RESEARCH ARTICLE OPEN ACCESS

Effect of Synchronization errors on OFDM performance

Turki Saleh Alharbi
(Department of Electrical and Computer Engineering, King Abdulaziz University,P.O. Box 80200, Jeddah 21589, KSA)

ABSTRACT
Orthogonal frequency Division Multiplexing is a multicarrier scheme, which is widely utilized in distinct wireless communication systems because of its high spectral efficiency, robustness to multipath fading channel and high data rate. In this paper, we focus mainly on Comparison of bit error rate versus signal to noise ratio for OFDM system for a uniform distribution and Gaussian distribution and based on the effect of variance on OFDM system. our findings suggest that OFDM system with gaussian distribution is the best choice for multicarrier scheme.
Keywords–Orthogonal Frequency Division Multiplexing**,**inter-symbol interference,Long term Evolution

---

Date of Submission: 25-02-2020 Date Of Acceptance: 05-03-2020

I. INTRODUCTION

In recent Wireless communication systems high data-rate is most desirable[1], Conventional single carrier modulation schemes can give only limited data rates because of the restrictions put by the multipath effects of wireless channels and complexity of receiver. In single carrier systems, when the da tartes in wireless communication system hikes, the symbol duration gets decreases. Hence, the wireless communication system ultilizing single carrier modulation mainly suffer from high inter symbol interference (ISI) cause by the dispersive-channel impulse response, and thereby needed a complex equalization technique .Orthogonal Frequency Division Multiplexing (OFDM) is a good candidate to fulfil the requirements of next and current generation wireless communication systems

The basic principle of OFDM came from the paper by Chang [3], and for many years various researchers have worked on this technique [4]-[9]. Despite of its conceptual elegance, its usage was limited to military systems in starting namely, ANDEFT,KINEPLEX, and KATHRYN [2] due to difficulties in implementations. Weinstein and Ebert's proposed to use the Discrete Fourier Transform (DFT) [10], to perform the subcarrier modulation with a single oscillator [5] which was a excellent effort. To reduce the computational complexity of DFT, Ebert. Schwartz, and Salz demonstrated the efficacy of Cooley-Turkey Fast Fourier transform (FFT) algorithm thereby making possible to utilize the OFDM technique in communication systems. It is widely used in commercial systems with a wire line standard that includes high bit rate Digital Subscriber Lines (HDSL) [11], Asynchronous Digital Subscriber Lines (ADSL) [12], and Very high-speed Digital Subscriber Lines (VDSL) [12], to support a throughput upto 100Mbps. Thereafter, it has been utilized by wireless standards like DAB [13] and WLAN [14], [15], DVB [16] and WMAN. In WMAN applications, OFDM is considered for the World wide Interoperability for Microwave Access (WiMAX) implementation via IEEE 802.16d, a, e [17], [18] standards. OFDM is also being considered for 3GPP Long term Evolution (LTE) and 3GPP LTE-Advanced. Undoubtedly, OFDM can be a potential air interface candidate for future generation high speed wireless communications systems [19]-[22].

OFDM systems use cyclic prefix insertion to eliminate the effect of ISI and require a simple one-tap equalizer at the receiving end. OFDM brings in unparalleled bandwidth savings, leading to higher spectral efficiency. These properties make OFDM system extremely attractive for high speed wireless applications [2]. In OFDM systems different modulation schemes can be used on individual sub-carriers which are adapted to the transmission conditions on each sub-carrier.

Despite the widespread acceptance of OFDM, it has its drawbacks:

1) OFDM signals with their high peak-to-average power ratios (PAPRs) require highly linear amplifiers. Otherwise, performance degradation occurs and out-of-band power requirement will be enhanced.
2) OFDM systems are more sensitive to Doppler spread than single-carrier modulated systems.
3) Phase noise caused by the imperfections of the transmitter and receiver oscillators degrades the system performance.

4) Accurate frequency and time synchronization is required.
5) Loss in spectral efficiency due to cyclic-prefix (CP) operation takes place in OFDM systems.
6) In addition to this, OFDM system requires tight frequency synchronization, in comparison to single carrier systems, due to narrowband subcarriers. Therefore, it is sensitive to a small frequency offset between the transmitted and the received signal. The frequency offset may arise due to Doppler effect or due to mismatch between transmitter and the receiver local oscillator frequencies. The carrier frequency offset (CFO) disturbs the orthogonality between the subcarriers, and therefore, the signal on any particular subcarrier will not remain independent of the remaining subcarriers. This phenomenon is known as inter-carrier interference (ICI), which is a big challenge for error-free demodulation and detection of OFDM symbols.

The current implementations of OFDM do not fully exploit its capabilities. There are still several avenues which can be explored to reduce intercarrier interference (ICI) of OFDM signal. Therefore, the necessity to reduce the intercarrier interference of standard OFDM signal is a prime motivating factor for this work in this paper.

In OFDM system, the receiver filter operates in order to provide inverse effect of the transmitter filter. However, it's performance depends on the assumption that there is perfect synchronization between transmitter and receiver. In practice, there is a big chance of synchronization error due to many reasons. In this paper, our aim is to investigate the impact of synchronization error on the BER performance of the OFDM system.

II. SYSTEM MODEL

A multi-carrier transmission system is considered, in which symbols are generally transmitted over a rectangular time-frequency grid. Block diagrams of standard OFDM scheme are illustrated in Fig.1.

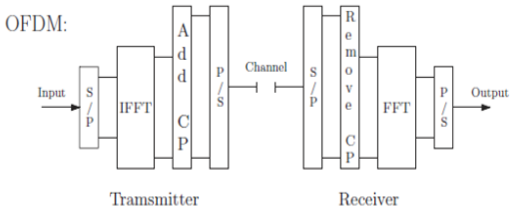

Figure 1OFDM system

The transmitted data symbol at time-position k and subcarrier position l is represented as $x_{l,k} \in A$, where A representing the symbol alphabet, for instance Pulse Amplitude Modulation or Quadrature Amplitude Modulation. The transmitted signal, represented as s(t), comprises of K time-symbols and L subcarriers, then, we can be write the equation as

$$s(t) = \sum_{k=1}^{K} \sum_{L=1}^{L} P_{l,k}(t)\, x_{l,k} \qquad (1)$$

Where$P_{l,k}(t)$ are the basis pulses which are the frequency and time shifted forms of the prototype filters p(t) and can be expressed as

$$P_{l,k}(t) = p(t - Kt) e^{j2\pi IF(t-Kt)} e^{j\theta_{l,k}} (2)$$

Note that, the frequency F and time T spacing's completes the spectral efficiency. By taking all basis pulse vectors in a large transmit matrix $P \in P_{N\times LK}$ we get:

$$P_{N\times LK} = \left(p_{0,0} p_{1,0} p_{2,0} \ldots.\ p_{L-1,0} p_{0,1} p_{0,2} \ldots.\ p_{L-1,k-1}\right)$$

To make easier the analytical observations, we supposed a time discrete type model of our transmission system. By expressing the sampled transmit signal x(t) in a vector x $\in C^{N\times 1}$, thus we can modify equation (1) by

$$\mathbf{X} = \mathbf{Pd}, \qquad (3)$$

Where

$$\mathbf{P} = \left[p_{1,1} p_{2,1} \ \ldots.\ \ p_{L,1} \ \ p_{L,2} \ \ldots..\ \ p_{L,K}\right] \ (4)$$

$$\mathbf{d} = \left[d_{1,1} d_{2,1} \ \ldots.\ \ d_{L,1} \ \ d_{L,2} \ \ldots..\ \ d_{L,K}{}^{T}\right] \ \ (5)$$

The Vector $p_{l,k} \in C^{N\times 1}$denotes the sampled basis pulses of equation (2) gives a transmit matrix G $\in C^{N\times LK}$, where x $\in C^{LK\times 1}$ arrange overall transmitted data symbols in big vector. Suppose, we represent receive matrix with V= $[v_{1,1} \ \ldots.\ \ v_{L,K}] \in C^{N\times LK}$ which is same and expressed as the transmit matrix, see equation (2) and equation (4), but a distinct prototype filter p(t) perhaps be used. With a matrix $\mathbf{H} \in C^{N\times N}$ which is a time-variant convolution. Then, overall transmission system can be represented as:

$$\mathbf{r} = \mathbf{V^H HPd} + \mathbf{n} \qquad (\mathbf{6})$$

Where $\mathbf{r} = [r_{1,1} \ \ldots.\ \ r_{L,K}] \in C^{LK\times 1}$ denotes the received symbols and n ~ CN $(0, P_n \mathbf{V^H V})$ represent the Gaussian distributed noise.

We can express the system model without effects of synchronization error as:

$$\mathbf{r} = \mathbf{V^H HPd} + \mathbf{V^H n} \qquad (7)$$

III. EFFECTS OF SYNCHRONIZATION ERROR

Consider there is a synchronization error which can be modelled as a random variable. Thus, we can express the erroneous receive filter matrix $\widetilde{\mathbf{V}}$ as follows

$$\widetilde{\mathbf{V}} = \mathbf{V} + \mathbf{Z} \qquad (\mathbf{8})$$

where Z is modelled as zero mean Complex random variable with variance σ_Z^2. As a result, the received vector can be formulated as

$$\mathbf{r_{new}} = (\mathbf{V}+\mathbf{Z})^{\mathbf{H}}\mathbf{HPD} + (\mathbf{V}+\mathbf{Z})^{\mathbf{H}}\mathbf{n}$$
$$= \mathbf{V^H HPd} + \mathbf{Z^H HGx} + \mathbf{V^H n} + \mathbf{Z^H n}$$

Now, by using Equation (7), we can rewrite the above as

$$\mathbf{r_{new}} = \mathbf{r} + \mathbf{Z^H}(\mathbf{HPd} + \mathbf{n}) \qquad (\mathbf{9})$$

or

$$\mathbf{r_{new}} = \mathbf{r} + \mathbf{Z^H r} \qquad (\mathbf{10})$$

where the second term in the equation (10) represents the error due to synchronization mismatch. In this work, we will investigate the BER performance of the OFDM systems for different choices of distribution for random variable Z.

IV. RESULTS

In this section,The Figure 2 and 3 provides the comparison of BER versus SNR for OFDM system. In Figure 1 and 2 we observe that BER for uniform distribution and Gaussian distribution with the Variance of 0.1 is worst when compare to the variance oat 0.01 and 0.001. So we can conclude that decreasing the variance results in good BER. when comparing the both the figure at SNR=6db we can observe that BER is better for Gaussian distribution when compare to uniform distribution. As we can see from figure 2 that with the decrease in the variance the BER of system gets improves. Thus, OFDM is a good candidate for multicarrier scheme. It is considered to be a potential scheme deployed in 5G communication system.

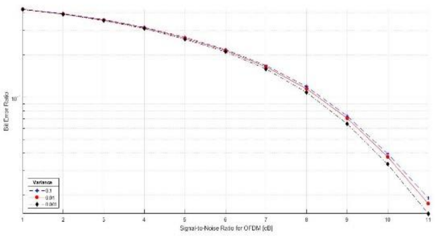

Figure 2 SNR for OFDM For uniform distribution

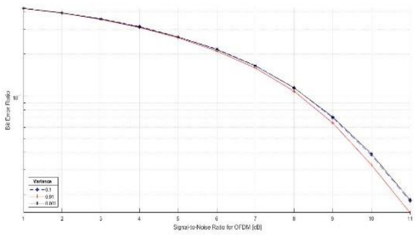

Figure 3 SNR for OFDM For gaussian distribution

V. CONCLUSION

In this paper, we simulated the OFDM system by using monte Carlo simulation and provide results for OFDM system in terms of BER versus SNR with the effect of synchronization error and we found that OFDM with gaussian distribution is a best choice for multicarrier transmission system. Thus, OFDM based transmission is a promising candidate to achieve high data rates via collective usage of a large number of subcarriers.

REFERENCES

[1]. Wu Y., W. Y. Zou, "Orthogonal frequency division multiplexing: A multi-carriermodulation scheme," IEEE Transactions on Consumer Electronics, vol. 41, no. 3, pp. 392–399, Aug. 1995.

[2]. Van Nee R., Prasad R., OFDM for wireless Multimedia Communications, Artech House, 2003.

[3]. Chang R. W., "Synthesis of band-limited orthogonal signals for multichannel data transmission", Bell Systems Technical Journal, vol. 46, pp. 1775-1796, Dec. 1966.

[4]. Zimmerman, M. S., Kirsch, A. L., "The AN/GSC-10 (KATHRYN) Variable Rate Data Modem for HF Radio", IEEE Trans. Commun. Tech., vol. COM-15, no. 2,197-205 Apr.1967.

[5]. Weinstein S. B., Ebert P. M., "Data Transmission for Frequency-Division Multiplexing Using the Discrete Fourier Transform," IEEE Transactions on Commun. Tech., vol. 19,no. 5, pp. 628–34, Oct. 1971.

[6]. L. Cimini, "Analysis snd simulation of a digital mobile channel using orthogonal frequencg division multiplexing", IEEE Transaction on Communications, vol. 3, pp.665-675, July 1985.

[7]. Powers E., Zimmeramann, "A digital implementation of a multichannel data modem", Proc. of IEEE International Conference on communication Technology, (Philadelphia,USA), Aug. 1968.

[8]. Chang R., Gibby R. "A theoretical study of performance of an orthogonal multiplexing data transmission scheme", IEEE Transactions on Communication Technology, vol. 16,pp. 529-540, Aug. 1968.

[9]. Saltzberg, B. R., "Performance of an Efficient Parallel Data Transmission System", IEEE Trans. Commun. Tech., vol. 15, no. 6, pp. 805–11, Dec. 1967.

[10]. Cooley J., Tukey, J., "An Algorithm for the Machine Calculation of Complex Fourier Series", Math. Comp., vol. 19, pp. 297–301, April 1965.

[11]. Chow P. S., Tu J.C., Ciof J. M., "A Discrete Multitone Transceiver System for HDSL Applications," IEEE Journal on Selected Areas in Communications, vol. 9, no. 6, Sep.1991.

[12]. Chow P.S., Tu J.C. and Cioffi J.M., "Performance Evaluation of a Multichannel Transceiver System for ADSL and VHDSL services", IEEE Journal on Selected Areas in Communications, vol. 9, no. 6, Aug. 1991.
[13]. ETSI, "Radio broadcasting systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers", European Telecommunication Standard, Standard EN-300-401, May 1997.
[14]. Hiperlan2, "Broadband Radio Access Networks (BRAN), HIPERLAN Type 2; Physical (PHY) layer", ETSI, Tech. Rep., 1999.
[15]. Part 11: Wireless LAN Medium Access Control (MAC) and physical layer (phy) specifications amendment 4: Further higher data rate extension in the 2.4 GHz band,"IEEE, Standard IEEE Std 802.11g.-2003, June 2003.
[16]. ETSI, "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television", European Telecommunication Standard, Standard EN-300-744, 2004-2006.
[17]. Part 16: Air Interface for Fixed Broadband Wireless Access Systems Amendment 2:"Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz", IEEE, Standard IEEE Std. 802.16a-2003, 2003.
[18]. Part 16: Air interface for fixed broadband wireless access systems. "Amendment for physical and medium access control layers for combined fixed and mobile operation in licensed bands," IEEE, Standard IEEE Std 802.16e/D12, October 2005, 2005.
[19]. Schulze H., Luders C., Theory and Applications of OFDM and CDMA: Wideband Wireless Communications, Wiley, 2005.
[20]. Goldsmith A., Wireless Communications, Cambridge University Press, 2005.
[21]. Bahai A.R.S., Saltzberg B. R., Ergen. M., Multicarrier Digital Communications Theory and Applications of OFDM, 2nd edition, Springer, 2004.
[22]. Yang L. L., Multicarrier Communications, 1st edition, John Wiley & Sons Ltd, 2009.

Turki Saleh Alharbi, "Effect of Synchronization errors on OFDM performance " *International Journal of Engineering Research and Applications (IJERA*), vol.10 (02), 2020, pp 70-73.