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Mitigation of Inter-Channel Interference (ICI) based on Zero Force Equalizer in Communication System

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Abstract: In this paper, we presents the mitigation of the inter channel interference (ICI) on the basis of equalization techniques. There are two techniques that are used to mitigation the effect of inter channel interference. Firstly, Pulse Shaping using Raised Cosine Filter is used to reduce the effect of inter channel interference (ICI) of band limited transmission pulses in optical communication. Second the received signal to cancel the inter channel interference (ICI) introduced by the channel impulse response and is known as equalization. Apply equalizer at the receiver to mitigate the effect of the channel by applying an inverse filtering. Here, we used zero forcing (ZF) equalizer to reduce the effect of inter channel interference (ICI) introduced by the channel impulse response. Simulation result shows that the bit error rates versus EbNo with optical communication in the presence of inter channel interference. Simulation results shows that the Zero force equalizer approximate the channel to the ideal Results are performed using 5-taps zero force equalizer. As the number of tap increases the performance of the equalizer improves.

Index Terms: **Inter channel interference (ICI), Zero force equalizer, Raised Cosine Filter, Bit error rate (BER).**

I. INTRODUCTION

In communication system [1] [2] has limited bandwidth to transmit digital data indicates that certainly a transmitted square pulse will be received differently at the receiver as the channel will filter some components of it. The difference depends on how narrow the bandwidth of the channel compared to the symbol rate in the signal. From last few decades Optical Communication is gaining momentum in many signal processing applications [3] [4]. Light plays a vital role in our daily lives. It is used in compact disc (CD) players, in which a laser reflecting of a CD transforms the returning signal into music. It is used in grocery store checkout lines, where laser beams read bar codes for prices. It is used by laser printers to record images on paper. It is used in digital cameras that capture our world and allow pictures to be displayed on the Internet. It is the basis of the technology that allows computers and telephones to be connected to one another over fiber-optic cables. The effect of filtering part of the transmitted signal by the channel on the quality of the received signal may be significant that a phenomenon called "Inter channel Interference (ICI)" occurs. ICI causes the transmitted pulses to get mixed together, meaning that a pulse that is transmitted between time instants will smear into adjacent pulses affecting the process of data detection and possibly causing errors not as a result of noise but as a result of symbols mixing together. Interference [5][6] is a phenomenon in which two waves superimpose to form a resultant wave of greater or lower amplitude. Interference usually refers to the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency. Interference effects can be observed with all types of waves, for example, light, radio, acoustic, and surface water waves [7]-[9]. In this paper, we presents the mitigation of the inter channel interference (ICI) on the basis of equalization techniques. There are two techniques that are used to mitigation the effect of inter channel interference. Firstly, Pulse Shaping using Raised Cosine Filter is used to reduce the effect of inter channel interference (ICI) of band limited transmission pulses in optical communication. Second the received signal to cancel the inter channel interference (ICI) introduced by the channel impulse response and is known as equalization. Apply equalizer at the receiver to mitigate the effect of the channel by applying an inverse filtering. Here, we used zero forcing (ZF) equalizer to reduce the effect of inter channel interference (ICI) introduced by the channel impulse response. The rest of thr paper is organized as follows: Section II presents the basic of optical communication system. Section III gives the brief introduction of inter channel interference. Equalization concept is explained in Section IV. Zero force (ZF) equalization is presented in section V. Section VI, simulation results are presented with bit error rate as the performance criteria to remove the effect of ICI. Finally, conclusions are made.

II. OPTICAL COMMUNICATION SYSTEM

Fiber optics [1][2] is a medium for carrying information from one point to another in the form of light. Unlike the copper form of transmission, fiber optics is not electrical in nature. A basic fiber optic system consists of a transmitting device that converts an electrical signal into a light signal, an optical fiber cable that carries the light, and a receiver that accepts the light signal and converts it back into an electrical signal. The complexity of a fiber optic system can range from very simple (i.e.,

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local area network) to extremely sophisticated and expensive (i.e., long distance telephone or cable television trunking).

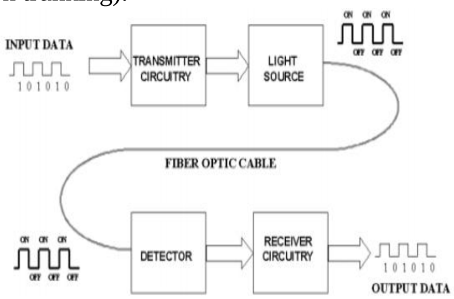

Fig. 1 Optical Communication System

II. INTER CHANNEL INTERFERENCE

The effects of inter channel interference on the performance of the receiver. There are two type of inter channel interference are

1. Single-Sided Interference
2. Double-Sided Interference

A. Single-Sided Interference

Interference is a central phenomenon in wireless communication when multiple uncoordinated links share a common communication medium.

1. orthogonalize the communication links in time or frequency, so that they do not interfere with each other at all;
2. Allow the communication links to share the same degrees of freedom, but treat each others interference as adding to the noise floor.

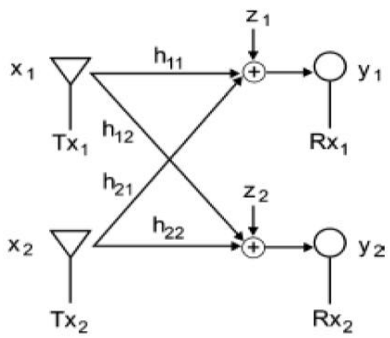

Fig. 2 Gaussian interference channel

It is clear that both approaches can be suboptimal. The First approach entails an a priori loss of degrees of freedom in both links, no matter how weak the potential interference is. The second approach treats interference as pure noise while it actually carries information and has structure that can potentially be exploited in mitigating its effect. These considerations lead to the natural question of what is the best performance one can achieve without making any a priori assumptions on how the common resource is shared. A basic information theory model to study this question is the two user Gaussian interference channel, where two point-to-point links with additive white Gaussian noise (AWGN) interfere with each other [10].

Initially, $z(t)$ is assumed to be the received signal. $z(t)$ is a zero mean Gaussian process. This signal has two possibilities

1 = data signal + noise + interchannel interference

0 = noise + interchannel interference

$z(t)$ can be divided in two parts:

$$z(t) = z_a(t) + z_b(t) \tag{1}$$

with $z_a(t)$ a having a rectangular bandwidth B_0 , and $z_b(t)$ b having a rectangular bandwidth kB_0 . The parameter k is referred to as the channel overlap parameter; it represents the overlapping percentage of an adjacent channel. It varies between 0 and 1, with 0 corresponding to no overlap and 1 corresponding to complete overlap [11][12].

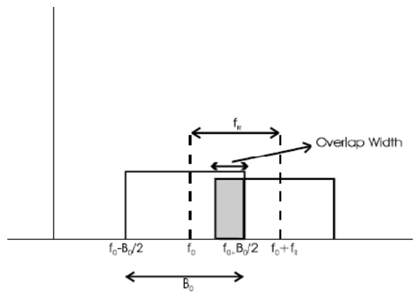

Fig. 3 Inter Channel Interference

Fig. 3 illustrates a scenario where one channel is interfering with another. With the aid of this figure we can obtain the mathematical definition of k. In fig. 3 B_0 is the optical bandwidth and f_R is the channel spacing. The overlap width is defined as

$$\text{Overlap Bandwidth} = B_0 - f_R \tag{2}$$

The moment generating function of the received signal $z(t)$ in the ON state can be represented as:

$$M_{ON}(s) = \left[1 - 2(\sigma_s^2 - \sigma_n^2)ks\right]^{-2mk}\left[1 - 2(\sigma_s^2 - \sigma_n^2)(1-k)s\right]^{-2m(1-k)} \tag{3}$$

For the OFF case the MGF is obtained in a similar fashion and is given by

$$M_{OFF}(s) = \left[1 - 2(\sigma_s^2 - \sigma_n^2)ks\right]^{-2mk}\left[1 - 2\sigma_n^2 2m(1-k)s\right]^{-2m(1-k)} \tag{4}$$

III. QUALIZATION

For many physical channels, such as telephone lines, not only are they band limited, but they also introduce distortions in their pass bands. Such a channel can be modelled by an LTI filter followed by an AWGN source as shown in Fig. 4. This is the dispersive channel model we describe before. In general, ISI is often introduced.

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For a communication system employing a linear modulation, such as BPSK, through a dispersive channel, the whole system can be described the conceptual model in Fig. 5, in which the sequence of information symbols is denoted by $\{Ik\}$ and $H_T(f)$, $H_C(f)$, and $H_R(f)$ are the transfer functions of the transmission (pulse-shaping) filter, the dispersive channel and the receiving filter, respectively.

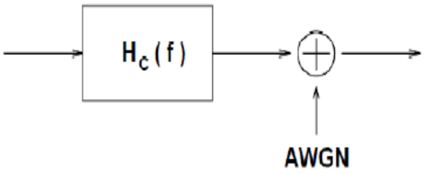

Fig. 4 Channel model

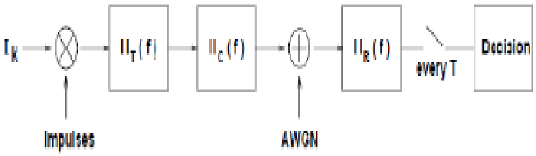

Fig. 5 ICI removal with equalizer

IV. ZERO-FORCING EQUALIZER

Let us consider the use of a linear equalizer, i.e., we employ an LTI filter with transfer function $H_E(z)$ as the equalizing circuit. The simplest way to remove the ICI is to choose $H_E(z)$ so that the output of the equalizer gives back the information sequence, i.e., $I_k = I_k$ for all k if noise is not present. This can be achieved by simply setting the transfer function $H_E(z) = 1=G(z)$. This method is called zero- forcing equalization since the ICI component at the equalizer output is forced to zero [4][5]. The corresponding impulse response can be an in finite length sequence. Suitable truncation and delay is applied to get an approximation. We note that the effect of the equalizing filter on the noise is neglected in the development of the zero-forcing equalizer above. In reality, noise is always present. The ICI component is forced to zero, there may be a chance that the equalizing filter will greatly enhancing the noise power and hence the error performance of the resulting receiver will still be poor. To see this, let us evaluate the signal-to-noise ratio at the output of the zero-forcing equalizer when the transmission filter $H_T(f)$ is fixed and the matched filter is used as the receiving filter,

V. IMULATION RESULTS

The simulation is carried out for mitigation of the inter channel interference (ICI) on the basis of equalization techniques such as zero force equalizer.. Transmitted symbol is given by

$$y(t) = \sum_{n=-\infty}^{\infty} a_n x(t - nT) \quad (5)$$

where T is the symbol period, a_n is the symbol to transmit, x(t) is the transmit filter,n is the symbol index and y(t) is the output waveform. The received signal gets corrupted by noise n, typically referred to as Additive White Gaussian Noise (AWGN). The value of the noise n follows the Gaussian probability distribution function

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}} \quad (6)$$

The received signal is

$$z[k] = y[k] \otimes h[k] + n \quad (7)$$

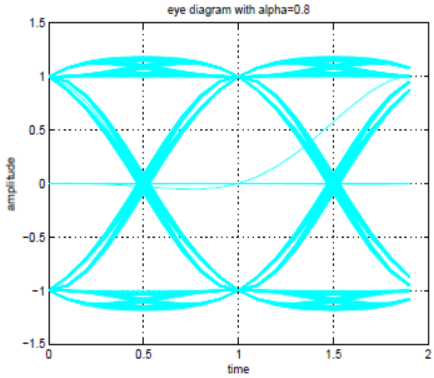

Fig. 6 Eye Diagram with alpha=0.8

Eye diagram of channel model is presented in fig.6 and 7 with different values of alpha. Fig. 8 shows the Theoretical Bit error probability to remove ICI using Zero Forcing (ZF) Equalizer. Fig. 9 demonstrates the Simulated Bit error probability to remove ICI using Zero Forcing (ZF) equalizer. Fig. 10 depicts the comparisons of Theoretical and Simulated Bit error probability to remove ICI using Zero Forcing (ZF) equalizer.

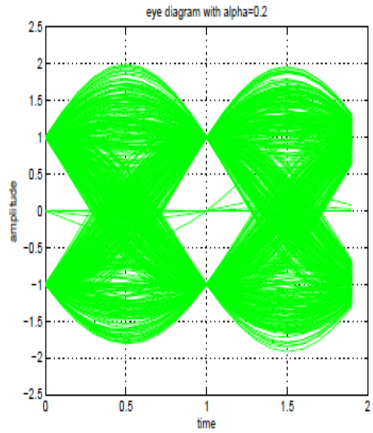

Fig 7 Eye Diagram with alpha=0.2

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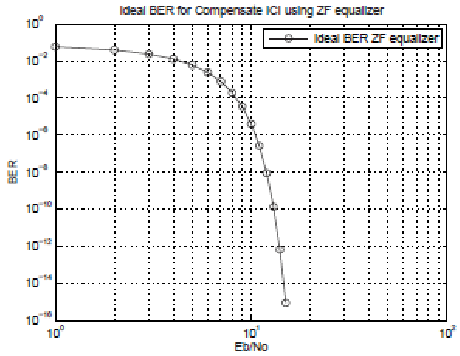

Fig. 8 Theoretical Bit error probability to remove ICI using Zero Forcing (ZF) Equalizer

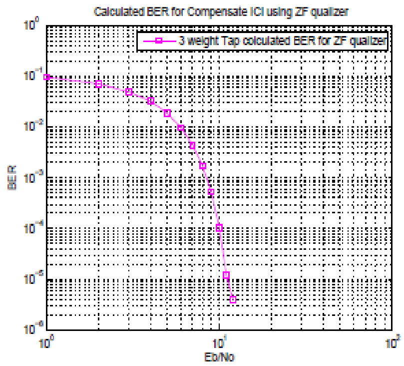

Fig. 9 Simulated Bit error probability to remove ICI using Zero Forcing (ZF) equalizer

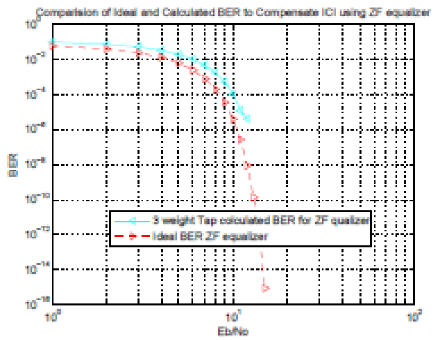

Fig. 10 comparisons of Theoretical and Simulated Bit error probability to remove ICI using Zero Forcing (ZF) equalizer

VI. CONCLUSIONS

There are two techniques that are used to mitigation the effect of inter channel interference. Firstly, Pulse Shaping using Raised Cosine Filter is used to reduce the effect of inter channel interference (ICI) of band limited transmission pulses in optical communication. Second the received signal to cancel the inter channel interference (ICI) introduced by the channel impulse response and is known as equalization. Apply equalizer at the receiver to mitigate the effect of the channel by applying an inverse filtering. Here, we used zero forcing (ZF) equalizer to reduce the effect of inter channel interference (ICI) introduced by the channel impulse response. Results are performed using 5-taps zero force equalizer. As the number of tap increases the performance of the equalizer improves.

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