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A Novel Approach for Minimization of Phase Noise in OFDM System over Multipath Fading Channel

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Abstract
Phase noise causes significant degradation in the performance of Orthogonal Frequency division multiplexing (OFDM) system. When phase noise is present in OFDM system at receiver , the effective signal-to-noise ratio and consequently ,limits the bit error rate (BER) and data rate . phase noise can result from undesired and often unexpected interaction between components. In this paper, one of the soft computing technique is proposed for minimizing phase noise in OFDM system based on LMS (Least Mean Square) algorithm and MSE (Mean Square Error) algorithm. The aim is to minimize phase noise in OFDM system for the better performance of Bit Error Rate (BER), so that the system will be improved.
Keywords -- Bit Error Rate (BER), Orthogonal Frequency division multiplexing (OFDM) system, Phase noise, RBF (Radial Basis Function) Network , signal to noise ratio (SNR).

I. Introduction

Orthogonal frequency division multiplexing (OFDM) is a favoured transmission scheme for many RF/microwave communications systems. It is both efficient and robust, even within a signal environment laden with interference and multipath signals, and is readily scalable in terms of number of users and bandwidth. Given the capabilities of modern application-specific integrated circuits (ASICs) and field-programmable gate arrays (FPGAs), the digital signal processing (DSP) needed to make OFDM work is not a barrier.

OFDM is of great interest by researchers and research laboratories all over the world. It has already been accepted for the new wireless local area network standards IEEE 802.11a, High Performance LAN type 2 (HIPERLAN/2) and Mobile Multimedia Access Communication (MMAC) Systems.

The analog technologies required for OFDM radios can still pose serious design challenges, especially when application requirements call for large numbers of OFDM radios within small enclosures at low cost and power consumption. Analog approaches cannot be upgraded as readily or quickly as digital technologies and, as a result, many basic performance parameters still present complex engineering tradeoffs. One of the more critical analog performance parameters, for example, is phase noise. It is especially relevant in OFDM radios due to the large number of closely spaced subcarriers. These subcarriers overlap in the frequency domain, with spectral peaks and nulls arranged to maintain orthogonality.

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bisynchronization errors.

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unitless performance measure, often expressed as a percentage.

Soft-Computing is a collection of techniques spanning many fields that fall under various categories in Computational Intelligence. Soft-Computing has three main branches: Fuzzy Logic, genetic algorithm, and Neural Networks.

Fuzzy Logic is Soft Computing technique necessary for analyzing complex systems, especially where the data structure is characterized by several linguistic parameters. Genetic algorithm is based upon the concept of evolution and “survival of the fittest”. A neural network can perform tasks that cannot have a linear program. When an element of the neural network fails, it can continue without any problem by their parallel nature.

A radial basis function (RBF) network is a software system that can classify data and make predictions. RBF networks have some superficial similarities to neural networks, but are actually quite different. An RBF network accepts one or more numeric inputs and generates one or more numeric outputs.

The paper is organised as follows. In section II ,the system model and principal concept of OFDM system are presented. In section III, Multipath Fading Channel and RBF network are structured. The simulation results are given in section IV and finally , section V concludes the paper.

II. SYSTEM MODEL

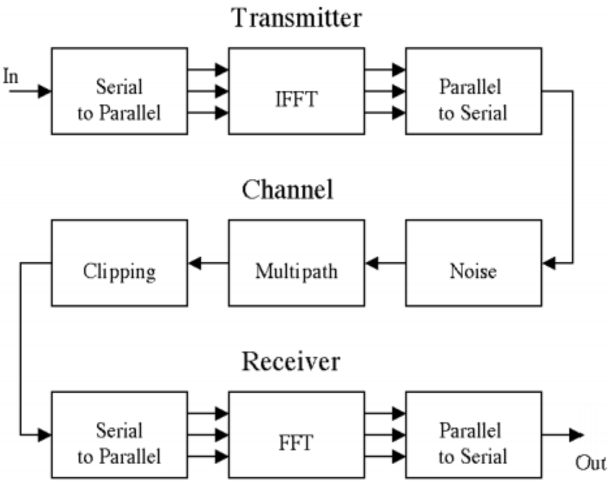

Fig.1 Block diagram of general OFDM system.

The transmitter first converts the input data from a serial stream to parallel sets. Each set of data contains one symbol, Si, for each subcarrier. For example, a set of four data would be [S0 S1 S2 S3].

Signal generators perform multiple roles in OFDM system design, and optimizing their use speeds the design process. Modern signal generators can produce modulated and fully coded signals to test receivers, as well as continuous-wave (CW) signals to substitute for frequency references and synthesizers. In both cases, they provide the biggest benefit when they can generate both ideal signals and those which have specific imperfections.

Then, the parallel to serial block creates the OFDM signal by sequentially outputting the time domain samples.The channel simulation will allow examination of the effects of noise, multipath, and clipping. By adding random data to the transmitted signal, simple noise can be simulated. Multipath simulation involves adding attenuated and delayed copies of the transmitted signal to the original. This simulates the problem in wireless communication when the signal propagates on many paths. For example, a receiver may see a signal via a direct path as well as a path that bounces off a building. Finally, clipping simulates the problem of amplifier saturation. This addresses a practical implementation problem in OFDM where the peak to average power ratio is high.

The receiver performs the inverse of the transmitter. First, the OFDM data are split from a serial stream into parallel sets. The Fast Fourier Transform (FFT) converts the time domain samples back into a frequency domain representation. The magnitudes of the frequency components correspond to the original data. Finally, the parallel to serial block converts this parallel data into a serial stream to recover the original input data.

Mathematical Description:

In order to do a Monte carlo simulation of an OFDM system, required amount of channel noise has to be generated that is representative of required Eb/N0. In Matlab it is easier to generate a Gaussian noise with zero mean and unit variance. The generated zero-mean-unit-variance noise has to be scaled accordingly to represent the required Eb/N0 or Es/N0. If we have Es/N0, the required noise can be generated from zero-mean-unit-variance-noise by,

Required noise = $10^{\frac{-Es}{N0}*\frac{1}{20}}$ * noise

Since the OFDM system transmits and received the data in symbols, it is appropriate/easier to generate required noise based on Es/N0 instead of Eb/N0 .To convert given Eb/N0 to Es/N0 for an OFDM system, normally for a simple BPSK system, bit energy and symbol energy are same. So Eb/N0 and Es/N0 are same for a BPSK system. But for a OFDM BPSK system, they are not the same. This is because, each OFDM symbol contains additional overhead in both time domain and frequency domain. In the time domain, the cyclic prefix is an additional overhead added to each OFDM symbol that is being transmitted. In the frequency domain, not all the subcarriers are utilized for transmitted the actual data bits, rather a few subcarriers are unused and are reserved as guard bands.

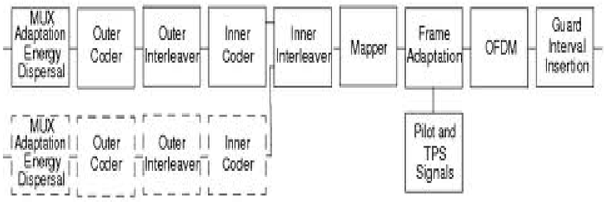

Fig.2 Block diagram of Digital Video Broadcast Terrestrial Transmitter.

DVB-T as a digital transmission delivers data in a series of discrete blocks at the symbol rate. DVB-T is a COFDM transmission technique which includes the use of a Guard Interval. It allows the receiver to cope with strong multipath situations. Within a geographical area, DVB-T also allows single-frequency network (SFN) operation, where two or more transmitters carrying the **same** data operate on the same frequency. In such cases the signals from each transmitter in the SFN needs to be accurately time-aligned, which is done by sync information in the stream and timing at each transmitter referenced to GPS.

To decrease receiver complexity, every OFDM block is extended, copying in front of it its own end (cyclic prefix). Cyclic prefix is required to operate single frequency networks, where there may exist an ineliminable interference coming from several sites transmitting the same program on the same carrier frequency.

III. STRUCTURAL MODELING

A. Multipath Fading Channel

Multipath fading is a common phenomenon in wireless signal transmission. When a signal is transmitted over a radio channel, it is subject to reflection, refraction and diffraction. Especially in the urban and sub urban areas where cellular phones are most often used, the communication environment changes quickly and thus introduces more complexities and uncertainties to the channel response. This simulator offers a better understanding of this phenomenon.

The channel multipath fading is represented by a randomly time-varying linear filter whose impulse response is limited to some multipath time spread T_0. The effect of this filter on the input over the given band can be represented as a complex, time varying, tapped-delay line filter with L complex taps at intervals of 1/WL . must be at least WT_0 because of the effective band limiting of the filter impulse response, but the exact value of L is noncritical in the arguments to follow. Let $F_{i,j}$ be the j[th] tap of the filter at discrete output time i . Thus, the signal, corrupted by the multipath fading but before the addition of noise, is given at time i by

$U_i = \sum_{m=0}^{L-1} Xi - m\, Fi,m.$

We denote $(F_{i,0}, F_{i,1} \ldots\ldots F_{i,L-1})^T$ as a random vector F_i

The sample value of this vector is called the channel state at time . We assume that the vector stochastic process ....F_0, F_1, F_i....... is zero mean, stationary, and complex Gaussian.

Fading is a rapid fluctuation of received signal strength over short time intervals and/or travel distances caused by interference from multiple copies of Tx signal arriving @ Rx at slightly different times.

It has two most important effects:

1. Rapid changes in signal strengths over small travel distances or short time periods.
2. Changes in the frequency of signals. Multiple signals arriving a different times. When added together at the antenna, signals are spread out in time. This can cause a smearing of the signal and interference between bits that are received.

Slow fading arises when the coherence time of the channel is large relative to the delay constraint of the channel. In this regime, the amplitude and phase change imposed by the channel can be considered roughly constant over the period of use. Slow fading can be caused by events such as shadowing, where a large obstruction such as a hill or large building obscures the main signal path between the transmitter and the receiver. The received power change caused by shadowing is often model using a log-normal distribution with a standard deviation according to the log-distance path loss model.

Fast fading occurs when the coherence time of the channel is small relative to the delay constraint of the channel. In this regime, the amplitude and phase change imposed by the channel varies considerably over the period of use.

B. RBF (Radial Bsis Function)Network

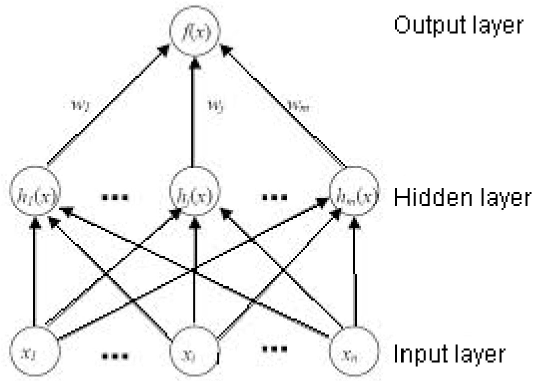

Fig.3 Structure of standard RBF Network

Radial basis functions are feed-forward networks consisting of

– A hidden layer of radial kernels.
– An output layer of linear neurons.

A radial basis function (RBF) network is a software system that can classify data and make predictions. RBF networks have some superficial similarities to neural networks, but are actually quite different. An RBF network accepts one or more numeric inputs and generates one or more numeric outputs. The output values are determined by the input values, plus a set of parameters called the RBF centroids, a set called the RBF widths, a set called the RBF weights and a set called the RBF biases.

Radial basis function (RBF) networks have the advantages of an easy design, simple structure, good generalization, high tolerance of input noise and rapid training process.

The j[th] output is computed as:

$X_j = f_j(u) = W_{0j} + \sum_{i-1}^{L} Wijhi$, $j = 1, 2 \ldots M$

Mathematical Model :

The mathematical model of the RBF network is expressed as:

$\mathbf{x} = \mathbf{f}(\mathbf{u})$, $\mathbf{f}$: RN→R^M

$Xj = f_j(u) = w_{0j} + \sum_{i-1}^{L} wij\, G(\|u - ci\|)$, j=1, 2, M

where $\|\cdot\|$ is the the Euclidean distance between **u** and **c***i*.

IV. SIMULATION RESULTS

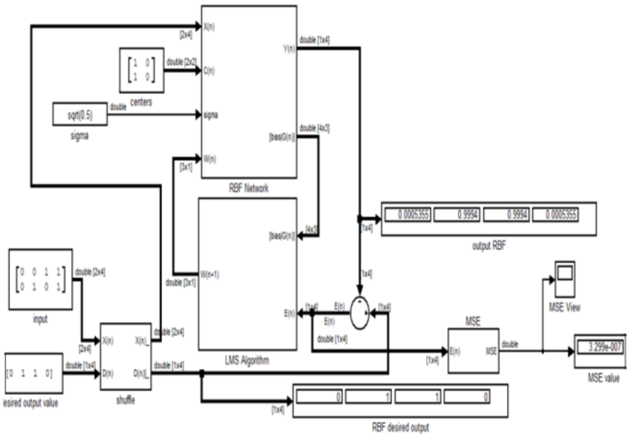

Fig.4 RBF network with LMS algorithm

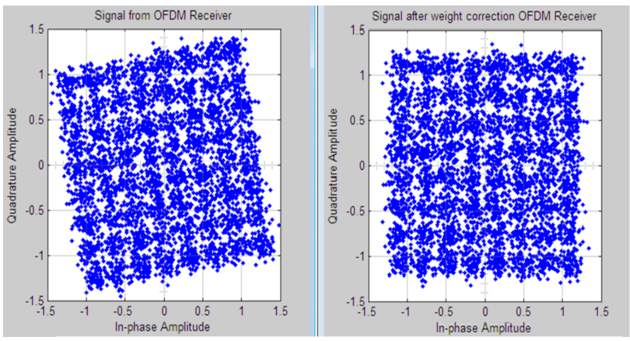

Fig.5 DVBT system using RBF network with phase noise and after correcting phase noise for AWGN channel

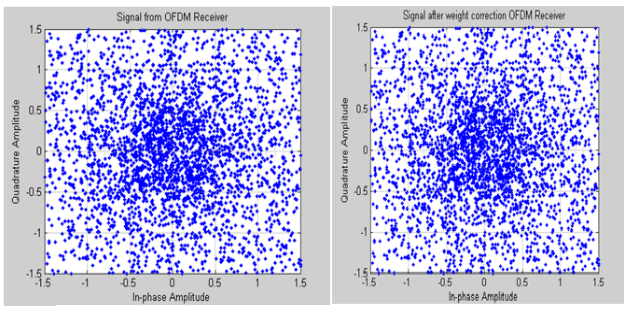

Fig.6 DVBT system using RBF network with phase noise and after correcting phase noise for Rayleig channel

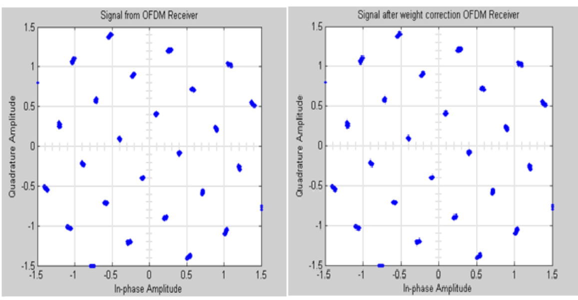

Fig.7 DVBT system using RBF network with phase noise and after correcting phase noise for Ricean channel

Table 1

Channel	Phase Noise (deg)	SNR (dB)	BER
AWGN	10	20	0.3473
Rayleigh	10	20	0.4030
Racian	10	20	0.4563

In this section, the simulation results proposed for minimization of phase noise in OFDM system. Fig.4 shows the RBF network based on LMS algorithm and MSE algorithm. Consider two inputs which are shuffled and transmitted to the RBF network which are then calculated with the MSE algorithm to get desired output. When using an RBF network for classification and prediction, to find a set of values for the centroids , widths, weights and biases so that computed outputs best match a set of known outputs. This is called training the RBF network.

The proposed RBF network which is a soft computing technique used for minimization of phase noise based on LMS algorithm and MSE algorithm.LMS(Least Mean Square) algorithms are a class of adaptive filter used to mimic a desired filter by finding the filter coefficients that relate to producing the least mean squares of the error signal.MSE (Mean Square Error) of an estimator is one of many ways to quantify the differnce between values implied by an estimator and the true values of the quantity being estimated. When training patterns contain outliers, the number of nodes determined by traditional growing techniques can only grow to a certain number beyond which a desired number cannot be reached.

This RBF network is added at the transmitter side of DVBT model , when the phase noise is zero ,BER will get zero. But when phase noise is added, that training RBF network will transfer at the receiver side of the DVBT model, so that after training , BER will get zero. That means the phase noise which is added to the model, is detected by training the RBF network.

Fig.5 shows the DVBT system using RBF network with phase noise and after correcting phase noise for AWGN channel. Fig.6 shows the DVBT system using RBF network with phase noise and after correcting phase noise for Rayleigh channel fixed at a point and spread in all quadrants. . Fig.7 shows DVBT system using RBF network with phase noise and after correcting phase noise for Ricean channel concludes the noise signal constellations in all four quadrant but in a less quantity.

In all the three channels, the signal constellations distributed between the in phase and quadrature phase modulation. All the signal constellations of 64 QAM divided in four quadrants. That means sixteen signal constellations or sixteen symbols are in each quadrant ,whereas each symbol carry four bits. Depending upon the phase noise value and parameters provided to the quadrature modulation, the signal constellations distributed.

Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium i.e. communications channel will vary randomly, or fade, according to a Rayleigh distribution ,the radial component of the sum of two uncorrelated Gaussian random variables. Ricean fading is a stochastic modelfor radio propagation anomaly caused by partial cancellation of a radio signal by itself , the signal arrives at the receiver by several different paths (hence exhibiting multipath interference), and at least one of the paths is changing.

Table 1 shows the comparison of phase noise , SNR and bit error rate for different channels. For phase noise as 10 degree and SNR as 20dB, different bit error rate has been got for different channels, but the less amount of bit error rate has been got for AWGN channel which becomes better channel for OFDM system.

V. CONCLUSION

In the proposed paper, RBF (Radial Basis Function) network which is one of the soft computing technique used for minimizing the phase noise in OFDM system with respect to LMS algorithm and MSE algorithm.It shows the performance of DVBT model using RBF network with phase noise and after correcting phase noise for AWGN channel, Rayleigh channel and Ricean channel. By comparing these three channels, the AWGN channel shows the better performance for the DVBT model.It also concludes that the RBF (Radial Basis Function) network is simple technique to minimize phase noise from the system. It also concluded that the bit error rate is performed better in QAM technique, so that the system is improved.

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