International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Improved Preamble-Aided Timing Estimation with pulse shaping filter for OFDM Systems

Anshuman Pushp[†*], Aditi Agrawal[†] and A. K. Jaiswal[†]

[†]ECE, SHIATS-DU Allahabad, U.P, India

Accepted 28 Nov 2015, Available online 03 Dec 2015, **Vol.5, No.6 (Dec 2015)**

Abstract

Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation technique in which the available spectrum band is divided into number of carriers and all of them are orthogonally modulated. It faces three main challenges i) high PAPR and ii) symbol timing offset iii) carrier frequency offset. In this paper we present a novel timing offset estimation method with pulse shaping filter for orthogonal frequency division multiplexing systems to avoid the ambiguity which occurs in Schmidt's, Park and Adegbenga timing offset estimation method. The performance of the proposed scheme is presented in terms of mean-square error (MSE) and auto-correlation and cross-correlation metric for no channel distortion. Here we can see, the simulation result has smaller MSE than the other estimators. In this paper, furthermore ambiguity of unwanted peak of noise has been reduced.

Keywords: *Orthogonal frequency division multiplexing, Carrier Frequency offset, Timing offset*

1. Introduction

A higher frequency bandwidth and high data rate transmission are highly desired in communication system, but high data rate encounter with the interference in the received signals. OFDM divides the available wideband among a set of orthogonal overlapping subcarrier and gives higher frequency bandwidth and overcomes the interferences. This is done by dividing the single high data rate stream into a several low data rate streams. OFDM is considered as a current trend for wireless communication due to its high data rate transmission capability with high bandwidth efficiency. OFDM has a number of uses and data applications. OFDM forms the basis for 4G wireless communication system, as 4G cellular standard is based on LTE (Long Term Evolution), whereas LTE is based on OFDM. It is also a basis for WiMAX. It is a key for broadband wireless technology which supports data rate in access of 100 Mbps. It is also a basis for LAN standard. IEEE standards like 802.11/a/g/n are based on OFDM and can support 200 mbps speed.

Since OFDM is one of the best techniques for data transmission at high data rate but it is also having some drawbacks like carrier frequency offset, inter channel interference; inter symbol interference and symbol timing offset (STO). STO is caused by frequency mismatch or relative motion between the oscillators at the transmitter and receiver. We need an exact symbol of transmitted signal on the receiver end to avoid the STO i.e. starting point of an OFDM signal needs to be estimated. Therefore timing synchronization is highly needed between both the transmitter and receiver.

2. Related Work

Synchronization has been a major research topic in orthogonal frequency division multiplexing (OFDM) systems due to the sensitivity to symbol timing and carrier frequency offset. Several approaches have been proposed to estimate time and frequency offset either jointly or individually. The most popular of the pilot-aided algorithms is the method proposed by Schmidl (M. Schmidl *et al*, 1997). His method uses a preamble containing the same two halves to estimate the symbol timing and frequency offset. Schmidl's estimator provides simple and robust estimates for symbol timing and carrier frequency offset. However, the timing metric of Schmidl's method has a plateau, which causes a large variance in the timing estimate. To reduce the uncertainty arising from the timing metric, Minn proposed a method (H. Minn *et al*, 1997) as a modification to Schmidl's approach (M. Schmidl *et al*, 1997). Minn's preamble yields a sharper timing metric and smaller variance than Schmidl's. While Minn's estimator provides accurate estimation, the variance of estimation is quite large in ISI channels. Minn proposed a method containing two halves as in Schmidl's method but for the second half he used negative samples. The timing metric get decreased because of the correlation of these negative samples. But then also MSE was quite

*Corresponding author: **Anshuman Pushp**

large in his estimator. Adegbenga used the same preamble as Schmidl used in his method because of its beneficial characteristics (A. B. Awoseyila *et al,* 2008). He used coherent cross-correlation between received and transmitted symbols under his coarse timing estimation method and found a very sharp impulse peak showing full symbol pattern match but there's also two set of minor impulse peaks showing half-symbol pattern match. He somehow decreased the MSE than others.

This paper contains our proposal for a new timing synchronization method for OFDM timing estimation which produces an even sharper timing metric than Adegbenga's.

3. Effects of frequency offset on OFDM signals

When CFO happens, it causes the receiver signal to be shifted in frequency (δF); this is illustrated in the figure 1. If the frequency error is an integer multiple I of subcarrier spacing δf, then the received frequency domain subcarriers are shifted by $\delta F \times I$[5].

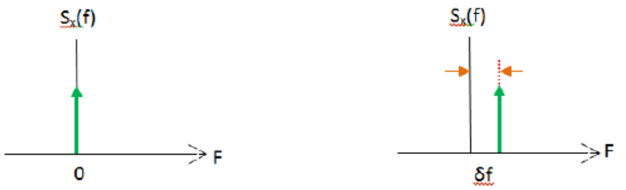

Fig.1 Frequency offset (δf)

On the other hand, as we know the subcarriers (SCs) will sample at their peak, and this can only occur when there is no frequency offset, however if there is any frequency offset, the sampling will be done at the offset point, which is not the peak point. This causes to reduce the amplitude of the anticipated subcarriers, which can result to raise the Inter Carrier Interference (ICI) from the adjacent subcarriers (SCs). Figure 2 shows the impact of carrier Frequency offset (CFO). It is necessary to mention that although it is true that the frequency errors typically arise from a mismatch between the reference frequencies of the transmitter and the receiver local oscillators, but this difference is avoidable due to the tolerance that electronics elements have.

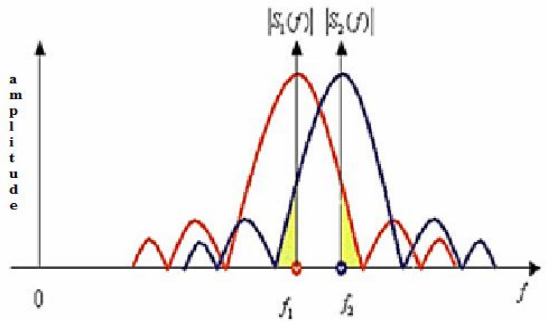

Fig.2 Illustration of ICI and carrier offset

Therefore there is always a difference between the carrier frequencies that is generated in the receiver with the one that is generated in transmitter; this difference is called frequency offset

$$\delta F = f2 - f1 \qquad (1)$$

Where, $f2$ is the carrier frequency in the transmitter and $f1$is the carrier frequency in receiver.

4. OFDM System Description

In a typical OFDM transmission IFFT and FFT function is used in transmitter and receiver side respectively. The Nth received sample has the standard form.

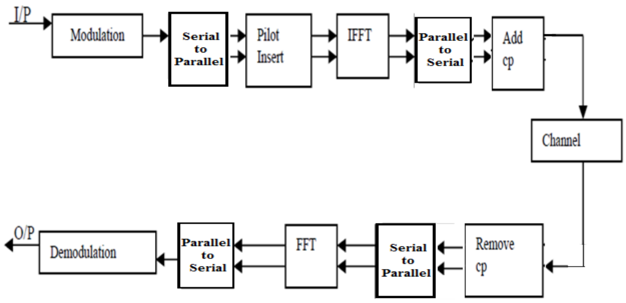

Fig.3 Typical structure of OFDM

Fig3 shows that in the transmitter side, the modulated sub-carrier signals are converted from serial to parallel by demultiplexing. Now, each modulated sub carrier signal is transformed into time domain by using IFFT. Again all the sub carriers are multiplexed to a serial from parallel. Now, by convolution, a cyclic prefix is added to the beginning of the serial. On the other hand receiver side, there is a removal of cyclic prefix, since it is subjected to ISI, then it is demuxed into parallel. Now N-point FFT is used to all the subcarriers to convert it into frequency domain. Then it is multiplexed for conversion into serial and finally demodulated.

5. OFDM Timing Synchronization

Some of the efficient timing synchronisation methods are as follows;

1) Schmidl's Method: According to Schmidl, time domain preamble is given by:

$$P = [A_{N/2} \ A_{N/2}] \qquad (2)$$

Where $A_{N/2}$ is sample of length N/2 for N no of subcarriers.

The maximum point of the timing metric given by

$$M_{Sch}(d) = \frac{|P_1(d)|^2}{|R_1(d)|^2} \qquad (3)$$

Where,

$$P_1(d) = \sum_{k=0}^{N/2-1} r^*(d+k).r(d+k+\frac{N}{2}) \quad (4)$$

$$R_1(d) = \sum_{k=0}^{N/2-1} |r(d+k+\frac{N}{2})|^2 \quad (5)$$

for r received sample, d sample index and k no of samples shifted.

2) *Park's Method:* Park's preamble has the following form:

$$P_P = [C_{N/2}\ D_{N/2}\ C^*_{N/2}\ D^*_{N/2}] \quad (6)$$

where,
$C_{N/2}$ is sample of length $N/2$,
$C^*_{N/2}$ is a conjugate of $C_{N/2}$,
$D_{N/2}$ is designed to be symmetric with $C_{N/2}$ to get impulse-shaped timing metric.

Then the timing metric is expressed as

$$M_{\mathrm{Pro}}(d) = \frac{|P_3(d)|^2}{|R_3(d)|^2} \quad (7)$$

Where,

$$P_3(d) = \sum_{k=0}^{N/2} r^*(d-k).r(d+k) \quad (8)$$

$$R_3(d) = \sum_{k=0}^{N/2} |r(d+k)|^2 \quad (9)$$

3) Adegbenga's Method

Adegbenga uses the same time domain preamble as in Schmidl's method

$$P = [A_{N/2}\ A_{N/2}] \quad (10)$$

The timing metric is as below

$$M_c(d) = \frac{1}{G+1}\sum_{k=0}^{G}|P_{Sch}(d-k)|^2 \quad (11)$$

$$\hat{d}_c = \underbrace{\arg\max}_{d}\{M_c(d)\} \quad (12)$$

Where d_c is peak of course timing metric and G is cyclic prefix length.

6. Proposed method

The proposed method has an addition of a pulse shaping filter to the output of Adegbenga proposed method whose preamble is given as

$$P = [A_{N/2}\ A_{N/2}] \quad (13)$$

where, $A_{N/2}$ is a sample of length N/2. The timing metric is also same as Adegbenga used in his method. The pulse shaping rcf is used to overcome the ISI factor. The rcf is a Nyquist filter. The frequency domain function of this low-pass filter for different roll-off factor β and T symbol period is given by

$$H(f) = \begin{cases} T, & |f| \le \frac{1-\beta}{2T} \\ \frac{T}{2}[1+\cos(\frac{\pi T}{\beta}[|f|-\frac{1-\beta}{2T}])], & \frac{1-\beta}{2T} < |f| \le \frac{1+\beta}{2T} \\ 0, & otherwise \quad 0 \le \beta \le 1 \end{cases} \quad (14)$$

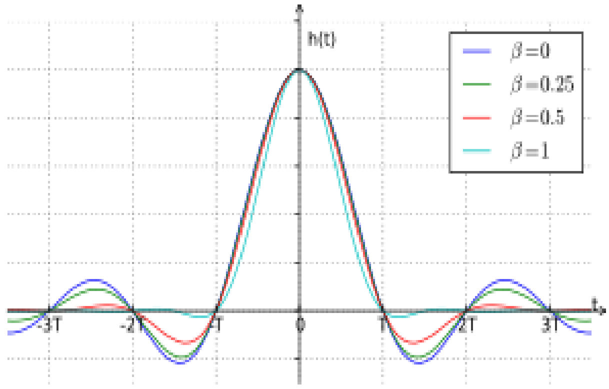

Fig.4 Raised-cosine filter (rcf)

From fig4 we can see that as roll-off factor β increases from 0 to 1, the peak at every increasing symbol period (other than zero) tends to zero. So, for the range of β between 0 and 1 (i.e. 0≤β≤1), the *H(f)* is taken as 0 or can be negligible.

7. Simulation Parameter and Result Discussion

MATLAB simulator tool are used to estimate the timing offset effect on OFDM system. Parameters for this simulation are as follows.

Table 1 Simulation Parameters

Parameter	Value
Channel model	Noise free, AWGN, mobile channel
Number of Subcarrier	64
System bandwidth	5MHz
FFT size	256
Sampling factor	4
Pulse shaping filter	Raised Cosine and root raised cosine filter
Modulation technique	QPSK
SNR range	0-30 db

MATLAB simulations were used to compare the performance among the proposed and the previous three techniques. QPSK sub-carrier modulation is used with a normalized timing offset $\Delta t = 0$, FFT size: N=64, cyclic prefix length: G=16 and ISI parameter: λ=0 is used in an AWGN channel.

The STO estimation on OFDM system can be analyzed by using Adegbenga model in addition with pulse shaping filter on the OFDM output by using complementary cumulative distribution function

[CCDF] plot between timing MSE and SNR on the MATLAB simulator. In Fig.5, there is a CCDF plot between timing MSE versus SNR (dB) for previous and existing technique with an additive white Gaussian noise [AWGN]. Here we can see that, in the STO estimation, timing mean square error is getting reduced as the signal quality is getting better (i.e., for every increment in SNR) for the proposed method than the previously proposed scheme. We can conclude that proposed scheme has better Timing MSE than the previously proposed schemes.

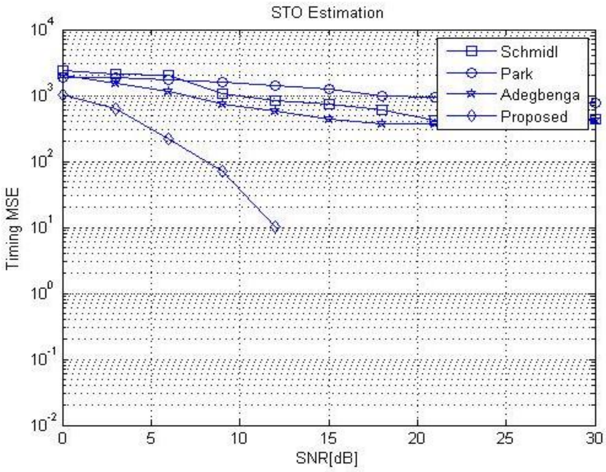

Fig.5 CCDF plot between Timing MSE and SNR under AWGN

Other than AWGN, timing MSE also depends upon the destination distance, as for shorter distance, the signal encounters with lesser noise than the longer distance. Fig.6 and Fig.7 shows the CCDF plot for indoor and outdoor ranges respectively. We can see even for different conditions also the proposed scheme has better timing MSE than previous techniques.

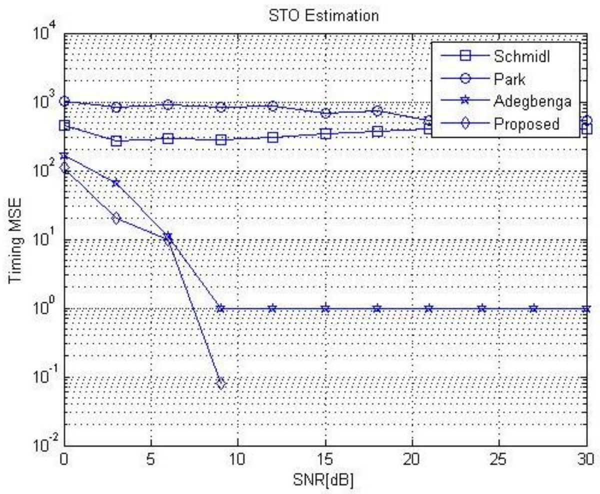

Fig.6 CCDF plot between Timing MSE and SNR for indoor ranges

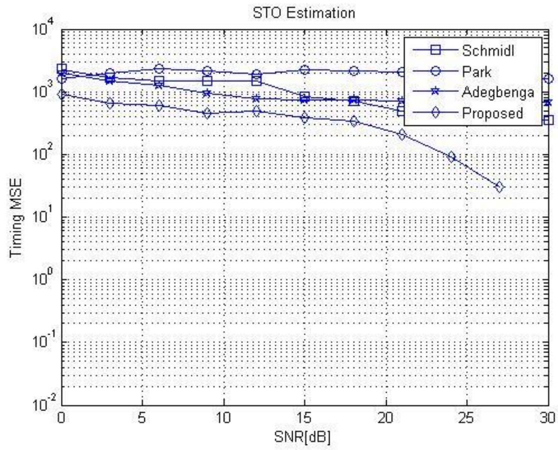

Fig.7 CCDF plot between Timing MSE and SNR for outdoor ranges

Conclusion

In this paper, the timing offset estimation has been improved by using a pulse shaping filter, RCF and RRCF. Using the simulation results, we conclude that the proposed method is having better elimination of timing offset than the previous methods.

References

Van de Beek, J-J., Sandell, M., and Börjesson, P-O. (1994), ML Estimation of Timing and Frequency Offset in OFDM Systems, *IEEE Trans on Comm*, 42(10):2908-2914.

T. Pollet, M. Van Blade1 and M. Moeneclaey (1995), BER sensitivity of OFDM systems to carrier frequency offset and wiener phase noise, *IEEE Tans. on Comms.*, Vol. 43, No. 2/3/4, pp. 191-193

H. Nogami and T. Nagashima (1995), A frequency and timing period acquisition technique for OFDM systems, *Personal, Indoor and Mobile Radio Commun. (PIRMC)*, pp. 1010–1015.

D. Lee and K. Cheun (1997), A new symbol timing recovery algorithm for OFDM systems, *IEEE Trans. on Consum. Electronics*, Vol. 43, No. 3, pp. 767-77

D. Landström, J. M. Arenas, J. J. van de Beek, P. O. Börjesson, M.-L. Boucheret, and P. Ödling (1997), Time and frequency offset estimation in OFDM systems employing pulse shaping, *Proc Int. Conf. on Universal Personal Communications*, vol. 45, San Diego, CA, pp. 279–283.

Timothy M. Schmidl and Donald C. Cox. Fellow (1997), Robust Frequency and Timing Synchronisation for OFDM, *IEEE Transaction On Communication*, Vol. 45. No.12.

H. Minn and V. K. Bhargava, Fellow (1997), Robust Frequency and Timing Synchronisation for OFDM, *IEEE Transaction On Communication*. Vol. 45. No. 12.

D. Agrawal, V. Tarokh, A. Naguib and N. Seshadri (1998), Space-time coded OFDM for high data-rate wireless communication over wideband channels, *Proc. 48th IEEE VTC 98 Vehicular Technology Conference*, vol. 3, pp. 2232-2236

B. McNair, L.J. Cimini Jr. and N. Sollenberger (1999), A robust timing and frequency offset estimation scheme for orthogonal frequency division multiplexing (OFDM) systems, *Proc. Vehicular Tech. Conf., Houston, Texas, USA*, pp. 690-694

D. Landström, S. K. Wilson, J. J. van de Beek, P. Ödling, and P. O. Börjesson (1999), Symbol time offset estimation in coherent OFDM systems, Proc. Int. Conf. on Communications, Vancouver, BC, Canada, pp. 500–505.

Y. H. Kim, I. Song, S. Yoon, and S. Park (2001), An efficient frequency offset estimator for OFDM systems and its performance characteristics, *IEEE Trans. Veh. Technol.*, vol. 50, no. 5, pp. 1307-1312

W. Xianbin *et al*. (2003), SER performance evaluation and optimization of OFDM system with residual frequency and timing offsets from imperfect synchronization, *IEEE Transactions on Broadcasting*, vol. 49, pp. 170-177.

Byungjoon Park, Hyunsoo Cheon, Changeon Kang, Daesik Hong (2003), A Novel Timing Estimation Method for OFDM System, *IEEE Comunications Letter*, Vol., 7, No.

Adegbenga B. Awoseyila, Christos Kasparis and Barry G. Evans (2009), Robust Time-domain Timing and Frequency Syncronization for OFDM System, *IEEE Communication*

K. Shi and E. Serpedin (2004), Coarse frame and carrier synchronization of OFDM systems: a new metric and comparison, *IEEE Trans Wireless Commun.*, vol. 3, no. 4, pp. 1271-1284.

N. Balamurali and D. Jalihal (2008), Robust timing and frequency synchronization algorithm for IEEE 802.16 OFDM systems, *Intl. Conf. Signal Process. Commun. (SPCOM)*, pp. 234-238

W. Xianbin *et al*. (2004), Robust channel estimation and ISI cancellation for OFDM systems with suppressed features, *IEEE Journal on Selected Areas in Communications*, vol. 23, pp. 963-972.

Y. Suckchel and S. Yoan (2005), A robust joint estimator for OFDM timing and frequency offsets based on PN codes, *Proc. Second IEEE Consumer Communications and Networking Conference*, pp. 577-579.

C. Kasparis and B. G. Evans (2006), A cross-correlation approach for improved timing estimation in OFDM broadcasting systems, *Proc. 24th AIAA Intl. Commun. Satell. Sys. Conf. (ICSSC)*, pp. 1039-1048

M. Morelli, C.-C.J. Kuo, and M.-O. Pun (2007), Synchronization techniques for orthogonal frequency division multiple access (OFDMA): a tutorial review, *Proc. IEEE*, vol. 95, no. 7, pp. 1394-1427

A. B. Awoseyila, C. Kasparis, and B. G. Evans (2008), Improved preambleaided timing estimation for OFDM systems, *IEEE Commun. Lett.,* vol. 12, no. 11, pp. 825-827

Y. Kang, S. Kim, D. Ahn, and H. Lee (2008), Timing estimation for OFDM systems by using a correlation sequence of preamble, *IEEE Trans. Consumer Electron.,* vol. 54, no. 4, pp. 1600-1608.

A. A. Quadeer and M. S. Sohail (2010), Enhanced channel estimation using Cyclic Prefix in MIMO STBC OFDM systems, *Proc. 2010 IEEE International Symposium on Signal Processing and Information Technology (ISSPIT)*, pp. 277-282.

A. A. Nasir *et al.* (2010), Performance of coarse and fine timing synchronization in OFDM receivers, *Proc. 2010 2nd International Conference on Future Computer and Communication (ICFCC),* pp. V2-412-V2-416.

Hamed Abdzadeh-Ziabari, Mahrokh G. Shayatesh, Member, IEEE, and Mahrdad Manaffar (2010), An Improved Timing Estimation Method For OFDM Systems*, IEEE Transaction On Consumer Electronics*, Vol. 56, No. 4

A. M. Khan, Varun Jeoti, M. A. Zakariya and M. Z. Ur Rehman (2014), Robust Symbol Timing Synchronization for OFDM Systems Using PN Sequence, *International Journal of Information and Electronics Engineering*, Vol. 4, No. 3.