ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Special Issue 1, February 2024

Adaptive Filter design using Adeline Neural Network for Modulated Signal De-noising

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Abstract*—The adaptive filter design is the still essential field of research. Since the acquired modulated data is suffered from AWGN additive noise while transmitted. Thus with the sophisticated receivers hardware's it is essential to design the adaptive filters at the front end. Filtering is intended to eliminate the AWFN noise. The paper is aimed to design the adaptive neural filter using Adeline and the BPNN based neural filter designs. The learning rates and weighing factor are varied to determine the best optimal solution based on the steepest decent search using both NN models. The modulated amplitude signals are simulated as the system of multichannel modulation. The noisy data is randomly generated to aid with the modulated signal. The noise eradication is achieved by using the BPNN and the ADALINE multi perceptron neural networks models based adaptive filters. The performance and results are based on expected error evaluation and proved BPNN superiority.

***Keywords*—Adaptive Filter, Neural Network, BPNN, ADALINE, Amplitude Modulation, AWGN Noise, Filter Design.**

I. INTRODUCTION

Any modern sensor suffers from a range of noises caused by random changes and predetermined distortions or shading. When we refer to an adaptive filter, it means one which is self-designing in the sense that it operates using a recursive algorithm. This allows the filter to function effectively even when full understanding of the essential signal attributes is not available. Filters can be categorized as the linear and non-linear. If a filter filters, it is considered to be linear. The linear distribution of the measurements applied to a filter input determines the smoothed or forecasted quantity at the filter's octant. The filter is non-linear in all other cases.

The current work proposes an adaptive noise cancellation technique-based neural network (NN) signal enhancement system. In a communication system, multi tone modulated signals are frequently being sent across a channel. In the current study, clean speech signals are simulated as multi tone and are exposed to additive weight random Gaussian noise (AWGN).

The noisy signals are then subjected to noise cancellation utilizing the BACK PROPAGATION (BP) and ADALINE based NN modeling. The effectiveness of the ADALINE and BPNN approach are compared, and the findings' functionality and evaluation are predicated using estimated error. By adjusting the system's learning parameters, and filtering order, for example, the effectiveness of the system is also evaluated. The basic design methodology diagram of the system is shown in the Figure 1. It can be clearly observed that filtering problem is first modeled and then weight adoption is achieved using the NN concept for optimum solution. The various filter application s are mentioned in the Table 1.These are categorized to class of identification, prediction, inverse modeling and interference cancelation to achieve the filtering.

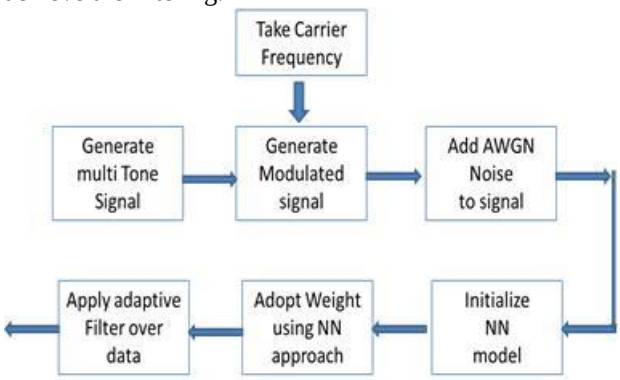

Fig 1: System block Diagram for adaptive Filter Design

Table.1. Applications of Adaptive Filters

Adaptive filtering Class	Application	Purpose
Identifications	Identification of System	Given an unknown dynamical system, the purpose of system identification is to design an adaptive filter that provides an approximation to the system.
	Modeling of Layered earth	In exploration seismology, a layered model of the earth is developed to unravel the complexities of the earth's surface.
Inverse modeling	Equalization of data	Given a channel of unknown impulse response. The purpose of an adaptive equalizer is to operate on the channel output such that the cascade connection of the channel and the equalizer provides an approximation to an ideal transmission medium.

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Prediction	Predictive coding	The adaptive prediction is used to develop a model of a signal of interest (e.g. a speech signal): rather than en-code the signal directly, in predictive coding the prediction error is encoded for transmission or storage. Typically the prediction error has a smaller variance than the original signal hence the basis for improved encoding.
	Spectrum analysis	Predictive modeling is used to estimate the power spectrum of a signal of interest.
Interference cancellation	Noise cancellation	The purpose of an adaptive noise canceller is to subtract noise from a received signal in an adaptively controlled manner so as to improve the signal to noise ratio. Echo cancellation, experienced on telephone circuits is a special form of noise cancellation. Noise cancellation is also used in electrocardiography.

II. MULTICHANNEL MODULATION GENERATION

The first step is the simulation of the amplitude modulated speech signal. The mathematical modeling equation for input sequence generation is shown in eq (1). . In this work the depth of modulation m is set to 0.8 to work near optimum.

$$X = (1 + m\ sin(2\pi * fa * t) +).* sin(2\pi fc * t) \quad (1)$$

The example of the amplitude modulated signal generation and the random noise addition is shown in the Figure 2.

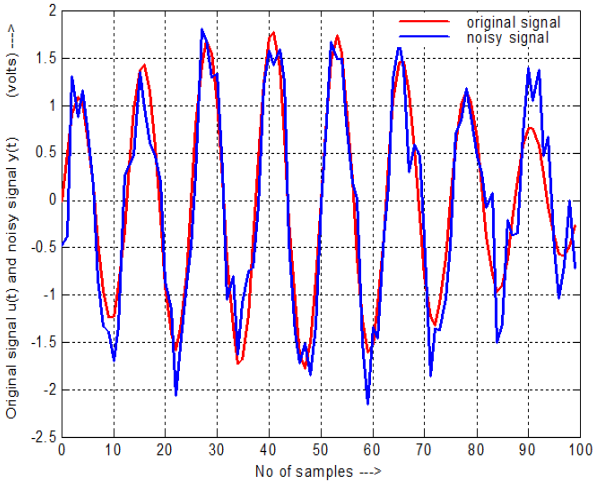

Fig. 2. Example of Modulated data and noisy data generation

III. REVIEW OF RELATED WORK

Stella, M et al [1] stated that ADALINE is a straightforward neural network they employ in their research as an adapting filter. Their tests were focused on how well car can cancel out engines noise. J. C. Montesdeoca et al [2] have preseted the performance evaluation of noise cancelers. In order to evaluate performance different changes are made, and there study provides an implementation example of a noise canceller utilizing the ADALINE network. Settings for audio recording, as well as a synaptic analysis Weights are used to assess the effectiveness of the adaptive filter. Pankaj Vyas et al [3] has preseted the design methodology of adaptive filter designs using the ADALINE and BPNN neural networks. They have preseted the estimation error and means square errors performance and stated that BPNN is best.

Yanji Jiang et al [4] has preseted enhanced BP technique for adapted noise cancellation is described in this research, which applies neural networks to adapted noise cancellation technology. First, a quick explanation of the adaptive noise cancellation technological premise is given, and then a list of some of the most popular adaptive noise cancelling algorithms is provided. Then, MATLAB simulates the adaptive noise reduction system built on neural networks from both perspectives. Two distinct signals are utilized to model the system when two noise sources are linearly coupled.

Ezilarasan et al [5] have proposed ADALINE (adaptive linear element), an effective flexible MAC (multiply accumulate) core-based finite impulse response (FIR) filter construction. The most popular techniques for maximizing filter coefficients are least mean square (LMS) and recursive least square (RLS). The RLS technique has not been favored for applications in real time despite surpassing the LMS because to its greater design arithmetic complexity. Rekha, K e al [6] has studied the NLMS algorithm is utilized to lower errors at the receiver's result in a wire-free communications system. A fifth order NLMS adaptive filter is designed with Verilog implementations. It has been demonstrated that the NLMS Algorithm exhibits good behavior when compared to conventional LMS. Together with charts produced in the Mat lab, the results of ModelSim simulations demonstrate the same.

Pari, B et al [7] have worked to suggest an efficient flexible FIR filter topology that uses a multiply-accumulate (MAC) core and is adaptable. The most popular filter coefficient optimization algorithms are recursive least square (RLS) and least mean square (LMS). Although the recursive least square (RLS) algorithm performs better than the least mean square (LMS), real-time applications have not favored it due of its greater design arithmetic complexity. Britto Pari et al [8] proposed a notion of time shared multiplier design is used in this research to present an effective adaptive FIR filter design employing a single multipliers and adder regardless of the number of taps. Output Product Code and paralleled pipe line multiplier are used for effective optimization of multiplier architectures. Verilog is used to

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create the suggested adapted FIR filter layout for 32 taps, and the XILINX VIRTEX-5 FPGA chip is used to synthesize it.

Q. Noman et. al. [9] has improved adapted noise cancelling (ANC) based on the normalized last-mean-square (NLMS) algorithms are the subject of this work. The filter length (Lj) parameter, which is determined in a 2n sequence of 2, 4, 8, 16,... 2048, and the step size (n), which is picked at random using variable n (VSS) optimization, are the parameters of the ANC-NLMS algorithm. The procedure is first put through an experimental process to determine the best n range for the particular situation of 11 Lj values.

J. Chhikara et al [10] have studied the least mean square (LMS) and non-local mean square (NLMS) algorithms are used to cancel noise on voice signals. Select algorithms that offers an effective performance while being less computationally complex. Jia-Haw Lee et al [11] basic noise-cancelling technique, the Least Mean Square (LMS) algorithm, is examined and improved with an adaptive filter in this study. The LMS adaptive filter method is used to simulate cancellation of noise. The LMS adaptive filter algorithm uses the engine noise signal and the speech signal that has been distorted by noise as inputs. To emphasize the degree of attenuation of the noise message, the filtered signal is contrasted with the initial noise-free speech signal.

IV. PROPOSED METHODOLOGY

The current study describes an adaptive noise cancellation-based NN signal quality enhancements system. Signals that have been multi tone modulated are sent through a channel in a wireless communication system. In this study, simulated signals have been transformed into noisy signals by introducing random or Gaussian noise. The noises from signals are subsequently cancelled using the BACK PROPAGATION procedure, and the results' effectiveness is assessed on the basis of estimated error before being subjected to the ADALINE method. The effectiveness of the system is also assessed by modifying filtering order, eta, and other factors. Similar noise cancelers are proposed by [12, 13 and 14] in recent times

A. ADALINE Network System

The ADALINE was recently used in a time domain noise cancelling investigation. The test statements are 100 amplitude-modulated samples in aggregate. Every word is sampled with a 4 KHz sampling rate and uses a 300 Hz modulation frequency. The pure voice signal is combined with the scalable and normalized random noise to create the contaminated speech. The ADALINE is then employed with the raw inconsistencies as the data being entered as signal and the degraded speech signal being the target signal. The ADALINE adjusts based on the LMS rule to remove noise out of the noisy signal and provide a pure speech signal. In this arrangement, the network's mistake is produced as a clean voice signal.

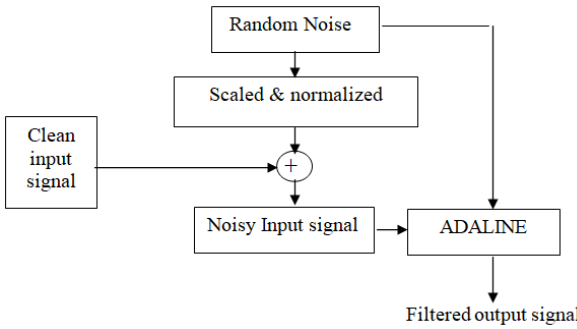

Fig.3.Block diagram of ADALINE NN network system

B. Filter Using Back Propagation

Basically, Back propagation [2, 3] is a gradient descent technique to minimize some error criteria E. In the batched mode variant the descent is based on the gradient $\nabla\acute{\varepsilon}$ for the total training set:

$$\Delta Wij\ (n) = -\eta \frac{\delta E}{\delta \omega} + \alpha * \Delta Wij\ (n\text{-}1) \quad (2)$$

It is based on steepest decent search. Where, η and α are learning rate along with momentum are two nonnegative constant quantities. When the error terrain is particularly flat, momentum may increase training, therefore leaning rate is kept low so as to preserve a smooth flight in the weight space. For the supervised development of multiplayer perceptron's, the back propagation NN (BPNN) technique has cemented its position as the backbone.

The algorithm offers a sophisticated approach to resolving the credit assignment issue. This issue is related to the fact because the error signals detected at the multiplayer perceptron's output layer are partially caused by the hidden neurons [13]. Since such neurons are physically unattainable, the application of intended responses for their individual outputs cannot be made, but the algorithm compensates for this shortcoming through layer-by-layer BPNN of erroneous signals through the network. Like the LMS Algorithm, the BPNN algorithm is resistant to disturbances.

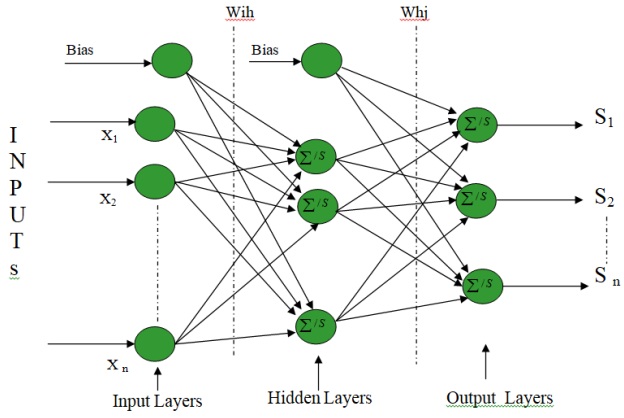

Fig.4. Multi perceptron NN model used for filter design

WEIGHT UPDATION For hidden to output layer weights are updated as:

ISSN: 2277-3754
ISO 9001:2008 Certified
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$$w_{hj}^{k+1} = w_{hj}^{k} + \Delta w_{hj}^{k} \quad (3)$$

$$= w_{hj}^{k} + \eta\left(-\frac{\partial \varepsilon_k}{\partial w_{hj}^{k}}\right) \quad (4)$$

$$+ w_{hj}^{k} + \eta\delta_j^{k}\delta\left(z_h^{k}\right) \quad (5)$$

For input to hidden layer weights:

$$w_{ih}^{k+1} = w_{ih}^{k} + \Delta w_{ih}^{k} \quad (6)$$

$$= w_{ih}^{k} + \eta\left(-\frac{\partial \varepsilon_k}{\partial w_{ih}^{k}}\right) \quad (7)$$

$$= w_{ih}^{k} + \eta\delta_j^{k}\delta_h^{k}x_i^{k} \quad (8)$$

This systematic approach is used as weight adoption procedure for BPNN Filter design.

V. RESULTS AND EVALUATIONS

In this section some of our adaptive filtering results are shown for AM signal modeling and filtering. Plots of the results are presented for number of samples N=100 for the sampling frequency as carrier frequency of audible range of fc=4kHz,. The message signal frequency range of the fa=300Hz, Ts=15 sec, is set as modulation frequencies sample duration.

The initial input data and the AWGN noisy data are shown in the Figure 5.

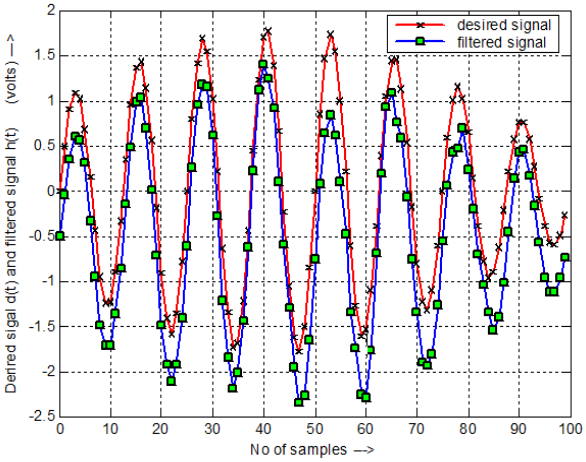


Fig.5.Simulation of the true data and noisy data

The desired signal is generated using the FIR filtered noisy data as shown in example of Figure 6. These desired signals are used to model the adaptive fitter from recursion process to filter the data. The adaptive filter is tuned and weights are updated optimally. Finally in this work the estimation error is calculated for the ADALINE and the BPNN based filter design models. The comparisons of the error with both models are shown in Figure 7. The BPNN offers minimum estimation error compared to that of the ADALINE. The respective parametric performance is plotted inn the Figure 8 the learning rate and momentum parameter are varied for the evaluation of the estimation error for BPNN based filtering.

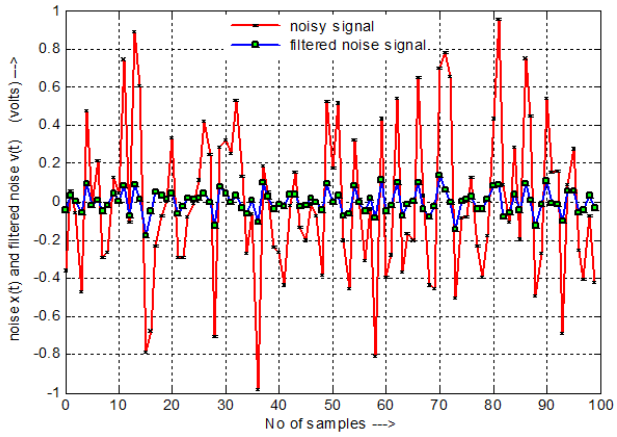


Fig.6. Results of desired signal using FIR filtering.

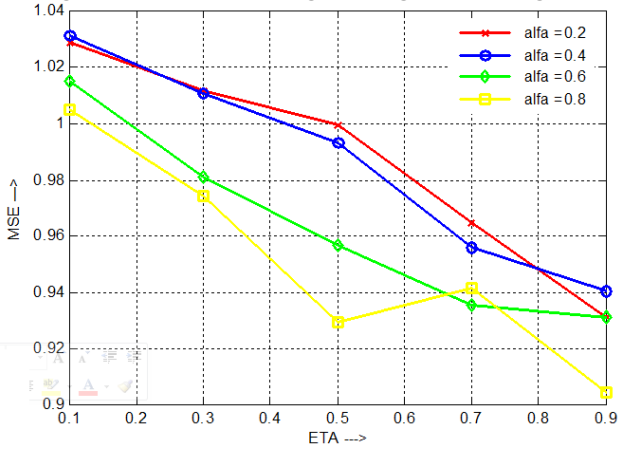
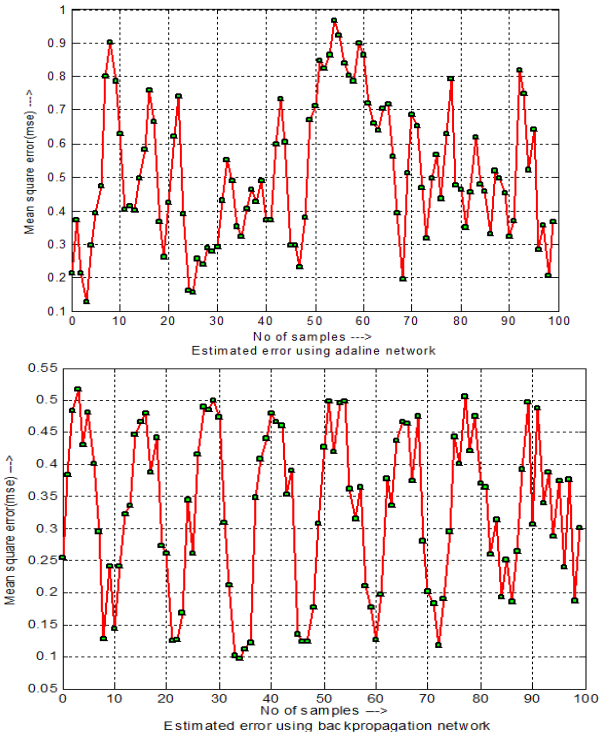


Fig.7. BPNN estimation error comparison for different η and α



a) Estimation error with ADALINE NN b) Estimation error with BPNN

Fig.8. Comparison of the estimation error of the ADALINE and BPNN based neural network for the sinusoidal input signal.

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ISO 9001:2008 Certified
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VI. CONCLUSIONS AND FUTURE WORKS

Adeline as well as BPNN-based NN filter designs will be used in this article to create an adaptive neural filter. To get the absolute result based upon the steepest decent search employing both NN models, the learning rates as well as momentum factor are changed. The multichannel modulation system is emulated using the modulated amplitude signals. For the benefit of the modulated signal, the noisy data is created at random. Adaptive filters based on the BPNN and ADALINE multi-perceptron neural networks models are used to eliminate noise. Based on predicted error evaluation, the performance and outcomes demonstrated the superiority of BPNN. The MSE is averaged from 0.5 to 0.6 with ADALINE network while the MSE is averaging from 0.25 to 0.3 with BPNN network.

In future the filter may be tested on real time communication system and can be tested under the fading environment.

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