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Analysis on Lowering the Effect of Timing Jitter in OFDM System using Oversampling

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Abstract: The limitation of the high speed analog to digital converters and synchronization systems causes the miss-timed sampling of the signals, which results the timing jitter. The seriousness of this effect greatly increases for the multicarrier systems like OFDM, because of their structure where all sub-carriers may get affected by single sample. The removal (or suppression) of the timing jitter is hence one of the challenging task for the system designers. This paper presents an analysis of one of the jitter suppressing technique named "Over-Sampling", for its effectiveness the paper presents a detailed analysis on the basis of most practical OFDM mathematical modeling and simulation. The presented model facilities to analyze different size, type of modulation symbol, effect of jitter probability, amplitude independently, and to select different OFDM modulation techniques. Finally the simulation result shows that the BER can be reduced by half for any value of jitter at fixed AWGN when the oversampling rate is doubled.

Keywords: Timing jitter, OFDM, oversampling.

I. INTRODUCTION

The OFDM (Orthogonal frequency-division multiplexing) provides very effective channel utilization in comparison with FDM (frequency-division multiplexing), it also provides good resistance against ISI (inter-symbol interference) and multipath fading. Also the recent development in semiconductor technology enables the engineers to design the complete system on single chip because the system can be completely developed in digital domain this eliminates many critical problems related with analog systems. The limitation of the semiconductor technology gets visible in the forms of time jitter. The basic cause of jitter is improper behavior of synchronization system and ADC (analog to digital converters). Although the jitter problem is caused by high frequency limitations but its impact also depends upon the signal amplitudes. For the lower amplitude signals it does not impact too much and can be neglected but as the amplitude increases it can greatly degrade the performance. Presently many literatures with different approaches are available on the study of timing jitter in OFDM systems, some of them preferred theoretical analysis while some goes for more practical simulation approaches, although the technique selection may be completely depends upon the objectives of the analysis but the exact results are always targeted. This paper is organized as follows.

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First section gives brief overview on OFDM timing jitter. Second section presents some recent literatures related to the same fields, and in section three the OFDM model with jitter is discussed. In section four the oversampling for the jitter suppression is analyzed. Section five presents the simulation results of the presented model for different configurations which is discussed in the form of conclusion in section six.

II. BACKGROUND

This section presents a brief review of some related literatures recently published. Timing Jitter Impact and I/Q Imbalance in OFDM Systems is presented by Lei Yang et al [1]. These systems, which analyzed the relation between timing jitter and I/Q imbalance which shows that the ICI (inter carrier interference) is added by such interaction which has the property of equal real and imaginary components and orthogonally to sub-carrier index however the magnitude of ICI remains small. The literature also presents that at higher jitter I/Q imbalance can be neglected. Sebastian Hoyos et al [5] present an analytical design for clock jitter tolerant low order multichannel filter bank receivers, with the techniques to reduce the sampling clock jitters. The literatures show that low order bandwidth optimized multichannel receivers can be configured to achieve jitter suppression. In their paper an optimized multichannel receiver presented for processing a 5-GHz baseband signal with 40 dB of signal-to-noise-ratio using sampling clocks. Jean Temga et al [6] presented Phase Noise Jitter Synchronization using Pilot-Data-Aided and Wiener Filter for Coherent Optical OFDM. The literatures show that phase jitter synchronization technique for square M-ary quadrature amplitude modulation (M-QAM) coherent optical orthogonal frequency division multiplexing (CO-OFDM) signal employing a unique pilot's system design, Feed forward maximum likelihood phase estimator as well as Wiener filter-type Minimum Mean square error (MMSE) interpolator. The wiener filter relies upon Kolmogorov type to interpolate the estimated phase noise with M taps. Ville Syrjälä et al [8] proposes a time-domain digital signal processing method for estimating and mitigating transmitter and receiver oscillator phase-noise effects in OFDM radio systems on the receiver side of the link. The idea is based on re-constructing time-domain OFDM signal at the receiver from initially detected symbols and using this as a reference in phase noise estimation. The knowledge of heavily low-pass nature of realistic phase noise processes is then utilized in the estimation process to improve the estimation quality. The algorithm can also be used iteratively, inside individual OFDM symbols, to further improve the accuracy of the obtained phase noise estimate.

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Another technique for Sampling Jitter Cancellation in Direct-Sampling Radio is presented in [9]. The literatures show that sampling jitter estimation and cancellation task in direct RF sub-sampling type radios. The proposed jitter estimation method is based on carefully injecting or superimposing an additional known reference signal to the received signal at the sampler input. Proper digital signal processing methods are then devised and applied to estimate the sampling jitter realizations from the obtained jittered samples. Using these jitter estimates, combined with proper jitter modeling, the jitter effects can then be efficiently removed from the actual received signal.

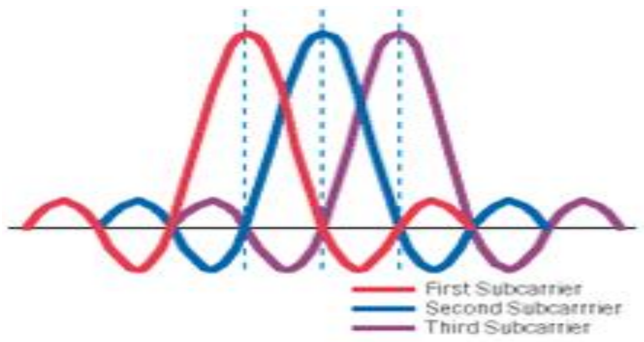

Figure 1. Three Subcarriers in MIMO-OFDM

III. OFDM SYSTEM MODEL

To avoid excessive bit errors on subcarriers that are in a deep fade, OFDM typically uses sub-carriers and the number of subcarriers needed is larger than the number of bits or symbols transmitted simultaneously. From the fig.1 it is clear that each symbol of input data is firstly converted into parallel then each then these parallel blocks are transmitted by orthogonal sub-carriers. OFDM subcarriers can overlap to make use of the spectrum, but at the peak of each subcarrier spectrum, the power in all the other subcarriers is zero. OFDM therefore offers higher data capacity in a given spectrum while allowing a simpler system design. Creating orthogonal subcarriers in the transmitter is easy using an inverse FFT [3].

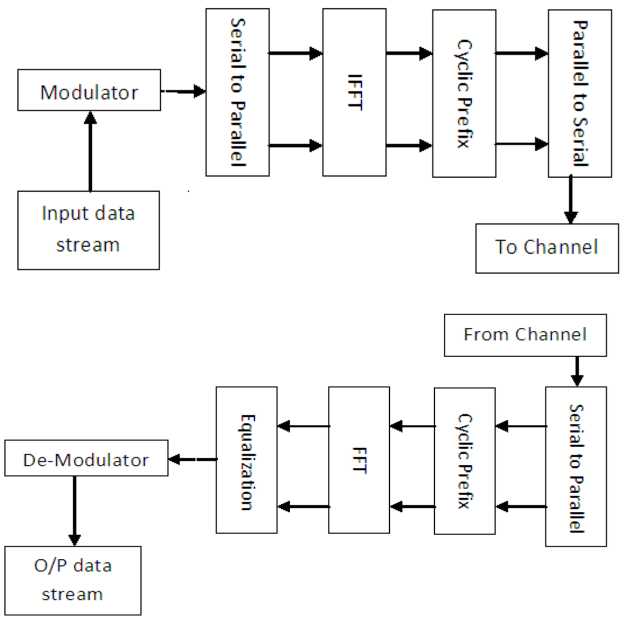

Figure 2. Implemented Model of OFDM Transmitter and Receiver

Each bit is transmitted over *N* different subcarriers. Each subcarrier has its own phase offset, determined by the input symbol. Fig.2. shows the block diagram of the OFDM system. At the transmitter, each user's modulated signal then converted into time domain by IFFT. At the receiver, after removing the CP, the time domain signal is converted into frequency domain by FFT and used to obtain the desired user's signal.

IV. TIMING JITTER

The sampling jitter in ADC generates symbol time offset (FFT window position) and subcarrier phase rotation which leads to synchronization errors and then to ICI. In the following Figure.3, the OFDM symbol drift, and sampling jitter are illustrated

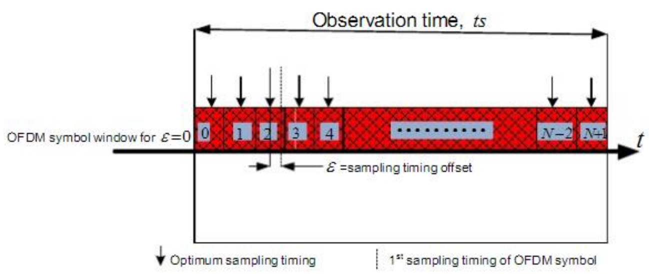

Figure 3. Sampling Jitters and Symbol Window Drift in OFDM Due to Sampling Jitter

V. PERFORMANCE SIMULATION

Computer simulations are done to simulate SNR vs. BER performance of OFDM for different Jitter value and noise conditions, different number of subcarriers and different oversampling ratios to analyze the effect in BER. Throughout the simulation, the information symbol is modulated with different methods (BPSK, PAM, and QAM) at the transmitters and demodulation at the receiver in same way. A cyclic prefix is added to protect the symbol. The simulation codes are written for MATLAB, and simulated. All results are calculated for 103 bits of transmission, the number of sub-carriers and results are collected for each SNR step changing from 0 to 20 dB with a step size of 1dB.

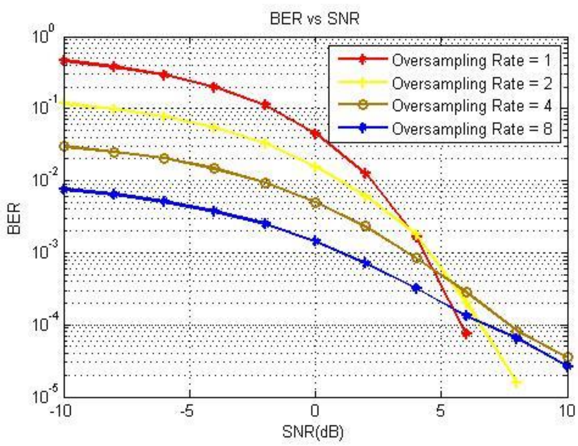

Figure 4. SNR/BER for Different Oversampling Rate at 10% Jitter for IDCT, and QPSK.

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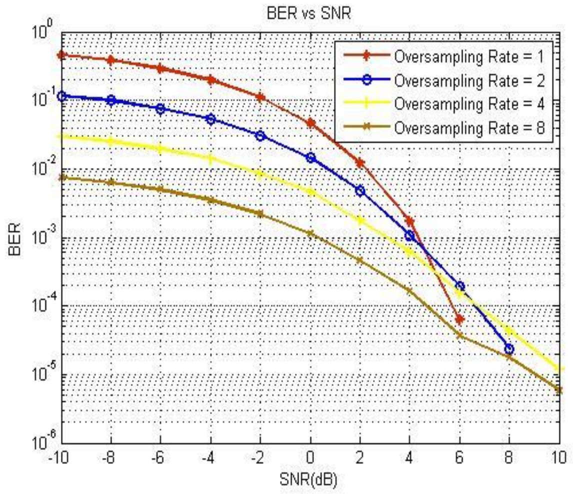

Figure 5. SNR/BER for Different Oversampling Rate at 10% Jitter for IFFT, and QPSK

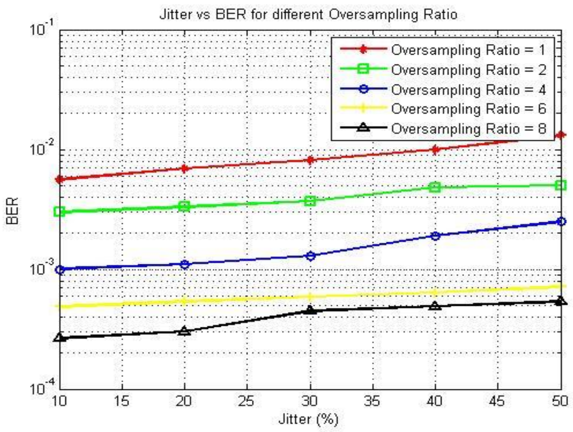

Figure.6. Jitter/BER at Different Jitter Percentage for Different Oversampling Ratio

Table 1: BER for Different Jitter (Columns) and Oversampling Ratio (Rows)

Oversampling Ratio	10%	20%	30%	40%	50%
1	0.0056	0.0069	0.0081	0.0100	0.0131
2	0.0030	0.0033	0.0037	0.0048	0.0050
4	0.0010	0.0011	0.0013	0.0019	0.0025
6	0.4861e-3	0.5382e-3	0.5903e-3	0.6411e-3	0.7133e-3
8	0.2637e-3	0.3027e-3	0.4492e-3	0.4904e-3	0.5388e-3

VI. CONCLUSION

This paper presents detailed simulation and analysis of the OFDM system for effect of timing jitters and its minimization by oversampling. Besides it the presented model provides greater flexibility on parameters configuration such different jitter percentage and probability, different modulation techniques and selection on IFFT and IDCT as orthogonal modulator. Also the impact of the jitter is directly estimated in the form of BER instead of jitter noise. Finally the analysis of the simulation results shows that the selection of IDCT can provide comparable performance of IFFT as reduced processing cost. Analysis for the BER shows that at 10% jitter, the BER reduces from 0.0056 to 0.0030 and 0.0010 for oversampling ratio 2 and 4 respectively while it reduces from 0.4861e-3 to 0.2637e-3 for oversampling rate 6 and 8 respectively. And at 50% jitter, the BER reduces from 0.0131 to 0.0050 and 0.0025 for oversampling ratio of 2 and 4 respectively while it reduces from 0.7133e-3 to 0.5388e-3 for oversampling rate 6 and 8 respectively. The analysis shows that BER reduces by half for any value of jitter by doubling the oversampling rate.

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