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A SURVEY ON DECISION FEEDBACK EQUALIZERS

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ABSTRACT

Wireless channels seldom fulfill the conditions needed for distortion-less transmission. Practical wireless channels suffer from the effect of a non-flat magnitude response and a non-linear phase response that leads for distortions in the received signals. Moreover effects such as small scale fading, large scale fading and Doppler shifts lead to dis-similarity between the transmitted and received signals. Wireless channels not showing the ideal impulse response leads to the reception of multiple copies of the transmitted signal at the receiver thereby resulting in Inter Symbol Interference (ISI). A cumulative and cascading effect of the above mentioned reasons results in the degraded performance of digital communication systems. To circumvent these detrimental effects, several equalizer designs have been proposed. This paper focuses on the design aspects of equalizers with an inclination towards decision feedback equalizers, due to their efficiency in nullifying the detrimental effects of practical wireless channels.

Keywords:* *Frequency Selective Channel, Equalizer, Decision Feedback Equalizer, Bit Error Rate (BER), Probability of Error (P_e), Throughput.

INTRODUCTION

As Since Wireless channels introduce several degradation effects on the signal passing through them, therefore its important to reverse the effects of the channel. A mechanism that reverses or nullifies the derogatory effects of distortion introducing channel is called an equalizer. The rate of data transmissions over a communication system is limited due to the effects of linear and nonlinear distortion. Linear distortions occur in from of inter-symbol interference (ISI), co-channel interference (CCI) and adjacent channel interference (ACI) in the presence of additive white Gaussian noise. Nonlinear distortions are caused due to the subsystems like amplifiers, modulator and demodulator along with nature of the medium. Sometimes burst noise occurs in communication system. Different equalization techniques are used to mitigate these effects. Different applications and channel models suit a different equalization technique.

SYSTEM IMPLEMENTATION

The block of a digital communication system with an equalizer is shown below

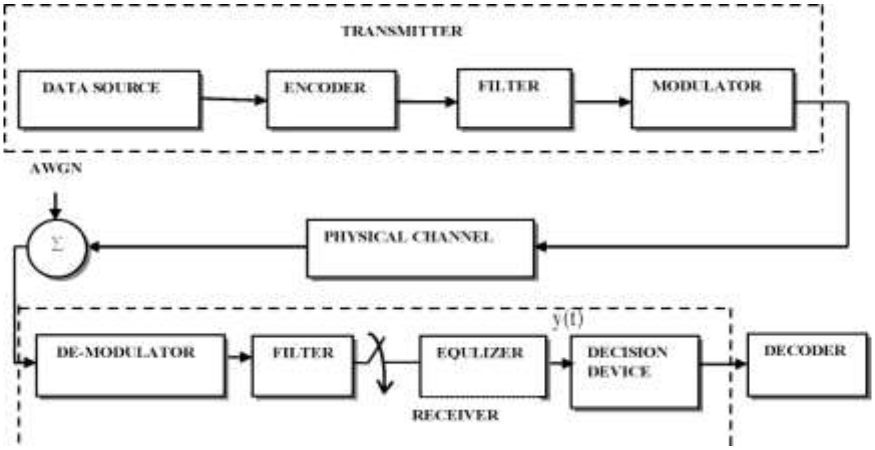

Fig.1 Block Diagram Digital Communication with Equalizer

The equalizer tries to mitigate the effects of the wireless channels that cause distortions at the receiver. It can be seen that the equalizer acts just prior to the receiver after sensing what the channel has done to a signal. . In mobile radio channels always changes and multipath causes time dispersion of the digital information is known as inter-symbol-interference, it makes too difficult to detect the actual information at the receiver. Moreover it cannot be rectified even by increasing the signal power at the transmitting end. Therefore such errors are called **irreversible errors.** The only way out is to reverse the detrimental effects using equalizers so as to improve the reliability of communication through wireless and broadcast modes.

Let the channel have an impulse response h(t). Since any practical system can sense the channel in the discrete time domain, therefore the channel impulse response can be re-considered as h(n). Let the channel in the frequency domain be H(z). Then the output of the channel is:

$$y(n) = x(n) * h(n) \qquad (1)$$

$$Y(z) = X(z).H(z) \qquad (2)$$

Where, * stands for convolution
x(n) is the input to the channel
y(n) is the output of the channel

The aim at design of an equalizer is the design of a system with a transfer function

$$E(z) = \frac{1}{H(z)} \qquad (3)$$

There are several ways in which the system with the transfer function E(z) can be practically implemented. The different techniques result in different equalizer structures. Different equalizer structures can be Linear Equalizers, MLSE Equalizers, Zero Forcing Equalizers, Adaptive Equalizers, and Decision Feedback Equalizers etc.

THE DECISION FEEDBACK EUALIZER

The main idea behind the design of a decision feedback equalizer is the fact that if bit errors in the output can be fed back to the system to update tap weights of the equalizer filter, then subsequent errors can be reduced. The following figure shows the design of a DFE.

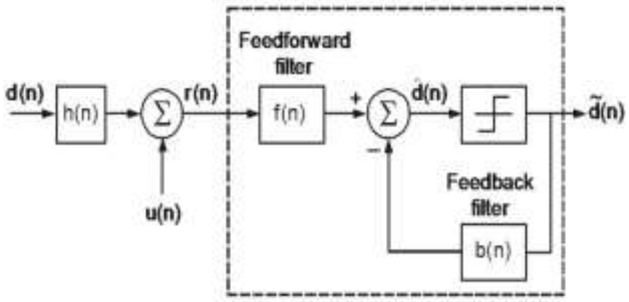

Fig.2 Block Diagram Digital of a Decision Feedback Equalizer

Here,
d(n) is the input to the equalizer,
f(n) and b(n) are the time domain response of the feed forward and feedback filter s respectively
d(n) is time domain response of the decision device

PREVIOUS WORK

In [1], Maurizio Magarini et.al proposed a hybrid decision feedback equalizer (DFE) as a combined time-frequency domain implementation of the conventional time-domain DFE that is able to provide a good trade-off between performance and computational complexity in single carrier transmission over severely frequency-selective channels. In the hybrid DFE the implementation of the feed forward filter is done in the frequency domain, while the feedback filter (FBF) is implemented in the time-domain. The computation of the coefficients for the two filters is usually done in the same domain where they are implemented. A method for frequency domain computation of the FBF is proposed in the paper. As is known, the key operation in the computation of the FBF is the spectral factorization. In the paper it is proposed to adopt the method for spectral factorization due to Kolmogoroff, which can be efficiently implemented by using the fast Fourier transform (FFT).

In [2] Fie Yuan et.al proposed a comprehensive review of decision feedback equalization (DFE) for multi-giga-bit-per-second (Gbps) data links. The state-of-the-art of DFE for multi-Gbps serial links reported in the past decade are compiled and presented. The imperfection of wire channels, in particular, finite bandwidth, reflection and cross-talk and their impact on data transmission are investigated. The fundamentals of both near-end and far-end channel equalization to combat the effect of the imperfection of wire channels at high frequencies are explored. A detailed examination of the principle, configuration, operation and limitation of DFE is followed. Design challenges encountered in design of DFE for multi-Gbps data links including timing constraints, sampling, error propagation, arithmetic operation, highly dispersive channels, power consumption and techniques and circuit implementations that address these challenges are studied. The need for adaptive DFE and the principles of adaptive DFE are investigated. Finally, the performance of various adaptive DFEs is examined and their pros and cons are compared.

In [3] Junwen Zhangh et.al presents Quadrature duo binary (QDB) signals can be generated from strongly filtered quadrature phase shift keying whose constellation becomes a 9-ary quadrature amplitude modulation. In this paper, the performance of multi-modulus equalization (MMEQ) to suppress noise and crosstalk for this QDB signal is experimentally investigated and compared with that of the constant-modulus equalization (CMEQ) with post filtering, under different filter bandwidth and carrier spacing. The results show that the MMEQ scheme has better performance for noise and crosstalk suppression, resulting in improved filtering tolerance. This improved filtering tolerance is demonstrated in an8-channel 112-Gb/s wavelength-division-multiplexing experiment with a 25-GHz grid over 2640-km single-mode fiber.

In [4] Meiyan Gong et.al presented the design for existing minimum-symbol-error-rate equalizers were derived based on the symbol-error-rate objective function. Due to the complexity of the objective function the derivation is not straightforward. In this paper we present a new approach to derive the minimum-symbol-error-rate adaptive equalizers. The problem is formulated as minimizing the norm between two subsequent parameter vectors under the constraint of symbol error-rate minimization. The constrained optimization problem then is solved with the Lagrange multiplier method, which results in an adaptive algorithm with normalization.

In [5] Amirhossein Rafati et.al proposed a low-complexity turbo-detection scheme is proposed for single-carrier multiple-input–multiple-output (MIMO) underwater acoustic (UWA) communication systems that employ low-density parity-check (LDPC) channel coding. The proposed iterative soft-decision feedback equalization (SDFE) algorithm offers a novel approach to combat error propagation by utilizing the past soft decisions to mitigate inter symbol interference. In addition, the authors utilize iterative data detection and channel estimation scheme to reduce the pilot overhead used in the data communication system. Performance of the proposed detection scheme is demonstrated through extensive communication data from two undersea experiments. The results show that the proposed SDFE algorithm provides robust detection for MIMOUWA communications with different modulations and different symbol rates, at different transmission ranges.

In [6] Hung-yi-Cheng et al the functioning of the decision feedback equalizer (DFE) which is an efficient scheme to suppress inter symbol interference (ISI) in various communication and magnetic recording systems. However, most DFE implementations suffer from the phenomenon of error propagation, which degrades its bit error rate (BER) performance. In this paper, The authors use sphere detector (SD) to achieve maximum likelihood (ML) detection and significantly reduce the system symbol error rate (SER).Simulations show that the proposed scheme with sphere detector decision feedback equalizer (SD-DFE) algorithm can efficiently reduce the SER. Based the matrix/vector signal model that is similar to the MIMO detection problem, this work proposesa novel and effective SD-DFE algorithm to enhance the DFE performance.

In [7] Ahmed Awny et.al introduced the a millimeter wave frequency mixed-signal design of a 1-tap half-rate look-ahead decision feedback equalizer for80 Gb/s short-reach optical communication systems is presented. On-wafer tests are developed to determine the maximum operating bit rate of the equalizer. Results are also presented for inter symbol interference mitigation at 80 Gb/s for a 20 GHz bandwidth-limited channel. Further improvements on the architecture of the 80 Gb/s equalizer are discussed and used in the design and on-wafer measurement of a 110 Gb/s equalizer. The equalizers are designed in a 0.13 μm SiGe: CBiCMOS technology. The 80 and110 Gb/s versions dissipate 4 and 5.75 W, respectively and occupy2 and 2.56 mm², respectively. Design of a 1-tap decision feedback equalizer for 80 Gb/shas been presented. A novel modification of the half rate parallel look-ahead architecture was used to reach such high bit rate. Simple measurement techniques were developed to indicate the maximum bit rate the DFEs can work at.

In [8] Nuno Souto et.al introduced the the deployment of increasingly dense heterogeneous mobile networks can create high levels of interference among users that, combined with severely time-dispersive channels, can result in substantial performance degradation. To cope with both effects, in this paper, we propose an iterative block decision feedback equalizer (IBDFE) for single carrier (SC) transmissions that makes use of the correlation between the interference in the receiving antennas and minimizes the mean squared error (MSE) of the detected symbols. The analytic and simulated performance results show that the proposed receiver can clearly outperform the conventional IBDFE and the linear interference rejection combining (IRC) detector.

In [9] Burcu Tepekule et.al proposed the concept of Molecular communication via diffusion (MCvD) is a new field of communication where molecules are used to transfer information. One of the main challenges in MCvD is the inter symbol interference (ISI), which inhibits communication at high data rates. Furthermore, at the nano scale energy efficiency becomes an essential problem. Before addressing these problems, a pre-determined threshold for the received signal must be calculated to make a decision. In this paper, an analytical technique is proposed to determine the optimum threshold, whereas in the literature, these thresholds are calculated empirically. Since the main goal of this paper is to build an MCvD system suitable for operating at high data rates without sacrificing quality, new modulation and filtering techniques are proposed to decrease the effects of ISI and enhance energy efficiency.

In [10] Jun Tao proposed a better understanding of the Soft-DFE, achieved via two comparisons: first, the two categories of designs classified by the way of treating the soft input and the soft-decision feedback (SDF), random or deterministic, are compared; second, the two different assumptions on the SDF, perfect or imperfect, are compared. The first comparison reveals the condition under which the two categories of designs are equivalent, and it is further shown the equivalence always holds for constant-modulus modulations. The second comparison indicates the perfect SDF assumption only incurs slight performance degradation.

PERFORMANCE METRICS

The major performance metrics to deicide the performance of equalizers are Bit Error Rate (BER) or Probability of Error (Pe) and throughput. The above parameters can be defined as:

$$BER = \frac{Bit\ Errors}{Total\ Number\ of\ Bits} \qquad (4)$$

$$Throughput = \frac{Bits\ Transmitted}{Time\ Consumed} \quad (5)$$

It should be noted that low value of BER is envisaged while a high value of Throughput is aimed in the design of equalizers.

CONCLUSION

It can be concluded from previous discussions that it is mandatory to design equalizers for avoiding distortions in the received signal. Moreover, the type of implementation of the equalizer filter is important. Once of the most effective designs is the decision feedback mechanism that aims at feeding back the errors of the system at the output in updating the tap weights of the equalizer filter. This paper focuses on different design aspects of the decision feedback equalizer along with its pros and cons.

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