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Minimization of Carrier Frequency Offset in OFDM System using Neural Networks

Khushboo Umredkar[1], Dr. S. V. Rathkanthiwar[2], Neha H. Dharmik[3]
[123]Department of Electronics Engineering

Abstract: In this paper an adaptive soft computing technique is proposed to minimize major weakness of OFDM i.e. Carrier Frequency Offset over frequency selective channel. The carrier frequency offset (CFO's) between the transmitter and the receiver destroy the orthogonality between the carriers and degrade the system performance significantly in the DVB_T OFDM system. The performance of OFDM system are evaluated by calculating the probability of Bit Error Rate (BER) versus the Signal Noise Ratio (SNR) under the frequently used three wireless channel models (AWGN, Rayleigh and Rician) Therefore the level of performance of the system depends first on the accuracy in minimizing the carrier frequency. Soft computing techniques have become popular in real world industrial applications. This paper provides insights into how Self organization mapping is used as the soft computing technique in this paper to reduce the effect of frequency offset.

Keywords: Gaurd interval (GI), Orthogonal Frequency division multiplexing (OFDM), system cyclic prefix (CP), Artificial intelligence (AI) Inter carrier interference (ICI), Bit error rate (BER), Carrier frequency offset (CFO).

I. INTRODUCTION

One of the promising transmission technique for high data rate wireless communication systems is Orthogonal Frequency Division Multiplexing (OFDM) as it has sufficient robustness to handle radio channel impairments and bandwidth efficiency [l].OFDM can be used efficiently and reliably for the high speed digital data communications through the multipath fading channels, here a single data stream is to be transmitted in parallel over a large number of lower rate Subcarriers, by splitting the available bandwidth into several orthogonal sub channels [2]. In 1971 Weinstein and Ebert [3] presented OFDM system, who used discrete Fourier transform DFT to perform baseband modulation and demodulation. He introduced efficient processing, eliminating the banks of subcarrier oscillators. To combat ISI and ICI they used both a guard space between the symbols and raised-cosine windowing in the time domain. Their system was considered one of the major contributions to OFDM system. Another important contribution was due to Peled and Ruiz [4] in 1980 who introduced "The Cyclic prefix" OR "Cyclic Extension" solving the Orthogonality problem. They filled the empty guard space with a cyclic extension of OFDM symbol which effectively simulates a channel performing cyclic convolution which implies Orthogonality over dispersive channels when the CP is longer than the impulse response of the channel. It introduced energy loss proportional to the length of CP, but zero ICI generally motivates the loss.

Most OFDM systems use a fixed modulation scheme over all carriers for simplicity. However, depending on the channel conditions each carrier in an OFDM system can have a different modulation scheme. Any coherent or differential, phase or amplitude modulation scheme can be used including BPSK, QPSK, SPSK, 16QAM and 64QAM. Each modulation scheme provides a trade off between spectral efficiency and the bit error rate (BER).It is important to Choose the highest modulation scheme that will give an acceptable bit error rate to maximize the spectral efficiency. Thus, an adaptive modulation scheme is one of the efficient schemes to increase the throughput 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.Artificial Intelligence (AI) enhances the capability of computers by giving them human-like intelligence. They are basically an attempt to simulate the brain. An artificial neuron model consists of a linear combination followed by an activation function. This network utilized the different type of activation functions; the common ones, which are the sufficient for most applications, are the sigmoidal and hyperbolic tangent functions.

The paper is organized as follows. Section II contains the basic principle of OFDM system model and effects of frequency offset on OFDM signals while in Section III we see OFDM system model with ANN. Section IV Describes different channel environment. In Section V, we validate the theoretical analysis by means of simulation results, while Section VI concludes the paper.

II. THE BASIC PRINCIPLE OF OFDM SYSTEM

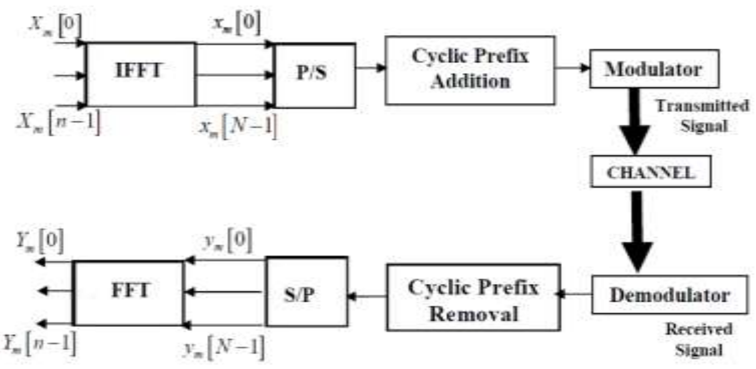

Fig. 1: An OFDM System Model

A basic OFDM implementation scheme is shown in Figure 1. Data at each sub-carrier (X_m) are input into the inverse fast Fourier transform (IFFT) to be converted to time-domain data (x_m) and after parallel-to-serial conversion (P/S), a cyclic prefix is added to prevent inter symbol interference (ISI). At the receiver, the cyclic prefix is re-moved, because it contains no information symbols. After the serial-to-parallel (S/P) con-version, the received data in the time domain (y_m) are converted to the frequency domain (Y_m) using the fast Fourier transform (FFT) algorithm.

OFDM structure basically relies on three principles:

- The IFFT and FFT are used for modulating & demodulating individual OFDM sub carriers to transform the signal spectrum to the time domain for transmission over the channel and then by employing FFT on the receiving end to recover data symbols in serial order.
- The second key principle is the cyclic prefix (CP) as Guard Interval (GI). CP keeps the transmitted signal periodic. One of the reasons to apply CP is to avoid Inter Carrier Interference (ICI).
- Interleaving is the third most important concept applied. The radio channel may affect the data symbols transmitted on one or several sub carriers which lead to bit errors.

A . EFFECTS OF FREQUENCY OFFSET ON OFDM SIGNALS

Frequency offset comes from a number of sources, such as Doppler shift or frequency drifts in the modulator and the demodulator oscillators. The first source of error arises when there is relative motion between transmitter and receiver. In this case, the frequency shift is given by

$$\Delta f = \frac{v}{c} f \ldots\ldots\ldots..(1)$$

where v is the relative velocity, is the speed of light, and $f_c$is the carrier frequency. Compared to the frequency spacing, this shift is negligible. For example, with a carrier frequency of $fc = 5$ GHz and a velocity of 100 km/h, the offset value is$\Delta f = 1.6$ kHz, which is relatively insignificant compared to the carrier spacing of 312.5 kHz. OFDM systems are more sensitive to frequency errors than single-carrier modulations (SCM) systems. In OFDM systems, a frequency offset destroys orthogonality between carriers and introduces inter carrier interference (ICI), which is not the case in SCM systems. Conversely, single-carrier systems are more sensitive to timing offset errors while OFDM generally exhibits good performance in the presence of timing errors.

B. FREQUENCY OFFSET AND INTERCARRIER INTERFERENCE

According to [8], the degradation of the SNR D_{freq} , caused by the frequency off-set, is approximated as

$$D_{freq} = \frac{10}{3 \ln 10} (\pi \Delta f T)^2 \frac{E_b}{N_0} \ldots\ldots\ldots..(2)$$

where Δf is the frequency offset, T is the symbol duration in seconds , E_b is the energy per bit of the OFDM signal and N_0 is the one-sided noise power spectrum density (PSD) . The frequency offset has an effect like noise and it degrades the signal-to-noise ratio (SNR),

where SNR is the $\frac{E_b}{N_0}$.

III. PROPOSED MODEL

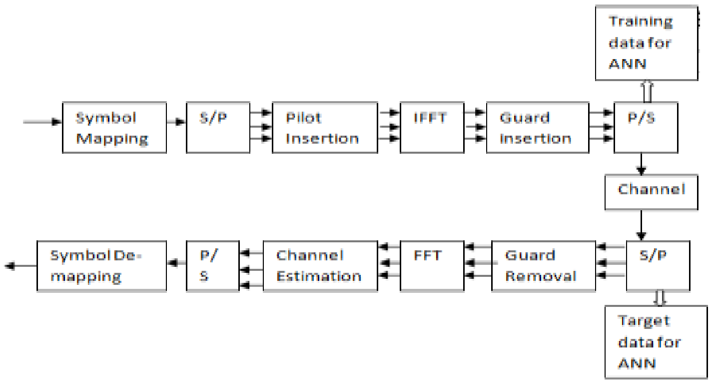

Fig. 2: OFDM with ANN

In this Paper the effect of frequency offset is reduced using artificial neural network in which we used Kohenens unsupervised learning method. We generate a simulink block in Mat lab using Kohenens unsupervised learning method as shown in fig 3

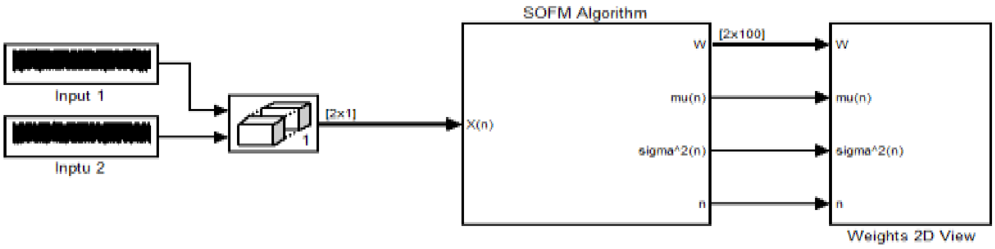

Fig. 3: SOM

Then insert the SOM block into fig 2 in receiving side with OFDM receiver thus reducing the effect of frequency offset. The goal of a Kohenens Unsupervised Learning Map is transforming an incoming signal pattern of arbitrary dimension to a one or two dimensional discrete map, and to perform this transformation adaptively in a topologically ordered fashion. We therefore set up our Kohenens Unsupervised Learning Map by placing neurons at the nodes of a one or two dimensional lattice. The neurons become selectively tuned to various input patterns (stimuli) or classes of input patterns during the course of the competitive learning. The locations of the neurons so tuned (i.e. the winning neurons) become ordered and a meaningful coordinate system for the input features is created on the lattice. The Kohenens Unsupervised Learning Map thus forms the required topographic map of the input patterns.

Kohenens Unsupervised Learning Map –

1) Initializing each node's weights.
2) Choosing a random vector from training data and
Present it to the SOM.
3) To examine each node in search of the Best Matching Unit (BMU).
4) To calculate radius of the neighborhood around the BMU.
5) Each node in the BMU's neighborhood adjusts its weights to become more like the BMU. Nodes closest to the BMU are altered more than the nodes furthest away in the neighborhood.
6) Repeat from step 2 for enough iteration for convergence.

IV. CHANNEL ENVIROMENT

A. Additive White Gaussian Noise Model:

The simplest radio environment in which a wireless communications system or a local positioning system or proximity detector based on Time of flight will have to operate is the Additive-White Gaussian Noise (AWGN) [5] environment. Additive white Gaussian noise (AWGN) is the used to transmit signal while signals travel from the channel and simulate background noise of channel. The mathematical expression in received signal r(t) = s(t) + n(t) that passed through the AWGN channel where s(t) is transmitted signal and n(t) is background noise. Basically AWGN channel adds white Gaussian noise to the signal which passes through it. It is the basic communication channel model. The channel capacity of AWGN Channel is given by

$$C = \frac{1}{2}\log\left(1+\frac{p}{n}\right) \dots\dots\dots(3)$$

where c is channel capacity.

B. RAYLEIGH FADING

In a mobile radio communication system, one of the most devastating phenomena is fading. Fading is the direct result of multi-path propagation where radio waves before arriving at the receiver antenna propagate along different paths These radio waves may arrive at receiver. Rayleigh fading is a rational model when there are large number of objects in the environment that scatter the transmitted signal before it arrives at the receiver. As per the central limit theorem if there is sufficiently much scatter, regardless of the distribution of the individual components, the channel impulse response will be well-modelled as a Gaussian process. [6]. When there are large numbers of paths, by Central Limit Theorem, with time as the variable every path can be modelled as circularly symmetric complex Gaussian random variable This model is called Rayleigh fading channel model [7]. A circularly symmetric complex Gaussian random variable is of the form, $Z = X + jY$.Where real and imaginary parts are zero mean Independent and Identically Distributed (IID) Gaussian random variables.

For a circularly symmetric complex random variable,

$$E[Z] = E\left[e^{j\theta} Z\right] = e^{j\theta} Z \dots\dots\dots(4)$$

The statistics of a circularly symmetric complex Gaussian random variable is completely specified by the variance,

$$\sigma^2 = E[Z^2] \dots\dots\dots(5)$$

The magnitude |Z|, which has a Probability Density Function (PDF) P(Z) , is called the Rayleigh Random Variable

$$p(Z) = \frac{z}{\sigma^2}\ e^{\frac{-Z^2}{2\sigma^2}} \dots\dots\dots(6)$$

C. RICIAN FADING

Rician Fading is a non-deterministic model for a transmitted signal that accidentally cancels itself. Rayleigh channel model is suitable for modeling urban areas that are characterized by many obstructions where a line of sight path does not exist between the transmitter and receiver. In suburban areas, a line of sight path may exist between the transmitter and receiver and this will give rise to Rician fading. In Rician fading, the amplitude gain is characterized by a Rician distribution. In absence of line of sight path occurring between the OFDM transmitter and receiver than the Rican Fading can be categorised by Rayleigh Fading [8]. Rician Fading [9] channel can be defined using two parameters: Kand Ω, where K is called the Rice Factor and it is the ratio between the power in the direct path and the power in the other, scattered, paths and Ω is the total power from both paths and acts as a scaling factor to the distribution. The received signal amplitude ignoring the power R is then Rice distributed with parameters:

$$v^2 = \frac{K}{1+K^2}\ ,\ \sigma^2 = \frac{\Omega}{2(1+K)} \dots\dots\dots(7)$$

DIGITAL MODULATION

64-QAM has signal combinations with each symbol represent six bits ($2^6 = 64$). 64-QAM [8] is a complex modulation technique with high Efficiency. This digital frequency modulation technique is primarily used for sending data downstream over a coaxial cable network. 64QAM is very efficient, supports up to 28-mbps peak and transfer rates over a single 6-MHz channel.

V. SIMULATION RESULTS

Simulations are carried out for different signal-to noise (SNR) ratios and for each value of the Bit Error Rate (BER) is calculated. The BER is calculated by the formula.

BER= (Bits in Error) / (Total bits received)….(8)

The BER is the number of bit errors divided by the total number of transferred bits during a particular time interval. BER is often expressed as a percentage, it is a unit less performance measure.SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation.

SNR = 10 log10 (Signal Power / Noise Power) dB…………..(9).

Eb/N0 is an important parameter in digital communication or data transmission, it is also known as the "SNR per bit". It is useful when comparision of the bit error rate (BER) performance of different digital modulation schemes is done without taking bandwidth into account.

In order to study the degradation in OFDM systems and its effects on the received signal, a number of computer simulations were run, and the results are shown below in Fig no. 4.

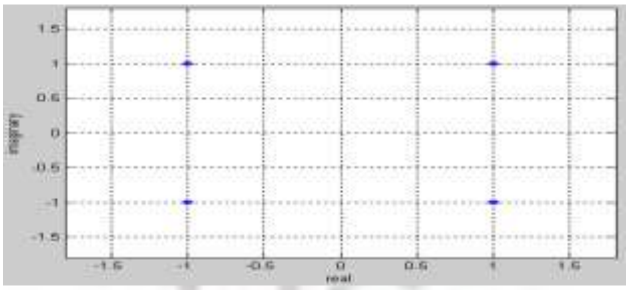

Fig no . 4

The fig 4 shows the received signal constellation in the absence of frequency offset. In the absence of frequency offset or noise,there is no ICI and no interference between the data and the other zeros. When frequency offset is introduced in the carrier, its effects are observed in terms of ICI. The result with 0.3% frequency offset is shown in Figure 5. In particular, we can see that the signal from neighboring carriers causes interference and we have a distorted signal constellation at the receiver.

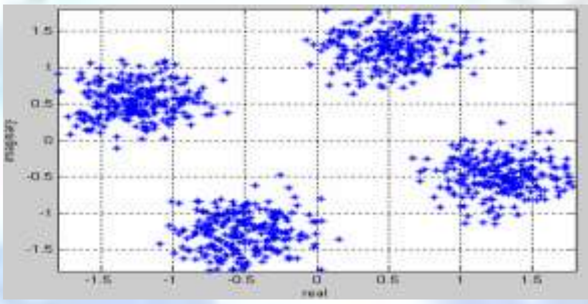

Fig no. 5

Received signal constellation with 0.3% frequency offset

BER in AWGN, Rayleigh and Rician fading channels in 64-QAM modulation scheme

E_b / N_o	BER in AWGN	BER in Rayleigh	BER in Rician
-5 : 0	0.0935	0.0905	0.1094
0: 5	0.0948	0.0935	0.0991
5: 10	0.0763	0.0769	0.0742
10: 15	0.0431	0.046	0.025728
15: 20	0.0168	0.02	0.000772
20 : 25	0.0056	0.0072	0.0000000263

Fig no. 6

In any digital communication system the Bit Error Ratio is an important figure of merit used to quantify the integrity of data transmitted through the system.

Considering a 2-D array of neurons which is required to learn two input signals. Both the inputs vary between -2 and 2 with a flat probability distribution. The response of the network is shown in Figure 7 & 8. 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-neighbour connections between neurons in the square array. Initially all the weights were assigned small random values.

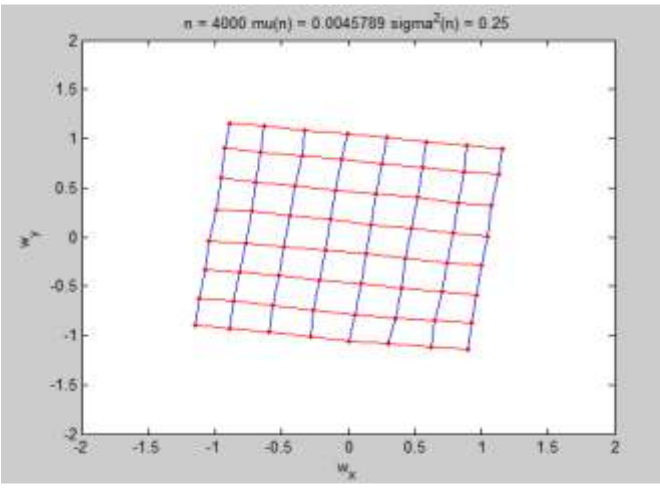

Fig no 7

The figure 7 shows the simulation results when known amount of frequency offset is introduced in the proposed model

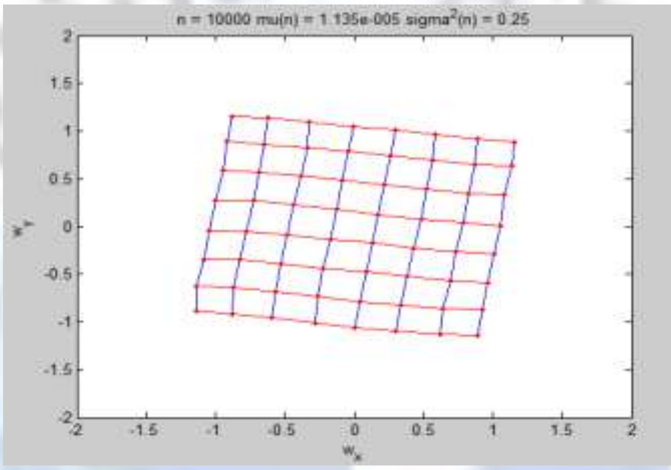

Fig no 8

The figure 8 shows the simulation results when known amount of frequency offset is reduced in the proposed model.

CONCLUSIONS

In this paper we compare the performance in terms of BER using different modulation schemes on Rayleigh, Rician and AWGN Channel the comparative performance analysis of the three wireless channels i.e. AWGN, Rayleigh and Rician can be described based on various parameters.. The Bit Error Ratio of a digital communication system is an important figure of merit used to quantify the integrity of data transmitted through the system. It is observed that the BER is minimum for AWGN and maximum for RAYLEIGH and RICIAN. For RICIAN it is found that the BER is less than AWGN and RAYLEIGH. For higher values of Eb / N0, the BER is decreasing in all the fading channels for different modulation schemes. 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

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REFERENCES

[1]. R. Nee and R. Prasad, OFDM for wireless multimedia communications. Artech House Publishers, Mar. 2000.

[2]. 1. Met, “The multi tone channel,” IEEE Trans. Comm., Vol. 37, No. 2,Feb. 1989,pp. 119-124.

[3]. S.B.Weinstein and P.M.Ebert data transmission by frequency division multiplexing using discrete fourier transform .IEEE Trans. Commun.COM-19(5):628-634 oct.1971.

[4]. A.Peled and A. Ruiz Frequency domain data transmission using reduced computational complexity algorithms. In proceedings IEEE.

[5]. Bernard Sklar (July 1997). "Rayleigh Fading Channels in Mobile Digital Communication Systems Part I: Characterization". IEEE Communications Magazine 35 (7): 90–100.

[6]. Robertson, P.; Kaiser, S. "The effects of Doppler spreads in OFDM (A) mobile radio systems", Vehicular Technology Conference, 1999. VTC 1999 - Fall. IEEE VTS.

[7]. Bernard Sklar (July 1997). "Rayleigh Fading Channels in Mobile Digital Communication Systems Part I: Characterization". IEEE Communications Magazine 35 (7): 90–100.

[8]. Abdi, A. and Tepedelenlioglu, C. and Kaveh, M. and Giannakis, G., "On the estimation of the K parameter for the Rice fading distribution", IEEE Communications Letters, March 2001, p. 92 -94.

[9]. S. Popa, N. Drahgiciu, R. Reiz, ―Fading Types in Wireless Communications Systems,‖ J. Elect. and Electron. Eng., vol. 1, pp. 232-237, 2008.

[10]. 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.

[11]. 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.

[12]. Lin Gui, Bo Liu, Wenfeng Ma, and Bowei Song’,” A Novel Method of Frequency-Offset Estimation Using Time Domain PN Sequences in OFDM Systems”. IEEE TRANSACTIONS ON BROADCASTING, VOL. 54, NO. 1, MARCH 2008.

[13]. Hong Jiang, Vinay Purohit, Paul A. Wilford, Isabelle Jeanclaude, and Joseph Blineau,” A Correlation for the Detection of Time and Frequency Offsets”. IEEE TRANSACTIONS ON BROADCASTING, VOL. 55, NO. 4, DECEMBER 2009.

[14]. Baile xie,wenxun qui, and haling minn,”Exact signal model and new carrier frequency offset compensation scheme for OFDM ” IEEE TRANSACTIONS ON WIRELESS OMMUNICATIONS,VOL 11.NO 2,FEBRUARY 2012.