Channel Estimation by Cosimulation of RF and Digital Simulation Environment for OFDM Systems

Cebrail ÇİFLİKLİ[1] A. Tuncay ÖZŞAHİN[2] A. Çağrı YAPICI[3]
e-mail: cebrailc@erciyes.edu.tr *e-mail: atozsahin@erciyes.edu.tr* *e-mail: cyapici@erciyes.edu.tr*
[1,2]*Erciyes University, Kayseri Vocational College, 38039, Melikgazi, Kayseri, Turkey*
[3] *Erciyes University, Faculty of Engineering, Department of Electrical & Electronics Engineering, 38039, Melikgazi, Kayseri, Turkey*

Key words: OFDM, channel estimation, cosimulation, artificial neural networks

ABSTRACT

In this study, the channel estimation technique for OFDM systems based on Artificial Neural Networks is investigated. This is realized by cosimulation environment to utilize the advantages of different modeling programs. In this cosimulation, Advanced Desing System (ADS 2005A) and MATLAB programs have been used. Both transmitter and receiver of OFDM system and the transmission medium are designed in ADS 2005A, and the channel estimator based on ANN is designed using MATLAB. We consider a multipath fading channel modeled to Rayleigh model. We have compared the performances of all schemes by measuring bit error rate (BER) with 4QAM, 16QAM, BPSK and QPSK as modulation schemes.

I. INTRODUCTION

The presence of multipath with different time delays causes inter-symbol interference (ISI) and degrades the performance of the transmission system. To improve performance of the system, complex adaptive equalization techniques are required. Recently, OFDM systems have been attracting much attention, because of its robustness against frequency-selective fading [1]. Some examples of existing systems, where OFDM is used, are digital audio and video broadcasting, asymmetric-digital-subscriber-line modems, and wireless local-area-networks systems, such as IEEE 802.11 and HiperLan/2 [2,3]. In mobile environment, since the radio channel is frequency selective and time-varying, channel estimation is needed at the receiver before demodulation process [4].

The channel estimation is a process of characterizing the effect of the transmission channel on the input signal. The estimation techniques can be divided into two major categories as training based estimation technique and blind estimation technique. In the training based techniques, pilot signals are inserted into OFDM symbols and used only in the received signal to estimate the effects of the channel [4]. This estimation technique can be based on least square (LS), least mean-square (LMS) or minimum mean-square (MMS) [5].

In blind techniques, no training sequence is required. It uses certain underlying mathematical properties of the data being sent. This technique has a drawback of being extremely computationally intensive. Since there is no training sequence required, it is appropriate for applications where bandwidth is scarce. This estimation technique can be based on recursive least square (RLS) or LMS [6].

In this study, an alternative method based on artificial neural network (ANN) to these estimation techniques is proposed by cosimulation. Cosimulation is the ability to run a single simulation using models developed in different modelling languages. To take the benefit of advantages of different programs, cosimulation environments are designed. A cosimulation environment provides a software development platform for programmers and encourages interactions among different programs.

Recently, combining RF and digital data flow is important to simulate real-time systems more correctly. So, for combining RF and digital data flow simulation environment, a cosimulation method is designed using ADS 2005A and MATLAB in this study. Both transmitter and receiver of OFDM system and the transmission medium are designed in ADS 2005A, and the channel estimator based on ANN is designed using MATLAB.

The rest of the study is organized as follows. Section II introduces OFDM system model. ANN based channel estimator is described in Section III. Simulation results are offered in Section IV and finally Section V concludes the study.

II. OFDM SYSTEM MODEL

In Figure 1, a block diagram of the baseband model of OFDM system is shown. The binary information is first mapped using baseband modulation schemes such as QAM or PSK. Than the serial-to-parallel conversion is applied to baseband modulated signals. The serial-to-parallel converted data is modulated using Inverse Fast Fourier Transform (IFFT). This is one of the main principles of the OFDM systems. After IDFT, the time domain signal is given as following equation;

$$s(n) = IFFT(S(k)), \qquad n = 0,1,2..., N-1$$
$$= \sum_{k=0}^{N-1} S(k) e^{j2\pi kn/N} \qquad (1)$$

where N is the length of FFT, $S(k)$ is baseband data sequence. After IFFT, the guard interval called as cyclic prefix is inserted to prevent inter-symbol interference (ISI). This interval should be chosen to be larger than the expected delay spread of the multipath channel. The guard time includes the cyclically extended part of the OFDM symbol in order to eliminate the inter-carrier interference (ICI). The symbol extended with the cyclic prefix is given as follows;

$$s_t(n) = \begin{cases} s(N+n), & n = -N_c, -N_c+1, ..., -1 \\ s(n), & n = 0,1,..., N-1 \end{cases} \qquad (2)$$

where N_c is the length of the cyclic prefix. The resultant signal $s_t(n)$ will be transmitted over frequency selective time varying fading channel with additive white Gaussian noise (AWGN). The received signal is given by following equation;

$$y_t(n) = s_t(n) \otimes h(n) + w(n) \qquad (3)$$

where $h(n)$ is the impulse response of the frequency selective channel and $w(n)$ is AWGN.

At the receiver, the cyclic prefix is first removed. Then the signal $y(n)$ without cyclic prefix is applied to FFT block in order to obtain following equation;

$$Y(k) = FFT\{y(n)\} \qquad k = 0,1,2,..., N-1$$
$$= \frac{1}{N} \sum_{n=0}^{N-1} y(n) e^{-j2\pi kn/N} \qquad (4)$$

After FFT block, assuming there is no ISI, demodulated signal is given by following equation;

$$Y(k) = S(k)H(k) + I(k) + W(K) \qquad (5)$$

where $H(k)$ is $FFT[h(n)]$, $I(k)$ is ICI and $W(k)$ is $FFT[w(n)]$.

It is obvious above from Equation (5) that before demodulation, dynamic channel estimation should be done at the receiver, because of the channel effects on the received signal.

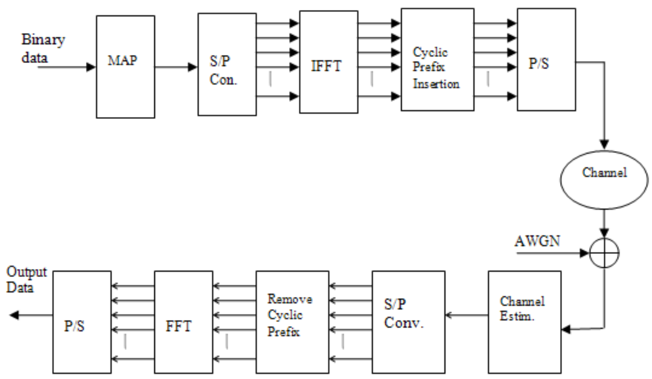

Figure 1. Block diagram of the baseband model of OFDM system

III. CHANNEL ESTIMATION BASED ON ARTIFICIAL NEURAL NETWORKS

Artificial neural networks (ANN's) can perform complex mapping between its input and output space and are capable of forming complex decision regions with nonlinear decision boundaries [7]. Further, because of nonlinear characteristics of the ANN's, these networks of different architecture have found successful application in channel estimation problem [7]. One of the earliest applications of the ANN in digital communication channel equalization is reported by Siu *et al.* [8].

In this study, the proposed ANN based estimation technique has multilayer perceptron (MLP) structure. In Table 1, the parameters of the proposed technique are given. These parameters are obtained with iterative methods.

Table 1. Parameters of Artificial Neural Networks

Parameter	Value
Number of Inputs	2
Number of Hidden Layers	2
Number of Neurons	5,12
Epoch Number	250
Training Function	Levenberg-Marquart
Transfer functions	tansig

OFDM signal is generated in ADS 2005A. Additive white Gaussian noise is added to OFDM signal. Then, this signal is applied to the wireless channel modelled to Rayleigh model. This channel is a multipath channel with 20 reflected paths. The channel model is also designed in ADS 2005A. The estimation of channel is realized in ANN based estimator block which is designed in MATLAB. Before estimation process, at first the training of ANN is realized. The training is done with the input of the channel. After training, the estimation of the channel can be realized. The estimated signal is then demodulated at receiver which is designed in ADS 2005A. Block diagram of the proposed cosimulation environment is shown in Figure 2. In Table 2, OFDM system parameters are given.

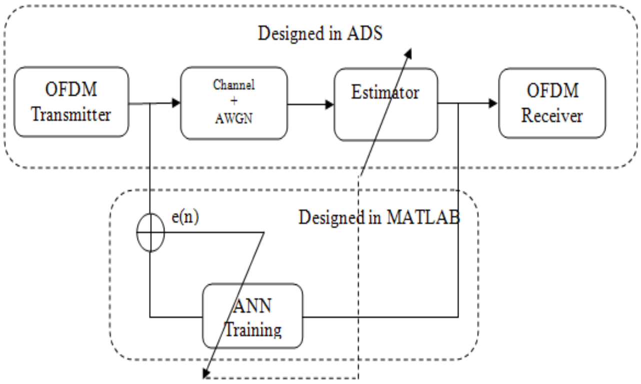

Figure 2. Block Diagram of the proposed cosimulation environment

Table 2. OFDM System Parameters

Parameter	Value
Baseband Modulation	QAM4, QAM16, BPSK,QPSK
FFT Size	2048
Number of Carriers	256
Guard Interval	32
Type of Guard Interval	Cyclic Prefix

IV. SIMULATION RESULTS

In this paper, we propose a channel estimation technique based on Artificial Neural Networks (ANN). We compare the performance of this technique by applying 4QAM (4 Quadrature Amplitude Modulation), 16QAM, 64QAM, BPSK (Binary Phase Shift Keying) and QPSK (Quadrature Phase Shift Keying) as modulation schemes with Rayleigh fading channels as channel model.

Simulation results obtained with Quadrature Amplitude Modulation such as QAM 4 and QAM 16 are shown in Figure 3. It can be seen from Figure 3 that constellation of the baseband modulation technique is getting more complex, the performance of OFDM system decrease.

In Figure 4, simulation results obtained with Phase Shift Keying such as BPSK and QPSK are shown. Comparison of all techniques is given in Figure 5.

Simulation results show that constellation of the baseband modulation technique is getting more complex, the performance of OFDM system decrease. As shown in Figure 5, best results among all baseband modulation schemes are obtained with BPSK.

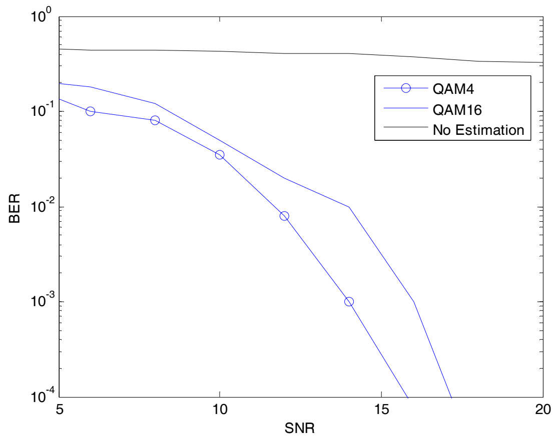

Figure 3. BER Comparison of QAM4, QAM16 Modulation Schemes with Rayleigh Fading

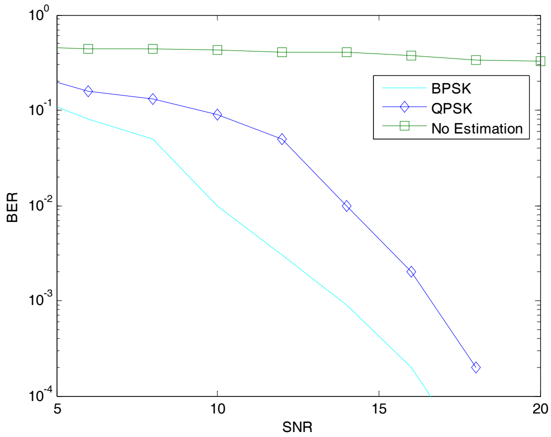

Figure 4. BER Comparison of BPSK, QPSK Modulation Schemes with Rayleigh Fading

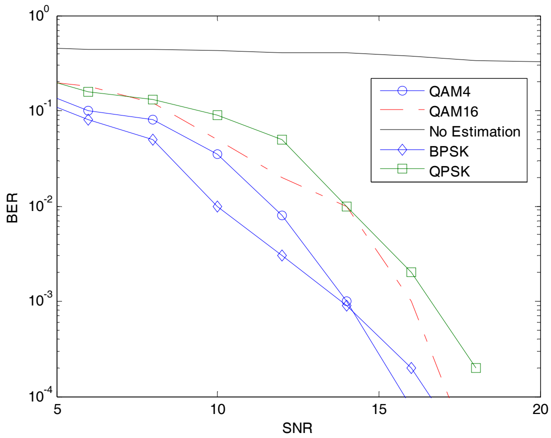

Figure 5. BER Comparison of QAM4, QAM16, QPSK, BPSK Modulation Schemes with Rayleigh Fading

V. CONCLUSION

Artificial Neural Network based channel estimation technique has been proposed over Rayleigh fading channel. In this study, a different approach to channel estimation based on ANN by cosimulation environment is investigated. As shown in Figure 2, cosimulation environment is designed using ADS 2005A and MATLAB programs. By using two different programs, it is aimed to utilize the advantages of these programs. Since RF and digital data flow environments are combined together, real-time system is designed more correctly. Finally, at the end of the simulations using different baseband modulation schemes, BER analysis of the ANN based estimator is obtained.

REFERENCES

1. H. Gacanin, S. Takaoka, F. Adachi, Generalized OFDM for Bridging Between OFDM and Single-Carrier Transmission, Communications Systems, 2004. ICCS 2004. The Ninth International Conference on Comm., pp. 145–149, 6-8 Sept. 2004.

2. J. G. Proakis, Digital Communications, McGraw-Hill, 3rd Ed., McGraw Hill.

3. R. D. J. van Nee, R. Prasad, R. van Nee, OFDM for Wireless Multimedia Communications, Artech House, Jan. 2000.

4. S. Colieri, M. Ergen, A. Puri, A. Bahai , A Study of Channel Estimation in OFDM Systems, Vehicular Technology Conference, 2002. Proceedings, IEEE 56th Volume 2, pp. 894 - 898, 24-28 Sept. 2002.

5. S. Colieri, M. Ergen, A. Puri, A. Bahai, Channel Estimation Techniques Based on Pilot Arrangement in OFDM Systems, IEEE Trans. On Broad., Volume 48, Issue 3, pp. 223 – 229, Sept. 2002.

6. X.G. Doukopoulos, G.V. Moustakides, Adaptive Algorithms for Blind Channel Estimation in OFDM Systems, 2004 IEEE International Conf. on Comm., Volume 4, pp. 2377 – 2381, 20-24 June 2004

7. J. C. Patra, R. N. Pal, R. Baliarsingh, G. Panda, Nonlinear Channel Equalization for QAM Signal Constellation Using Artificial Neural Networks, IEEE Transactions on Systems, Man, and Cybernetics, vol.29, no.2, Apr. 1999.

8. S. Siu, G. J. Gibson, and C. F. N. Cowan, Decision Feedback Equalization using Neural Network Structures and Performance Comparison with Standard Architecture, *Proc. Inst. Elect. Eng.*, vol. 137, pt. 1, pp. 221–225, Aug. 1990

9. C. Ciftlikli, A. T. Ozsahin, A. C. Yapici, Using Artificial Neural Networks for Channel Equalization in OFDM Systems, 3th URSI Scientific Symposium, URSI 2006, 6-8 Sep. 2006.