ANN Based Equalization using Coded Inputs in Nakagami-m Faded Channel

Bidyut Bikash Baruah
Dept. of Electronics and Communication Technology Gauhati University Guwahati-781014, Assam, India,
bidyutb_baruah@yahoo.com

Kandarpa Kumar Sarma
Dept. of Electronics and Communication Technology Gauhati University Guwahati-781014, Assam, India,
kandarpaks@gmail.com

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[1]Bidyut Bikash Baruah & [2]Kandarpa Kumar Sarma

Dept. of Electronics and Communication Technology
Gauhati University
Guwahati-781014, Assam, India
Email: bidyutb_baruah@yahoo.com, kandarpaks@gmail.com

Abstract—**Equalization is often used in wireless communication to mitigate the effects of Inter Symbol Interference (ISI). The Artificial Neural Network (ANN) has been a preferred tool for performing equalization to reduce ISI. This work describes the use of ANN and coding to improve performance of an equalizer, designed to tackle fading effects of Nakagami-*m* channel. Improvement in performance has been shown for coded transmission over uncoded one in Nakagami-*m* channel with ANN based equalization.**

Keywords- ANN; Hamming Code; Nakagami-m.

I. INTRODUCTION

Due to the recent developments and advancements in mobile communication, there is a necessity of robust system which can minimize channel effects. The wireless network propagation environment shows stochastic behavior and is spread out in time, creating a phenomenon called ISI. To mitigate these multipath effects of the wireless channel, equalization is performed [1].

It can be stated from the available literature that, different feed-forward Neural Networks can be used for ANN equalization [2]. Nakagami-*m* channel can be well used in OFDM, MIMO, SISO system for linear channel estimation and channel equalization [3]. Nakagami random variable can be decomposed into orthogonal random variables with Gaussian distribution envelopes [4]. This work has been carried out as a continuation of such work considering the application of ANN as an equalizer in time varying multipath faded channel, described by Nakagami-*m* distribution. The joint effect of coding and equalization [5] has also been exploited to improve BER performance.

The first section gives a brief report about the necessity of equalization. Section II gives the system model of the work and a brief introduction of wireless transmission related concepts, problems and the means to tackle these problems. Section III provides the experimental details of the work. Section IV shows the detail of findings and results derived from the work and the last section concludes the work.

II. SYSTEM MODEL

The system model for the proposed work is designed as shown in Fig. 1. The model shows clearly how the ANN is used for equalization. The system components are briefly described next.

A. Equalization:

Equalization is a signal processing technique that can minimize ISI in the wireless channel. The designed equalizer is of supervised kind, where a training sequence is sent parallelly with the data. The equalization can be describe as,

$$Heq = \frac{1}{H} \qquad (1)$$

The equalized output becomes,

$$Y = XH_{eq} \qquad (2)$$

B. Hamming Coding:

In the proposed work, the (7, 4) Hamming code is used to encode *m* message vectors to *c* coded vectors [8], The coding operation can be denoted in matrix form as,

$$c=mG \qquad (3)$$

The decoding is done by finding the error syndrome of received vector *r* as,

$$S = rH^T \qquad (4)$$

where, *G* is the generator marix and *H* is parity check matrix . If there are no errors in the received codeword, then *S = 0*. If any error occurs in the received vector, then *S* will be,

$$S = (c \oplus e)H^T \qquad (5)$$

Where, *e* is the error vector.

C. Nakagami-m Fading Channel:

Fading signifies rapid fluctuations in amplitude, phase or multipath delays of radio channel over short period of time and distances [8]. In this work, the Nakagami-*m* distribution is used to generate the fading channel characteristics. The *pdf* of which is given by,

$$p_r(r) = \frac{2m^m r^{2m-1}}{\Gamma(m)\Omega^m} \exp(-\frac{mr^2}{\Omega}) \; ; r{\geq}0 \qquad (6)$$

where, $\Gamma(\cdot)$=gamma function.

Ω=average signal power.

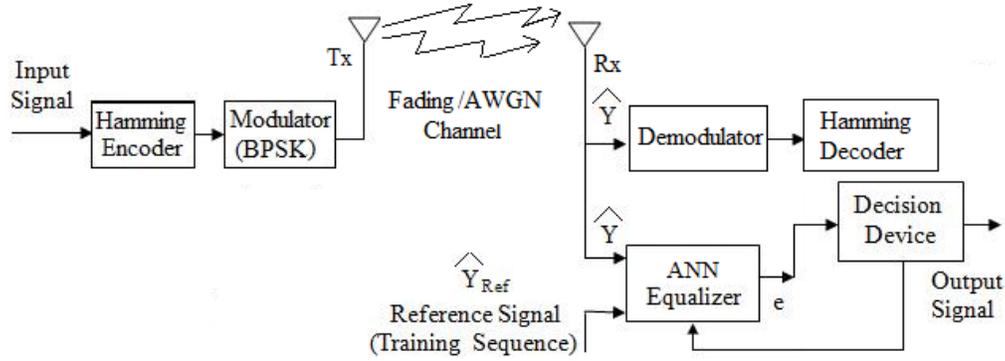If *m=1*, then the Nakagami-*m* distribution model becomes Rayleigh model. The Nakagami-*m*, will become Rician when,

Figure 1. System Model

$$m = \frac{(M+1)^2}{2M+1} \qquad (7)$$

where,
$$M = \frac{A}{2\sigma}$$

when, m→∞, Nakagami-*m* fading becomes impulse channel.

The Nakagami channel envelop, is generated using the envelop for Line of Sight (LOS), i.e. Rayleigh and Non Line of Sight (NLOS), i.e. Rician channel as,

$$R_{naka}(t) = |R_{Ray}(t)| \, exp(1-m) + |R_{Rice}(t)| \, (1-exp(1-m)) \,) \quad (8)$$

D. ANN model for Equalization:

Figure 2(a). Neural Network Model of the system showing Training Phases
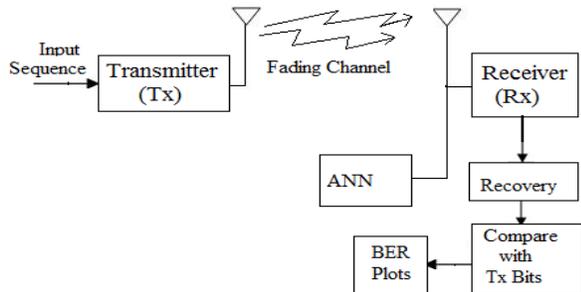
Figure 2(b). Neural Network Model of the system showing Testing Phases.

The ANN is a soft computational tool that can solve complex problems in communication by utilizing Transmitter, Receiver and Channel Side Information (TRCSI) properly [6]. ANN can be used for equalization by minimizing the Mean Square Error (MSE) between the desired signal and the received signal at the system output, where error can be define as [7],

$$e(t)=d(t)-Y_k(t) \qquad (9)$$

Fig. 2(a) and 2(b) shows the ANN based training and testing model for equalization.

III. EXPERIMENTAL DETAILS

Table I gives the details of specifications of the simulated system. The Nakagami-*m* fading channel is simulated by taking various values of *m* and Ω, and the detail specification of it is shown in Table II.

To perform equalization, ANN is first trained with the coded input signal in the transmitter and then it is sent through the Nakagami-*m* channel. At the receiver, the received signal, after suffering from fading, is tested and compared with the reference signal to check out the BER performance. The equalizer evaluates the error difference between the reference training signal and the received signal. The equalizer algorithm tries to achieve a minimum value of MSE [2]. The parameters for the ANN are considered by trial and error method. Table III presents the specification of the ANN.
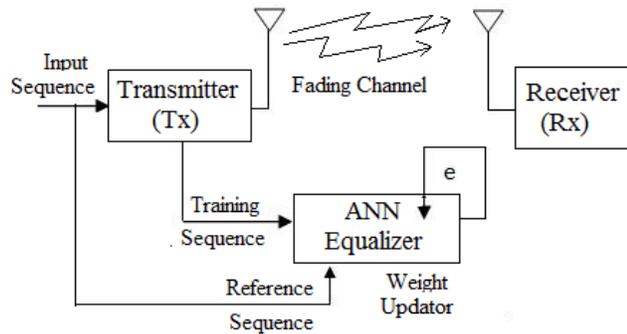
TABLE I.   PARAMETERS AND SPECIFICATION OF THE SYSTEM

Data set size	10^5
SNR Range	0-10 dB
Channel Type	Nakagami with AWGN
Modulation Type	BPSK
Error Correction Code	(7,4) Hamming code
Size of coded matrix	[250×7]

TABLE II. SPECIFICATIONS FOR NAKAGAMI CHANNEL

m- values	[1, 1.8, 4.5, 7]
Ω- *VALUES*	[1, 2, 3, 4]

TABLE III. ANN PARAMETER USED FOR TRAINING

ANN type	Feed forward
Number of Layers	One input, one hidden, one output
Hidden layer size	1.5 times of input
Input layer	Equal to transmitted data sequence
SNR consideration	±10 dB
Transfer function combination	Tansig- logsig-pureline
Convergence limit	10^{-6}
Training type	Back propagation with LM optimization
Training Set	20
Testing Set	30

TABLE IV. BER PERFORMANCE FOR DIFFERENT '*M*' VALUES

SNR(dB)	Ω-values	*m*-values	BER
10	1	1	10^{-1}
10	1	1.8	5×10^{-2}
10	1	4.5	5×10^{-3}
10	1	7	10^{-3}

TABLE V. BER PERFORMANCE FOR DIFFERENT 'Ω' VALUES

SNR(dB)	*m*-values	Ω-values	BER
10	3	1	10^{-1}
10	3	2	2×10^{-2}
10	3	3	5×10^{-2}
10	3	4	10^{-2}

IV. SIMULATION RESULTS

The Nakagami-*m* distribution is generated for different values of *m* and Ω values. Fig. 3 shows the probability density function (*pdf)* of the Nakagami-*m* distribution for different *m* values. Fig. 4 shows the BER performance of the equalizer without using coding. The use of coding improves the BER performance of the system as shown in Fig. 5, where the channel is simulated for different values of *m*. When the channel is simulated for different values of Ω, the BER responses are found to be as shown in the Fig. 6. Table IV and

Table V describes the BER results in details for different *m* and Ω values. It is tried to show the benefits of using coding in sense of error correction with uncoded ANN equalizer as shown in Table VI and Fig. 7, where, a coding gain of about 1.8dB is obtained at a BER value of 10^{-2}.
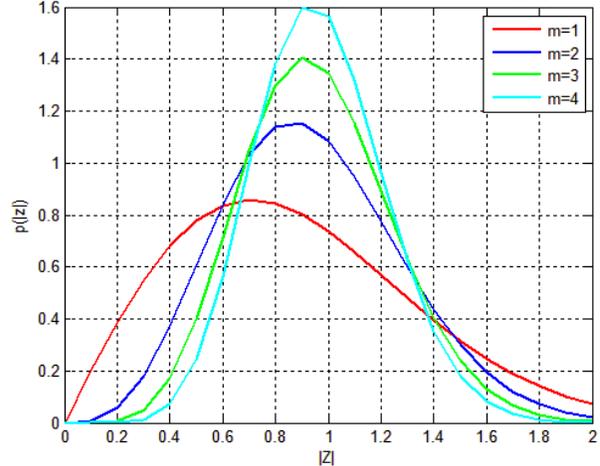
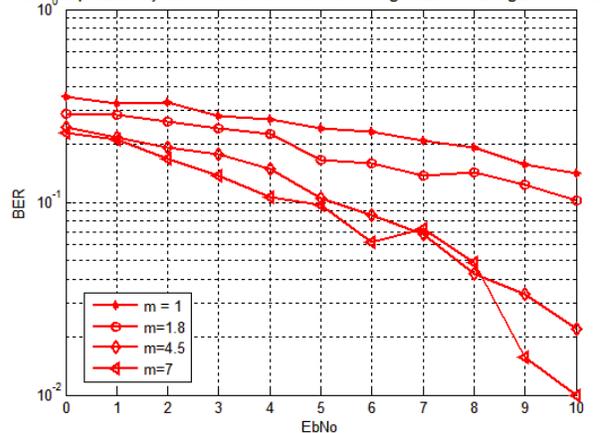Figure 3. Probability Density Function (*pdf*) for Nakagami-*m* channel for different *m* values.

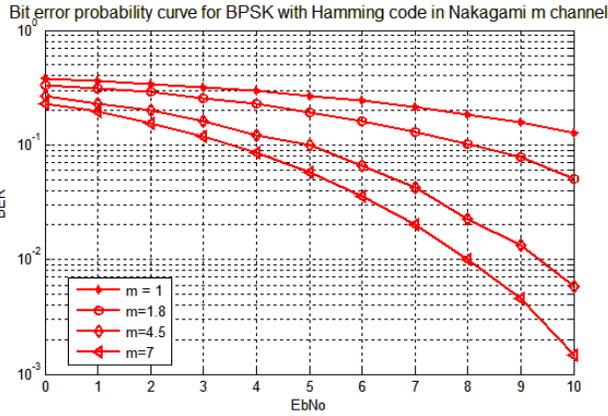Figure 4: BER response for Uncoded ANN Equalizer in Nakagami-*m* channel

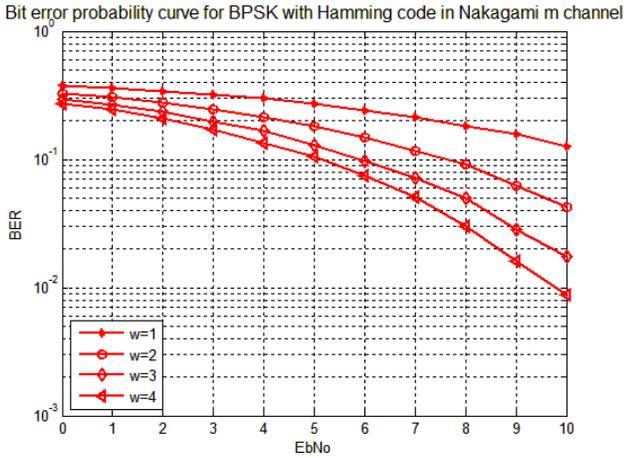Figure 5: BER response for coded ANN Equalizer in Nakagami-*m* channel

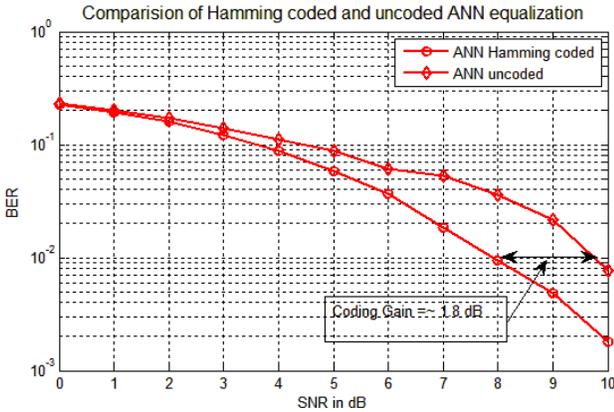Figure 6: BER response for Hamming coded ANN Equalizer in Nakagami-*m* channel for different Ω values.

Figure 7. BER response comparision for for Uncoded ANN and Hamming coded Equalizer in Nakagami-*m* channel.

TABLE VI. CODING GAIN.

BER Values	SNR of ANN Coded Signal	SNR of ANN Uncoded Signal	Coding Gain(dB)
10^{-1}	4dB	5dB	1dB
10^{-2}	8dB	9.8dB	1.8dB

The ANN during training meets the fixed goal with a time elapse of about 4.23 seconds and after successive batches of learning, it is applied for doing the equalization at the receiver end. The result shows the robustness of the designed system against ISI and other kinds of channel disturbances. The system output is equalized with reduced ISI along with minimization of induced noise effects. This way the proposed design can work as an equalization and noise cancellation system for faded wireless channel.

V. CONCLUSION

The result shows that, the ANN based equalization is much more reliable in lowering the ill-effects of ISI. The ANN based equalizer due to its adaptive learning capability generates a BER value which makes the reception quality superior. It also reduces noise related effects. Thus the designed system works well for equalization and noise cancellation, with an extra benefit by utilizing channel coding scheme.

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