A Novel Blind Frequency Offset Estimation Method for OFDM Systems

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Abstract— **OFDM digital communication system is highly frequency sensitive to carrier frequency offset between transmitter and receiver local oscillators, which disturbs orthogonality among carriers. Consequently, the performance of OFDM system is reduced greatly due to inter-carrier-interference (ICI). In this paper, we have presented a novel approach for the frequency offset estimation of the OFDM communication systems and the results have been compared with other reported literature.**

Index Terms — **Frequency offset, OFDM, ICI, multicarrier, Bayesian mean square error.**

INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) digital communication system is a multicarrier transmission technique, which divides the available spectrum into many carrier, each one being modulated by a low rate data stream. This system is similar to FDMA (frequency division multiple access) in which the multiple user access is achieved by sub-dividing the available bandwidth into multiple channels, which are then allocated to users. However, OFDM uses the spectrum much more effectively by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers. Orthogonality of carriers means that each carrier has an integer number of cycles over a symbol period. Due to this, spectrum of each carrier has null at entire frequency of each of other carries in the system. This results no interferences between carriers, allowing them to be as close as theoretically possible. This overcomes the problem of overhead carrier spacing required in FDMA.

Accurate frequency and time synchronization of OFDM system is required in order to achieve good performance. The very important property that these systems rely on — orthogonality of the sub-carriers — will be lost if synchronization in inaccurate. The main problem with OFDM communication system is that, it is highly frequency offset sensitive caused by the oscillator inaccuracies and the Doppler shift of the mobile channel, because frequency offset disturbs orthogonality between the sub-carriers which results crosstalk and reduces the performance of OFDM system [1-3], so there is need to estimate the frequency offset and correct it to maintain the orthogonality. The estimation of frequency offset from the noisy data is difficult but important task, since this enables mitigation of unwanted inter-channel interference in OFDM. Recently, many frequency offset estimation algorithms [2-8] have been developed and these can be divide in two categories, data added and non-data added (blind), but data-added technique is less bandwidth efficient due to use of pilot. Therefore, blind estimation algorithms have received great attention because of their better spectral efficiency. Method suggested [3] in which the received sequence is repeated after N interval and maximum likelihood function is obtained and maximum likelihood estimate is found but data acquisition range is $\pm 1/2$ carrier spacing. Method suggested in [4] utilizes cyclic prefix for frequency offset estimation if delay spread is comparable with cyclic prefix length then performance of estimator is decreased greatly.

In this paper, we have discussed frequency offset estimation technique by using Bayesian function. The new proposed technique provides a high accuracy carrier estimates by taking advantage of inherent orthogonality among OFDM sub-channel. This paper is organized as follows. The section II discusses the system model. The section III concern with the proposed method for frequency offset estimation method. The section IV discusses about the results of the proposed scheme for frequency offset estimation. Finally, section V concludes the work.

SYSTEM MODEL

A typical discrete-time base band equivalent model of an OFDM communication system is shown in Fig. 1. The input binary serial data stream is encoded using suitable modulation technique (M- QAM, BPSK, and QPSK). The input bit stream is encoded into N symbols X_m using M-QAM or QPSK as shown in Fig. 1. The N symbols are transferred by the serial-to-parallel converter (S/P) in this stage duration of bits is increased. Parallel bit stream is subjected to IFFT block and modulation is performed. The modulated symbols are serialized using a parallel-to-serial converter (P/S). Now, guard band addition is performed because at the receiver, one OFDM symbol is over lapped with the other due to multipath distortion. To eliminate the problem of inter-symbol interference (ISI) a guard time inserted between two symbols, duration of guard interval should be greater than maximum delay spread. Guard time consists with no signal at all. In next block digital signal is converted to analog via the digital-to-analog converter (D/A) before being sent down to the channel. At the receiver side, the received symbols are converted from

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analog to digital using the analog-to-digital converter (A/D) and guard band is removed. In next process data is transferred to the serial to parallel converter and in next block data is sent in OFDM demodulator.

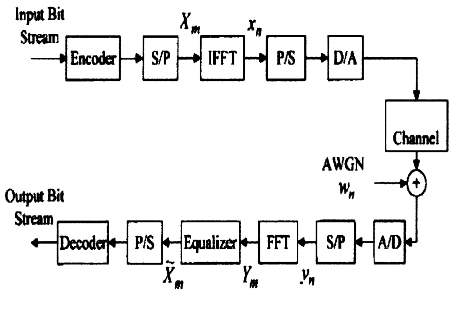

Fig. 1. A base band block diagram for an OFDM communication system.

PROPOSED APPROACH FOR FREQUENCY OFFSET ESTIMATION

In this paper, we have discussed method for frequency offset estimation. It is a blind technique for frequency offset estimation because pilot is not used. This frequency offset estimation technique is Bayesian approach which offers three basic advantages in estimation of frequency offset when synchronize with a communication system to a base station in an OFDM system. One is a systematic way to include important information via prior probability, another advantage of this approach is its ability to update probability distribution consistently using Bayes theorem and it also access to reliability measures for the actual estimate at hand. The Bayesian approach in these ways enables fast frequency acquisition without pilots at lower SNR, and also provides a good indicator when communication system is sufficiently synchronized to transmit for the first time. In this approach no pilot symbol is used so it has better spectral efficiency than the pilot symbol approach as discussed in [9]. Since in OFDM communication systems there are many carriers, their interference can be modeled as additive white Gaussian noise (AWGN). Therefore OFDM systems with carrier frequency offset need to increase the power to maintain same bit error rate in the absence of carrier frequency offset. Let $S(m) = [s_0(m), s_1(m), \cdots\cdots\cdots S_{N-1}]^T$ be the m^th^ OFDM data block to be transmitted, where N is the number of sub-carriers. These data are used to modulate N orthogonal sub-carriers; inverse discrete Fourier transform is used to modulate the input signal. After modulation, signal can be represented as $x(m) = [x_0(m), x_1(m), \cdots\cdots\cdots x_{N-1}]^T = W\,S(m)$, where, W is $N \times N$ IDFT matrix, given by:

$$W = \begin{bmatrix} 1 & 1 & \cdots\cdots & 1 \\ 1 & e^{j\omega} & \cdots\cdots & e^{j(N-1)\omega} \\ \vdots & & \ddots & \vdots \\ 1 & e^{j(N-1)\omega} & \cdots\cdots & e^{j(N-1)(N-1)\omega} \end{bmatrix}$$

where $\omega = 2\pi / N$. Cyclic prefix is inserted after IDFT modulation, which is removed before demodulation at the OFDM receiver and the resultant signal is up converted to RF before transmission. At the receiver down converted and demodulated using DFT. The received signal after removal of cyclic prefix can be represented as [5]: $y(m) = \theta W\,H\,S(m) + n(m)$, where n(m) denotes the AWGN and $\theta = diag(1, e^{j\theta_0}, \ldots\ldots e^{j\theta_0(N-1)})$ is the carrier frequency offset and $\theta_0 = 2\pi \Delta f T_s / N$. $H = diag(H_0(m), H_1(m), \cdots\cdots, H_{N-1}(m))$ represents channel characteristics in frequency domain. Here we consider AWGN channel so H = diag (1,1,-----------1)Let us consider normalized frequency offset $\varepsilon = \Delta f\, T_s$ where T_s is the OFDM symbol duration. Bayesian mean square error as given in [3] is:

$$\text{Bmse}\left(\hat{\theta}\right) = \left[\left(\left(\sigma_\theta{}^2\right)^{-1} + \frac{NE_b}{N_\circ}\right)^{-1}\right]$$

$$\text{Bmse}\left(\hat{\varepsilon}\right) = \frac{1}{2\pi}\left[\left(\left(\sigma_\theta{}^2\right)^{-1} + \frac{NE_b}{N_\circ}\right)^{-1}\right]$$

and the normalized carrier frequency offset is given as [3].

$$\hat{\varepsilon} = \frac{1}{2\pi}\tan^{-1}\left[\frac{imag\left\{\left(C_{\theta\theta}(WHS)^T\right)\left((WHS)\sigma_\theta{}^2(WHS)^T + \sigma_n{}^2\right)^{-1}\sigma_\theta{}^2(WHS)^T y\right\}}{real\left\{\left(C_{\theta\theta}(WHS)^T\right)\left((WHS)\sigma_\theta{}^2(WHS)^T + \sigma_n{}^2\right)^{-1}\sigma_\theta{}^2(WHS)^T y\right\}}\right]$$

RESULTS

Simulation has been performed for N = 64 and guard interval 7 with AWGN channel and QPSK modulation scheme. Figure 2 compares estimated frequency offset obtained by the proposed Bayesian approach and MLE (maximum likelihood) approach as proposed in [3].

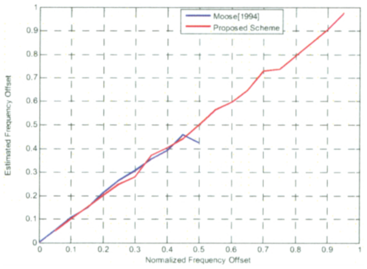

Fig. 2. Comparison of MLE scheme by Moose [3] and proposed scheme for 17 dB signal to noise ratio.

In [4] an algorithm for maximum likelihood estimation of frequency offset using the DFT values of a repeated data symbol has been presented. For small error in estimate, the estimate unbiased and is consistent in the sense that the variance is inversely proportional to the number of carrier in the OFDM Signals. The acquisition range obtained from the proposed scheme is 0.95 where as it is only 0.5 in [3] for 17dB signal to noise ratio, however the estimation accuracy is comparable with this.

In Fig 3 E_b/N_0 (signal to noise ratio) varies from 0 to 30 dB. The Bayesian mean square error decrease with increasing N as shown N = 64 Bmse at $E_b/N_0 = 0$ dB is near 10^{-3} approaches 10^{-5} at $E_b/N_0 = 30$ dB. For N=256 Bmse approaches = 10^{-7} at $E_b/N_0 = 30$ dB for N=512 Bmse is better than for N=256 our results are comparable with [5]. In Fig. 4, it is observed that, there is no significant variation in the value of Bmse due to changes in the number of data at any constant E_b / N_0 value. The frequency offset estimated by using maximum likelihood estimation algorithm. In the event that frequency offset exceeds ± 1 the inter carrier spacing, the maximum limit of algorithm, a strategy is required for initial acquisition.

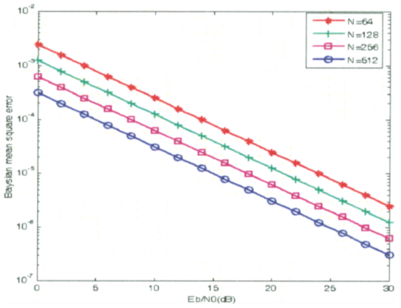

Fig. 3. Plot of Bayesian mean square errors versus SNR.

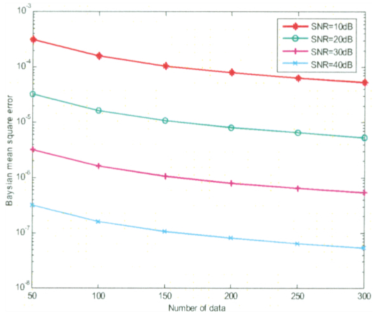

Fig. 4. Number of data versus Bayesian mean square error.

CONCLUSION

In this paper, we have suggested a novel approach for frequency offset estimation of the OFDM digital communication systems using Bayesian mean square error approach. The Bayesian approach is adapted because it focuses on efficient information processing tools for inclusion of cogent prior information, consistent processing of new data and reliability measures for estimates obtained with actual data set. The estimation accuracy of the frequency offset of the proposed scheme is comparable with [3] however; it gives a better data acquisition range. The performance of the proposed estimator is not affected, if delay spread is comparable with cyclic prefix which is the problems found in [4]. As well as the proposed scheme gives better accuracy compared to [9] at the same time it is bandwidth efficient because this scheme does not employ training symbol or the pilot carriers

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A High Speed Design of Rectangular and Square Shape MSA for Higher Accuracy through RBF of ANN

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***Abstract* — in this work radial basis function algorithm of artificial neural network has been developed to design the analysis and synthesis model of rectangular and square shape microstrip antenna. Rbf is used to design the parameters of square and rectangular patch antenna. Ann method gives very high computational efficiency as compared to the electromagnetic techniques which is time consuming. Rbf is developed for 40 data samples for both models. It gives the best result with zero error for trained and tested data of both models of msa. This is the most optimizing tool adopted of late in the field of computational electromagnetics. Synthesis model gives the dimensions while analysis model gives the resonant frequency of patch antenna. The theoretical values obtained by both models are in very good agreement with experimental results reported elsewhere**

***Keywords* - RBF (Radial base function) ANN (Artificial Neural Network), R &S(rectangular and square) , MSA (Microstrip Antenna), EM. (Electromagnetic).**

INTRODUCTION

With the ever growing applications of complex wireless communication, there is need for faster methods to design MSA[1]. ANN is one such fast and effective means of modeling complex electromagnetic devices along with the NN as a powerful tool for predicting the behaviour of the device in absence of a mathematical model [2]. ANN is trained to capture arbitrary input and output relationship to get the maximum accuracy. As soon as the model is trained it is tested for number of data. Hence the trained model gives very fast output parameters. NN is the very effective tool for nonlinear approximation.

The Microstrip antenna can be developed in a variety of shapes like square, rectangular, circular, elliptical, triangular etc. The MSA is an excellent radiator for many applications such as mobile antenna, aircraft and ship antennas, remote sensing, missiles and satellite communications [3]. It consists of radiating elements (patches) photo etched on the dielectric substrate as shown in fig.1. They are low profile, conformal configuration, light in weight, simple in design and inexpensive antennas, most suitable for aerospace and mobile communication. Because of their low power handling capability these antennas can be used in low power transmitting and receiving applications [1].

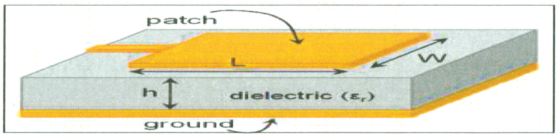

Fig1: Rectangular Microstrip Antenna.

MICROSTRIP PATCH ANTENNA

Several methods are available for the design of microstrip antenna, but the critical need is to develop a real prototype and do the experiment to yield the actual reading/data. For this ANN is the best solution to get the design parameters. Hence, in this work we have tried to develop the radial base function algorithm for the design of square /rectangular patch antennas. This design consists of two models [4] i.e. analysis model and synthesis model.

In the first design, we have tried to determine the accurate value of dimensions i.e. width and length, while in the second design we have tried to get resonant frequency. Here ANN is used to model the relationship between patch dimensions and resonant frequency depending upon the height of substrate and permittivity .

RBF NN MODEL DEVELOPMENT

Feed forward neural network with a single hidden layer that uses radial basis activation function for hidden neurons is called radial basis function networks [4].The hidden layer of RBF consists of radial kernels while o/p layer consists of linear neurons.

The proposed RBF model consists of two layers -- output layer and hidden layer in the middle as shown in fig.2. The hidden layer performs the non linear transformation of input space while the output layer performs linear regression to predict the desired targets. Several forms of radial basis are used but the most commonly used function is Gaussian Kernel. The hidden layer of RBF is nonlinear while the output layer of RBF is linear.

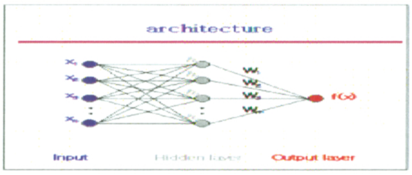

Fig2: Architecture of RBF

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a) RBF model for Analysis Design:

In analysis model, NN is trained with the input and output data. The input parameters to the NN model are W, L, h and ε_r while the output parameter is fr [5]. The RBF model is trained to give the resonant frequency as shown in Fig 3.

Fig3: Analysis Model of ANN

W - Width of the radiating patch
L - Length of the radiating patch
h - Height of dielectric substrate
ε_r - Permittivity of dielectric substrate

The RBF model is developed in Matlab7.0. The 40 samples of data is generated from microstip patch calculator [6]. The analysis model of RBF gives zero error for training.The 40 data samples are used to train and test the RBF model. The training completes within a second and gives zero error result in 25 epochs. The performance of analysis model is shown in fig 4.

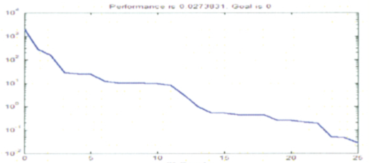

Fig4: Performance result of Analysis Model NEWRB, neurons = 25, SSE = 0.0273831

b) RBF model for Synthesis Design:

In synthesis model the input parameters are fr, h and ε_r. The NN model is developed to design the dimensions of patch antenna in terms of Wand L as shown in fig 5. The RBF is trained in 25 epochs (fig 6).

The training and testing of RBF gives zero error for analysis and synthesis design. The NEWRB function is used for the development of RBF[7].

Fig5: Synthesis Model of ANN

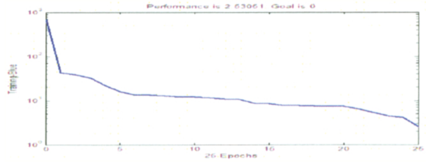

Fig6: Performance result of synthesis Model NEWRB, neurons 25, SSE = 2.53051

RESULT

The rectangular/ square shape antenna is developed by using RBF algorithm in NN tool of MATLAB7.0. The comparison of analysis and synthesis model is as shown in table 1. The result gives zero error for training and testing of both the models. The ANN model for analysis has been developed and tested to get minimum error of zero. The trained ANN model of analysis is tested for new (untrained) data with variation of spread and goal (constant) parameters. The RBF is tested for five new data in which goal is 0.001 and nine times it is executed for the different values of spread. All the values and result corresponding to the optimized parameters (spread=0.888, 0.8888, 0.89) are shown in table 2. the synthesis work for the ANN has also been carried out and work is in progress.

CONCLUSION

In RBF the radial basis function is applied in hidden layer to the input data. The developed technique is applied to 40 data samples for analysis and synthesis design of MSA. In both the designs, we got zero error for trained and tested data. Analysis model gives one of the best result for untrained data. Hence this can be considered as one of the fastest method for designing of rectangular and square shape MSA for mobile communication. The time required for the analysis and synthesis on PC with P IV 2.40 GHz. is of the order of second.

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Table 1: Details of RBF algorithm

Sr. No.	RBF	Analysis Model	Synthesis Model
1	Inputs	4	3
2	Outputs	1	2
3	No. of Data	40	40

4	epochs	25	25
5	SSE	0.0273831	2.53051
6	Error in Training	0	0
7	Error in Testing	0	0
8	Time in Second	1	1

TABLE 2
TESTED RESULT OF ANALYSIS FOR UNTRAINED DATA

Testing Result	Goal 0, Spread 0.4
fr	Error
16.3929	4.9861
8.1245	-0.1777
4.6934	-0.0434
2.72	0
5.1124	-3.1594

Testing Result	Goal 0.001 , Spread 0.4
fr	Error
15.9918	5.3872
6.9263	1.0205
3.454	1.196
2.7209	-0.0009
2.267	-0.314

Testing Result	Goal 0.001 , Spread 0.8
fr	Error
17.387	3.992
8.2856	-0.3388
4.8198	-0.1698
2.7198	0.0002
1.2042	0.7488

Testing Result	Goal 0.001 Spread0.888
fr	Error
17.6718	3.7072
8.0452	-0.0984
5.1784	-0.5284
2.7202	-0.0002
1.4306	0.5224

Testing Result	Goal 0.001 , Spread0.8888
fr	Error
17.7089	3.6701
8.0771	-0.1303
5.2054	-0.5554
2.7202	-0.0002
1.7863	0.1667

Testing Result	Goal 0.001 , Spread 0.89
fr	Error
17.7121	3.6669
8.0733	-0.1265
5.209	-0.559
2.7202	-0.0002
1.7849	0.1681

Testing Result	Goal 0.001 , Spread0.895
fr	Error
17.6046	3.7744
7.9383	0.0085
5.1219	-0.4719
2.7201	-1E-04
0.5276	1.4254

Testing Result	Goal 0.001 , Spread0.899
fr	Error
17.6129	3.7661
7.9211	0.0257
5.1342	-0.4842
2.72	0
0.4955	1.4575

Resting Result	Goal 0.001 , Spread 0.9
fr	Error
17.615	3.764
7.9167	0.0301
5.1372	-0.4872
2.72	0
0.4876	1.4654

Testing Result	Goal 0.001 , Spread 1
fr	Error
17.8459	3.5331
7.5122	0.4346
5.3729	-0.7229
2.7204	-0.0004
-0.0416	1.9946

Testing Result	Goal 0.001 , Spread 1.5
Fr	Error
18.9007	2.4783
6.2399	1.7069
5.3103	-0.6603

2.7198	0.0002
0.2762	1.6768

Testing Result	Goal 0.001 , Spread 1.55
Fr	Error
19.0416	2.3374
6.5314	1.4154
5.2006	-0.5506
2.72	0
2.3364	-0.3834

Testing Result	Goal 0.001 , Spread1.999
fr	Error
19.4049	1.9741
6.3886	1.5582
5.0282	-0.3782
2.7201	-1E-04
1.182	0.771

Testing Result	Goal 0.001 , Spread1.9999
fr	Error
19.4054	1.9736
6.3888	1.558
5.0279	-0.3779
2.7201	-1E-04
1.1761	0.7769