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SIMPLEST PHASE NOISE MITIGATION TECHNIQUE IN OFDM SYSTEM

Mehraj Din Mir*, Avtar Singh Buttar
* Deptt. of ECE PITK (PTU Main Campus) Kapurthala, Punjab, India.
Deptt. of ECE PITK (PTU Main Campus) Kapurthala, Punjab, India.

ABSTRACT

In Orthogonal Frequency Division Multiplexing Communication systems, the local oscillator used for the up-conversion and down-conversion at the transmitter and receiver respectively introduces phase noise which causes two effects, common phase error (CPE) and inter-carrier interference (ICI). OFDM is one of the futures of wireless communications system, but exhibit great sensitivity to the phase noise and the time-varying propagation channel, inter-channel interference (ICI) result to the loss of orthogonality among subcarriers and common phase error (CPE) causes the rotation of constellation of the OFDM signal. Due to the presence of phase noise, produced by the local oscillator at the transmitter and receiver result in reduction of signal to noise ratio (SNR), and hence reduce the bit error rate (BER) and data rate.

There are various methods of high complexity of phase noise mitigation already proposed in the literature. In this paper simple technique has been proposed. The computer simulations of the proposed scheme shows how effectively the effect caused by phase noise gets mitigated and improve the BER of OFDM systems..

KEYWORDS: Common phase error (CPE), inter-carrier interference (ICI), orthogonal frequency division multiplexing (OFDM), phase noise, least square estimation (LSE).

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is defined as a form of multi-carrier modulation where the carrier spacing is carefully selected so that each sub carrier is orthogonal to the other sub carriers. Two signals are said to be orthogonal if their dot product is zero. As the sub carriers are orthogonal to each other, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system, which results in no interference between the sub-carriers, hence sub-carrier are spaced as close as theoretically possible. The advantages of OFDM are its ability to convert a frequency selective fading channel into several nearly flat fading channels, high data rate and high spectral efficiency.

OFDM system shows high sensitivity towards phase noise which causes leakage of DFT which destroys the orthogonalities among subcarrier signals, causing both CPE and ICI. CPE results in signal phase rotation which stays invariant within an OFDM symbol, while ICI introduces interferences to each subcarrier of a certain symbol from all the other subcarriers of that symbol and therefore exhibits noise-like characteristics.
To compensate phase noise in OFDM system, several methods have been proposed and these methods can be categorized into two approaches: [7] time domain and frequency domain

OFDM system

Multiplexing).Orthogonal frequency division multiplexing (OFDM) is becoming the most chosen modulation technique for wireless communications. OFDM can provide higher data rates with sufficient robustness to radio channel impairments.

Orthogonal Frequency Division Multiplexing (OFDM) is a special type of multi-carrier modulation scheme which is used to generate sub-carrier signal which are mutually orthogonal. In an OFDM modulation scheme, a large number of orthogonal, narrow band sub-carriers are transmitted in parallel. These carriers divide the available transmission bandwidth in such a way that the separation between the sub-carriers is such that there is a very compact spectral utilization. In OFDM, overlapping sub channels is possible in the frequency domain, thus increasing the transmission rate. In order to avoid a large number of modulators and filters at the transmitter and receiver, it is desirable to be able to use modern digital signal processing techniques, such as fast Fourier transform (FFT). After so many years of research and development carried out in OFDM, OFDM is now being widely implemented in high speed digital communications. OFDM has been characterized as standard in several wire line and wireless applications.

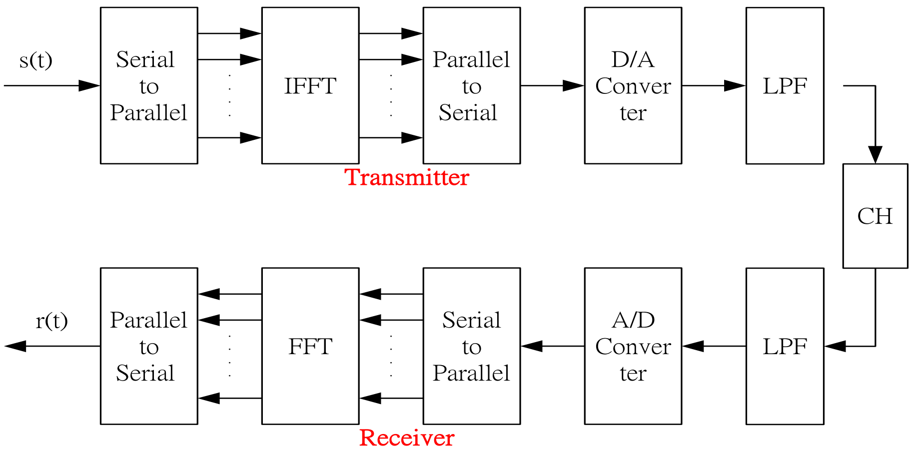

Fig: OFDM block diagram

EFFECT OF PHASE NOISE ON OFDM SYSTEM

Phase noise is cause by imperfect local oscillator, for the sake of simplicity we always consider oscillator to be ideal [14], but practically impulse response of practical oscillator has got some side bands which causes phase noise in the OFDM signal at the receiver. For the local oscillator at centre frequency f_c, the oscillator output at time instant t is expressed as $\exp\{j(2\pi f_c t + \Phi(t))\}$, where $\Phi(t)$ is the phase noise at the time instant t. phase noise produced by a phase locked loop (PLL). It is mainly modeled by a stationary Gaussian process with zero mean and specified power spectrums. Ofdm system with phase noise

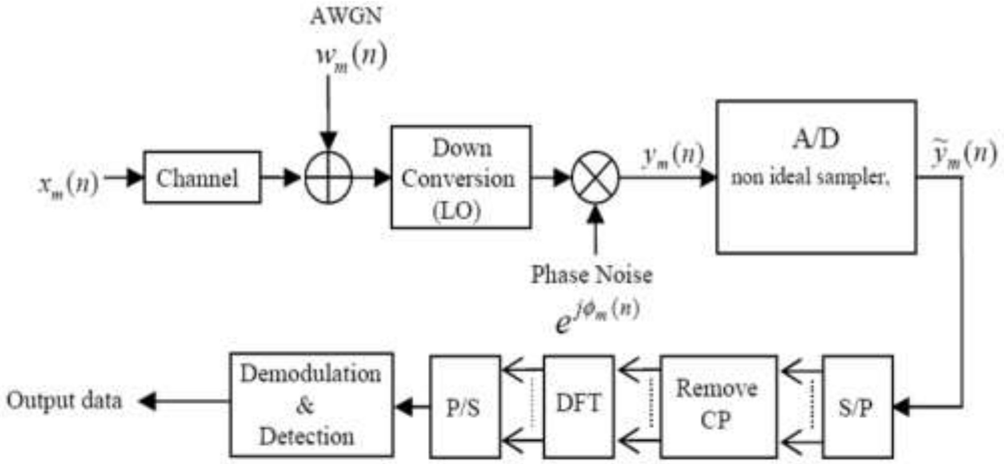

Figure OFDM system model (receiver section) in the presence of phase noise

A theoretical analysis of phase noise effects in OFDM system is found in [9]. The received OFDM signal corrupted by phase noise
$\Phi(n)$ is given as:

$$Y_m(n) = \left(X_m(n) \otimes H_m(\mathrm{n}) + W_m(n)\right) e^{2j\Phi m(n)} \quad (4)$$

Where X(n) , H(n) and Φ(n) denotes the sample of transmitted signal, impulse response of the channel and phase noise respectively.

After taking the discrete Fourier transform (DFT), the information signal at the at the subcarrier k (k=0, 1, 2………,N -1) is given as

$$Y_m(k) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} Y_m(n)\, e^{-j2\pi nk/N}$$

$$= \sum_{i=0}^{N-1} H_m(i)\, H_m(i) C_m(k-i) + W_m(k) \quad (5)$$

Where $Hm(k), Cm(k)$ and $Wm(k)$ are the DFT of the channel impulse response, phase noise and AWGN noise respectively.

The received symbol $Ym(k)$ can be written as

$$Y_m(k) = X_m(k) H_m(k) C_m(0) + \sum_{\substack{i=0 \\ i\neq k}}^{N-1} H_m(i)\, X_m(i) C_m(k-i) + W_m(k) \quad (6)$$

Where

$$C_m(k) = \frac{1}{N} \sum_{n=0}^{N-1} e^{j\Phi m(n)} e^{-j2\pi nk/N}$$

In order to separate the signal and noise terms, let us suppose that phase noise is small, so that:

$$e^{j\Phi(n)} = 1 + j\Phi(n) \quad (7)$$

In this case the demultiplexed signal is

$$y(k) \cong s_k + \frac{j}{N} \sum_{r=0}^{N-1} s_r \sum_{n=0}^{N-1} \Phi(n) . e^{j\frac{2\pi}{N}(r-k)n} \quad (8)$$

$$y(k) \cong e_k + s_k \quad (9)$$

There is an error term e_k for each sub-carrier which is added to useful signal s_k .Discussing the noise contribution we get:

if r= k: common phase error

$$\frac{j}{N} \sum_{r=0}^{N-1} s_r \sum_{n=0}^{N-1} \Phi(n) = j . s_r . \Phi \quad (10)$$

Common phase error rotate the constellation by an angle Φ .This angle is the average of phase noise

$$\Phi = \frac{1}{N}\sum_{n=0}^{N-1}\Phi(n\,) \qquad (11)$$

Since it is constant for all sub-carriers, it can be corrected by some kind of phase rotation.

if r ≠ k: inter carrier interferance:

$$\frac{j}{N}\sum_{\substack{r=0\\ r\neq k}}^{N-1} s_r \sum_{n=0}^{N-1}\Phi(n\,)\,.\,e^{j\frac{2\pi}{N}(r-k)n} \qquad (12)$$

since we have taken the phase noise value very small hence we will consider the ICI term as a Gaussian noise. Now we have to eliminate only the CPE.

PHASE NOISE ESTIMATION AND MITIGATION

OFDM suffers severe performance degradation in the presence of phase noise. Different methods have been proposed in the literature to correct phase noise either in the time domain or in the frequency domain. The method proposed here is computationally efficient. This method is applied for the case of only if the phase noise is very small. If we consider phase noise to be small then we have to estimate only CPE and consider inter carrier interference (ICI) as Gaussian noise. Directly estimating CPE saves computational complexity needed for extracting its phase from pilot signals, and results in an improved estimation accuracy and hence better receiver performance.

Equation (6) can be rewritten as:

$$y_m(k) = X_m(k)H(k)\,C_m(0) + \acute{n}_m(k) \qquad (13)$$

Where $\acute{n}_m(k)$ contain AWGN noise and ICI term.

$$\acute{n}_m(k) = \sum_{\substack{i=0\\ i\neq k}}^{N-1} H_m(i)\,X_m(i)C_m(k-i) + W_m(k) \qquad (14)$$

In the sequel, we use the estimate of $C_m(0)$ obtained by [20]

$$C'_m(0) \;=\; \arg\min_{C_m(0)} \sum_{k\in p} \|y_m(k) - X_m(k)H(k)\,C_m(0)\| \quad (15)$$

$$C'_m(0) \;=\; \frac{\sum_{k\in p} y_m(k)X*(k)H*(k)}{\sum_{k\in p}|X_m(k)H(k)|^2} \qquad (16)$$

Where ‘p’ represent the set of pilot signals. Channel fading gain H(k) can be obtained through OFDM channel estimation. CPE estimation is not only used to correct phase rotation error, but also helps reduce extra channel estimation errors introduced by random phase noise.
The detected data bit $\dot{x}(k)$ can be obtained from the CPE-corrected signal

$$\dot{x}(k) \;=\; C_m(0)^{-1}Y_m(k)$$

SIMULATION RESULTS

The OFDM model used in this simulation is IEEE.802.11a (WLAN)

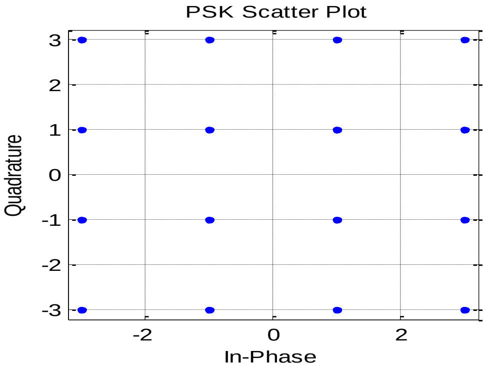

Fig.4. scatter plot of 16 QAM without phase noise

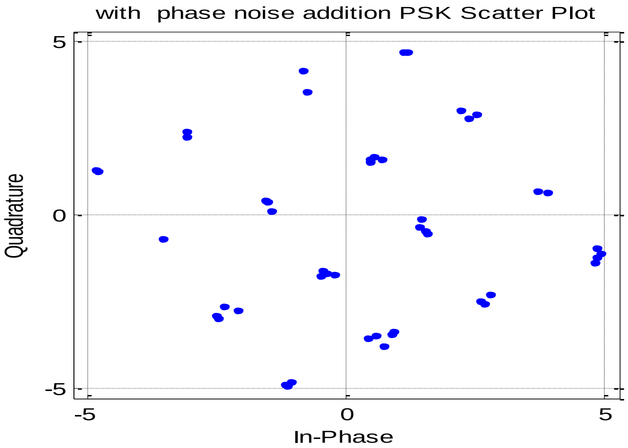

Fig.5. scatter plot of 16 QAM with phase noise added at a variance of 1.5

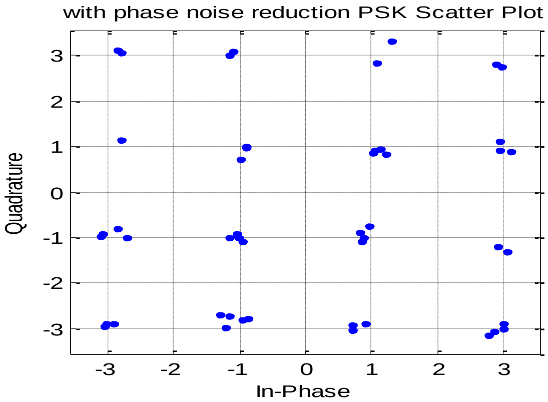

Fig.6. scatter plot of 16 QAM with phase noise removed

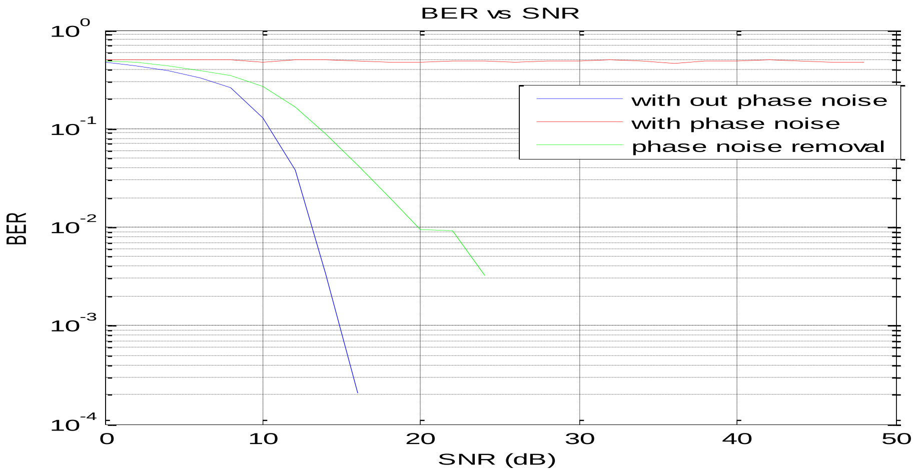

Fig.7. BER vs SNR plot at a phase noise variance of 1.55

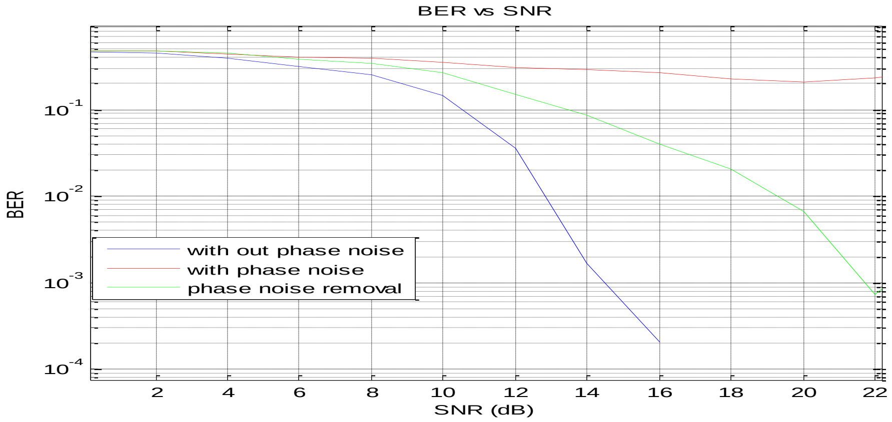

Fig.7. BER vs SNR plot at a phase noise variance of 0.0945.

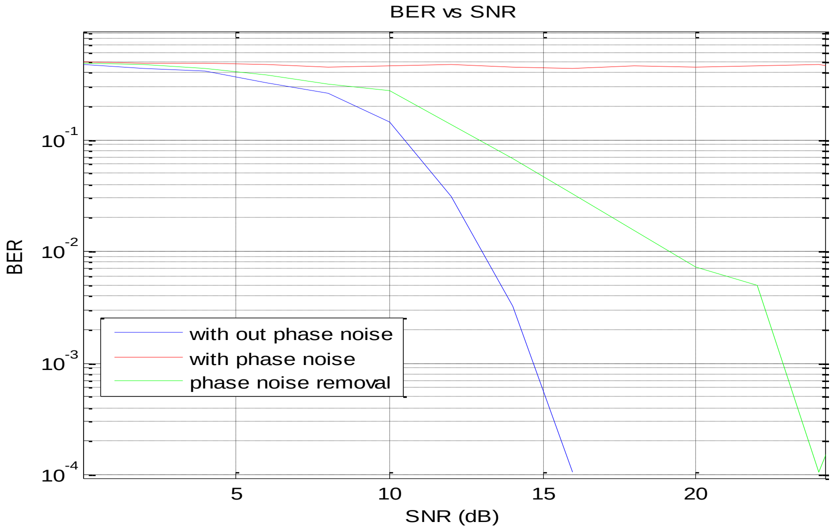

Fig.8. BER vs SNR plot at a phase noise variance of 0.500

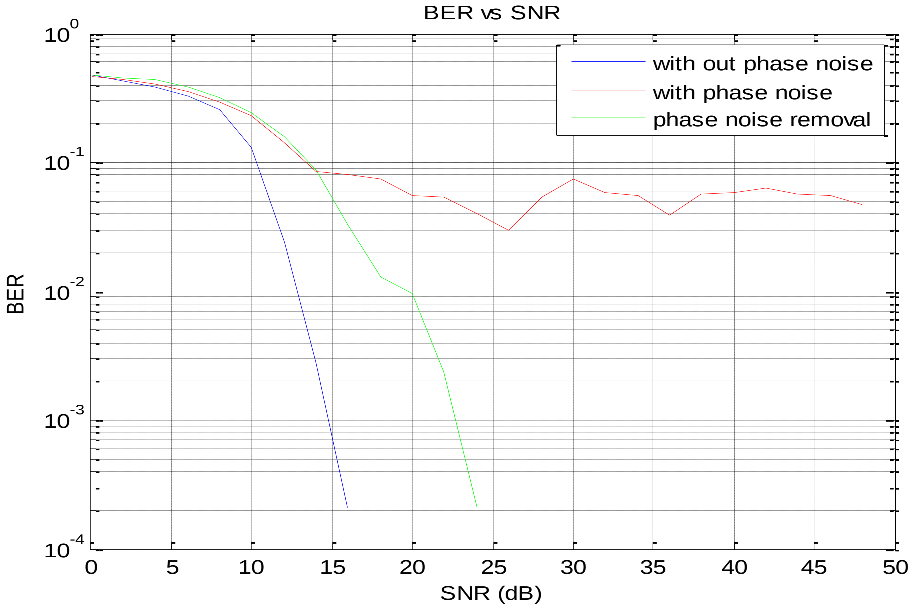

Fig.9. BER vs SNR plot at a phase noise variance of 0.034

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