**ABSTRACT**

The fundamental function of adaptive channel equalization is to compensate, eliminate or minimize distortion in a communication channel between a transmitter and a receiver. In this thesis, a Nonlinear Neuro Fuzzy Equalizer (NNFE) is proposed for the equalization of Quadrature Amplitude Modulation (QAM) signals in communication channels by improving the quality of complex signal transmission which eventually leads to more efficient communication. The presence of noise, intersymbol interference (ISI) and the time-varying characteristics of the communication channel necessitate the use of adaptive equalizers. A fuzzy adaptive filter is constructed from a set of fuzzy If-Then rules that change adaptively to minimize some criterion functions as new information becomes available. The fuzzy adaptive filter with the combination of neural networks is a significant type of adaptive equalizer which allows short training time of the equalizer, yields better results in terms of bit error rate (BER) and convergence rate with its efficient structure and design algorithms. The use of neuro-fuzzy equalizer in digital signal transmission allows decreasing the training time of the equalizer’s parameters and decreasing the complexity of the network. Normalization method applied at the transmitter side of the communications system is utilized and nonlinear neuro-fuzzy equalizer (NNFE) is employed for the equalization of QAM signals.

The purpose of this thesis is to successfully equalize QAM signals that are distorted by noise and channel conditions when transmitted through a communications channel before being received by an equalizer at the end of the system. It’s possible to reach fast and accurate equalizer output results with the aid of normalization technique in relatively small number of iterations. Convergence rate and BER performance comparisons have been carried out for 4-QAM and 16-QAM signals. The simulation results have revealed that the proposed nonlinear neuro-fuzzy equalizer (NNFE) can successfully minimize the errors and equalize both linear and nonlinear channels in addition to providing better convergence rate and improved BER performance for linear channel in severely noisy channel conditions.

Key words: Equalization, Quadrature Amplitude Modulation (QAM), bit error rate, nonlinear neuro-fuzzy equalizer, communications system, normalization.

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**ABBREVIATIONS USED**

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AM Amplitude Modulation

ANFIS Adaptive Neuro-Fuzzy Inference System

ANN Artificial Neural Network

AWGN Additive White Gaussian Noise

BCH Bose-Chaudhuri-Hocquenghem

BER Bit Error Rate (Probability of Bit Error)

CMA Constant Modulus Algorithm

COA Center of Average

COG Center of Gravity

CPU Central Processing Unit

DCS Digital Communications System

DFE Decision Feedback Equalizer

DSB Double Sideband

DSP Digital Signal Processing

DVB Digital Video Broadcasting

FBF Feedback Filter

FFF Feedforward Filter

FFNN Feedforward Neural Network

FIR Finite Impulse Response

FIS Fuzzy Inference System

IMD Intermodulation Distortion

ISDN Integrated Services Digital Network

ISI Intersymbol Interference

LMS Least Mean Square

LTE Linear Transversal Equalizer

MISO Multi-Input Single Output

MLP Multilayer Perceptron

MLSD Maximum Likelihood Symbol Detection

MLSE Maximum Likelihood Sequence Estimator

MMA Multimodulus Algorithm

MMSE Minimum Mean Square Error

MSE Mean Square Error

MQAM *M*-ary Quadrature Amplitude Modulation

NF Nonlinear Function

NN Neural Network

NNFE Nonlinear Neuro-Fuzzy Equalizer

NNFN Nonlinear Neuro-Fuzzy Network

NTSC National Television Standards Committee (USA)

PSD Power Spectral Density

PSK Phase Shift Keying

QAM Quadrature Amplitude Modulation

|  |
| --- |
|  |

PAL Phase Alternate Line (TV)

PAM Pulse Amplitude Modulation

RBF Radial Basis Function

RLS Recursive Least Squares

RNN Recurrent Neural Network

SISO Single Input Single Output

SNR Signal-to-Noise Ratio

TDMA Time Division Multiple Access

TSK Takagi-Sugeno-Kang

TV Television

**DECLARATION OF ORIGINALITY & CONTRIBUTION**

The originality and contribution of the thesis include the followings:

* *Development of a Normalizer-based nonlinear neuro-fuzzy equalizer for the channel equalization of multilevel Quadrature Amplitude Modulation (QAM) signals ,*
* *The construction of the mathematical model of the neuro-fuzzy equalizer based on gradient-descent algorithm,*
* *Simulation, analysis and comparison of the results of the Normalizer-based equalizer for QAM signaling by using MATLAB programming language,*

The routine used to carry out literature research is an exception.

**CHANNEL EQUALIZATION OF**

**QUADRATURE AMPLITUDE MODULATION (QAM) SIGNALS USING A NEURO-FUZZY EQUALIZER**

**A THESIS SUBMITTED TO**

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