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Intersymbol Interference Reduction and Bit Error Rate Reduction in Wireless Channels Using Zero Forcing Equalizer

Nisha Wadhwa[1], Savita Rangi[2], Dheeraj Rathee[3]
[1](Dept. of ECE, FET, Manav Rachna International University, INDIA)
[2](Dept. of ECE, FET, Manav Rachna International University, INDIA)
[3](Dept. of ECE, FET, Manav Rachna International University, INDIA)

Abstract: *In telecommunication, Intersymbol interference (ISI) is a form of distortion of a signal in which one symbol interferes with subsequent symbols. The presence of ISI in the system introduces errors in the decision device at the receiver output. Therefore, in the design of the transmitting and receiving filters, the objective is to minimize the effects of ISI, and thereby deliver the digital data to its destination with the smallest error rate possible. In this paper, we design a zero forcing equalizer, which is a type of linear equalizer used to mitigate the effects of ISI (Intersymbol Interference). The zero forcing equalizer does this by finding the inverse of the impulse response of the channel. The ISI can be studied using eye diagram, which overlays many samples of a signal and can give a graphical representation of the signal characteristics. In this paper the results have been shown with proper eye diagrams. In this paper we also investigate the bit error rate, which is used to estimate the performance characteristics of the zero forcing equalizer.*

Keywords: *Zero forcing equalizer, intersymbol interference, eye diagram, Rayleigh fading, bit error rate*

I. Introduction

The mobile radio channel is dynamic due to multipath propagation and Doppler spread, these effects have a strong negative impact on the bit error rate of any modulation technique. Equalization, diversity, and channel coding are basically three techniques which can be used independently to improve received signal quality and link performance over small-scale times and distances [5]. An Equalizer is a compensator for Channel Distortion. For communication channels in which the channel characteristics are unknown or time-varying, optimum transmit and receive filters cannot be designed directly. For such channels, an equalizer is needed to compensate for the ISI created by the distortion in the channel. Inter symbol interference (ISI) must be compensated by using different equalization techniques created by multi path within time dispersive channels [1]. If the modulation bandwidth exceeds the coherence bandwidth of the channel, intersymbol interference occurs and pulses spread in time into adjacent symbols and cause pulse broadening [5]. Also, In the case of using the single carrier modulation, frequency selective fading and inter symbol interference occur, which leads to high probability of errors, consequently, affecting on the system performance. So, it is crucially important to study the elimination process of ISI effect [5].

A channel equalizer is an important component of a communication system and is used to mitigate the ISI (inter symbol interference) introduced by the channel. The equalizer depends upon the channel characteristics. These are usually employed to reduce the depth and duration of the fades experienced by a receiver in a local area which are due to motion. An equalizer within a receiver compensates for the average range of expected channel amplitude and delay characteristics. Equalizers must be adaptive since the channel is generally unknown and vary with time [5]. This paper mainly concentrates on the zero forcing equalizer. ZF unlike MMSE is useful in mitigating the ISI effect rather than induced noise in the signal [3].

II. Rayleigh Fading

In a mobile communication environment the channel is not time invariant and is slowly varying. This characteristic feature of the channel leads to a phenomenon called Fading. Fading channels induce rapid amplitude fluctuations in the received signal. If they are not compensated for then this will lead to serious performance degradation [4]. Rayleigh fading is the main cause of ISI. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and

2π radians. The envelope of the channel response will therefore be Rayleigh distributed calling this random variable R, it will have a probability density function:

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, \ r \geq 0$$

Where $\Omega = E(R^2)$.

III. System Model

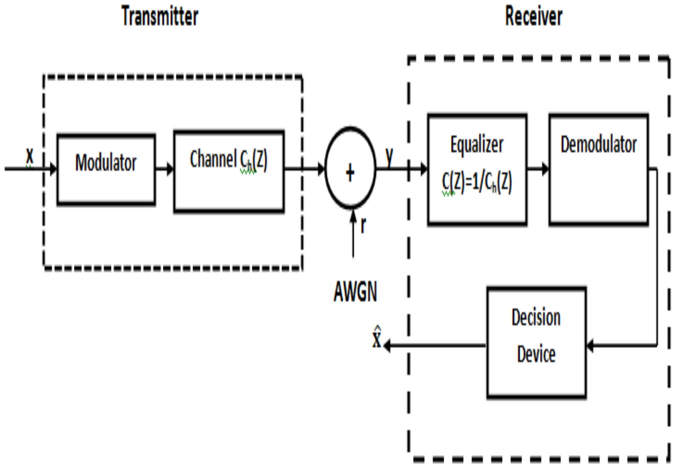

Figure 1: Block diagram of a zero forcing equalizer

First, let us consider the use of a linear equalizer, i.e., we employ an LTI filter with transfer function C(Z) as the equalizing circuit. The simplest way to remove the ISI is to choose C(Z) so that the output of the equalizer gives back the information sequence, i.e., x = $\hat{x}$, k if noise is not present. This can be achieved by simply setting the transfer function $C(Z) = 1/C_h(Z)$.This method is called zero-forcin*g* equalization since the ISI component at the equalizer output is forced to zero.

IV. System Algorithm

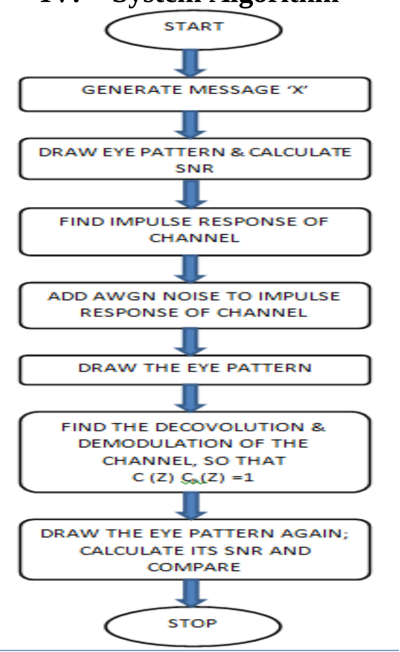

Figure 2: Algorithm for zero forcing equalizer

V. Results

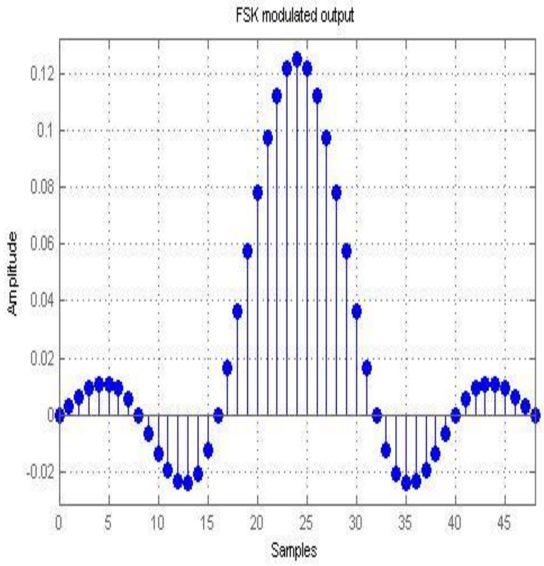

Figure 3: FSK Modulated output at the transmitter side

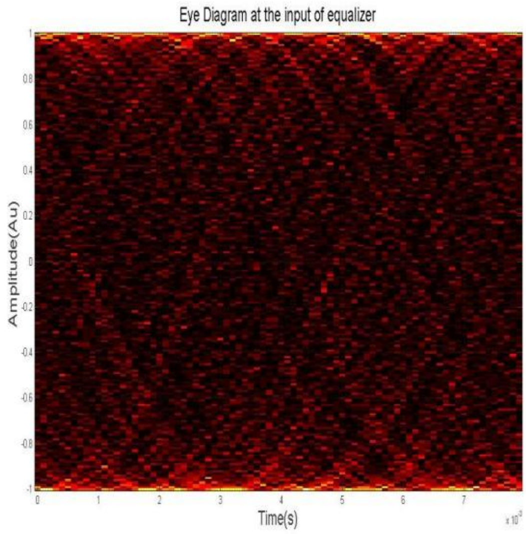

Figure 5: Eye diagram of the noisy signal, which is an input to the equalizer

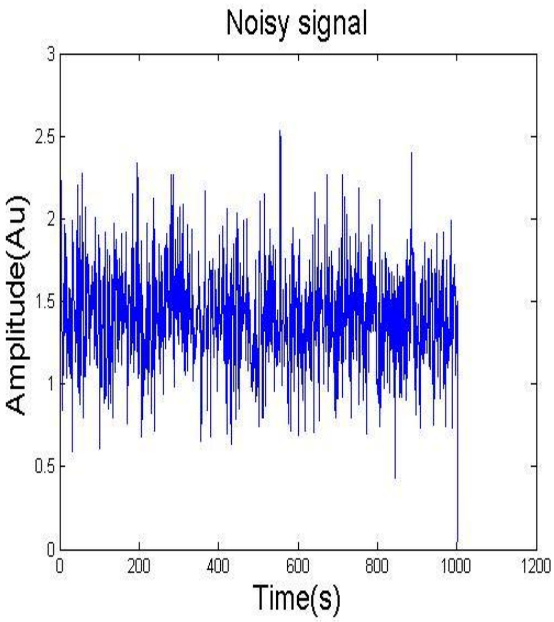

Figure 4: Noisy Signal

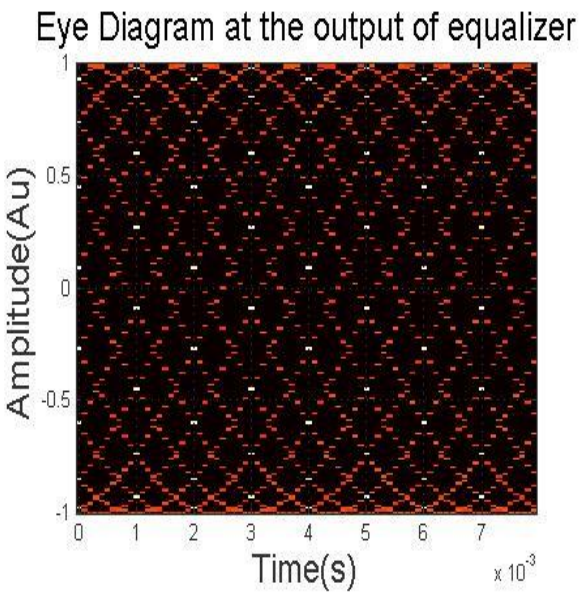

Figure 6: Eye diagram at the output of the equalizer

Table1: BER Calculation

Symbol Error	10	20	30	40	50	60
BER before equalization	1	1	1	1	1	1
BER after equalization	0.99	0.80	0.77	0.70	0.68	0.62

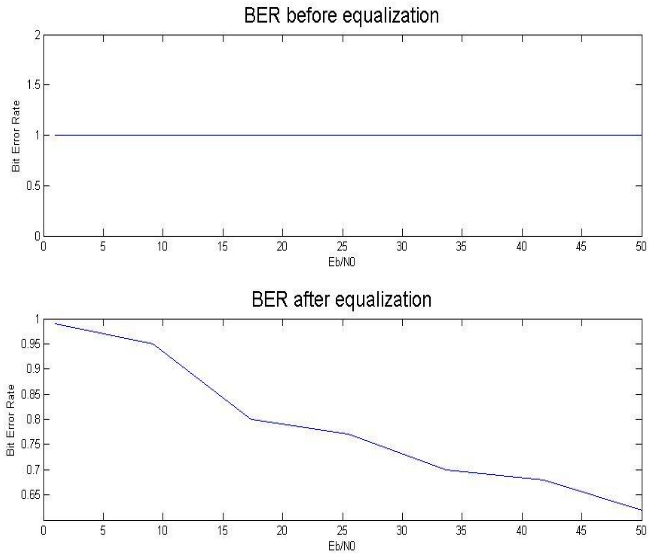

Figure7: Graph showing BER before and after equalization

VI. Conclusion

In this paper, the output of zero forcing equalizer has been shown with proper eye- diagram. Hence, it becomes easy to compare the performance of two signals by looking at the eye-diagrams. This paper also calculates the bit error rate of the symbols before as well as after the equalization. Hence the results have been shown in a tabular form that the zero forcing equalizer has reduced the error. The above figures show that the bit error rate increases as the effect of ISI. But the zero forcing equalizer has reduced the ISI and the bit error rate also.

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