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Reduction of Inter-Symbol Interference using Artificial Neural Network System in Multicarrier OFDM System

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ABSTRACT

The work proposes Inter-Symbol Interference (ISI) reduction scheme, ISI is a major problem in Optical systems, which produces various types of non-linear distortions. So the implementation of OFDM system using Artificial Neural Network (ANN) scheme with M-QAM modulation technique is proposed and compared with the conventional OFDM system without using ANN. This proposed scheme is an implementation of Back-propagation (BP) algorithm over AWGN channels to achieve an effective ISI reduction in orthogonal frequency division multiplexing (OFDM) systems. Simulation results prove that ANN equalizer can further reduce ISI effectively and provide acceptable BER and better MSE plotcompared to the conventional OFDM system.

Keywords:OFDM, Artificial Neural Network (ANN), FFT, QAM, BER, ISI, MMSE

I. INTRODUCTION

OFDM facilitates the possible growth of wireless communication for high quality multimedia services, high speed internet access, as well as data, video and voice transmission at higher rates. This multi-carrier modulation technique is limited to 4G mobile communication; it will also be implemented in the 5G communication system [1]. It also provides a possible solution to multipath frequency selective fading effect. However, the problem of ISI occurs due to causes of multipath propagation, dispersive, noisy and fading channels present in the original signal in OFDM system. If the ISI is not mitigated properly, then decision device may interpret the logic wrongly [2].

In this paper, ANN is proposed and implement after decoder of an OFDM system and this approach minimizes the error. Further, this proposed technique compares to conventional ISI reduction techniques.

The paper constitutes: Section II, which deals with relevant literature; Section III, proposed OFDM system description; ISI system model; Section IV, explains about proposed methodology; Section V, gives simulation setup and results; Section VI, highlights conclusions and future scopes and Section VII, presents references.

II. RELATED WORK

In [3] illustrated the performance of OFDM system by the use of low symbol rate, long symbol duration of the modulation scheme as well as use of guard bands for the reduction of ISI. In [4] proposed V-BLAST, Decision feedback signal detection method of cancellation of ISI and cyclic reconstruction method for the ICI removal purpose. In [6] proposed zero insertion (ZI) which insert zeros and each OFDM frames contain the same length. It also compares different guard interval (cyclic prefix, zero padding and known symbol padding) insertion techniques and shows that the ZI approach reduces the transmission rate, distortion in the channel as well as a 20 % data reduction in the redundant data as compared to CP. In [7] proposed zero-forcing equalizer, which used longer filter span to compensate for the multipath channel distortion. In [9] highlighted CP and ZP effect on the BER and give better performance under Rayleigh fading channel as compared to AWGN. In [10] presented a two-dimensional 9/12 modulation code to combat 2D ISI and achieve ~2Db gain as compared to without encoding modulation code. In [11] proposed unique word (UW) sequence which improved bandwidth efficiency, 15% throughput, and spectral efficiency 17% as compared to CP but CP-OFDM give better BER than UW-OFDM system. In [12] proposed two channel estimator in which MMSE estimator gives more complexity than the LS estimator but MMSE need low SNR and LS need high for better performance.

III. BASIC OFDM SYSTEM MODEL

Any OFDM system consists of N subcarriers, suppose that the complex symbol $X(n)$ is the signal point from the modulation signal constellation, which is modulated on the nth subcarriers and transmitted signal $x(t)$ defined in [5] as follows:

$$x(t) = \sum_{n=0}^{N-1} X(n)\mathrm{e}^{(\mathrm{j}2\pi \mathrm{f_n t})},\ \ 0 \le t \le T, \qquad (1)$$

Where $f_n = f_0 + {}^{n}/_{T}$, $T = NT_s$, is the interval of OFDM symbol, T_s Is the symbol data period. To synthesize the above OFDM signal in equation (1) use Inverse Fast Fourier transforms (IFFT) which samples the $x(n)$ signal with sample rate $\frac{T}{N}$. After IFFT the original time domain symbolic signal $x(n)$ given as below: $x(n) = IFFT\{X(K)\}$

$$\mathrm{x(n)} = \sum_{\mathrm{n=0}}^{\mathrm{N-1}} \mathrm{X(K)e^{j\left(2\pi nk/_N\right)}}, \mathrm{n = 0, N-1} \qquad (2)$$

Where N and $X(K)$ is the FFT length, baseband data sequence. To reduce, the ISI [6] inserted cyclic prefix, which extends the duration of symbols, which given below as:

$$x_t(n) = \begin{cases} x(N+n), n = -N_g, N_g+1, \ldots\ldots, -1 \\ x(n), n = \ 0,1,2, \ldots\ldots\ldots\ldots\ldots\ldots N-1 \end{cases} \ (3)$$

Then fading channel with white Gaussian noise transmitted $x_t(n)$ Signal and calculated the received signal $y_t(n)$in the form below:

$$y_t(n) = x_t(n)y(n) + w(n) \qquad (4)$$

Where, $h(n)$ is the response of impulse for selective fading channel and $w(n)$ is the AWGN. After, that signal $y(n)$ transmits without using CP given as:

$$Y(K) = FFT\{y(n)\}$$

$$\mathrm{Y(K)} = \frac{1}{\mathrm{N}} \sum_{\mathrm{K=0}}^{\mathrm{N-1}} \mathrm{Y(n)\ e^{\left(-j\frac{2\pi nl}{N}\right)}}, \mathrm{n = 0,..N-1} \quad (5)$$

IV. INTER-SYMBOL INTERFERENCE (ISI)

In band limited region, when the number of pulses is transmitted in succession, then these pulses will interfere with each other and hence receiver will not be interpreted the transmitted logic. Therefore, the BER in the receiver will increase. We can visualize inter-symbol interference (ISI) effect in "Fig. 1".

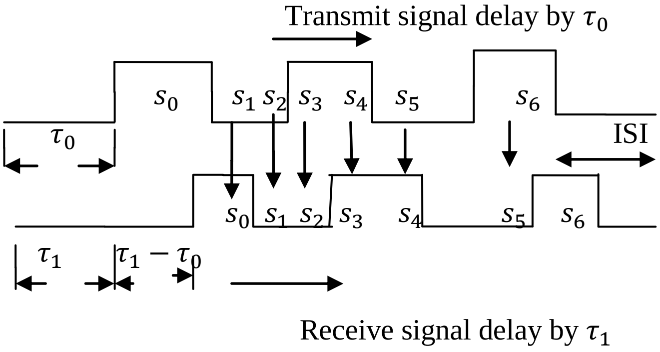


Figure1. Inter-Symbol Interference (ISI) effect

When $\tau_1 - \tau_0 > T$, then different symbol creates interference with each other as shown in above figure where T is the symbol time, τ_0 Is the transmitted signal delay and τ_1Is the received signal delay. $\tau_1 - \tau_0 = \sigma_\tau$. If $\sigma_\tau > T$ then this lead to inter-symbol interference (ISI) where σ_τ is the delay spread. ISI is undesirable since it leads to distortion of the original transmitted signal, but if we can make $T > \sigma_\tau$ this implies no ISI. The ISI channel described as:

$$y(k) = h(0)x(k) + h(1)x(k-1) + v(k) \qquad (6)$$

Where $y(k)$ received symbol at time k, $x(k)$ transmitted symbol at time k, $x(k-1)$ is the previous transmitted symbol at k-1, $v(k)$ is the noise signal. The past symbol $x(k-1)$ Interference with the present symbol $x(k)$ and introduce ISI.

V. PROPOSED METHODOLOGY

In this work, we have proposed an artificial neural network combined technique, which provides an ISI reduction in OFDM systems.

A. Proposed OFDM with ANN:

The proposed OFDM with ANN scheme is given in below "Fig.2" Where 9600 information bits are randomly generated by using 96 bits single frame size and 100 total number of frames. Again convolution channel coder encodes the information bit by using the input\output size of the encoder, constraint length and specified poly2trellis (171,133] matrix and provide 1×192 coded data. Matrix interleaving, block is employed to further restrict the burst error developed during transmission. The output of the interleaver is 4×48 coded output data is obtained. Further, a data converter is available, which converting the binary interleaving coded data into decimal format.

After that, M-QAM modulation scheme, the symbol values are generated. The proposed method provides better BER performance by (16, 64, and 256) QAM modulation schemes. This modulation value determines the number of bits (4, 6, and 8) per sub-carriers. Further, the pilot insertion concept introduced which adds data subcarrier values, 4 pilot symbols, and one DC subcarrier. Again, we take 64 points IFFT lengths that is equal to a number of carriers. The IFFT length, data subcarriers, pilot value and DC subcarrier also determine the guard band values. The 16 cyclic prefix lengths are inserted before the AWNG channel. CP means prefixing of symbols from the last part to front part. Here, the AWGN channel transmits original information data from transmitter to receiver. It adds some noise, which destroys the signal. This can only be rectified by the use of the ANN technique at the receiver side as shown in “Fig. 2”.

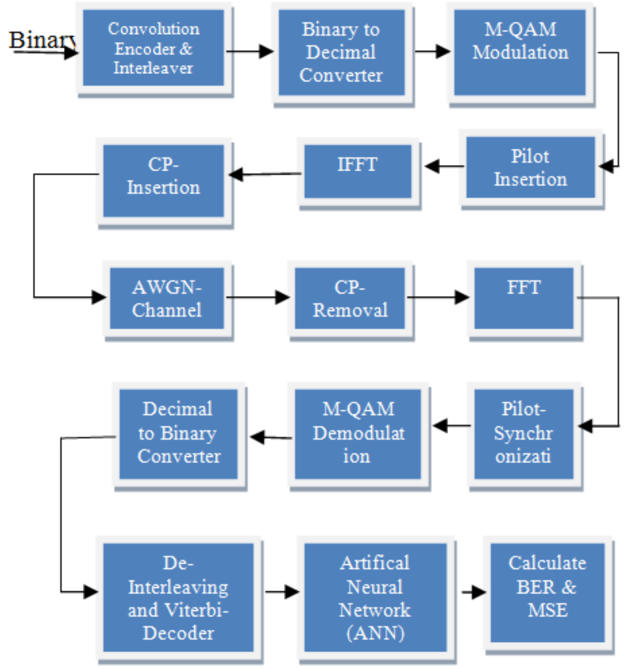


Figure2. Block diagram of proposed (OFDM-ANN) technique

B. Proposed Artificial Neural Network (ANN) Algorithm:

The artificial neural network implements after Viterbi decoder block of an OFDM system; it takes input from an OFDM system and output set as a target value. ANN is an artificial intelligence method used to enhance the capacity of computer by sending human like intelligence. This proposed work depends on back-propagation (BP) algorithm, which sends signals in a forward direction, and propagate error in backward direction. The multilayer BP network shown in “Fig.3” and the Log-Sigmoid function in [8] given as below:

$$f(x) = \frac{1}{1+e^{-x}} \qquad (7)$$

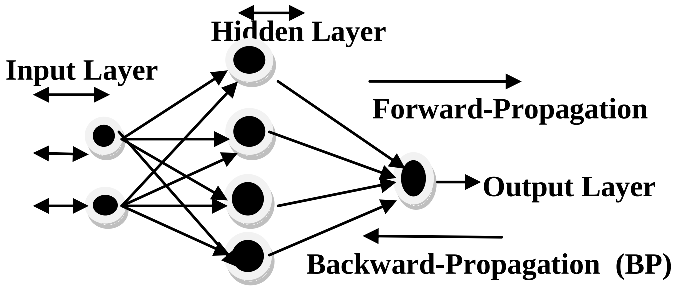
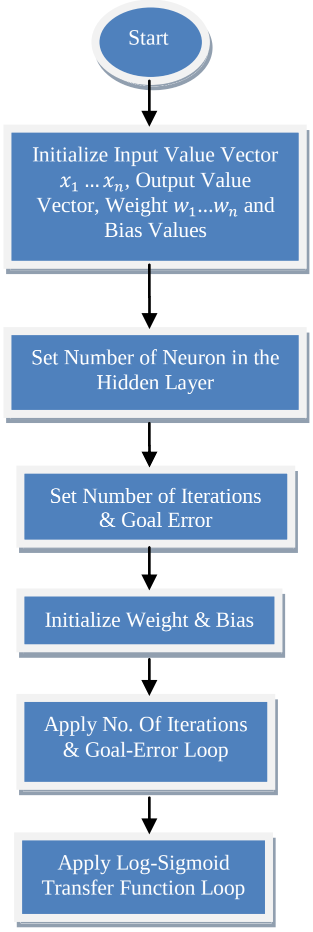


Figure3. Multilayer back-propagation network

Fig. 4 shows, the flowchart of ANN, which give Error, $e(n)$ as the difference between the target (actual) value and expected value in [10] [14] as below:

$$e(n) = d(n) - y(n) \qquad (8)$$



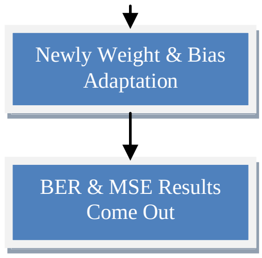


Figure4. Flow chart of ANN algorithm

VI. SIMULATION SETUP AND RESULTS

A. Simulation Setup:

In this section, the simulation setup of an OFDM system is shown in Table 1and Table 2 shows the simulation setup of an ANN which evaluate the BER, MSE performances of an OFDM system.

Table -1 Parameters of OFDM system

Parameter	Value
FFT size	64
Number of carriers	64
Single frame size	96bits
Total number of frames	100
Cyclic-prefix	16
Modulation	16,64,256QAM

Table -2 Parameters of artificial neural networks

Parameter	Value
Number of inputs	2
Number of hidden layers	1
Number of neurons	90,1
Iteration	1000
Goal error	10e-7
Training function	Back-Propagation
Transfer function	Log- Sigmoid

B. Simulation Results:

In this section, Fig.6", "Fig.7" shown the simulation results of a proposed OFDM system & this proposed results compare with the conventional OFDM system as shown in Table 3 & Table 4.

(1). BER performances of conventional OFDM systems with varying QAM Modulation schemes:

In "Fig.5", the BER performance of conventional OFDM systems with varying 16, 64, 256 QAM modulation scheme was studied. It shows the highest BER at the lowest signal to noise ratio (SNR) of 0dB for 64 and 256QAM modulation scheme. After that, with increasing the SNR at 9.9dB the BER will be decreased at 10^-1 sharply in the system by using the 16QAM modulation, but the other 64, 256 QAM modulation at 9.9dB gives highest 10^0 BER and does not tend to decrease. After SNR=15dB the BER in the system by using 16QAM modulation has little BER but the system with 64 and 256 QAM Modulation have high BER.

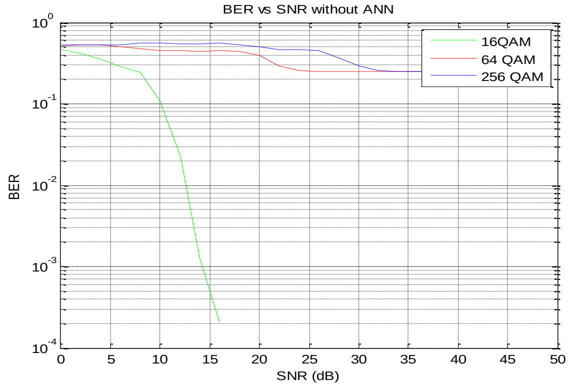


Figure5. Comparison between M-QAM BER of the conventional OFDM system

(2). BER performances of Proposed OFDM Systems with varying M-QAM Modulation schemes:

In "Fig.6", the BER of proposed OFDM systems with different 16, 64, and 256 QAM modulation scheme is to be considered. After that, with increasing the SNR the BER tends to be decreased more in the system by using 16QAM modulation scheme. After SNR=20dB all of the three M-QAM modulation scheme provide little BER.

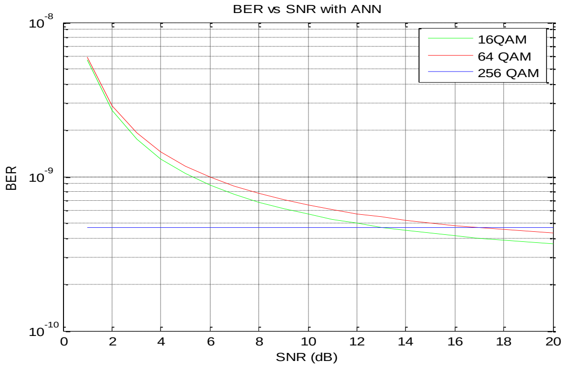


Figure6. Comparison between M-QAM BER of the proposed OFDM system

Table-3 BER for Conventional and Proposed OFDM systems

BER for M-QAM Modulation	BER for Conventional OFDM System	BER for Proposed OFDM System
16QAM	0.0002	1e-9
64QAM	0.25	1e-9
256QAM	0.25	1e-9

Table-3 shows the BER performance by varying signal to noise ratio. It shows that the proposed system provides lesser BER approximate (10^-9) in all M-QAM (16, 64, and 256) modulation scheme, but the conventional OFDM system provide highest BER (10^-4) in 16 QAM and (10^0) in 64 and 256 QAM modulation scheme.

(3). MSE performances of the Proposed OFDM Systems with varying QAM Modulation schemes:

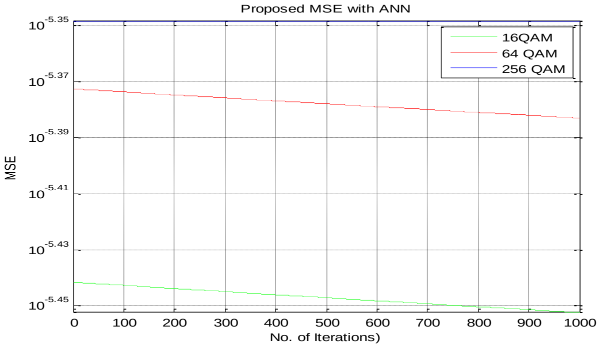


Figure7. Comparison between M-QAM MSE of the proposed OFDM system

Table-4 MSE for Conventional and Proposed OFDM systems

MSE for M-QAM Modulation	Conventional OFDM	Proposed OFDM
16QAM	0.05067	0.00000354
64QAM	0.00301	0.00000412
256QAM	0.49765	0.00000400

Table-4 and “Fig.7” shows MSE performance by varying one thousand times the number of iterations. It shows that the Proposed OFDM with ANN under M-QAM modulation require minimum MSE as compare to conventional OFDM without ANN.

VII. CONCLUSION AND FUTURE SCOPE

This paper proposed, Back-propagation (BP) based ANN channel estimator, which is further combine with OFDM system. This proposed combined technique provides better ISI reduction performance than an OFDM system without adding ANN. In this work, ISI is directly proportional to BER and inversely proportional to the SNR. The future scope of this paper is to apply ANN with MIMO-OFDM system or use of all other modulation technique.

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