Channel Equaliser for Communication Channel using Neuro-Fuzzy Approach

Nikita Jain[1], Vineeta Choudhary[2]

Abstract- **Channel equalisation is the process of compensating distortion in a communication channel. This paper presents channel equalisation using neuro-fuzzy approach. The combination of neural network and fuzzy technology is used to design channel equaliser. Fuzzy logic (FL) provides a mathematical strength for handling the uncertainties associated with the data or information. Neural network (NN) has adaptability property for performing well when system is time varying. The integration of NN and FL provides us advantage of both the technologies. The proposed equaliser performance is evaluated for training and bit error rate (BER) through simulation.**

Index Terms- **Neural network, Fuzzy logic, Channel equaliser**

I. INTRODUCTION

Signals transmitted through a channel suffer many distortions causing intersymbol interference (ISI). To eliminate this channel equalization is required. Fig.1 shows a basic component of transmission system.

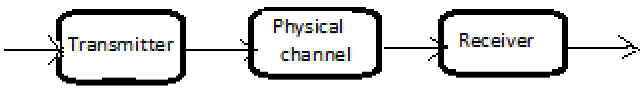

Figure 1. Basic component of a system

In physical channels, filters are used for specifying band-limited of transmitted signal. Such channels may be characterised mathematically by linear filter or nonlinear filter channels with additive noise *n(k).*

The role of equaliser is that, it has to give estimate of transmitted sequence *s(k-d)* as a desired response *s'(k-d).* If the channel is linear filter channel *h(k),* signal input is *s(k),* d is the equaliser delay, k is any time instant ,then the output of channel is represented as

$$x(k)=s(k) * h(k) + n(k) \quad (1)$$

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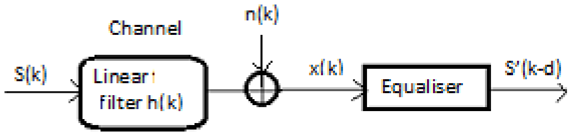

Figure 2. Transmission model using linear filter channel

The output of channel is represented in the form of vector as

$$x(k)=[x(k),x(k-1)............x(k-m)]^T \quad (2)$$

where, the order of equaliser is m.

Various equalisers have been applied to equalise these distortions. Such as adaptive filtering in digital communication system [1]. Linear equaliser has restriction of nonlinear distortion, when channel characteristics are time-varying, So adaptive equalisation based on digital filtering, multilayer perceptron (MLP) and radial basis function (RBF) are used. Non-linear equalisers have the potential to combat the effect of both linear and non-linear distortions [2].

In [3], [4], introduced adaptive equalization of BPSK signal for Rayleigh fading_channel using multiplicative neural network. In [5], proposed a new learning algorithm is known as Wilcoxon learning algorithm. This algorithm is used in channel equalization for minimizing the effect of intersymbol interference (ISI) and burst noise by using radial basis function equalizer (RBF) [6], [7], and mitigate the effect of co-channel interference by using multilayer perceptron neural network [8]. In [9], introduced equalization of linear and nonlinear channel using chebyshev artificial neural network.

Recently, the more effective way of equalization is the combination of fuzzy logic and neural network [10], [11]. Type-1 fuzzy set cannot manage uncertainty in better way than type-2 fuzzy set [12]. That's why combine advantage of type-2 fuzzy system and wavelet neural network are used. In [13], many applications have found such as modelling, time series prediction [14], exchange rate prediction etc. It describes the clustering method for generating the rules and gradient learning algorithm for identifying the parameters. By the use of these algorithms, we can identify the time-varying systems, equalization of time-varying channel [15], [16], control of uncertain system, and control of dynamic plant [17].

In [18], proposed the nonlinear neuro-fuzzy structure for equalization of channel distortion. This equaliser used the non-linear function for increasing the computational power. In [19], introduced the fully complex multiplicative neural

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network for extracting the quadrature amplitude modulation (QAM) signal from time-variant noisy channel. One more nonlinear equaliser is introduced in [20], for compensating the linear and nonlinear distortion is the combination of finite impulse response (FIR) and functional link artificial neural network. The C-means algorithm is presented in [21] for controlling uncertainty of fuzzifier parameters in interval type-2 fuzzy set. Type-2 fuzzy set has more computational complexity. Thus, interval type 2 fuzzy set for reducing the complexity.

In [22], genetic algorithm based equalizer is presented for partial response data equalisation. In [23], introduced frequency domain equalization is based on genetic algorithm for direct sequence-ultra wideband (DS-UWB) system in absence of guard interval. Adaptive decision feedback equaliser is based on least mean square (LMS) algorithm is presented in [24], for the application of wireless and mobile communication.

In this paper a neuro fuzzy approach is applied to obtain a good performance equalizer. .

II. METHODOLOGY

A. Generalised Structure Of Fuzzy Neural System

The channel equaliser is implemented using neuro-fuzzy network (NNFN) structure [2]. Due to combination of neural network and fuzzy logic, it can eliminate linear and nonlinear distortions. Fig.3 shows architecture of NNFN structure. The value of N2 (hidden neurons) is 20.

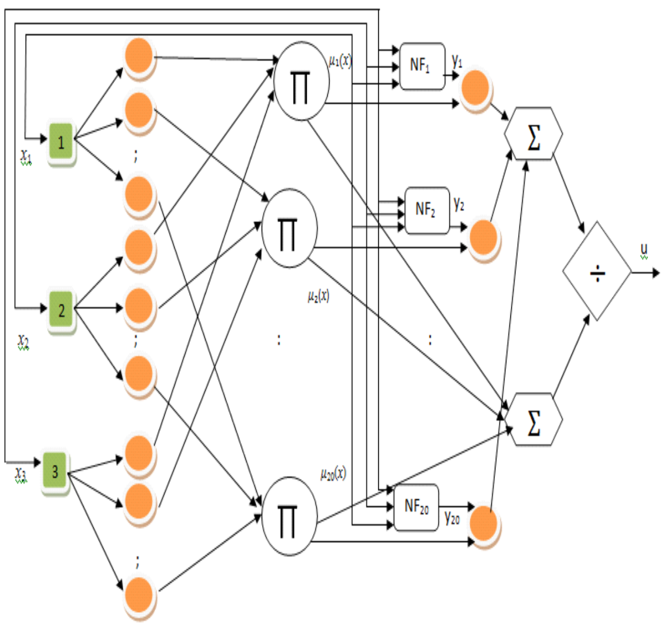

Figure 3. Architecture of NNFN system.

The rule is used in the form of IF-THEN rule and non-linear quadratic function is employed. Due to non-linear function computational power is increased. This model includes seven layers. In first layer, three nodes are used for input signal. In second layer, each input signal enters in system and in this system use Gaussian membership functions and then calculates fuzzy set

The mathematical expression is as follows for Gaussian membership function as

.

$$\mu(x) = \exp\left(\frac{-(x-c)^2}{2\sigma^2}\right) \tag{3}$$

Where, c and σ are the centre and widths of the membership function, x is the input fuzzy rule (R_1,R_2,R_3.......R_N) and use AND operator for calculating a value is the min operation. In fourth layer includes nonlinear functions that are represented by NF_1, NF_2...NF_N. Here, calculate the output of each NF. In the fifth layer, multiplication of the third layer output and NF output and last layer shows defuzzication. It calculates the output of the whole network. Training of the network start after calculating the output of the system.

The network input signal $x(k)$ are the channel output signal applied to the network at time k, $x_i(k-i)$ $(i=1,....4)$,the no. of hidden neurons is equal to 20 in this proposed model and it gives good result.

III. SIMULATION

A. Simulation of the Neuro Fuzzy Equalizer

In this thesis, we use the linear channel model to simulate the channel. It represents in below as :-

$$X(k)=0.3482s(k)+0.8704s(k-1)+0.3482s(k-2)+n(k) \tag{4}$$

This represent linear filter channel, $n(k)$ is the additive noise. The random sequence of 1000 duo-binary signals of [1,-1] are generated and passed through the channel. A few hundred symbol use for training and 10^5 signals for testing. The additive Gaussian noise $n(k)$ is added to the transmitted signal in the output of the channel. For minimizing mean square error (MSE) use few hundred training sequence and get steady state error. k represent number of epochs. 3000 epoch is enough for reaching stationary state. The following training patterns represent the graph of MSE versus epochs at SNR 20dB.

Extensive simulation studies, it have been found that with 200 training samples, 3000 epochs are sufficient for the giving better convergence result of minimum square error(MSE) in the variation of SNR(2-20dB). Fig.4 Shows convergence curve that describes the training performance of equalisers for 3000 epochs for linear model of N2=20 (hidden neuron) at SNR=20

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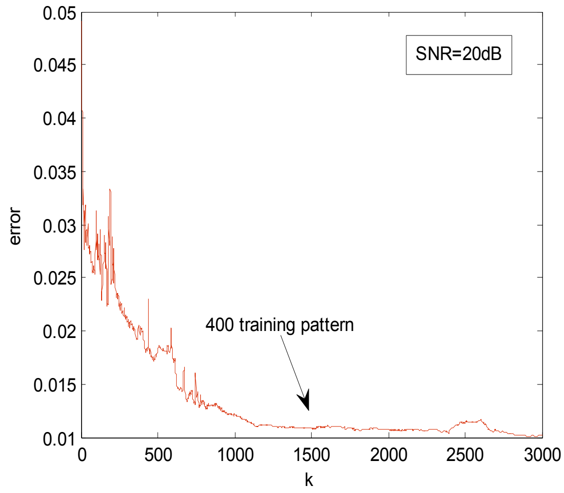
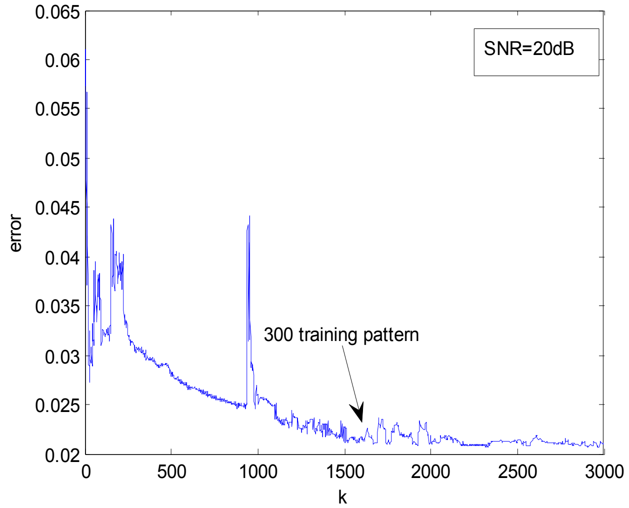


(a)



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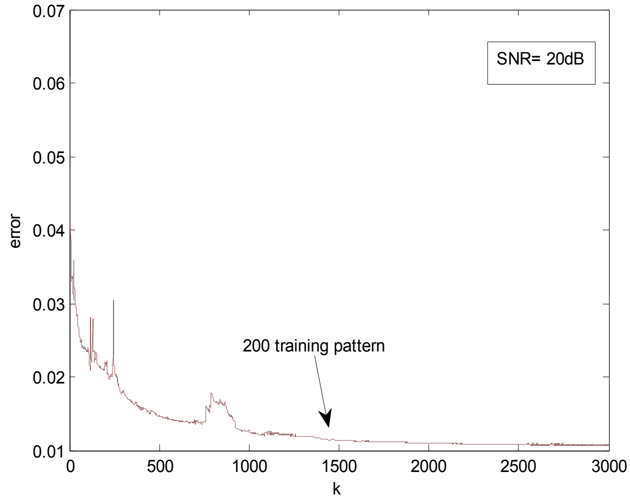
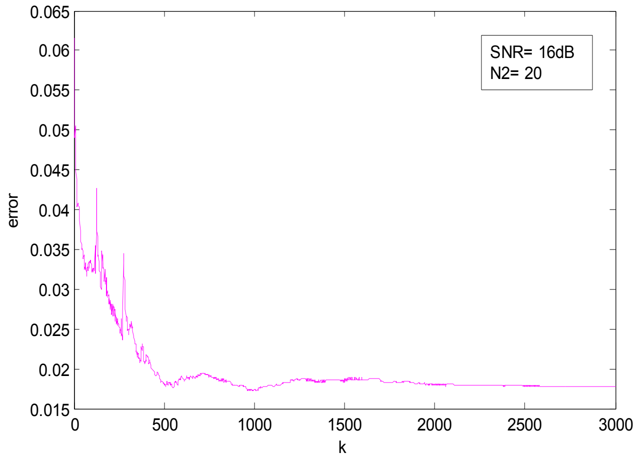


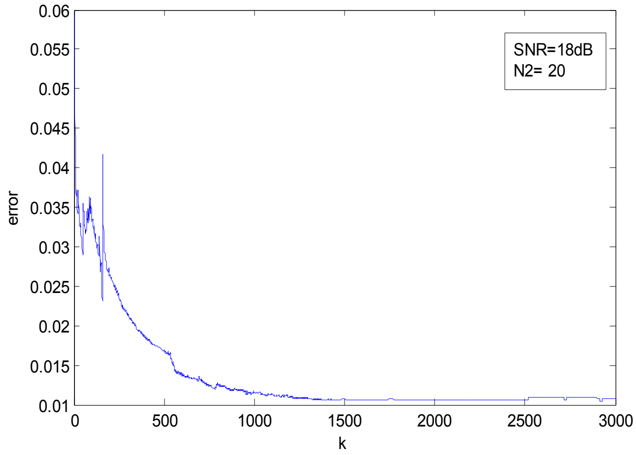
(c)

Figure 3. Convergence curve at SNR =20dB. (a) 400 training pattern, (b) 300 training pattern, (c) 200 training pattern.

The variety of graphs represents the convergence curve at SNR =16, SNR=18, and SNR=20 at N2=20 and N2=27 respectively.



(a)



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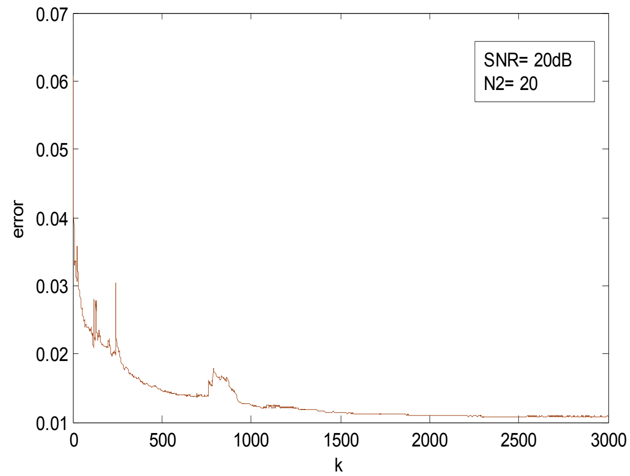

(c)

Figure 4. Convergence curve at N2=20. (a) SNR=16dB, (b) SNR=18dB, (c) SNR=20dB.

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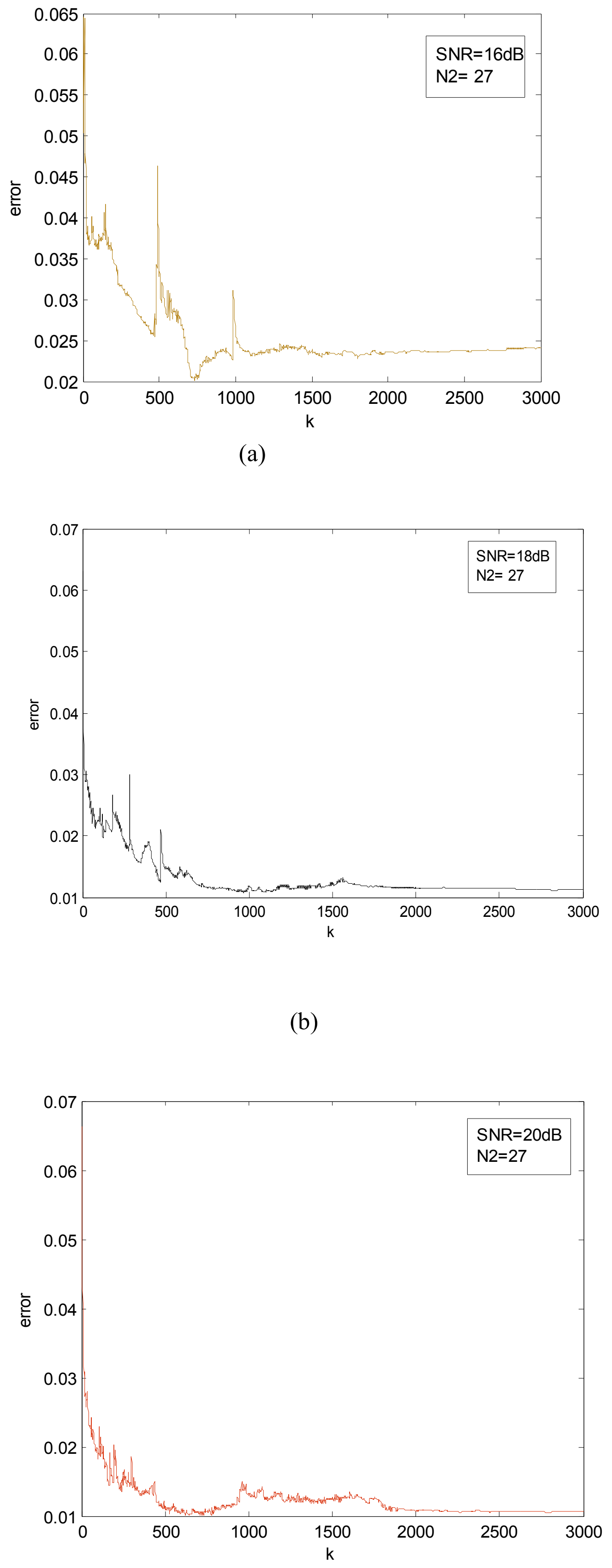

(a)

(b)

(c)

Figure 6. Convergence curve at N2=27, (a) SNR=16dB, (b) SNR=18dB, (c) SNR=20dB.

Comparatively study of N2=20 and N2=27 shown in fig.7 of proposed structure

The result obtains by averaged over 10 independent repetitions using testing samples of size 10^5 each. Fig.7 shows the plot of bit error rate (BER) performance of linear channel at N2=20 and N2=27. The variation of SNR from 2dB to 20dB and obtained the value of BER at every value of SNR.

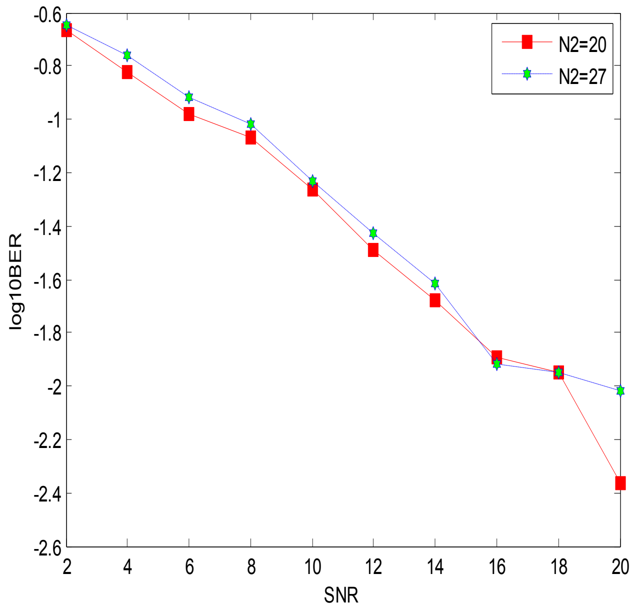

Figure 7. Plot of SNR versus BER

IV. CONCLUSION

Traditional equalizers using neural networks based on MLP, require large training time and RBF use large no. of structure thus increases complexity. The proposed structure of neuro-fuzzy system offers advantages of both the neural network and fuzzy logic. Gives us good training and BER performance.

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