RESEARCH ARTICLE OPEN ACCESS

Minimization of Frequency Offset in OFDM System using SOM

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ABSTRACT
ONE of the problems in OFDM system is its sensitivity to frequency offset. The performance of OFDM system degrades due to intercarrier interference. The major source of ICI in OFDM is its vulnerability to frequency offset errors between transmitted and received signals. . To find a solution to this problem is to study DVBT system using Self organization Map (SOM). The Proposed model reduces the effect of Frequency Offset in DVBT OFDM system using artificial neural network in which we use kohennes unsupervised learning method. This paper provides insights into how carrier frequency offset affects the system performance and how it can be reduced using soft computing technique.
Keywords – ANN, BER, CFO, OFDM.

I. INTRODUCTION

The DVB-T standard is the most successful digital terrestrial television standards in the world. First published in 1995, it has been adopted by more than half of all countries in the world. Since the publication of the DVB-T standard, however, research in transmission technology has continued, and new options for modulating and error-protecting broadcast steams have been developed. Simultaneously, the Demand for broadcasting frequency spectrum has increased as has the pressure to release broadcast spectrum for non-broadcast applications, making it is ever more necessary to maximize spectrum efficiency. The greatest advantage of the digital system is the effective use of the frequency spectrum and its lower radiated power in comparison with the analogue transmission, while the covered area remains the same. Another key feature is the possibility of designing a so-called Single Frequency Network (SFN), which means that the neighboring broadcast stations use the same frequency and the adjacent signals don't get interfered. The digital system transmits a data stream, which means that not only television signals but data communication (e.g. Internet service) may be used according to the demands. The data stream consists of an MPEG-2 bit stream, which means a compression is used, enabling the transfer of even 4 or 5 television via the standard 8 MHz wide TV channel. Orthogonal Frequency Division Multiplexing (OFDM) has gained significant interest recently due to its ability to enable high data rate transmission over dispersive channels. OFDM is a multi-carrier modulation technique that splits high data rate symbol stream into much lower data rate parallel streams and transmits these streams on different carriers.

Orthogonal frequency-division multiplexing (OFDM) is well known as an efficient technique to mitigate the frequency-selective behavior of wideband communications channels. However, OFDM signals suffer from increased sensitivity to synchronization mismatch problems [1]. One major factor that causes synchronization mismatch is the carrier frequency offset (CFO) caused by mismatch between the transmitter's and the receiver's local oscillators, the nonlinear characteristics of the wireless channel, and Doppler shift. CFO destroys the orthogonality of the subcarriers, and the resulting inter carrier interference degrades the bit error rate (BER) performance severely [1]–[3]. Several techniques have been proposed to estimate and remove CFO [4]. A major disadvantage of the OFDM system is its sensitivity to frequency offset errors and differences in the oscillator frequencies at the transmitter and the receiver. The carrier frequency offset causes a net shift of the signal spectrum which may damage the subcarrier orthogonality and increase the noise level due to ICI, which degrades system performance. Therefore, frequency offset minimization in OFDM systems is essential to improve communication system performance. The Proposed model reduces the effect of Frequency Offset in DVBT OFDM system using artificial neural network in which we use kohennes unsupervised learning method. Soft computing techniques are becoming popular in designing real world industrial applications.

The word "adapt" means to make suitable to requirements or condition. The principal property of adaptive systems is its time varying self-adjusting performance. The adaptive systems are digitally implemented. Soft computing technique could be considered as adaptive modulation technique. Soft computing technique such as artificial neural network (ANN) is increasingly gaining popularity in designing real world applications such as household appliances, consumer electronics etc. to achieve low production cost, robustness and automation. These products possess impressive capability to reason, make intelligent decisions and learn from experience.
The soft computing techniques behind the design of modern automated intelligent systems exploit the tolerance for imprecision, uncertainty, approximate reasoning and partial truth unlike traditional hard computing which fails to cope with fault tolerance, adaptively and uncertainty management needed to handle real lie decision or classification problems.
The paper is organized as follows. Section II contains the OFDM system model with CFO, while in Section III, we derive the BER expressions for fading channels. Section IV extends the analysis to take into account the possible presence of frequency offset introduced in the transmitter side. In Section V, we validate the theoretical analysis by means of simulation results, while Section VI concludes the paper.

II OFDM SYSTEM MODEL

The basic principle of OFDM system .Fig. 1 shows the block diagram of OFDM transceiver. OFDM system is very sensitive to frequency offset, which may be introduced in the radio channel, so accurate frequency offset synchronization is essential.

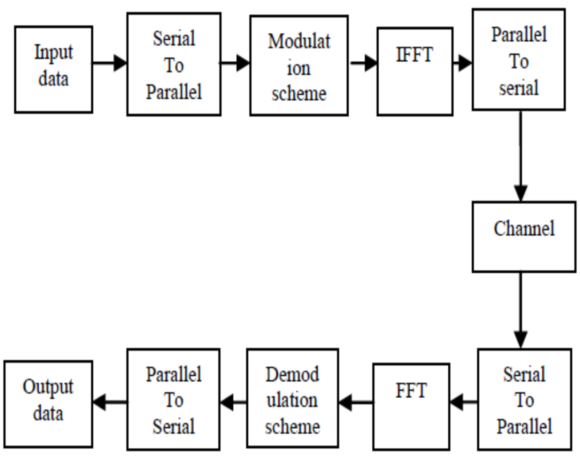


Fig 1. OFDM block

We consider an OFDM system implemented by the inverse fast Fourier transform (IFFT) and fast Fourier transform (FFT). X (k) is the modulated data on the k_{th} subcarrier. N is the FFT length. The OFDM samples at the output of IFFT are given by

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(K) e^{\frac{j2\pi kn}{N}} \qquad (1)$$

At the receiver, when the normalized frequency offset is under ideal time synchronization, the receiver signal in AWGN channel is

$$r(n) = x(n) e^{\frac{j2\pi\varepsilon n}{N}} + \mu(n) \qquad (2)$$

Where μ(n) is white Gaussian noise with zero mean and variance $\sigma_{\mu^2} = E(|\mu(n)|^2)$, normalized frequency offset is

$$\varepsilon = \varepsilon_I + \varepsilon_F = \frac{N\Delta f}{f_s} \qquad (3)$$

Where ε_I is the integer frequency offset, ε_F is the decimal multiple frequency offset , Δf is the carrier frequency offset between transmitter and receiver, f_s is sampling frequency, $\frac{f_s}{N}$ is the frequency separation between the subcarriers in the OFDM signal. Each subcarrier is shifted in frequency by a constant amount of $\frac{2\pi\varepsilon}{N}$, the peaks of the spectra on each subcarrier are no longer aligned with the sampled frequencies of the DFT. The adjacent subcarrier spectra are nonzero at the sampled frequencies. Hence, carrier frequency Offsets have the cumulative effect of reducing the signal energy and increasing the interference. Moose demonstrated that a lower-bound on the effective SNR due to carrier frequency offset can be derived as

$$SNR_\varepsilon = \frac{SNR}{1 + 0.5947\, SNR \sin^2(\pi\varepsilon)} \frac{\sin^2(\pi\varepsilon)}{(\pi\varepsilon)^2} \qquad (4)$$

The DVB-T standard defines two orthogonal frequency division multiplexing (OFDM) modes of operation. The "2K mode" uses OFDM symbols with *N* _ 2048 carriers, of which *K* _ 1705 are active. The bandwidth *B* of the OFDM signal is given by *B* _*K*/(*NT*), because no power is applied to the higher frequency OFDM bins. It can be easily verified that *B* < 7/8 *Bn*. This mode uses *KU* _ 1512 carriers to transport information, and the other 193 active carriers are used as pilots for synchronization, equalization, and conveying of transmission parameter signaling (TPS) information. The 2K mode is suitable for single transmitter operation and for small SFNs with a limited radius. The "8K mode" uses OFDM symbols with *N* _ 8192 carriers, of which *K* _ 6817 are active. This mode, which uses *KU* _ 6048 carriers to transport information and 769

carriers as pilots, can be employed both for single transmitter operation and for small and large SFNs.
The DVB-T system uses 68 OFDM symbols per OFDM frame, and 4 OFDM frames per super frame. The duration of a super frame equals *TS* _ 4 _ 68 _ (*TU* _*TG*): that is, it ranges from 62.8 milliseconds (ms) for an 8 MHz channel where a 2K mode with *TG* _ 1/32 *TU* is used, to 406 ms for a 6 MHz channel where an 8K mode with *TG* _ 1/4 *TU* is used.

A. Problem statement:-Frequency Offset

The sensitivity of OFDM systems to frequency offset compared with single carrier systems is a major disadvantage. In general, Frequency offset is defined as the difference between the nominal frequency and actual output frequency. In OFDM, the uncertainty in carrier frequency, which is due to a difference in the frequencies of the local oscillators in the transmitter and receiver, gives rise to a shift in the frequency domain. This shift is also referred to as frequency offset. It can also be caused due to the Doppler shift in the channel. The demodulation of a signal with an offset in the carrier frequency can cause large bit error rate and may degrade the performance of a symbol synchronizer. It is therefore important to estimate the frequency offset and minimize/eliminate its impact. If frequency offset is denoted as fc, the OFDM signal generated by the transmitter denoted as s(t) and y(t) is the signal received by the receiver, then

$$S(t) = e^{jwt} * x(t) \qquad (5)$$

$$Y(t) = \left(e^{jwt} - e^{j\widetilde{w}t}\right) * x(t) \qquad (6)$$

$$\Delta w = w - \widehat{w} = 2\pi\Delta f_c \qquad (7)$$

Then the received signal has phase offset equal to

$$Y(nt) = e^{j\Delta wnt} * x(nt) \qquad (8)$$

$$\emptyset n = \Delta wnt \qquad (9)$$

The frequency response of each sub-channel should be zero at all other sub-carrier frequencies, i.e the sub-channels shouldn't interfere with each other. The effect of frequency offset is a translation of these frequency responses resulting in loss of orthogonality between sub-carriers and leading to ICI.

III. BER OF OFDM SYSTEMS WITH CFO IN FADING CHANNELS

The main weakness of [7]–[9] is that they consider the CFO effects only in AWGN channels, whereas OFDM systems are usually designed to cope with multipath channels [1]. On this subject, by using the Gaussian approximation of the ICI, Cheon and Hong proposed a BER analysis in Rayleigh fading channels, incorporating both the effects of the CFO and of the channel-estimation errors [10].An approach to obtain the BER (or equivalently, the SER) consists of two steps. Firstly, we should calculate the conditional bit-error probability $P_{BE(S,\lambda)}$ that depends on the symbols in $S = [S1 \ldots\ldots SN]T$ and on the channel amplitudes in λ = [λ1………λN]T. Successively, $P_{BE(S,\lambda)}$ should be averaged over the joint probability density function (pdf), *f*S, Λ(**s**,λ) = *f*S(**s**)*f*Λ(λ) of the symbols and the channel amplitudes, as expressed by

$$\text{BER} = \int_{s,\lambda}^{\infty} \text{PBE}(s,\lambda) f\text{S}(s) f\Lambda(\lambda) ds d\lambda. \qquad (10)$$

The main difficulty in evaluating (10) is due to the presence Of the *N*-dimensional (pdfs) *f*Λ(λ). Indeed, when dealing with Multidimensional integrations, it would be easier to evaluate many single-variable integrals one at a time. *f*Λ(λ) cannot be expressed as a product of *N* separate one-dimensional (pdfs). In order to overcome this problem, we bypass the multidimensional integration by using the equality given by *f*Λ(λ) = *f*Λ|*λ*1 (λ|*λ*1)*fλ*1 (*λ*1), where *f*Λ|*λ*1 (λ|*λ*1) is the conditional pdf of λ = [*λ*2 · · · *λN*]T given *λ*1, and *fλ*1 (*λ*1) is the pdf of *λ*1.Therefore, (10) becomes

$$\text{BER} = \int_{\lambda_1}^{\infty} P_{BE}(\lambda_1) f_{\lambda_1} d\lambda_1 \qquad (11)$$

Where

$$PBE(\lambda 1) = \int_{s,\bar{\lambda}}^{\infty} PBE(s,\lambda) f\Lambda|\lambda 1(\lambda|\lambda 1) f S(s) ds d\lambda \qquad (12)$$

IV SOM - NEURAL NETWORK APPROACH FOR MINIMIZING FREQUENCY OFFSET IN OFDM SYSTEM.

The subject of Artificial Neural Network (ANN) has matured to great extend over the past few years and especially with the advent of very high performance computing the subject has assumed a tremendous significance and has got very big application potential in various areas.

Neural network is one of the soft computing techniques. Basically a neural network can perform a task that a linear program cannot. When an element of the neural network fails, it can continue without any problem by their parallel nature. A neural network learns and does not need to be reprogrammed. It can be implemented in any application and without any problem. Disadvantages of neural network are that it needs training to operate, the architecture of a neural network is different from the architecture of microprocessors therefore needs to be emulated and it requires high processing time for large neural networks.

SOM: Self organization map works on the principal of "competitive learning". Self-Organizing Map (SOM) is an unsupervised learning algorithm. One particularly interesting class of unsupervised system is based on competitive learning, in which the output neurons compete amongst themselves to be activated, with the result only one is activated at any one time. This activated neuron is called a winner-takes all neuron or simply the winning neuron. Such competition can be induced/implemented by having lateral inhibition connections (negative feedback paths) between the neurons. The result is that the neurons are forced to organize themselves. For obvious reasons, such a network is called a Self Organizing Map (SOM).

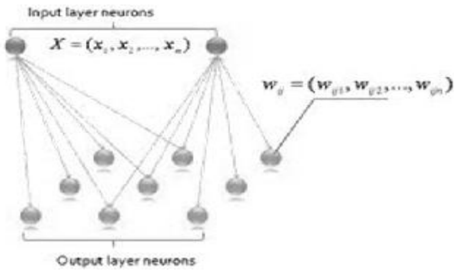


Fig.2 SOM STRUCTURE

In the fig. 2 a "SOM" structure is shown .It has output layer organized in lattice form arranged in 2-D lattice and also there are 2 input vectors. Here we don't need to organize input vectors in lattice form. The input to output connections are called bundle of synaptic connection. Also there is data compression because number of input will be less than number of outputs.

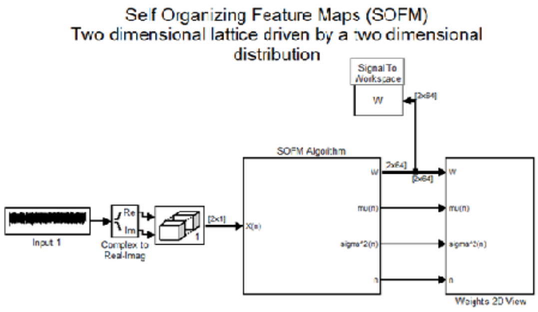


Fig.3 An addaptive block of SOM

THE FIG 3 SHOWS A BLOCK OF SOM THAT IS TO BE ATTACHED IN THE RECEIVER SIDE OF THE PROPOSED MODEL AFTER COMPETITIVE LEARNING

V. PROPOSED MODEL

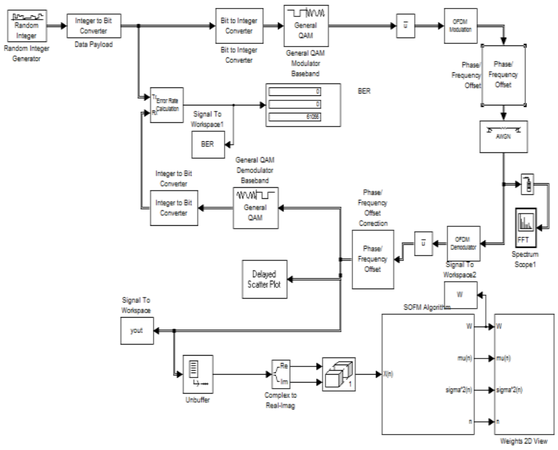


Fig.4 OFDM WITH SOM

SOM Training

The SOM consists of a regular, usually two-dimensional (2-D), grid of map units. Each unit i is represented by a prototype vector

$m_i = [m_{i1} \ldots\ldots m_{id}]$ ......(13)

Where d is input vector dimension. The SOM is trained iteratively. At each training step, a sample vector x is randomly chosen from the input data set. Distances between x and all the prototype vectors are computed. The best matching unit (BMU), which is denoted here by b, is the map unit with prototype closest to **x,**

$x - m_b = \underbrace{\min}_{i} [x - m_i]$ ......(14)

Next, the prototype vectors are updated. The BMU and its topological neighbors are moved closer to the input vector in the input space. The update rule for the prototype vector of unit" i" is

$m_i(t+1) = m_i(t) + \alpha(t)h_{bi}(t)[x - m_i(t)]$ ..(15)

Where

t=time; $\alpha(t)$=adaptation coefficient; $h_{bi}(t)$=neighborhood kernel centered on the winner unit

$$h_{bi}(t) = \exp\left(-\frac{(r_b - r_i)^2}{2\sigma^2(t)}\right) \ldots\ldots(16)$$

Where r_b and r_i are positions of neuron b and I on SOM grid. Both $\alpha(t)$ and $\sigma(t)$ decrease monotonically with time.

VI SELECTING APPROPRIATE PARAMETERS

The selection of a suitable gain factor, a (t), appears to be a compromise between learning rate and learning accuracy. If a high gain factor is chosen then learning will proceed rapidly but the net will be constantly shifting with each new input pattern and so the entire input space may not be evenly categorized. Alternatively, if a low gain factor is chosen then learning will be very slow but should eventually reach a very accurate result. The gain factor is therefore typically chosen to be initially rather large (to ensure rapid initial learning) and is then reduced to increase the accuracy of the final result.

VII SIMULATION RESULT

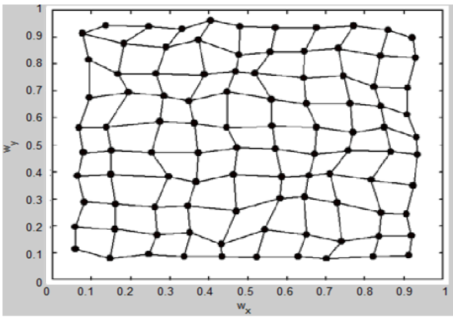
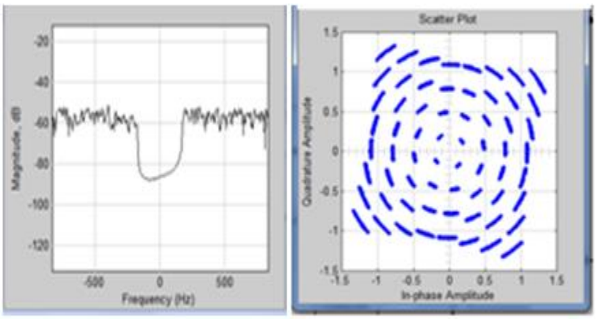


Fig 5

Considering a 2-D array of neurons which is required to learn two input signals. Both the inputs vary between **0** and 1 with a flat probability distribution. The response of the network is shown in Figure 5. Each point in the graph represents the point in the input space to which one neuron has become maximally responsive. The lines joining these points indicate nearest-neighbor connections between neurons in the square array. Initially all the weights were assigned small random values.



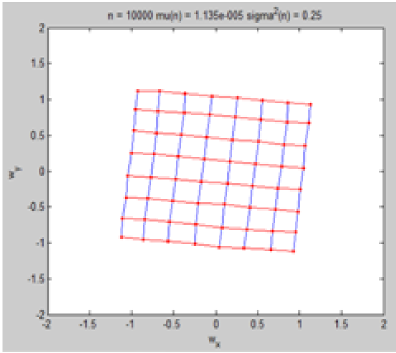
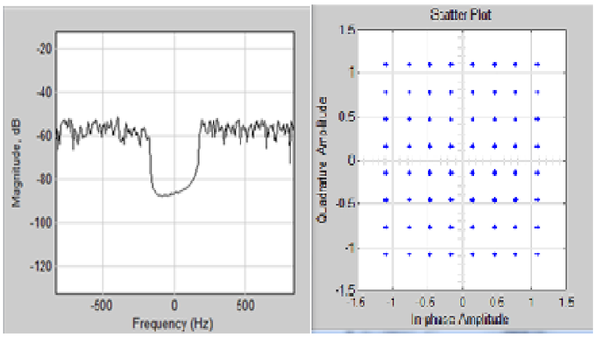


Fig.6 shows the Simulation Results for DVB-T system using AWGN channel with frequency offset



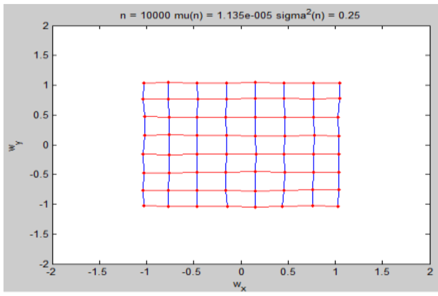


Fig.7 shows the Simulation Results for DVB-T system using AWGN channel with frequency offset removed with the help of SOM

VIII. CONCLUSION

To combat with the current demands of wireless technologies, still the performance of the DVB_T system can be improved by reducing the carrier frequency offset in the OFDM based system and thus a better performance can be achieved with the help of Kohenens unsupervised method. The adaptability inherent in Kohenens self-organizing feature maps provides the ability to learn abstract representations of systems in which the relationships between the inputs are not known. Also the plasticity inherent in this type of network allows it to adapt to changes in the environment.

IX. ACKNOWLEDGEMENTS

I WOULD LIKE TO EXPRESS MY SINCERE GRATITUDE TO MY ADVISOR, **DR. S. V. RATHKANTHIWAR** FOR HER GUIDANCE AND UNRESERVED HELP DURING THE STUDY PERIOD .WITHOUT HER THEN COMPLETION OF THIS PAPER WOULD HAVE BEEN IMPOSSIBLE.

REFERENCES

[1] T. Pollet, M. van Bladel, and M. Moeneclaey, "BER sensitivity of OFDM systems to carrier frequency offset and Wiener phase noise," *IEEE Trans. Commun.*, vol. 43, no. 234, pp. 191–193, Feb./Mar./Apr. 1995.

[2] J. Li and M. Kavehrad, "Effects of time selective multipath fading on OFDM systems for broadband mobile applications," *IEEE Commun.Lett.*, vol. 3, no. 12, pp. 332–334, Dec. 1999.

[3] Luca Rugini AND and Paolo Banelli," BER of OFDM Systems Impaired by Carrier Frequency Offset in Multipath Fading Channels". *IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 4, NO. 5, SEPTEMBER 2005.*

[4] Juha Vesanto and Esa Alhoniemi*, "* Clustering of the Self-Organizing Map*".* IEEE TRANSACTIONS ON NEURAL NETWORKS, VOL. 11, NO. 3, MAY 2000

[5] Teuvo Kohonen,"The Self Organizing Map", PROCEEDINGS OF IEEE, VOL 78,NO 9,SEPTEMBER 1990.

[6] A. Al-Dweik, Hazmi, S. Younis, and C. Tsimenidis, " Carrier Frequency Offset Estimation for OFDM Systems Over Mobile Radio Channels" . IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 59, NO. 2, FEBRUARY 2010.

[7] T. Keller and L. Hanzo, "Adaptive multicarrier modulation : A convenient framework for time–frequency processing in wireless communications,"*Proc. IEEE*, vol. 88, no. 5, pp. 611–640, May 2000..

[8] Baile xie,wenxun qui, and haling minn,"Exact signal model and new carrier frequency offset compensation scheme for OFDM " IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS,VOL11.NO 2,FEBRUARY 2012.

[9] K. Sathananthan and C. Tellambura, "Probability of error calculation Of OFDM systems with frequency offset," *IEEE Trans. Commun.*, vol. 49, no. 11, pp. 1884–1888, Nov. 2001

[10] H. Cheon and D. Hong, "Effect of channel estimation error in OFDM Based WLAN," *IEEE Commun. Lett.*, vol. 6, no. 5, pp. 190–192,
May 2002.

[11] Feifei Gao, Tao Cui, A. Nallanathan and C. Tellambura."Maximum Likelihood Based Estimation of Frequency and Phase Offset in DCT OFDM System Under Non-circular Transmissions: Algoriths,Analysis and Comparisons" IEEE TRANSACTIONS ON COMMUNICATIONS,VOL.56, NO.9,SEPTEMBER 2008.

[12] Paolo Banelli and Saverio Cacopardi. "Theoretical Analysis and performance of OFDM Signals in Nonlinear AWGN Channels" IEEE TRANSACTIONS ON COMMUNICATIONS, VOL.48, NO.3,MARCH 2000.

[13] T. Pollet, M. Van Bladel, and M. Moenaclaey, "BER sensitivity of OFDM systems to carrier frequency offset and Wiener noise,"*IEEE Trans. Commun.*, vol. 43, pp. 191–192, Feb./Mar./Apr. 1995.

[14] X. B. Wang, T. T. Tjhung, Y. Wu, and B. Caron, "SER performance evaluation and optimization of OFDM system with residual frequency and timing offsets from imperfect synchronization," *IEEE Trans .Broadcast* ., vol. 49, no. 2, pp. 170–177, June 2003

[15] B. Ai, Z. Yang, C. Pan, J. Ge, Y.Wang, and Z. Lu, "On the synchronization techniques for wireless OFDM systems,"*IEEE Trans. Broadcast.*,vol. 52, no. 2, pp. 236–244, June 2006