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Retraining Data Sequence for Combined Detector

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Abstract. This work presents two detectors that are employed to manage the intersymbol interference that the communication channels introduce. These two detectors work by combining a Viterbi detector and a nonlinear equalizer. The second detector, which this study contributes, is called Combined Detector-2(CDR2). The first detector, which was previously constructed, is known as Combined Detector-1(CDR1). With a different data sequence, CDR2 is comparable to CDR1. Data transfer at 9.6 kbps over telephone channel is used to test these detectors with a nonlinear equalization. According to simulation data, the CDR2 performs better than the CDR1, whereas the nonlinear equalizer performs better than the CDR1.

Keywords: Viterbi detector, retraining data sequence, nonlinear equalizer, MLSE.

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Последовательность данных повторной тренировки для комбинированного детектора

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Аннотация. В этой работе представлены два детектора, которые используются для управления межсимвольными помехами, которые вносят каналы связи. Эти два детектора работают, объединяя детектор Витерби и нелинейный эквалайзер. Второй детектор, который вносит вклад в это исследование, называется комбинированным детектором-2 (CDR2). Первый детектор, который

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был ранее сконструирован, известен как комбинированный детектор-1 (CDR1). С другой последовательностью данных CDR2 сопоставим с CDR1. Передача данных со скоростью 9,6 кбит/с по телефонному каналу используется для тестирования этих детекторов с нелинейным эквалайзером. Согласно данным моделирования, CDR2 работает лучше, чем CDR1, тогда как нелинейный эквалайзер работает лучше, чем CDR1.

Ключевые слова: детектор Витерби, последовательность данных повторной тренировки, нелинейный эквалайзер, MLSE.

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Introduction

Intersymbol interference (ISI) is one of the various types of impairments that the communication channel contributes into the digital data transmission system. At the receiver end, ISI is handled using adaptive linear or nonlinear (decision-feedback) equalizers [4]. It is generally known that using the Viterbi algorithm and a maximum likelihood sequence estimation (MLSE), one can significantly outperform equalization approaches in terms of detection performance [6, 7].

The Viterbi technique includes an excessive quantity of storage and an excessive number of operations per received data symbol when the channel's sampled impulse response has a large number of component parts. To accomplish the performance of the MLSE at reduced complexity, extensive study has been done.

The article in [3] investigates and contrasts two approaches for simplifying the Viterbi detector (VD) using feedback from the VD's built-in preliminary judgments.

Both techniques employ these choices to eliminate trailing ISI in an effort to shorten the channel's effective memory and, consequently, the number of states kept in the detector. They are different in that the second technique performs local cancellations for each state in the VD based on the related survivors, whereas the first method does a single cancellation based on the most likely survivor living in the VD.

In accordance with one implementation of the present invention detailed in patent [5], an MLSE sub-receiver has an MLSE equalizer device that generates equalized data in response to input data. The transferred data is used to generate the input data via wireless transmission. With the use of a known codebook and the residual channel response, the MLSE equalizer device analyses the incoming data to create an MLSE codebook. The MLSE sub-receiver also has an MLSE decoder that can process the equalized data and the MLSE codebook to find the combination of the two that has the highest likelihood. The MLSE decoder employs the highest probability for decoding the equalized data in order to produce a decoded transmission of data while minimizing the effects of multi-path communication channel.

A device and method for implementing an equalizer that combines the advantages of a decision feedback equalizer (DFE) and a maximum-a-posterori (MAP) equalizer (or MLSE) are described in patent number [11]. This results in an equalization device that is significantly less complex than a full-state MAP device but still performs better than a conventional DFE. Two DFE-like structures precede a MAP equalizer in the equalizer design. The initial DFE makes hesitant symbol selections. The channel response is then truncated using the second DFE to a desired memory of L1 symbols, which is less than the channel's total delay spread of L symbols. The MAP equalizer operates on a channel with L1 symbols in memory (where L1=L), decreasing the equalizer's complexity overall.

The topic of the study in [10] is the development of coupled linear Viterbi detection, or optimal channel shortening, methods for ISI and MIMO channels. In the case of MIMO channel shortening, a trellis is used in place of a tree structure to represent MIMO signals. The feasible information rates of the shorter models are computed, and optimization is carried out from an information theoretical standpoint. All of the parts of the class's best detector are deduced from closed form expressions. Additionally, we demonstrate how the obtained model can be understood as a specific example of previously described channel shortening strategies.

A unique MLSD receiver structure for nonlinear channels is presented in the study in [8]. The NLC is viewed as a multiple input/many output system in order to develop this strategy. Then, using a unique variant of the space-time whitened matched filter (ST-WMF) created by modifying the Gram-Schmidt orthogonalization of the NLC's Volterra kernels, orthogonal signal components are computed. The ST-WMF is followed by a VD with multidimensional branch metrics in the MLSD receiver. In the presence of highly dispersive NLC, the ST-WMF's space orthogonalization and noise whitening provide an effective solution to reduce receiver complexity. In real-world applications like intensity modulation/direct detection (IM/DD) optical channels, complexity reduction is essential. For instance, compared to an oversampled MLSD, the number of states of the VD in ST-WMF-MLSD required over a 10 Gb/s, 700 km, IM/DD fiber-optic link is decreased by eight times.

Two low-complexity 2-D soft-output Viterbi algorithm (SOVA) detector design methodologies are presented in the study in [12], and they each represent a different complexity versus performance trade-off for multitrack joint 2-D detection. This research demonstrates that, in comparison to the best symbol-based 2-D SOVA, it is possible to achieve nearly the same detection performance while reducing the silicon area by more than 60 % in three-track joint detection. This is done through simulations and application-specific integrated circuit design..

The adaptive near maximum likelihood detector, which combines pseudobinary and pseudoquaternary near maximum likelihood detection methods, is described in the article in [1]. According to simulation data, adaptive near maximum likelihood detector performance is slightly better than pseudoquaternary near maximum likelihood detector performance, but slightly poorer than pseudobinary near maximum likelihood detector performance.

Data transmission system

The model of the data transmission system is shown in Fig. 1. Each 4-bit of binary data generated by the model's first component, a random data generator, is mapped into a 16-point QAM constellation. As a result, the random number generator outputs the data symbol «si,» and all combinations of «1, «3, and «j1, «j3» are valid si values. The Quadrature Amplitude Modulation (QAM) transmitter, which comprises of a transmitter filter and a QAM modulator, then receives the data symbols. Before the signal is modulated, the transmitter filter, which is a low-pass filter, limits the signal spectrum. The QAM transmitter's output is a QAM signal with an information rate of 2400x4bits=9600 b/s=9.6kb/s and a carrier frequency of 1800Hz. Before approaching the QAM receiver, the QAM transmitter's output travels over a telephone channel and is amplified by Additive White Gaussian Noise (AWGN). The QAM demodulator and receiver filter make up the QAM receiver. To provide realistic levels of intersymbol interference, the transmitter filter is used with the receiver filter, a low-pass filter. The Least Mean Square (LMS) estimator uses the data symbols ri from the output of the QAM receiver to

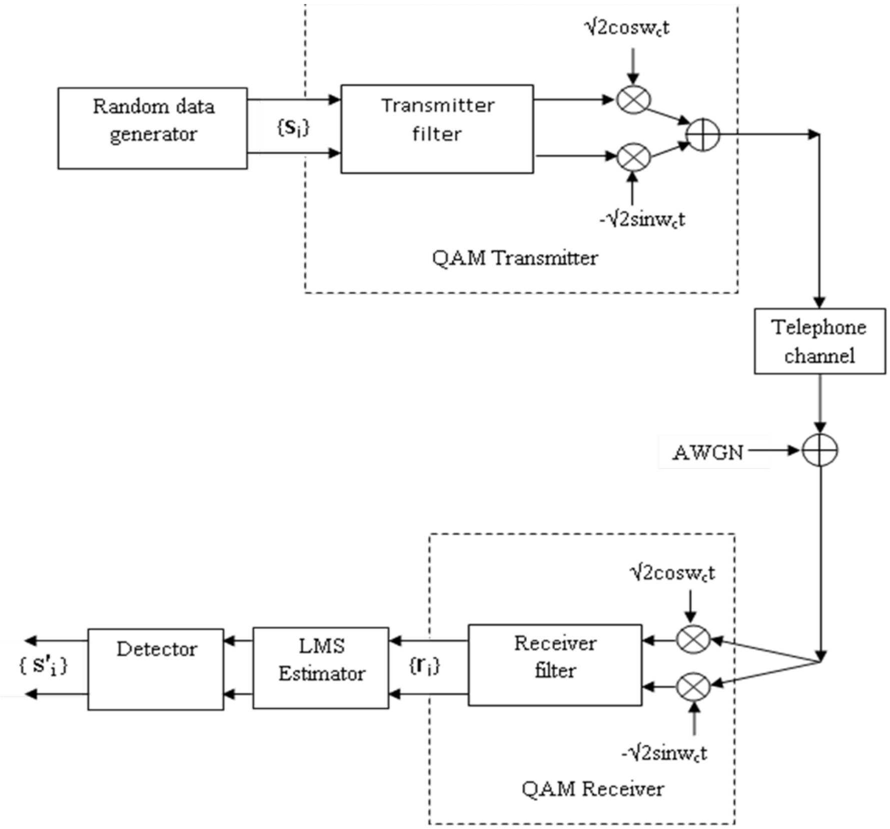

Fig. 1. Model of data transmission system

estimate the sampling impulse response (SIR) of the baseband telephone channel. Finally, the detector uses the data symbols ri and SIR to produce the observed symbols (s'i).

Detectors

Combined Detector-1(CDR1)

This detector, which was first created in [5], combines a Viterbi detector and a nonlinear equalizer, as seen in Fig. 2. The output of the VD, which is the identified sample s'i, is sent to the NLE through a linear feedforward transversal filter. To provide the input signal to VD, the output signal from this filter is subtracted from the sample ri that was received. Because of this, the NLE employs the quantized feedback correction to completely or partially remove ISI from the detector input signal, as will be discussed below.

The sampled impulse response of the baseband channel is given by (g+1) component row vector as

$$h = [h_0 h_1 \dots\dots\dots\dots\dots\dots h_g] \tag{1}$$

Thus the received sample value is

$$r_i = s_i h_0 + \sum_{j=1}^{g} s_{i-j} h_j + w_i \tag{2}$$

Where S_i is the wanted transmitted sample, w_i is noise component, and ISI is

$$ISI = \sum_{j=1}^{g} s_{i-j} h_j \tag{3}$$

The input signal to VD will be as follows, if ISI is completely eliminated by a linear feedforward transversal filter (assumed to be the case that the detected sample s'i= transmitted sample

$$x_i = s_i h_o + w_i \tag{4}$$

In this scenario, VD functions as a straightforward threshold circuit, and CDR1 acts as an NLE. However, if a portion of the ISI is eliminated by a linear feedforward transversal filter, VD then deals with the remaining portion of the ISI, as mathematically depicted below.

The received sample in eq.2 can be rewritten as

$$r_i = s_i h_0 + \sum_{j=1}^{m} s_{i-j} h_j + \sum_{j=m+1}^{g} s_{i-j} h_j + w_i \tag{5}$$

and the input to VD is

$$x_i = r_i - \sum_{j=m+1}^{g} s_{i-j} h_j = \sum_{j=1}^{m} s_{i-j} h_j + w_i \tag{6}$$

Where the second part of ISI is removed by linear feedforward transversal filter.

It is evident from eq. 6 that as m increases, the portion of ISI addressed by VD grows and, consequently, the complexity of VD increases; nonetheless, performance will improve as m increases. In this case, m is set to one (m=1) to reduce the complexity of VD, and the input to VD becomes

$$x_i = s_i h_o + s_{i-1} h_1 + w_i \tag{7}$$

From eq. 7, it is clear that the length of the channel's SIR becomes g+1=2, which considerably reduces the complexity of VD.

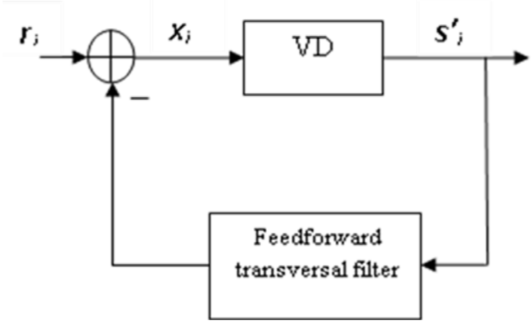

Fig. 2. Block diagram of CDR1

Combined Detector-2(CDR2)

This detector is comparable to CDR1, with the exception that it begins using correct discovered data symbols (si) from the known retraining period at the end of the training period. As a result, at the end of each retraining period, the intersymbol interference (which is the second part of Eq. 6) will be correctly cancelled. Fig. 3 depicts the transmission order of information data and training. Communication systems currently employ retraining [2, 9].This detector employs it.

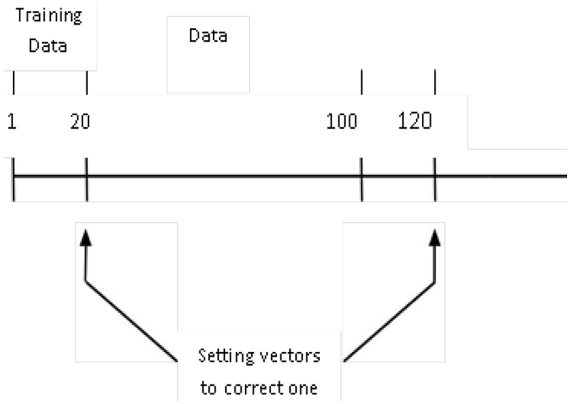

Fig. 3. Retrainingcase

Simulation results

To find out how well the three types of detectors, NLE, CDR1, and CDR2, tolerate AWGN when operating across telephone channels, a series of computer simulation tests have been run on the system in Fig. 1.

By plotting symbol error rate (SER) vs signal-to-noise ratio (SNR), the performance of the entire system is evaluated. SER is provided by

$$SER= NEDS/NTS$$

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

The performances of the three detectors are shown in Fig. 4. The performance of CDR2 appears to be 2 dB better than that of CDR1 at an error rate of 10–5. Additionally, CDR1's performance is 0.6dB better than NLE's performance.

Summary and conclusion

On the basis of computer simulation, a bandpass transmission system model was created. The system uses a QAM signal that is transmitted through a telephone channel to operate at a rate of 9.6 kbps. This simulation has utilized the NLE, CDR1, and CDR2 detectors. The outcomes demonstrate that CDR1 performs better than NLE, but less well than CDR2.

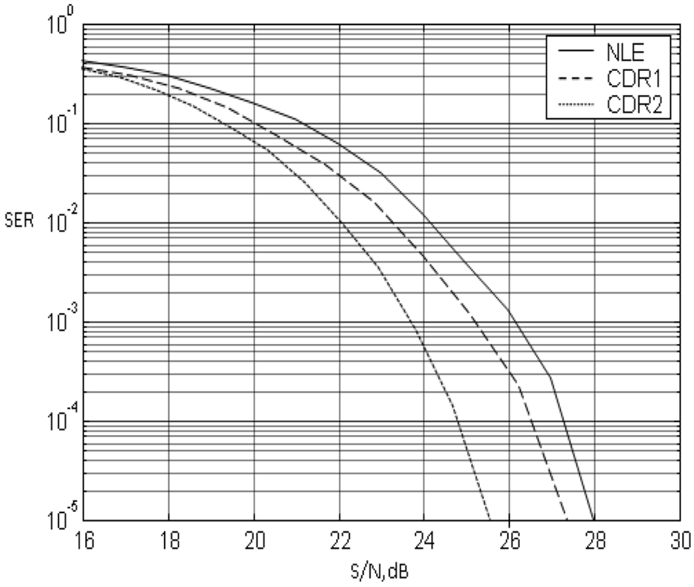

Fig. 4. Error rate performance

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