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Detection Processes for Mitigating Intersymbol Interference

Muhanned AL-Rawi[1] and Muaayed AL-Rawi[2]

[1]Department of Electrical Engineering,University of Ibb,Ibb, Yemen
[2]Department of Electrical Engineering,University of AL-Mustansiryia,Baghdad, Iraq
[1]muhrawi@yahoo.com ,[2]muaayed@yahoo.com

Abstract—This paper deals with detection processes that used to mitigate intersymbol interference introduced by bandlimited communication channels. Three detectors have been considered, Nonlinear Equalizer, Equalized Viterbi Detector, and new Modified Equalized Viterbi Detector which represents the new contribution of this paper. Simulation results show that the performance of Equalized Viterbi Detector is better than the performance of Modified Equalized Viterbi Detector and the latter is better than the performance of Nonlinear Equalizer

keywords -Detection Processes; Intersymbol Interference

1. Importance of Study

Over the past decades, an increased demand for high-speed digital transmission was witnessed. This has resulted from the need for fully integrated speech and data services, as well as from an increased demand of high-speed radio communications, such as, indoor and mobile communications. On the other hand, the need to increase the efficiency of digital communication channels has led to the development of efficient high-level modulation schemes. High signaling rate digital communication systems utilizing high-level modulation schemes are very sensitive to intersymbol interference (ISI). The ISI degrades the performance of these systems and impose limitation on the data transmission rate.

2. Statement of Problem

Various detection techniques have been developed to overcome ISI. In general, detection processes may be classified into two groups depending on the way in which the detector tackles ISI.

In the first group, an equalizer is used to remove ISI from the received signal such that the individual data symbols are detected independently from the resultant signal. The process of removing ISI by the equalizer results in using only part of the transmitted signal energy in the detection of the data symbol with a consequent reduction in the tolerance to additive noise [14].

A second group takes account of ISI without removing it, thus using the entire transmitted energy. This technique is known as Maximum Likelihood Sequence Estimation (MLSE) [9]. Unlike equalizer, MLSE is optimum in the sense that under appropriate conditions, it minimizes the probability of error in the detection of the whole message. Viterbi algorithm (VA),[10], provides an efficient way of performing MLSE recursively when the length of channel impulse response (CIR) is finite. However, the complexity of VA increases with increasing CIR and data rate which in most cases prevents its usage in practice.

3. Methodology of Solution

Many techniques had been developed to reduce the complexity of VA. Some of these techniques employ a linear pre-filter equalizer in conjunction with VA. The aim of this equalizer is to shorten CIR in order to reduce the complexity of VA. These techniques are well known as Combined Linear-Viterbi Equalization (CLVE)[1],[2],[5],[8],[17].

Other techniques use nonlinear (decision feedback) equalizer (NLE) in conjunction with VA. The purpose of NLE is to make partial equalization for the channel [3], [4], [6], [7], [11], [12] ,[13] ,[15] , [16] ,[18] ,[19]. The Equalized Viterbi Detector (EVD) [3],[4] developed by AL-Rawi in 1997 is considered as one of these techniques.

4. Objetives

The main objective of this paper is to develop new detection technique that reduces the complexity of the VA and hence the complexity of whole detector model.

5. Model of Data Transmission

The data transmission system considered here is shown in Fig.1. The input to the transmitter is data symbols $\{s_i\}$ which are statistically independent and equally likely to have any of (m) given values. In the application over telephone channel to be considered here, m=16 and possible values of s_i are given by all combinations of ±a, ±b, ±ja, & ±jb where a=b=1&3, & $j=\sqrt{-1}$. The resulting output of the transmitter is Quadrature Amplitude Modulation (QAM) signal with carrier frequency of 1800Hz and symbol rate of 2400 baud giving an information rate of 9.6 kb/s to be sent over telephone channel which adds ISI and additive white Gaussian noise (AWGN) to the QAM signal. The receiver demodulate the QAM signal and its output is fed to the estimator to estimate impulse response of the channel and finally the detector model combats ISI and detects the original data.

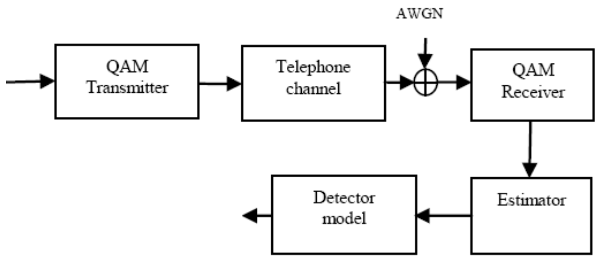

Figure 1. Model of data transmission

6. Detector Model

The detector model which is considered here is shown in Fig.2. When switch S1 is placed on position 1 or 2, and switch S2 is placed on position 1, then the detector model acts as nonlinear equalizer (NLE) with adaptive filter (S1 on position 1) or without adaptive filter (S1 on position 2). NLE works better with adaptive filter. The slicer in NLE is simple decision circuit, while, the feedforward transversal filter is responsible for removing ISI.

The adaptive filter operates so that all the roots of the channel impulse response lie inside the unit circle in the Z-plane. It concentrates the energy of the channel towards the earlier samples of the channel making CIR with minimum phase (or delay). This improves the performance of NLE since it works better without delay.

When S1 is placed on position 1 and S2 on position 2, the resulting detector is equalized Viterbi detector (EVD) developed by AL-Rawi in 1997 [3],[4].

When S1 is placed on postion 2 and S2 on position 2, new detector is developed named Modified Equalized Viterbi Detector (MEVD). Its complexity is less than EVD since it dose not use adaptive filter but its performance is little bit worse than EVD specially when most of the ISI is cancelled by feedforward transversal filter. This filter plays significant role in reducing the complexity of EVD & MEVD. If all ISI is removed by this filter, then EVD & MEVD act as NLE and Viterbi detector (VD) acts as simple decision circuit. If this filter does not remove ISI, then EVD & MEVD act as ideal VD and the complexity becomes very high. Here, only the first sample of ISI is treated by VD, while, the remaining ISI is removed by the feedforward transversal filter, therefore, EVD & MEVD work closer to NLE rather than closer to VD.

7. Computer Simulation Tests

A series of computer simulation tests have been carried out on the system in Fig.1 with three types of detectors, NLE, EVD, and MEVD, to determine their relative tolerance to AWGN when operating over telephone channel.

The performance of the whole system is measured by drawing symbol error rate versus signal-to-noise-ratio (SNR). The error rate is given by

$$\text{Error rate} = \text{NEDS/NTS}$$

Where NEDS is the number of erroneous detected samples & NTS is the number of total transmitted samples.

Fig.3 shows comparison among the three detectors. It seems that at error rate of 10^{-5} , the performance of EVD is better than the performance of MEVD by approximately 0.4dB. Also, the performance of MEVD is better than NLE by approximately 0.6dB.

8. Summary and Conclusion

Model of bandpass transmission system based on computer simulation was developed. The system operates at rate of 9.6kb/s using QAM signal to be transmitted over telephone channel. Three detectors have been involved in this simulation, NLE, EVD, and MEVD. The results show that the performance of EVD is better than MEVD and the latter is better than NLE.

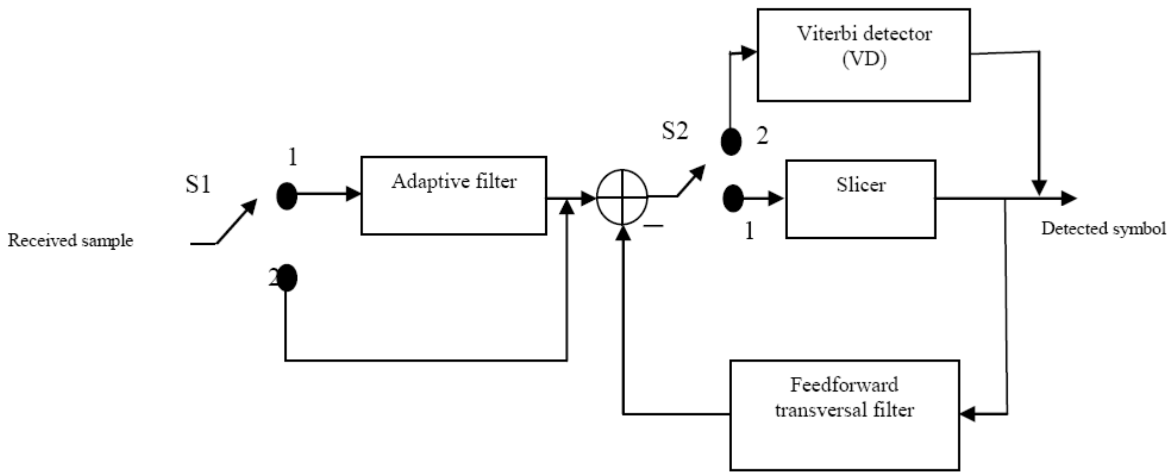

Figure 2. Detector model

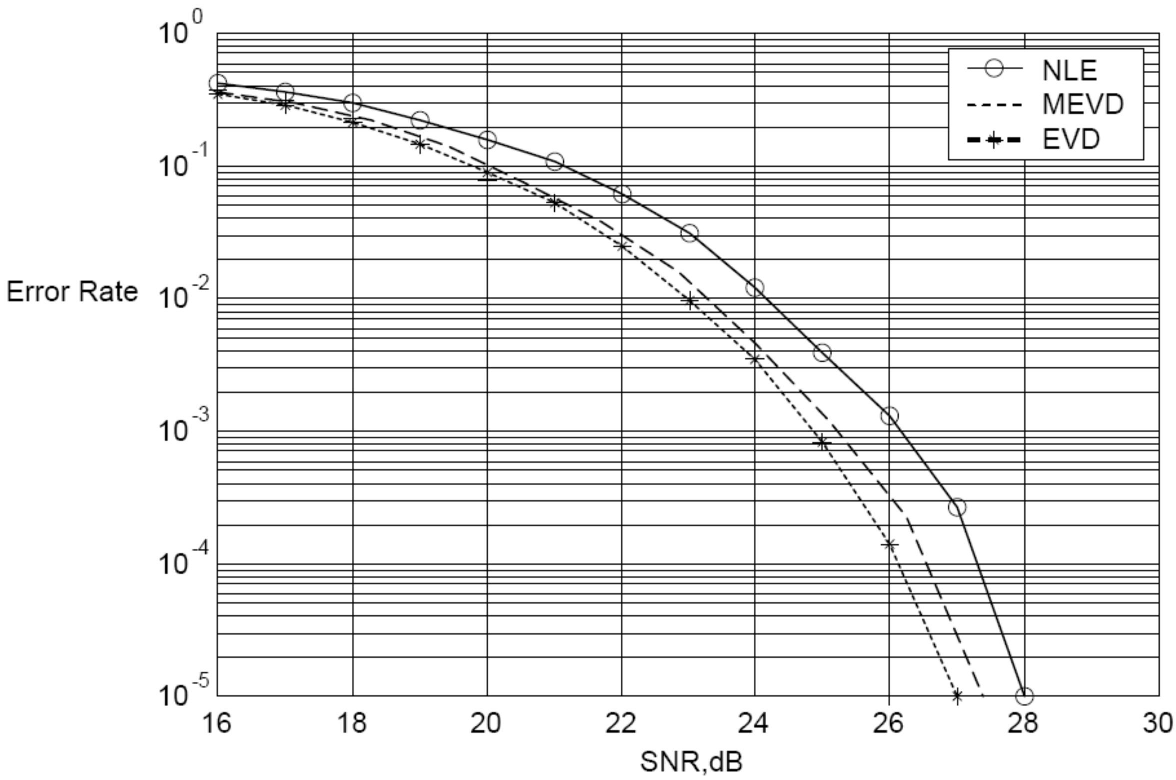

Figure 3. Error rate performance

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