Blind Channel Equalization Using Constant Modules Algorithm

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Abstract: Signals when pass through a channel undergo various forms of distortion, most common of which is Inter Symbol Interference (ISI). ISI induced error can cause the receiver to misinterpret the received samples. Equalizers are important part of receivers, which minimizes the linear distortion produced by the channel. Equalizers are used to compensate Inter Symbol Interference. For bandwidth efficient communication systems operating in high Inter Symbol Interference environments, Blind Equalizers (BE) have become a necessary component of the receiver architecture. Blind Equalizers are able to compensate the amplitude and delay distortions of the communication channel using only the channel output sample and knowledge of the basic statistical properties of the data symbol. Constant Modulus Algorithm (CMA) is the popularly used Blind Equalization Algorithm.

Keywords: Constant Modulus Algorithm, Blind Equalization, Bussgang Algorithm, CMA (2, 2), and Property Restoral Technique.

I. INTRODUCTION

A Blind Equalizer, as opposed to a data-trained equalizer, is able to compensate amplitude and delay distortions of a communication channel using only the channel output samples and knowledge of the basic statistical properties of the data symbols. Sato was the one who first introduced the concept of Blind Equalizers in 1975, since than blind equalization has attracted significant scientific interest due to its potentials in terms of Overhead reduction and Simplification of point to multipoint communication. Blind Equalizers do not need any training sequence and therefore conserve bandwidth. Similarly, it offers lot of simplicity in multipoint communication. When a communication link is reset, equalizer adjustment from scratch is necessary. In this case, using a training sequence is in inefficient, since the transmitter has to retransmit the training sequence specifically for each receiver, which is reset.

Among the most popular adaptive schemes for blind equalization are the so called constant modulus algorithms (CMAs) – see [1], [2], [3]. The update equations of these algorithms are nonlinear in nature. CM algorithm due to their inherent nonlinear updates is also used for interference cancellation – see [5]. A major feature of this approach is that it bypasses the need for working directly with the weight error vector. This CMA works mainly to restore the constant modulus property of the output signal.

II. ADAPTIVE EQUALIZATION

In digital communications, a considerable effort has been devoted to the study of data transmission system that utilizes the available channel bandwidth efficiently. The objective here is to design a system that accommodates highest possible rate of data transmission, subject to a specified reliability that is usually measured in terms of error rate or average probability of symbol error. The transmission of digital data through a linear communication channel is limited by two factors.

1) Inter Symbol Interference (ISI).
2) Thermal noise.

ISI is caused by dispersion in the transmit filter, the transmission medium, and receive filter. The receiver at its front end generates thermal noise. For bandwidth-limited channels (eg., voice-grade telephone channels), we usually find that inter symbol interference is the chief determining factor in the design of high data rate transmission   system
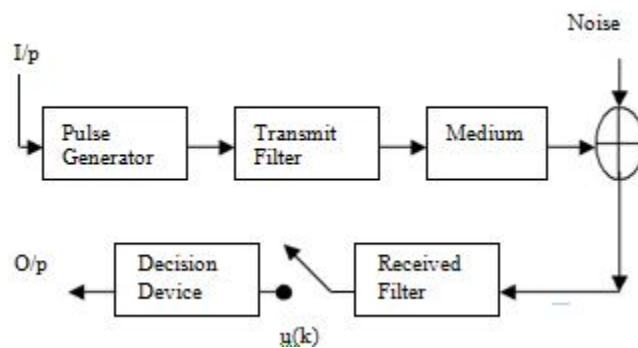
Fig. 1. Binary PAM System

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An adaptive filtering algorithm requires the knowledge of the "desired" response so as to form the error signal needed for adaptive process to function. The transmitted sequence originating at the transmitter output is the "desired" response for the adaptive equalizer located at the receiver, the equalizer is physically separated from the origin of its ideal desired response.

it is more tricky to directly locate the nonlinearity. Rather, the nonlinearity is combined with the data detection process. These methods can extract most of the information from little data, but often at the huge computational cost.

The third type consists of methods that have nonlinearity at the output of the equalizer filter. Nonlinearities are often memory less and underlie Bussgang Property. Because such methods have often-shorter convergence times than polyspectral methods, they are more popular.

Blind Equalization performs channel equalization without the aid of a training sequence. The term blind is used because the equalizer performs the equalization blindly on the data without a reference signal. Instead the blind equalizer relies on the knowledge of signal's structure and its statistics to perform the equalization. The major advantage of blind equalizers is that there is no training sequence at the start up, hence no bandwidth is wasted by its transmission. In highly non stationary environments like digital mobile communications, it is impractical to use training sequences. Hence blind equalization is important in this field.

estimated blindly. This is usually done in an adaptive

$\square$ is also known as the dispersion constant. For a BPSK

One method to generate the desired response locally in the receiver is the use of training sequence, in which a replica of the desired response is stored in the receiver. With this known training sequence, the adaptive filtering algorithm used to adjust the equalizer coefficients corresponds to searching for the unique minimum of quadratic error-performance surface.

III. BLIND EQUALIZATION
A. Classification of algorithms

Blind Equalization algorithms are classified according to the location of their nonlinearity in the algorithm chain. There are three different types of blind equalization algorithms.

1) Polyspectral Algorithm.
2) Probabilistic Algorithm.
3) Bussgang-type Algorithm.

In the first method the nonlinearity sits at the output of the channel, right before the equalizer filter. The nonlinearity has thus the function of estimating the channel and feeding that information to the equalizer for adapting the filter taps.

B. The Sato Algorithm

Sato was the first researcher to propose a blind channel equalizer for communication signals [27]. He had an application in mind, where transmission routes might be reconnected, thus incurring drastic changes of transmission conditions. He proposed the following update equation for a blind equalizer

$$\mathbf{w_{t+1}} = w_t + \mu(\gamma \, \text{sign}(u) - u)\mathbf{x} \qquad (5)$$

which, if interpreted as the stochastic-gradient update associated with the mean square of the error signal

$$e_s = g(u) - u \qquad (6)$$

for $g(u) = \gamma \, \text{sign}(u)$, minimizes the cost function

$$J(\mathbf{w}) = E\{e_s{}^2\}$$
$$= E\{(\gamma \, \text{sign}(u) - u)^2\}$$
$$= E\{(|u| - \gamma)^2\} \qquad (7)$$

Here $\mathbf{x} = \mathbf{x_t}$ and $\mathbf{u} = \mathbf{u_t}$. The Sato parameter γ is defined as

$$\gamma = \frac{E\{s^2\}}{E\{s\}||}$$

Signal, the Sato algorithm is equivalent to a decision-directed equalizer. For M-ary signaling with M > 2,

minimization of the error in the MSB (most significant bit) is achieved.

C. Godard's Algorithm

Godard [21] came up with a more general expression for the cost function

$$J(\mathbf{w}) = E\{(|u|^p - R_p)^2\} \tag{8}$$

A special case of which (for p = 1) is the Sato algorithm. The Godard parameter R_p is defined as

$$\mathbf{R_p} = \frac{E\{|s|^{2p}\}}{E\{|s|^p\}} \tag{9}$$

and acts as a scaling parameter (see also [23]) in the same way as the Sato parameter γ ; it also normalizes the output of the equalizer.

D. Constant modulus algorithm (CMA)

The CMA is the most often used algorithm for blind equalization [24]. It is a special case of Godard's algorithm and was independently of Godard discovered by Treichler and Agee [25]. The cost function is given by

$$J(w) = E\{(|u|^2 - R_2)^2\} \tag{10}$$

The update equation for CMA is given by

$$\mathbf{w_{t+1}} = \mathbf{w_t} - \mu u(|u|^2 - R_2)\,\mathbf{x^*} \tag{11}$$

The gradient of the CM cost surface is dependent on the source kurtosis. For many mismatches, the CMA cost function will behave similarly to an MMSE criterion [22]. For perfect equalization the CMA cost function is minimum.
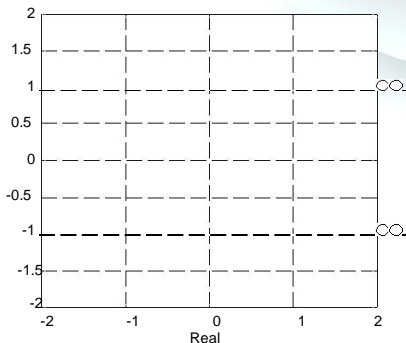
IV.   RESULTS
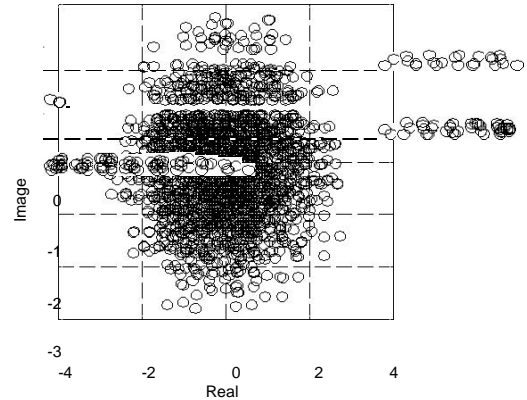

Fig. 3. Transmitted QPSK Signal

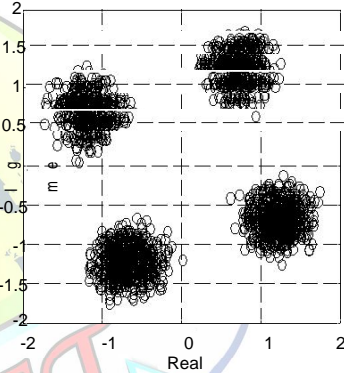**Fig. 4. Received Noisy Signal**

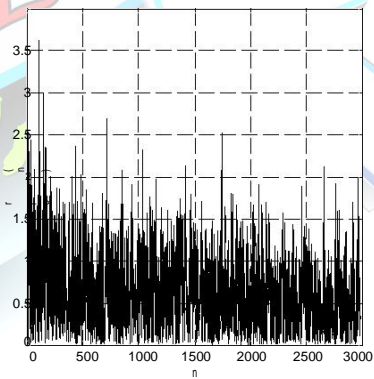**Fig. 5. Equalized QPSK Signal**

Fig. 6. Convergence

V.   CONCLUSION

The proposed Blind Equalization Algorithm is used in wireless communication applications, which save bandwidth, and also able to extract channel information in the presence of carrier frequency offset. Its LMS-like update equation makes CMA very easy to analyse and can be

implemented in Power-limited applications. CMA converges to the desired solutions without the permutation and phase ambiguities. Also it may be extended to other types of Constant Modulus Algorithms like CMA (2, 2), CMA (1, 2) and Normalised Constant Modulus Algorithm (NCMA). It has been suggested that CMA (2, 2) has the best performance when compared to other algorithms stated [26]. When CMA (2, 2) is implemented in a fractionally spaced form, it has no undesired minima. Also it converges faster than other algorithms. It is also noted that for a fixed Signal to Noise Ratio (SNR) and if step size ($\square$) decreases, Signal to Error Ratio (SER) increase.

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