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Research paper

A difference of absolute value based timing metric for timing synchronization in OFDM system

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Abstract

Traditional time synchronization schemes are based on autocorrelation between identical parts of the reference OFDM symbol. However, the time metric of the traditional schemes have a plateau or significant quantity of side lobe. This results in a poor timing synchronization performance. In this paper we are proposing a modified timing metric based on difference of absolute value as a normalized factor. The timing synchronization based on the modified timing metric reduces side lobe and improves the timing synchronization performance.

Keywords: *OFDM; Timing Metric; Symbol Timing Synchronization; Differential Absolute Value.*

1. Introduction

In recent times there is an exponential rise in the demand of multimedia wireless services based on broadband standard. A common technology in most of the broadband standards designed to provide broadband services is Orthogonal Frequency Division Multiplexing (OFDM) [1]-[2]. OFDM is a multicarrier modulation technique [3], where high data rate serial bits are converted into low data rate parallel paths and the signals in each of the parallel paths modulate orthogonal sub-carriers. This process of transmission of OFDM signal converts frequency selective channel into frequency flat fading channel. In contrast to mono carrier communication, OFDM combats the effects of frequency flat fading channel in frequency domain using bank of simple one tap equalizer. Due to the robustness of OFDM to multipath fading, it is adopted in WLAN, DVB-T, LTE-A, MB-OFDM UWB to provide wireless broadband services. However, OFDM is highly sensitive of time and frequency synchronization error [4].

In an OFDM system, the timing and frequency of the received OFDM signal should be synchronized [5] with the reference signal at the receiver. However, due to Doppler shift, multipath fading delay and oscillator frequency instability at the receiver results in the frequency offset between transmitted carrier frequency and timing offset.

Frequency synchronization error in OFDM system [3] is resulted by the Inter Channel Interference (ICI). Timing synchronization error in OFDM system [5] results in Inter Symbol Interference (ISI), Inter Channel Interference (ICI) and change in the amplitude of the received signal. So, needs development of timing and frequency synchronization scheme for an OFDM system.

Several timing synchronization schemes have been reported for OFDM system, which are mostly based on the auto-correlation between identical repeated parts of OFDM symbol. Schmidl & Cox [6] have proposed timing synchronization scheme based on the correlation between two identical parts of a symbol. However, its performance is poor due to the presence of plateau in the timing metric. Minn [7] has proposed a synchronization scheme based on several repeated sequences in one OFDM symbol. However, the performance is limited due to presence of side lobe in the timing metric. Subsequently Park [8] has proposed synchronization scheme based on repeated complex conjugated sequence in the ODFM symbol. The scheme reduced side lobe, but the performance is poor in a fading environment. Ren [9] has multiplied the preamble with two identical parts by pseudo noise (PN) sequence, but this scheme has poor performance in fast fading channel. Kang [10] has proposed a new sequence obtained from the circular shift of the given preamble. Kang's scheme can be used for any of the OFDM system regardless of their preamble structures. Sheng [11] has proposed a new timing metric, which uses the noise subspace of channel estimates to find out the starting point of the symbol and it can also be applied to any preamble, but this method has lower performance than Minn's scheme at lower SNR value. In [10] only a fraction of available products are used. The utilization of unused products can improve the estimator performance in noise conditions. So Ziabari [12] has proposed a scheme which is independent of the preamble structure and it can utilize the whole product available from a given preamble for its correlation. But [12] is a complex scheme. In [13] Ziabari explains the scheme where the two preambles are utilized but this scheme is applicable for WLAN. In [14] a new timing synchronization scheme for OFDM based WLANs is presented where one long OFDM symbol in the frame format of IEEE802.11 is suggested for timing synchronization.

In this paper we have proposed a new timing metric with a normalized factor based on the difference of absolute value, which reduces the side lobe to a great extent and improves the performance. We determine timing metric, mean square error of timing offset, peak to side lobe ratio, and probability of detection of the proposed scheme and compare the performance with the existing schemes.

The rest of the paper is organized as follows. Section 2 describes synchronization in OFDM system. The proposed scheme is presented in Section 3 followed by its performance in Section 4. The paper is concluded in Section 5.

2. Timing synchronization in OFDM system

In most of the multicarrier systems, timing synchronization is the first operation performed in receiver to detect start of the OFDM symbol. The popular methods of timing synchronization involve an OFDM symbol with several repeated identical sequences in time domain [6]-[8]. At the receiver, correlation between the repeated parts is performed and timing metric is defined. The start of the OFDM symbol is found by searching the peak of the timing metric. Few of the popular schemes are discussed below.

2.1. Schmidl & cox's scheme

Timing synchronization scheme due to Schmidl and Cox is based on a time domain OFDM symbol having two equal parts with identical sequences as shown below.

$TR_{Sch} \quad =$	$A_{\frac{X}{2}}$	$A_{\frac{X}{2}}$

Samples of length X/2 is represented by $A_{X/2}$.

A correlation between the identical parts of OFDM symbol is performed at the receiver and subsequently a timing metric is defined, which is given in (1).

$$M_{Sch}(\alpha) = \frac{|P_{Sch}(\alpha)|^2}{{R_{Sch}}^2(\alpha)} \tag{1}$$

Where, α is the time index in a window of 2 L = X samples.

$$P_{Sch}(\alpha) = \sum_{m=0}^{L-1}(r^*{}_{\alpha+m} r_{\alpha+m+L}) \tag{2}$$

Where, L = X/2 and the energy received for the second half-symbol is defined by

$$R_{Sch}(\alpha) = \sum_{m=0}^{L-1}|r_{\alpha+m+L}|^2 \tag{3}$$

The start of the OFDM symbol is determined by searching the peak value of the timing metric. Fig.1 represents the timing metric of the scheme due to Schmidl & Cox. It is observed that the timing metric exhibit a plateau and results in the uncertainty in determining the start of the OFDM symbol and high Mean Square Error (MSE) of timing offset.

2.2. Minn's scheme

In order to mitigate the uncertainty due to plateau in timing metric estimator, and high MSE of timing offset, Minn have proposed a modified training sequence consisting of repeated sequences with different sign. The training sequence expressed as:

$TR_{Minn} \quad =$	$B_{\frac{X}{4}}$	$B_{\frac{X}{4}}$	$-B_{\frac{X}{4}}$	$-B_{\frac{X}{4}}$

Samples of length X/4 is represented by $B_{X/4}$.
The timing Metric is given by

$$M_{Minn}(\alpha) = \frac{|P_{Minn}(\alpha)|^2}{{R_{Minn}}^2(\alpha)} \tag{4}$$

Where,

$$P_{Minn}(\alpha) = \sum_{k=0}^{1}\sum_{m=0}^{L-1} r^*(\alpha+2Lk+m).r(\alpha+2Lk+m+L) \tag{5}$$

And

$$R_{Minn}(\alpha) = \sum_{k=0}^{1}\sum_{m=0}^{L-1}|r(\alpha+2Lk+m+L)|^2 \tag{6}$$

Due to repeated sequence with different signs, it produces sharper timing metric and smaller timing offset Mean Square Error (MSE) than Schmidl& Cox [6]. However, the presence of multipath fading channel results in higher MSE of Timing synchronization of Minn's scheme .Because of this the performance in a multipath fading channel is limited. Park has proposed a timing synchronization scheme with modified OFDM symbol in time domain so as to reduce the side lobes.

2.3. Park's scheme

To overcome the drawback of Minn's timing synchronization scheme Park have proposed a timing synchronization scheme based on a modified OFDM symbol having repeated conjugate and symmetric sequences as shown below.

$TR_{Park} =$	$C_{\frac{X}{4}}$	$D_{\frac{X}{4}}$	$C^*{}_{\frac{X}{4}}$	$D^*{}_{\frac{X}{4}}$

Samples of length X/4 and $D_{X/4}$ are represented by $C_{X/4}$ and symmetric by with conjugate of $C_{X/4}$ [8].
The Timing Metric is given by:

$$M_{Park}(\alpha) = \frac{|P_{Park}(\alpha)|^2}{{R_{Park}}^2(\alpha)} \tag{7}$$

Where,

$$P_{Park}(\alpha) = \sum_{k=0}^{\frac{N}{2}-1} r(\alpha-k).r(\alpha+k) \tag{8}$$

And

$$R_{Park}(\alpha) = \sum_{k=0}^{\frac{N}{2}-1}|r(\alpha+k)|^2 \tag{9}$$

The timing metric due to Park scheme has impulse-shape at the correct time of OFDM symbol. However, it has side lobes at other positions and increases the MSE of timing offset of scheme. To improve the MSE of timing offset and probability of detection, we propose a new timing metric described in the next section.

3. Proposed timing synchronization scheme

Most of the popular schemes for timing synchronization for OFDM system are based on timing metric and this is the ratio between the correlation between the N/2 samples of two identical parts over a window of length X and the energy of half of the OFDM symbol. The normalization factor which is half of symbol energy helps to reduce fluctuation in the timing metric. It is observed that the scheme due to Park has a lower MSE compared to Schmidl& Cox and Minn. However, Park scheme MSE performance is affected due to the presence of side lobes. In deep fading channels, Park method degrades as there are side lobes which give rise to false alarm and detection failure. So it is a new timing metric scheme based on normalization factor is proposed which is the sum of the square of difference of the absolute values over X/2 samples. This normalization factor reduces the side lobes and reduces MSE of timing offset. The proposed normalization factor is expressed as in the equation below:

$$R_{Proposed}(\alpha) = \sum_{k=0}^{\frac{X}{2}-1}(|r(\alpha-k)| - |r(\alpha+k)|)^2 \tag{10}$$

This normalizing factor is called Difference of Absolute value.
The structure of the pilot OFDM symbol is given by:

$TR_{Proposed} =$	$C_{\frac{X}{4}}$	$D_{\frac{X}{4}}$	$C^*{}_{\frac{X}{4}}$	$D^*{}_{\frac{X}{4}}$

Samples of length X/4 is represented by $C_{X/4}$ which is generated by IFFT of a PN sequence and $C^*{}_{X/4}$ represents a conjugate of $C_{X/4}$. $D_{X/4}$ is symmetric to $C_{X/4}$[8].
The timing metric is given by:

$$M_{Proposed}(\alpha) = \frac{|P_{Proposed}(\alpha)|^2}{{R_{Proposed}}^2(\alpha)} \tag{11}$$

Where,

$$P_{Proposed}(\alpha) = \sum_{k=0}^{\frac{N}{2}-1} r(\alpha-k).r(\alpha+k) \tag{12}$$

The proposed method determines a threshold value of the timing metric and the timing metric is compared with the threshold value. The time index of the OFDM sample for which the timing metric is higher than threshold value is estimated to be the start of OFDM symbol. A suitable threshold value which results in the lowest probability of detection failure is determined using simulation and the same value is used to determine the performance of the proposed scheme.

4. Performance analysis of the proposed scheme

The performance of proposed scheme is evaluated using timing metric in an exponential decay Rayleigh distributed multipath fading channel. An OFDM system with 1024 subcarriers and 128 cyclic prefix with a normalized frequency offset of 0.1 is considered for the evaluation of the performance of the proposed timing synchronization scheme. Timing metric, peak to side lobe ratio, Mean square error of timing offset and probability of detection are the performance metrics used for the evaluation of the performance the proposed scheme.

4.1. Timing metric

Fig. 1, Fig.2, Fig.3 and Fig.4 depict the timing metric for Schmidl& Cox's scheme, Minn's scheme Park's scheme and proposed scheme respectively. It is observed from Fig. 1 that the Schmidl& Cox's scheme has a plateau for the whole interval of cyclic prefix that leads to uncertainty in determining the start of OFDM symbol. It is observed from Fig. 2 that the Minn's scheme has the timing metric value at the correct time being almost same as the timing metric value at other sample instances around correct time. In order to improve the performance of timing synchronization scheme, it is required to increase the difference between timing metric value at correct time and the value at any other time. Timing metric for the Park's scheme in Fig.3 observed to have several side lobe of higher amplitude. This decrease affects the performance the Park's scheme. Fig.4 indicates timing metric of the proposed scheme at an SNR of 10dB. It is observed that the timing metric of the proposed scheme has a high value at the correct time i.e. at 1152 (1024 subcarrier+128 cyclic prefix) and the value of side lobe is negligible.

4.2. Peak-to-side lobe ratio vs. SNR

Presence of side lobe in the timing metric affects the timing synchronization to a great extent. Peak-to-Side lobe Ratio (PSR) vs. SNR is presented in Fig.5.It is observed that the PSR for Schmidl& Cox's and Minn's scheme attain no changes but PSR for Park's and Proposed scheme increases with increase in SNR value. However the PSR of proposed scheme is observed to have higher PSR of 10.5 as compared to PSR of 3.5 for Park's scheme at SNR of 15db.

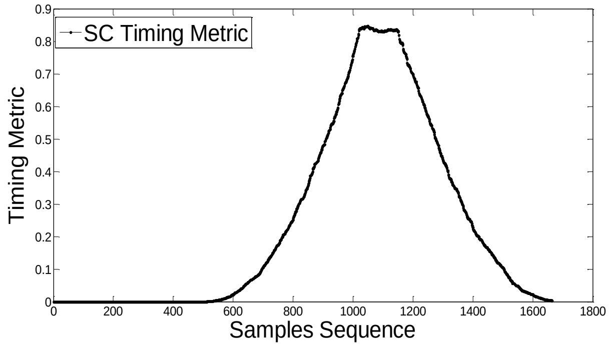

Fig. 1: Timing Metric of Schmidl & Cox Scheme at an SNR of 10dB.

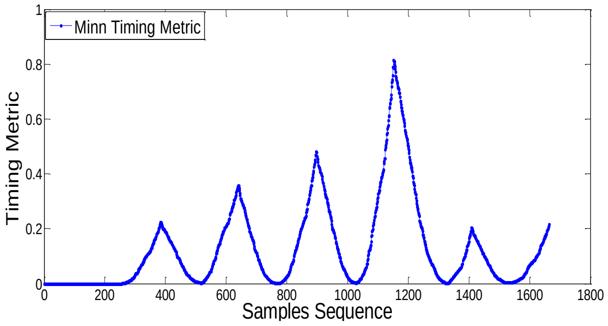

Fig. 2: Timing Metric of Minn Scheme at an SNR of 10db.

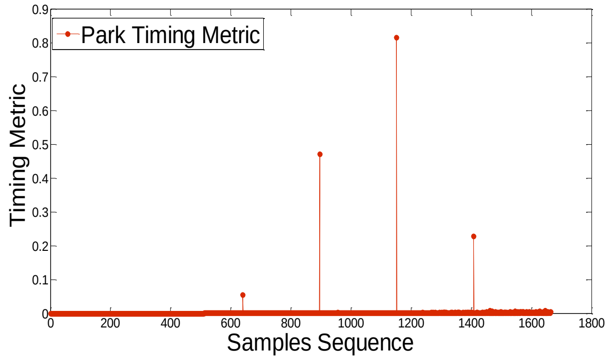

Fig. 3: Timing Metric of Park Scheme at an SNR of 10db.

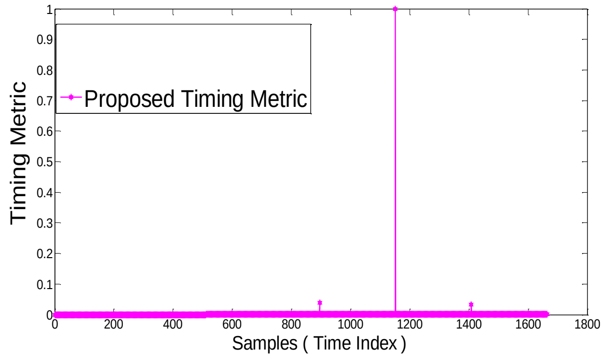

Fig. 4: Timing Metric of Proposed Scheme at an SNR of 10db.

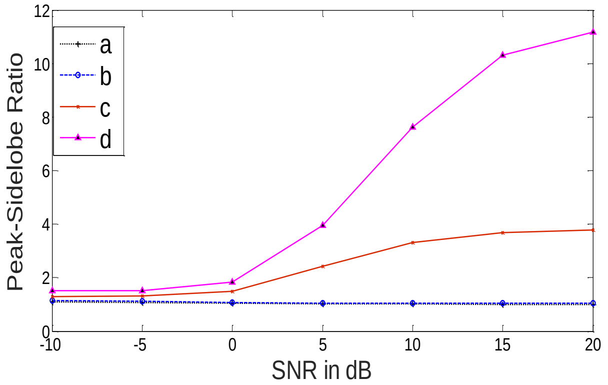

Fig. 5: Peak-To-Side Lobe Ratio vs. SNR in Db (A) SC Scheme, (B) Minn Scheme, (C) Park Scheme and (D) Proposed Scheme.

4.3. Threshold detection

The starting timing of the OFDM symbol is determined to be the sample for which the timing metric greater than the threshold value. So, there is a need to determine the appropriate threshold value for the evaluation of the performance. Fig 6 presents the probability of detection failure vs. threshold of timing metric for the Minn's scheme and Park's scheme. Probability of detection failure vs. threshold value of proposed scheme at a SNR of 10dB is presented in Fig 7. Probability of detection failure is the combination of probability of false detection and probability of miss timing. It is observed from Fig 6 that the probability detection failure for Minn's and Park's schemes decrease with increase in threshold value due to the decrease in the probability of miss timing. This trend continues till the threshold value becomes 0.39 and 0.69 for the Minn's and Park's scheme respectively. Further increase in threshold value beyond 0.39 and 0.69 for Minn's and Park's scheme, the probability of detection failure increases due to increase in the false detection. Similar trend for the probability of detection failure is also observed in the Fig 7 for the proposed scheme. The threshold value for minimum probability of detection failure is observed to be 4.5 for the proposed scheme.

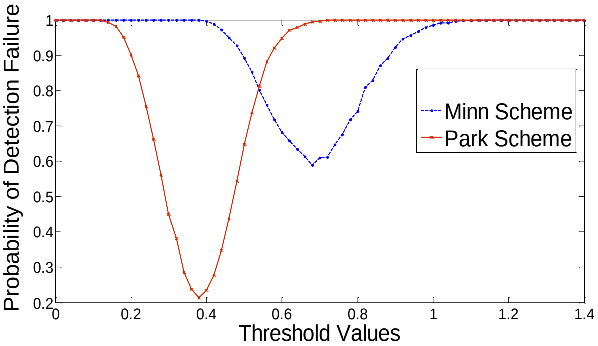

Fig. 6: Probability of Detection Failure vs. Threshold Values for the Minn's and Park's Scheme at SNR of 10db.

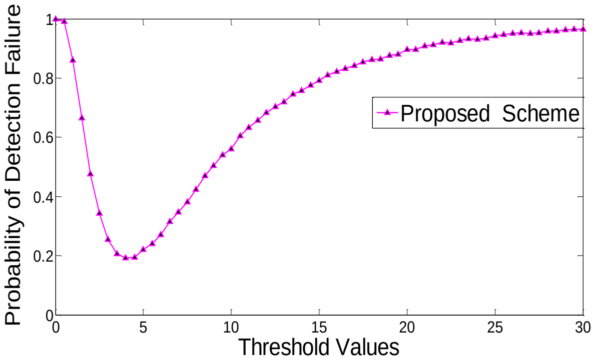

Fig. 7: Probability of Detection Failure vs. Threshold Values for the Proposed Scheme at SNR of 10db.

4.4. Mean of the timing offset

Mean of the timing offset vs. SNR is depicted in Fig.8. It is noticed from the plot that the mean of the timing offset decreases with increase in SNR for all schemes and approaches zero. However, the mean timing offset for the proposed scheme approaches zero at a lower SNR than Minn's and Park's scheme. Mean timing offset of the proposed scheme approaches zero at an SNR of 4dB compared to Park's scheme where MSE approaches zero at SNR of 12dB.

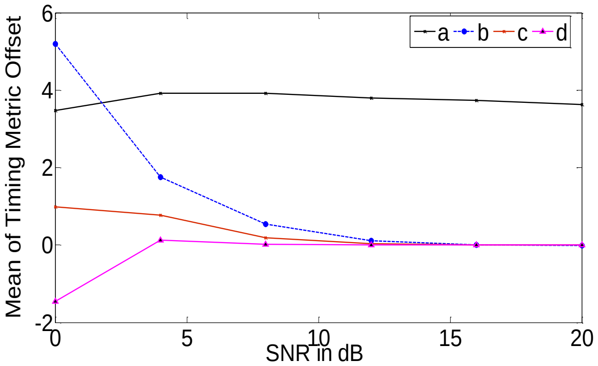

Fig. 8: Mean of Timing Metric Offset vs. SNR in Db. (a) SC Scheme, (b) Minn Scheme, (c) Park Scheme and (d) Proposed Scheme.

4.5. MSE of the timing offset

Fig.9 presents Mean Square Error (MSE) of timing offset vs. SNR for the proposed scheme, Schmidl & Cox's scheme, Minn's scheme and Park's scheme. It is observed that the MSE for Schmidl &Cox's scheme does not change with SNR. However, the MSE of timing offset for Minn's scheme, Park's scheme and proposed scheme deceases with SNR. MSE of the proposed scheme is higher than the Park's scheme by a factor of 10 at SNR of 10dB.

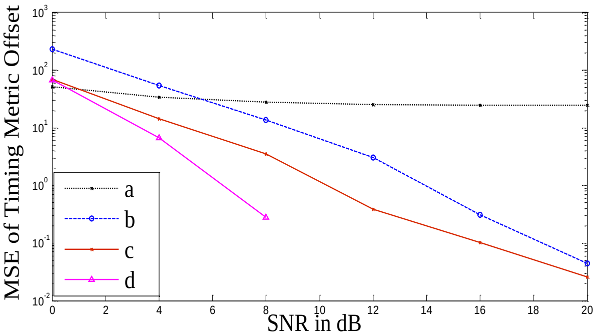

Fig. 9: MSE of Timing Offset vs. SNR in Db SC Scheme , (B) Minn Scheme, (C) Park Scheme and (D) Proposed Scheme.

4.6. Probability of detection

Probability of Detection (P_D) of the timing synchronization scheme vs. SNR is shown in Fig.10. It is observed that the P_D for the Schmidl& Cox's scheme remains almost unchanged with SNR. However, P_D for Minn's scheme, Park's scheme and the proposed increases with increase in SNR.P_D increases and saturates at higher SNR. It is observed that the P_D of the proposed scheme found to be the higher than Park's scheme by 0.08 at 10dB SNR.

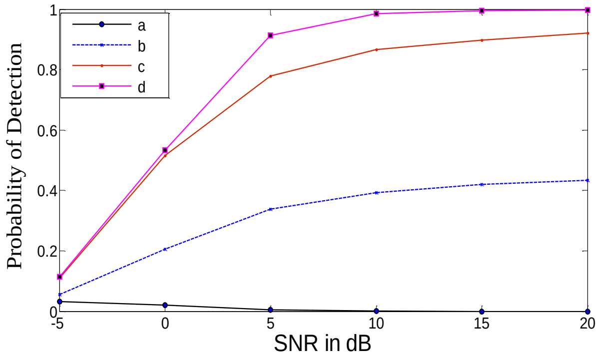

Fig. 10: Probability of Detection vs. SNR in Db (A) SC Scheme, (B) Minn Scheme, (C) Park Scheme and (D) Proposed Scheme.

5. Conclusion

In this paper, we proposed a new timing metric based on normalized factor consisting of differential absolute value for timing synchronization in OFDM system. The use differential absolute value reduced the side lobes in the Timing Metric to a greater extent. The proposed timing metric results in the lower MSE of timing offset and higher Peak-to-Side lobe Ratio and Probability of Detection compared to Schmidl& Cox's, Minn's, and Park's scheme. This scheme can also be applied to MIMO OFDM system.

References

[1] L. J. Cimini , Jr., “Analysis and simulation of a digital mobile channel using orthogonal frequency division multiplexing,” IEEE Trans. Commun., Jul. 1985, vol. COM-33, no. 7, pp. 665–675

[2] S. Weinstein and P. Ebert, “Data transmission by frequency-division multiplexing using the discrete Fourier transform,” *IEEE Trans. Commun.Technol.*Oct. 1971, vol. COM-19, no. 5, pp. 628–634.

[3] Thomas keller and lajoshanzo,” adaptive multicarrier modulation: a convenient Framework for time-frequency processing in Wireless communications”, IEEE proceedings of the IEEE, May 2000, vol. 88, no. 5.

[4] M. Speth, S. Fechtel, G. Fock, and H. Meyr. Optimum Receiver Design for Wireless Broadband Systems Using OFDM - Part I. IEEE Trans. On Comm., November 1999, 47(11):1668–1677.

[5] HamedAbdzadeh-Ziabari and Mahrokh G. Shayesteh.” Robust Timing and Frequency Synchronization for OFDM Systems,” IEEE Transactions on vehicular technology, October 2011, vol. 60, no. 8.

[6] T. M. Schmidl and D. C. Cox, “Robust frequency and timing synchronization for OFDM,” IEEE Trans. Commun., Dec. 1997 vol. 45, pp. 1613–1621.

[7] H. Minn, M. Zeng, and V. K. Bhargava, “On timing offset estimation for OFDM systems,” IEEE Commun. Lett., July 2000, vol. 4, pp. 242–244.

[8] B. Park, H. Cheon, C. Kang, and D. Hong, “A novel timing estimation method for OFDM systems,” IEEE Commun. Lett., May 2003, vol. 7, pp. 239–241.

[9] Guangliang Ren, Y chang, Hui Zhang, and H Zhang,’Synchronization Method Based on a New Constant Envelope Preamble for OFDM System,” vol. 51, no.1, pp. 139-143, March 2005.

[10] Y. Kang, S. Kim, D. Ahn, H. Lee, "Timing estimation for OFDM systems by using a correlation sequence of preamble", *IEEE Trans. Consumer Electronics*, vol. 54, no. 4, pp. 1600-1608, Nov. 2008.

[11] B. Sheng, J. Zheng, X. You, L. Chen, “A Novel Timing Synchronization Method for OFDM Systems”, IEEE Communications Letters,Vol. 14, NO. 12, December 2010.

[12] H.A.Ziabari, M . G. Shayesteh, M . Manaffar, “An Improved Timing Estimation Method For OFDM Systems” , *IEEE Trans. Consumer Electronics*, vol. 56, No. 4, Nov. 2010.

[13] H.A.Ziabari, M. G. Shayesteh, M. Manaffar, “A Novel Preamble-Based Frame Timing Estimator for OFDM Systems”, IEEE Communications Letters,Vol. 16, NO. 7, JULY- 2012.

[14] B. Sahu, Saswat Chakrabarti, S. L. Maskara, “A New Timing Synchronization Metric for OFDM Based WLAN Systems”, Springer Wireless Personal Commun. (2010) 52:829–8.