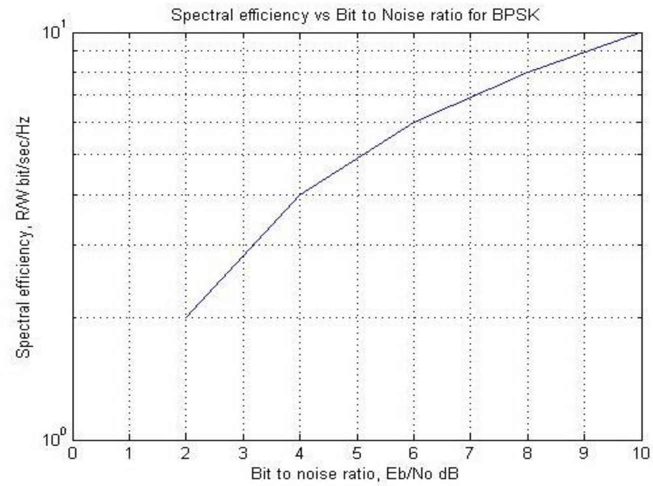

Figure 4: Spectral Efficiency vs Signal to Noise Ratio for BPSK CFO=0.05

Spectral Efficiency (R/W) (Bit/ Sec/ Hz)	Signal to Noise Ratio (E_b/N_0) (dB)
$10^{0.2}$	2
$10^{0.3}$	3
$10^{0.4}$	4
$10^{0.5}$	5
$10^{0.6}$	6
$10^{0.7}$	7
$10^{0.8}$	8
$10^{0.9}$	9
10^{1}	10

Table 4: Spectral Efficiency vs Signal to Noise Ratio for BPSK CFO=0.05

6.4 SNR Degradation of Frequency Offset

Figure 5 shows the calculated degradation of the SNR due to the frequency offset. For smaller CFO values, the degradation is less than as compared to higher CFO values. Also, as the supplied SNR is more the degradation in SNR is less.

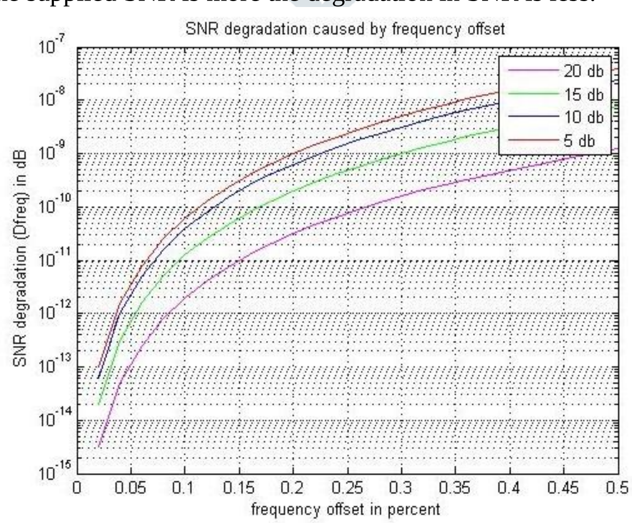

Figure 5: SNR degradation of frequency offset for different values of E_b/N_0

CFO	5 dB	10 dB	15 dB	20 dB
	SNR Degradation ↓			
0.05	10^{-13}	10^{-12}	10^{-11}	10^{-11}
0.1	10^{-12}	10^{-11}	10^{-10}	10^{-10}
0.15	10^{-11}	10^{-10}	10^{-9}	10^{-9}
0.2	10^{-11}	10^{-10}	10^{-9}	10^{-9}
0.25	10^{-10}	10^{-9}	10^{-8}	10^{-8}
0.3	10^{-10}	10^{-9}	10^{-8}	10^{-8}
0.35	10^{-9}	10^{-9}	10^{-8}	10^{-8}
0.4	10^{-9}	10^{-9}	10^{-8}	10^{-8}
0.45	10^{-9}	10^{-8}	10^{-8}	10^{-8}
0.5	10^{-9}	10^{-8}	10^{-8}	10^{-8}

Table 5: SNR degradation with CFO for different values of $\boldsymbol{E_b/N_0}$ for Figure 5

6.5 Simulation Results Comparison

In [3] the performance of four algorithms are shown for CFO estimation under no CFO case for QPSK modulation, it is compared with our proposed algorithm, given in table 6. This shows 6-7 dB improvement at the target BER of 10-2. Also we can clearly see that 12-13 dB improvement with [3] at the target BER of 10-3.

Target BER	SNR (E_b/N_0) for QPSK			
	This Work	MMSE [3]	Semi Blind ICA [3]	CAZAC [3]
10^{-2}	**7 dB**	13-14	16-17	25
10^{-3}	**10 dB**	23-24	26-27	--
10^{-4}	**13-14 dB**	31-32	35-36	--
10^{-5}	17-18 dB	--	--	--
10^{-6}	18-19 dB	--	--	--

Table 6: Simulation Results Comparison under NO CFO case

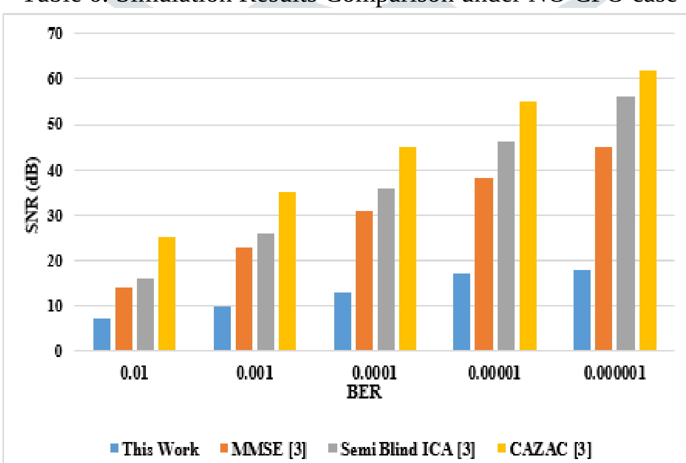

Figure 6: Simulation Results Comparison under no CFO case (Table 6)

In Ref. [1] the performance of two algorithms named joint estimation algorithm [1] &Perfect Sync. & Chan. has been compared for CFO estimation with CFO=0.05, it is compared with our proposed algorithm, given in table 6.7. This shows 15 dB improvement at the target BER of 10^{-2}. Also we can clearly see that an 15 dB improvement with [5] for CFO=0.05 at the target BER of 10^{-3}.

Target BER	CFO=0.05		
	This Work	Joint Estimation Algo. [1]	Perfect Sync. & Chan. [1]
10^{-2}	4-5 dB	20 dB	23 dB
10^{-3}	7 dB	25 dB	--
10^{-4}	9 dB	--	--
10^{-5}	10 dB	--	--
10^{-6}	11-12 dB	--	--

Table 7: Simulation Results Comparison for CFO=0.05

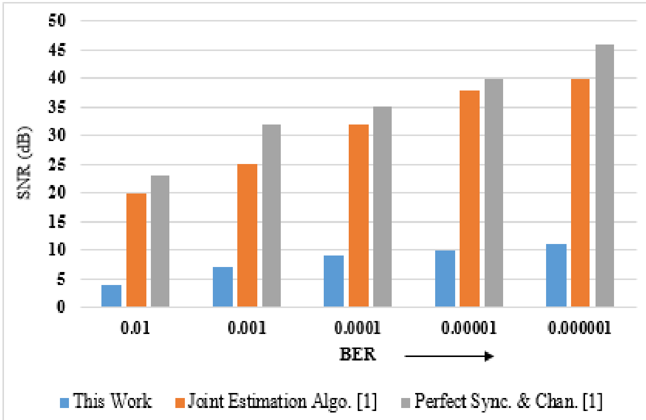

Figure 7: Simulation Results Comparison for CFO=0.05 (Table 7)

7. CONCLUSION

In this paper we have implemented CFO correction under the influence of the CFO on OFDM transmission over AWGN channels. OFDM is very much sensitive to carrier frequency offset, which attenuates the desired signal & causes inter carrier interference, thus reducing the SNR. In this paper we have analyzed the Adaptive modulation with CFO and compared the average spectral efficiency with non-adaptive modulation methods. proposed adaptive modulation algorithm with CFO=0.05 achieves average spectral efficiency of that the proposed adaptive modulation algorithmgives optimum average spectral efficiency up to 5-6 bps/Hz for the target BER of 10^{-3}& up to 8-9 bps/Hz for the target BER of 10^{-6}. The proposed modulation technique is tested by MATLABcomputer simulations and the simulation results exhibits better performance than the conventional adaptive modulation techniques.

8. REFERENCES

[1] P. Muneer et-al, “Joint Estimation of Doubly Selective Channels and Carrier Frequency Offsets in High Mobility MIMO-OFDMA Uplink”, Wireless Personal Communications, Springer Science Business Media New York, 2017.

[2] Ann-Chen Chang, “Blind CFO Estimations Based on Subspace-Based Approaches Under Single Data Block for Interleaved OFDMA Uplink”, Wireless Personal Communications, Springer Science Business Media New York, 2017.

[3] Roee Shaked et-al, “Carrier Frequency Offset Estimation for Linear Channels with Periodic Characteristics”, IEEE 17th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), 2016.

[4] Dajin Wang et-al, “An Approximate Method of Carrier Frequency Offset (CFO) Estimation for OFDM System”, IEEE 80th Vehicular Technology Conference (VTC Fall), Vancouver, 2014.

[5] Tzu-Chiao Lin et-al, “A Low-Complexity Blind CFO Estimation for OFDM Systems”, IEEE International Conference on Acoustic, Speech & Signal Processing (ICASSP), Pp. 8083 – 8086, Florence, 2014.

[6] Yufei Jiang et-al, “Semi-Blind MIMO OFDM Systems with Precoding Aided CFO Estimation and ICA Based Equalization”, Signal Processing for Communications Symposium, Globecom, Pp. 3499 – 3503, Atlanta, 2013.

[7] P. Malarvezhi et-al, “A Modified Preamble structure based Carrier Frequency Offset (CFO) and Phase noise compensation in an OFDM system”, IEEE International Conference on Emerging Trends in Computing, Communication & Nanotechnology (ICECCN), Pp. 13 – 18, Tirunelveli, 2013.

[8] S. Kumarapandian et-al, “Performance analysis of CFO mitigation algorithms in Asynchronous Cooperative OFDM Communication system”, 2nd IEEE International Conference on Sustainable Energy & Intelligent System (SEISCON), Pp. 632-637, Chennai, 2011.

[9] ChiSung Bae and Dong Ho Cho, ‘Fairness-Aware Adaptive Resource Allocation Scheme in Multihop OFDMA Systems’, IEEE Communications Letters, Vol. 11, pp.134-136, 2007.

[10] Ernest S.L., Vincent K.N., Roger S.C. and Ross D.M., ‘Adaptive Resource Allocation and Capacity Comparison of Downlink Multiuser MIMO-MC-CDMA and MIMO-OFDMA’, IEEE Transactions on Wireless Communications, Vol. 6, pp. 1083 -1093, 2007.

[11] HassenKaraa., Raviraj S.A. and Adam J.T., ‘Linear Precoding for Multiuser MIMO-OFDM Systems’, IEEE International Conference on Communications, pp. 2797-2802, 2007.

[12] Jeong-Sang Park, Jae-Kwon Lee and Jin-Up, ‘KimSimple Amplitude and Phase Predistortion for PAPR Reduction in OFDM Systems’, ETRI Journal, Vol. 29, No. 2, pp. 231 -233, 2007.

[13] Liang Chen and Krongold B., ‘An Iterative Resource Allocation Algorithm for Multiuser OFDM with Fairness and QoS Constraints’, IEEE Vehicular Technology Conference, pp.2985-2989, 2007.

[14] Gao X. and Araghi Pour M., ‘Computationally Efficient Resource Allocation for Multiuser OFDM Systems’, Proceedings of the IEEE Wirless Communication and Networking Conference, (WCNC2006), Vol. 2, pp. 804-809, 2006.

[15] Jung Won Lee, Hui-Ling Lou and John M.C., ‘SNR analysis of OFDM system in the presence of carrier frequency offset for fading channels’, IEEE Transactions on wireless communications, Vol. 5, No. 12, 2006.

[16] Jian Xu, Jongkyung Kim, Wonkyu Paik and Jong-Soo Seo, ‘Adaptive Resource Allocation Algorithm with Fairness for MIMOOFDMA System’, Proc. VTC- IEEE, Vol. 4, pp. 1585-1589, 2006.

[17] Chengkang Pan., YuemingCai and Youyun Xu, ‘Adaptive Subcarrier and Power Allocation for Multiuser MIMO-OFDM Systems’, IEEE International Conference on Communications, Vol. 4, pp. 2631 – 2635, 2005.

[18] Jiang T., Yang Y. and Song Y H., ‘Exponential companding techniques for PAPR reduction in OFDM systems’, IEEE Trans. Broadcast, Vol. 51, No. 2, pp. 244-248, 2005.

[19] Jiang T. and Zhu G. (2004), ‘Nonlinear companding transform for reducing peak-to-average power ratio of OFDM signals’, IEEE Trans. Broadcast., Vol. 50, pp. 342-346, 2004.

[20] Feng-TsunChien, Chien-Hwa Hwang and C.-C. Jay Kuo, ‘An Iterative Approach to Frequency Offset Estimation for Multicarrier Communication Systems’, IEEE 58th Vehicular Technology Conference, VTC 2003-Fall. 2003.