Neural Detection of Quadrature Amplitude Modulated Signal

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Abstract— **Real communication channels with multipath propagation, various interference effects and possible nonlinearities pose difficult problem to the detecting receiver. Traditional receivers are unable to compensate for nonlinearities and they do not act well for interference effects also. This paper presents self-organizing (SOM) based receiver structure. It has been proved that the neural based structure is able to cancel the nonlinear effects and all the interference effects such as Inter-symbol interference. The results clearly indicate that the performance of this receiver structure is superior as compared to conventional ones.**

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. Introduction

Reliable detection of nonlinearly distorted and multipath propagated signal is the major problem of all telecommunication systems [1,5,6,7]. In a wireless mobile communication system, a signal which travels from transmitter to receiver gets corrupted due to various interference effects such as intersymbol interference (ISI), adjacent channel interference (ACI) and co-channel interference (ACI) as well as various distortions and noises. It also travels over multiple reflective paths, which is called multipath propagation. This causes fluctuations in amplitude, phase and angle of arrival of received signal, giving rise to multi path fading. Fading results from superposition of transmitted signals that have experienced differences in attenuation, delay and phase shift while traveling from transmitter to receiver. Thus fading refers to time variation of received signal power caused by changes in the transmission path. Detection comes across various complexes, random and unpredictable problems. Literature survey on digital communication through fading multipath channels, gives some clues regarding improvement of system performance after interference cancellation problems.

Conventional receivers are unable to compensate for nonlinearities and many complex problems. Hence some computational intelligence is required to deal with the complex problems, i.e. identify the problem and take necessary corrective action. Intelligent system is able to modify its action in the light of ongoing events. Such systems are adaptive and give the appearance of being intelligent as they change their behavior without the intervention of the user. Neural networks are non rule based intelligent systems with adaptive feature, which can further be made stochastic, so that the same action does not take place each time for the same input. Neural networks aim to perceive and comprehend significance of data with which they are trained. Stochastic behavior allows a neural network to explore its environment more fully and potentially to arrive at better solution than linear methods might allow [1,2,3]. Neural networks can be used in applications where a conventional process is not suitable or cannot be easily defined or cannot fully capture complexity in the data.

The results presented in this paper clearly indicate that the performance of this receiver structure is superior as compared to conventional ones. This is basically due to inherent capability of neural networks to adapt to various nonlinearities.

Basic system model used for this work is shown in figure 1. In this model, both the wanted signal s(t) and the interfering signal c(t) are 16 QAM, i.e. quadrature amplitude modulated digital signals. These signals are first Nyquist filtered with rolloff parameter of 0.5 and then transmitted through channels 1 and 2. The wanted signal channel is a two-path model whereas the interfering signal channel is a one-path model. The signals are then summed up and then the white Guassian noise is added. It is assumed that the transmitter causes nonlinear distortion to the signal of interest.

The complex valued received signal is first Nyquist filtered. The filtered result r(t) is then sent to rest of the receiver, i.e. combination of self organizing map (SOM) and decision feedback equalizer (DFE). The symbol interval is T and it is assumed that the interferer has a time shift of T/4 seconds as compared to source of interest. Bandwidth of the interferer is half than the bandwidth of the wanted signal. The wanted signal and the interferer are assumed to have a phase difference of $\pi/4$.

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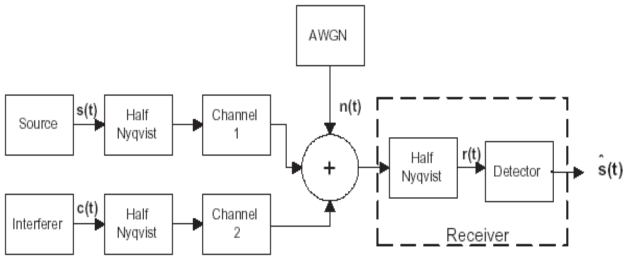

Figure 1. System model.

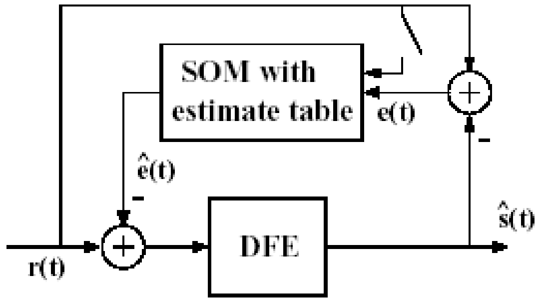

Figure 2: SOM detector

SOM detector:

Self-organizing map is a competitive neural network algorithm, which implements a characteristic of nonlinear projection from higher dimensional array of neurons to lower dimensional ones. SOM is able to map a structured data in ordered fashion.

In communication systems, as the signals are corrupted with various interfering effects, distortions, noise sources and various multipath fading effects. The errors caused by all these effects can be adaptively compensated using on line adaptive capability of SOM. It follows the nonlinearities of the signal constellation.

In the detector shown in fig.2, DFE is used to cancel the intersymbol interference. Other disturbances such as nonlinear distortions and co channel interference are cancelled by the feedback loop in which error signal corresponding to distortion are calculated.

In the SOM detector, samples are concatenated and classification is performed using sequence of samples. The input sequences of the map consists of error signals e(t) and current signal r(t). The best matching unit b(t) and its neighbors are updated. Error signal e(t) and the classification result of the previous round b(t – T) are used in updating an error estimate table.

Two versions of this detector are studied.

1. In the first one, (SOM1), the input signal vector to the SOM is a concatenation of the current signal and previous error [r(t)e(t-T)]
2. In the second case, (SOM2), input to the map is a concatenation of current and previous signal [r(t)r(t-T)]

Real and imaginary parts of QAM signal are processed independently.

Length of the SOM input vectors is 4 and size of the map is 4^4.

Simulation:

In this paper, interference cancellation in the receiver structure using ‘self- organizing map’ i.e. SOM algorithm has been investigated. Interference effects are provided by ‘Interferer’ block shown in figure 1. Here, Modulation method is 16 Quadrature amplitude modulation (16QAM). If the receiver structure is nonlinearly distorted then the signal constellations of 16QAM signal will appear in corner collapse or grid collapse form as shown in figure 3.

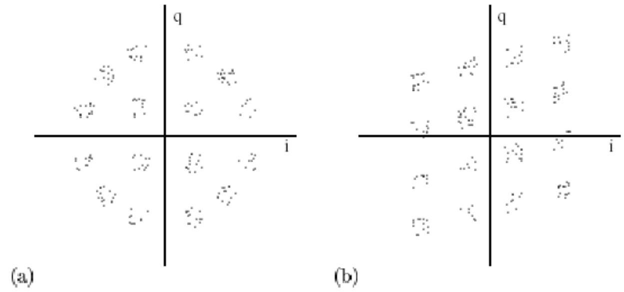

Figure 3 (Nonlinearly Distorted QAM constellation) a) Corner collapse b) Grid collapse.

Receiver structure with Decision Feedback Equalizer (DFE) without SOM has been simulated. Some simulation results are showing corner collapsed condition for 16QAM constellation as shown in part a of Figure 3, and some results show the grid collapsed constellation. When SOM part is included, then we get the results as shown in figure 4

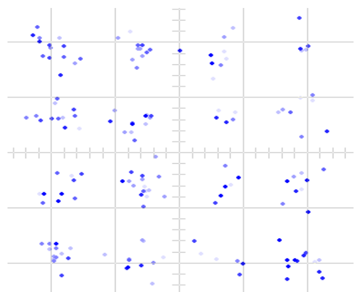

Figure 4 (16 QAM signal constellation)

In the simulation as shown in figure 5, effect of symbol to interference ratio has been studied on bit error rate of the system.

Simulation has been run 20 times using the same SIR values. In each run of 2000 samples, first 1000 samples are used to teach DFE and SOM. SOM and DFE coefficients are frozen after this pilot sequence.

Simulation results for this detector structure are shown for four cases as shown in fig.5. In this figure, bit error rate (BER) ratio versus symbol to interference (SIR) ratio plots can be seen for four cases.

a) Case-1: current signal and previous error are concatenated, and classification is performed using this sequence. (SOM1)
b) Case-2: current signal is processed and classified alone. (SOM2)
c) Case-3: In the case termed as 'without', the signal is only classified using predefined decision levels.
d) Case-4: In the case termed as 'DFE', the signal is equalized with the help of decision feedback equalizer.

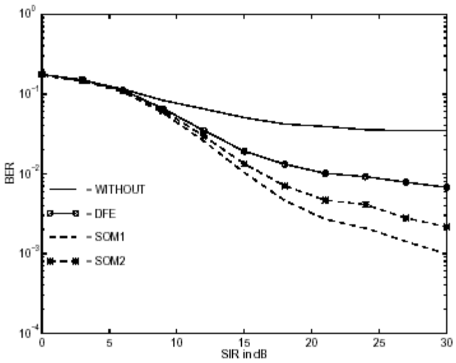

Figure 5: BER vs. SIR plot

II. Conclusion

When the receiver structure without SOM & DFE is simulated by processing current signal using predetermined decision levels, we get higher BER for SIR values ranging from 0-30dB. This is because of the interference effects. When DFE is included in the structure, we get improved BER vs SIR plot. This can be further improved using SOM block as the nonlinearities are compensated by SOM. When transmitter or receiver amplifiers introduce nonlinear distortions, QAM constellation gets distorted. SOM. This increases BER to some extent. When SOM is included, BER reduces.

Thus, the performance of neural detector is better than the conventional structures.

Acknowledgment

The preferred spelling of the word "acknowledgment" in American English is without an "e" after the "g." Use the singular heading even if you have many acknowledgments. Avoid expressions such as "One of us (S.B.A.) would like to thank ... ." Instead, write "F. A. Author thanks ... ." **Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page**.

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