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IMPACT OF SYNCHRONIZATION ISSUES IN OFDMA SYSTEMS

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ABSTRACT

In this paper the impact of joint time and frequency synchronization issues in OFDM has been analyzed. Further link adaptation in such system too has been analyzed. The conclusion is that non idealities in OFDM results into rotation and inter-carrier interference jointly. The impact of these synchronization issues is that spectral efficiency decreases in the link adaptation processes as well.

Keywords: OFDM; synchronization issues; Link Adaptation; Spectral Efficiency

INTRODUCTION

OFDM is the physical layer technique in LTE (Long Term Evolution) and for the future cellular generations as well. OFDM being multi-carrier concept has the feature of higher spectral efficiency and hence more data rate can be supported for the same bandwidth.

OFDM based systems are generally not ideal and hence its advantages cannot be harnessed. Practical OFDM systems are generally non-ideal. It is thus important to deal with synchronization issues and to combat these effects. Also what is the impact of these synchronization issues on spectral efficiency and hence on the data rate needs to be discussed too.

In this work OFDM under non-ideal system i.e when timing and frequency synchronization errors are there, has been discussed and analysed. Joint effect of both timing and frequency synchronization in OFDM has been dealt as practical systems do have. Link adaptation process which deals with sending optimized data rate based on channel condition. Under the case of non ideal OFDM system, this link adaptation process of optimized data rate gets hampered, though the channel conditions remain same optimized data rate gets lessened. Thus link adaptation is adversely affected.

Some of the works deals with time and frequency synchronization issues in OFDM are [1], [2], [3] and [4]. In [5], [6], [7] and [8] authors have discussed about the link adaptation.

The rest of the paper is organized as follows: Section II presents the system model . Section III deals with the OFDM under non ideal conditions. Section IV describes about the mathematical analysis about spectral efficiency under synchronization issues. Section V describes the results and their analysis, while the last section VI talks about the conclusions.

SYSTEM MODEL

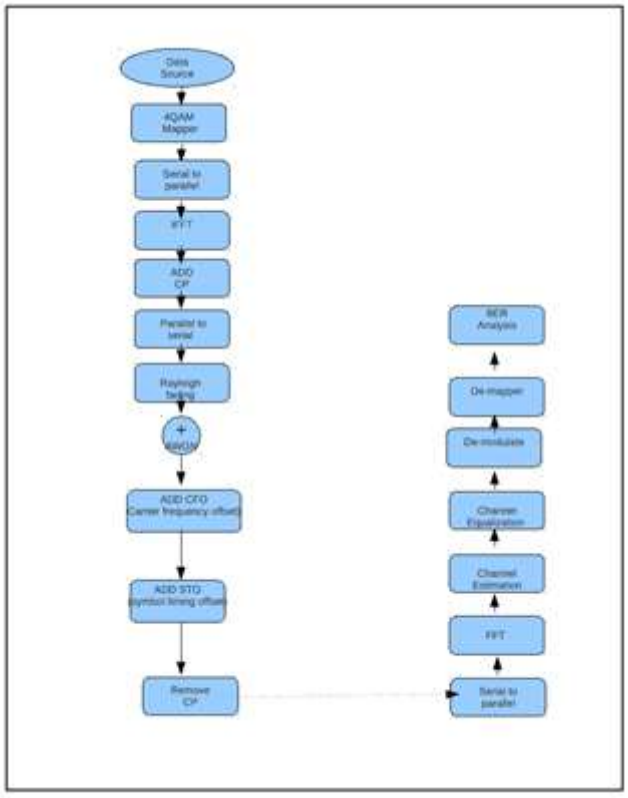

Figure 1

The system model is as shown in the figure above.

EFFECT OF COMBINED FREQUENCY AND TIMING SYNCHRONIZATION

The received signal due to mismatch in the carrier frequency offset ε and timing offset δ at the receiver can be expressed as

$$y_m[n] = \frac{1}{N}\sum_{k=1}^{N}[X_m[k]H_m[k]e^{j2\pi(k+\varepsilon)(n+\delta)/N}d(n,k) + z_m[n]$$

MATHEMATICAL DEVELOPMENT OF ANALYSIS

Normalized capacity i.e spectral efficiency per link can be expressed as

$$SE = \sum_{k=1}^{N}(1 + |H[k]|^2\frac{P[k]}{N_0})$$

as all the carriers are not used rather N_{used} are the carriers . In the work OFDM 1200 carriers are used out of 2048, hence

$$SE = \sum_{k=1}^{N_{used}} (1 + |H[k]|^2 \frac{P[k]}{N_0})$$

The effect of CFO and STO combined results into effective loss in SNR hence SDNR where SDNR represents signal to Noise + distortion, the above equation can be expressed as

$$SE = \sum_{k=1}^{N_{used}} (1 + |H[k]|^2 \frac{P[k]}{N_0 + D[k]})$$

The effect of this is loss in spectral efficiency, and hence loss in system capacity

RESULTS

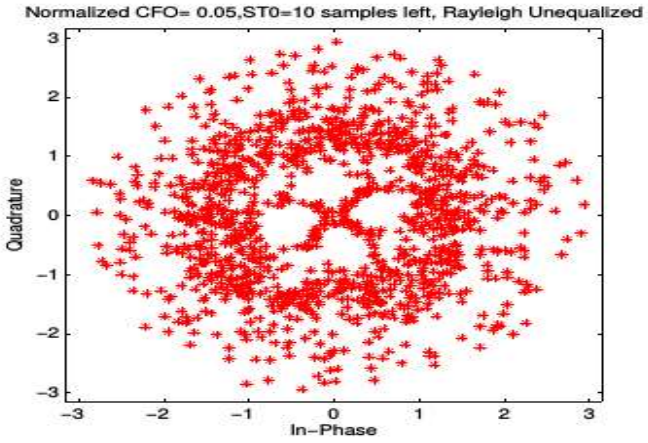

Figure 2 Combined Carrier and Timing Synchronization Error reflection on received QAM symbols

The figure 2 shows the combined timing and frequency offset effect under the multi-path effect being Rayleigh. In this plot CFO taken is 0.05 and STO is 10 samples left. It is seen from the figure that the symbols due to the joint effect of timing and frequency synchronization the symbols have scattered to random locations from the destined locations.

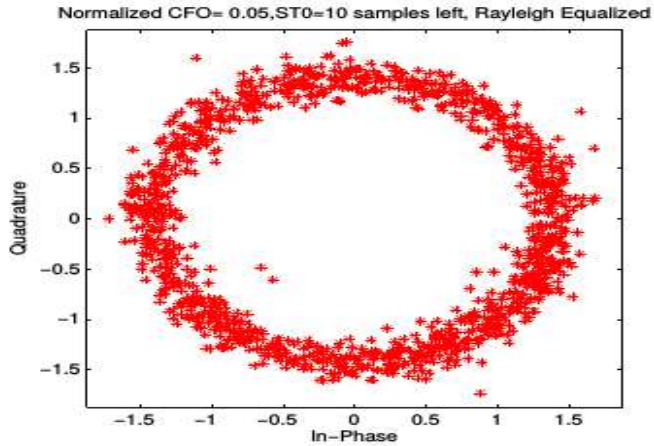

Figure 3

The fig. 3 depicts QAM symbols under joint synchronization issue after equalization. It is seen from the figure that the even after equalization the rotational effect remains. The below figure 4 depicts under AWGN Channel

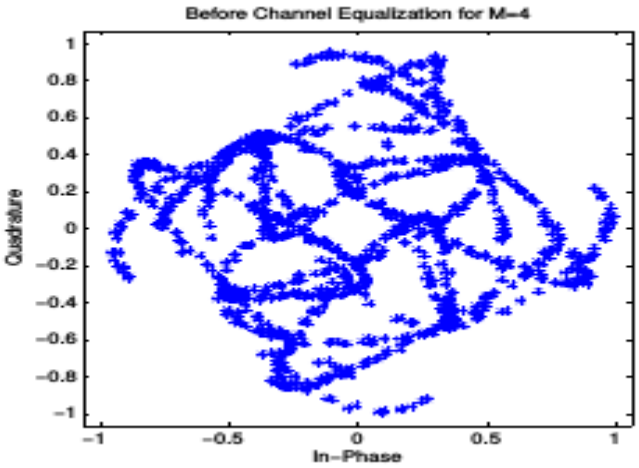

Figure 4 Under AWGN prior to equalization

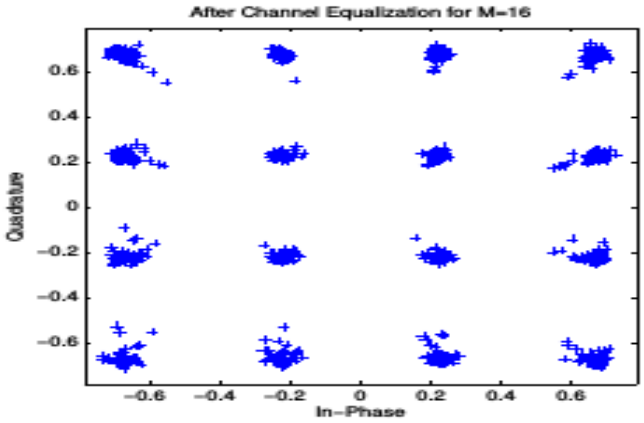

Figure 5 Under AWGN after equalization

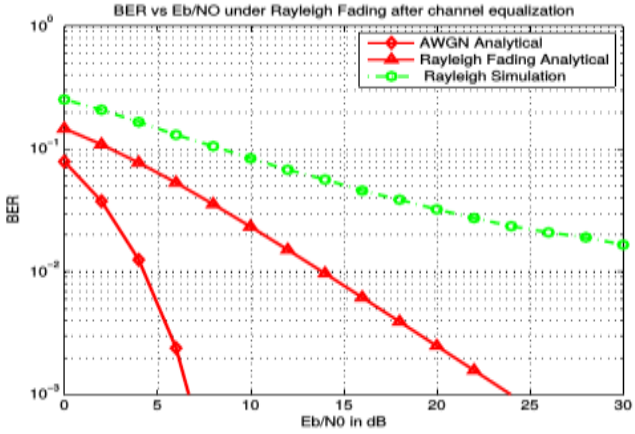

Figure 6 BER Degradation and Spectral Efficiency with Adaptive Modulation in OFDM based system due to Non Ideal Transmitter and Receiver

The above figure shows that timing offset and carrier offset as well as the fading channel effect can be nullified by using channel estimation and then equalization. In the above simulation and plots pilot symbols have been sent, then Least Square channel estimation done and after interpolation equalization has been done. As the channel estimation method followed is Least Square there is still gap in BER performance as compared with analytical. Least Square has been employed as it is simple, using complex estimation performance can be further improved.

CONCLUSIONS

In this work the effect of carrier frequency offset and timing offset effect for the OFDM symbol for LTE Physical Layer has been analyzed and simulated. In the work 4QAM has been taken for mapping for each of the carrier. There are two effects due to Carrier frequency offset i) Equal phase rotation and attenuation of all subcarriers ii) Inter Carrier Interference. BER vs EbNO plots shows that in both, AWGN and Rayleigh fading with increase in carrier frequency offset BER goes on deteriorating. The effect of timing offset at the receiver has been observed. It is evident from plots that a timing offset gives rise to a progressive phase rotation of the signal constellations. The phase rotation is zero at the center frequency and it linearly increases towards the edges of the frequency band. An analytical effort has been done to compensate carrier frequency offset and timing offset effects.

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