Performance Analysis of Zero-Forcing Equalizer for ISI Reduction In Wireless Channels.

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Abstract

The technique of equalization to compensate for the effect of the channel which causes distortion in transmitted signal. Different kinds of equalizers are used depending upon the application of the system and upon the kind of communication channel. These application range from acoustic echo cancellers to video de-ghosting system. The purpose of equalization system is to compensate for transmission-channel distortion such as signal affected as frequency depended phase or as amplitude attenuation. Besides correcting for channel frequency response anomalies, The equalizer can cancel the effects of multipath signal component. They may require significantly longer filter spans than simple spectral equalizers, but the principle of operations are essentially the same. This project aims at studying and simulation of ZF equalization technique. Simulation results shows that ZF equalization can greatly improve the bit error rate of the system as compared to system without using the same equalizer. The effect has been observed at different effects of ISI.

Keywords-Zero Forcing equalizers ,ISI, BER, Linear Equalizer.

1. Introduction

In the design of large and complex digital systems, it is often necessary to have one device communicate digital information to and from other device. One advantage of digital information is that it tends to be far more resistant to transmitted and interrupted errors than information symbolized in an analog medium, this accounts for the clarity of digitally encoded telephone, compact audio disks and for much of the enthusiasm in the engineering community for digital communication technology. However digital communication has its own unique pitfalls and there of different and incompatible ways in which it can be sent. There main paths of the telecommunication system are transmitter Receiver, Channel. our main focus will be imparted to the receiver in this section called equalizer. The equalizer is used to estimate the transmitted bits/symbols in such a way that it eliminates the effect of channel. The Zero forcing equalizer is used in this context.Main objective of ZF equalizer is to compensate the effect of ISI.ZF unlike MMSE is useful in mitigating the ISI effect rather than induced noise in the signal. comparison of using ZF algorithm as equalizer will be done against using a simple algorithm for equalization.

2. Equalization

There are number of procedures presented to counter the outcome of Multipart promulgation. Space diversity, frequency diversity channel equalization and amplitude equalization are the most commonly used. Among these ,space diversity and frequency diversity need a all common classification .In analogue broadcasting systems bandwidth overhead ,which is not eagerly obtainable in nearly,these signal diversity procedures were used and have been modified to digital systems without any difficulty that go through extremely discerning interference

2.1 Linear Equalization

A renowned receiver system for mitigating Inter-Symbol Interference (ISI) is the linear equalization. Least squares error cost function or mean square error cost functions are usually minimized for the computation of linear equalizers.

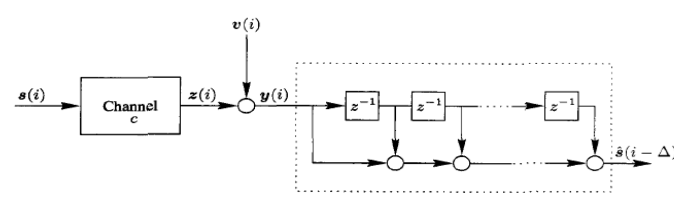

Fig: The presence of additive noise in Linear equalization of an FIR channel.

We can calculate the zero –forcing equalizer. if we identify the noise first order and second order statistics and channel impulse response and the input. A supposition that will be used all over this effort is that the input is self sufficient and identically disseminated, among unit variance and zero mean and noise is white Gaussian therefore the recipient can utilize this information.

2.1.1 Principle of ISI

If the channel response (or the channel transfer function) for a specific channel is H(s) then the input signal is multiplied by the reciprocal of this. This is intended to remove the effect of channel from the received signal, in particular the ISI. The zero forcing equalizer removes all ISI, and is ideal when greatly at frequencies *f* where the channel response H(j2π*f*) has a small magnitude (i.e. near zeroes of the channel) in the attempt to invert the channel completely. A more balanced linear equalizer in this case is the minimum mean-square error equalizer, which does not usually eliminate ISI completely but instead minimizes the total power of the noise and ISI components in the output.

2.1.2 Functions of Linear Equalizer

Linear Equalizers are normally useful on channels with a comparatively plane frequency response, Where the ISI is not harsh. Though, when there are null in the frequency range of the acknowledged signal, a linear equalizer execute badly, in its efforts to reverse the channel frequency response. a linear filter extensively increases the noise at the locality of the void (Null).The deprived presentation of linear equalizers in channels with harsh ISI limits their utilization in wireless channels, which frequently have spectral nulls.

2.1.3 Decision feedback Equalization

Decision feedback Equalization feed forward path,like an linear equalization, a DFE utilizes a reaction filter with the intention of feedback preceding conclusion and utilize them to minimize ISI .It is observed from the figure that input to the feedback filter approaches from the production of the decision device, symbolized by $\check{s}(i-\Delta)$

The objectives of this device is to plot the estimator $\check{s}(i-\Delta)$ which is achieavable by joining the productivity of the feed-forward filter and feedback filter, to the continuous position in the symbol collection .Now in linear equalization ,the feed-forward filter decreases ISI by endeavouring to strength the collective scheme $C(z)F(z)$ to be nearby to

$$C(z)F(z) \approx z^{-\Delta}$$

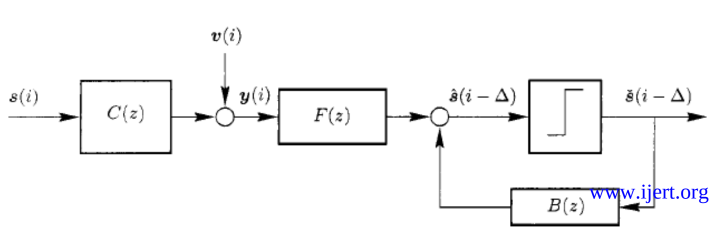

Fig: A feedforward filter, a feedback filter and a decision device in a decision feedback equalizer.

3. Zero Forcing Algorithm

In first insight let us consider different parameters used in Zero forcing equalization .Let $H_E(z)$ be the equalizing circuit filter. The LTI filter with transfer function $H_E(z)$ is considered to be the ZF equalizer. The only way to the ISI is to choose $H_E(z)$ such that the output of equalizer gives back the estimated output., i.e., $\hat{I}_k = I_k$ for all k. The filter transfer function needs to be specified such that it becomes the multiplicative inverse of the channel response G(z) i.e., $H_E(z) = 1/G(z)$. This method is what we call the Zero-Forcing equalization as the ISI component is forced to Zero. It must be noted that the impulse response $h_{E,k}$ need to be an infinite length sequence. 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, i.e.,

$$H_R(f) = H_T^*(f)H_C^*(f) \quad (1)$$

In this case , it is easy to see that the digital filter $H(z)$ is given by

$$H(e^{j2\pi fT}) = \frac{N_0}{2T}\sum_{n=-\infty}^{\infty}\left|H_T\left(f-\frac{n}{T}\right)H_C\left(f-\frac{n}{T}\right)\right|^2 \quad (2)$$

and the PSD of the colored Gaussian noise samples n_k is given by

$$\Phi_{n_k}(e^{j2\pi fT}) = \frac{N_0}{2T}\sum_{n=-\infty}^{\infty}\left|H_T\left(f-\frac{n}{T}\right)H_C\left(f-\frac{n}{T}\right)\right|^2 \quad (3)$$

Hence, the noise-whitening filter $H_W(z)$ can be chosen as

$$H_W(e^{j2\pi fT}) = \frac{1}{\sqrt{H(e^{j2\pi fT})}}$$

And the PSD of the Whitened-noise samples $\tilde{n}_k$ is $N_0/2$ .As a result, the overall digital filter G(z) is

$$G(e^{j2\pi fT}) = H(e^{j2\pi fT})H_W(e^{j2\pi fT}) = \sqrt{H(e^{j2\pi fT})} \quad (5)$$

Now, we choose the zero forcing filter $H_E(z)$ as

$$H_E(e^{j2\pi fT}) = \frac{1}{G(e^{j2\pi fT})} = \frac{1}{\sqrt{H(e^{j2\pi fT})}} \quad (6)$$

Since the zero forcing filter simply inverts the effect of the channel on the original information symbols I_k, the signal component at its output should be exactly

I_k .If we model the I_k as iid random variables with zero mean and unit variance ,then the PSD of the signal component is 1and hence the signal energy at the output of equalizer is just $\int_{-1/2T}^{1/2T} df = \frac{1}{T}$ .on the other hand ,the PSD of the noise component at the output of the equalizer is $\frac{N_0}{2}\left|H_E(e^{j2\pi fT})\right|^2$ .hence the noise energy at the equalizer output is $\int_{-1/2T}^{1/2T} \frac{N_0}{2}\left|H_E(e^{j2\pi fT})\right|^2 df$ .defining the SNR as the ratio of the signal energy to the noise energy ,we have

$$SNR = \left\{ \frac{N_0}{2} \int_{-1/2T}^{1/2T} \left[\sum_{n=-\infty}^{\infty} \left| H_T\left(f-\frac{n}{T}\right) H_C\left(f-\frac{n}{T}\right) \right|^2 \right]^{-1} df \right\}^{-1}$$

Notice that the SNR depends on the folded spectrum of the signal component at the input of the receiver. if there is a certain region in the folded spectrum with very small magnitude, then the SNR can be very poor

4. Simulation Results

The simulation of the project is comprised of a number of comparisons. We have compared the effect of received signal by applying the zero forcing equalizer with and without the effect of ISI .The analytical result of the Rayleigh-faded channel and AWGN (Additive White Gaussian Noise) are also compared with the simulation results.

In first scene, we will look towards the effect of ISI on the received signal with some noise without applying the ZF equalizer at receiver. The graph obtained in this case is shown below

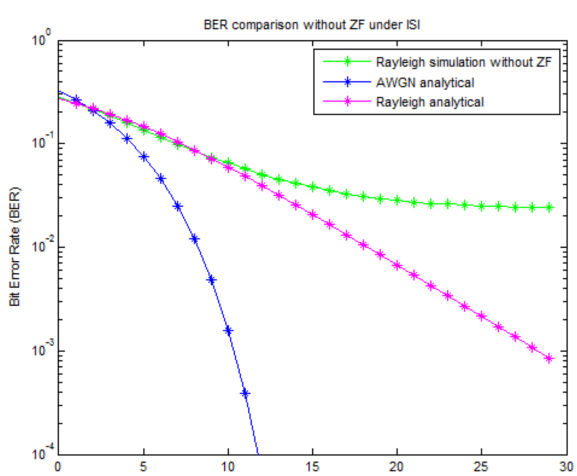

Fig:BER comparison without applying the ZF equalizer under the effect of ISI

In second scene, we will look towards the effect of ISI on the received Signal with some noise with using ZF equalizer at receiver. The graph obtained in this case is shown below:

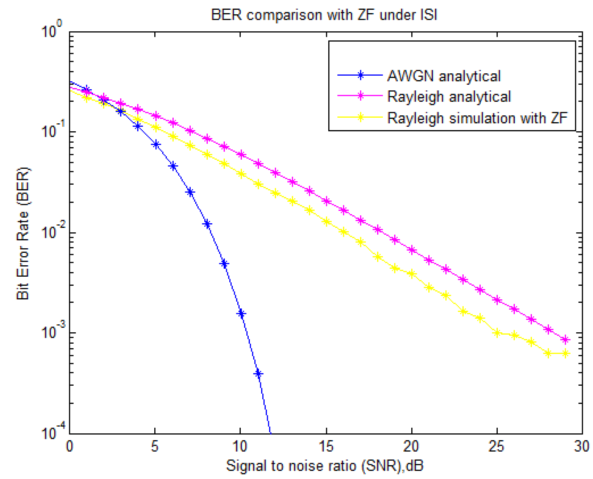

Fig: BER comparison using ZF equalizer under the effect of ISI.

If we combine both of the above mentioned graphs, we see that by applying the ZF equalizer the BER v/s SNR result is better than without applying the same equalizer For creating the effect of ISI in received signal while using MATLAB tool, we apply a filter which is freq (frequency) cut. The frequency cut is designed in such a way that if increases its value, the ISI effect decreases. Let us first consider case in which the value of freq cut is 50. The graph shows the effect of BER v/s SNR for freq cut=50

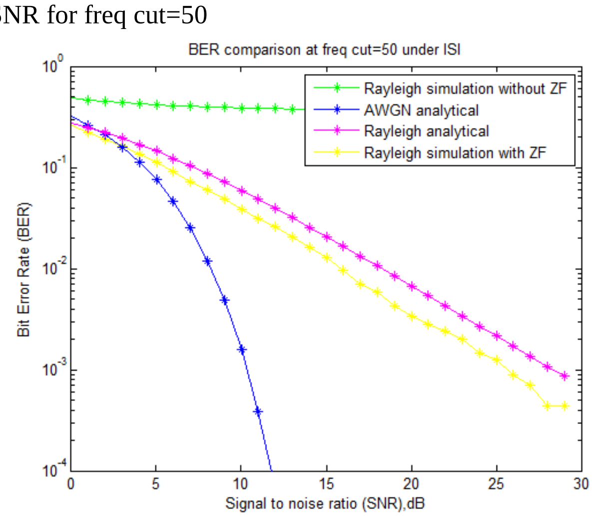

Fig: BER comparison by setting the ISI co-efficient freq cut=50

Now let us consider the second case in which the value of co-efficient freq cut=100. The ISI effect decreased. The graph shows the effect of ISI on the received signal at freq cut=100

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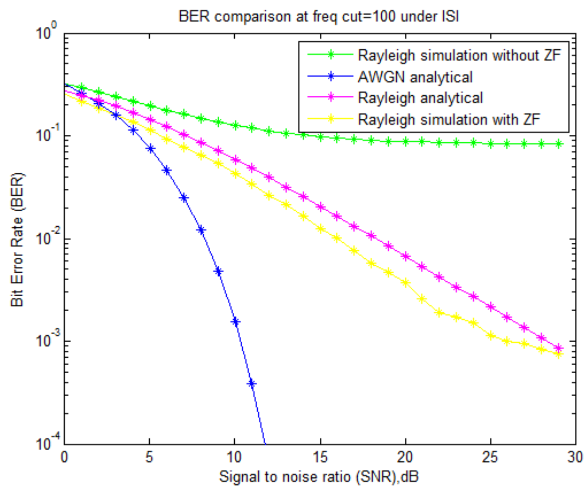

Fig: BER comparison by setting the ISI co-efficient freqcut=100

If the value of ISI coefficient is further increased to freq cut=200, we can see that the effect of ISI is further decreased.

The graph shows the effect of ISI on the received signal for freq cut=200

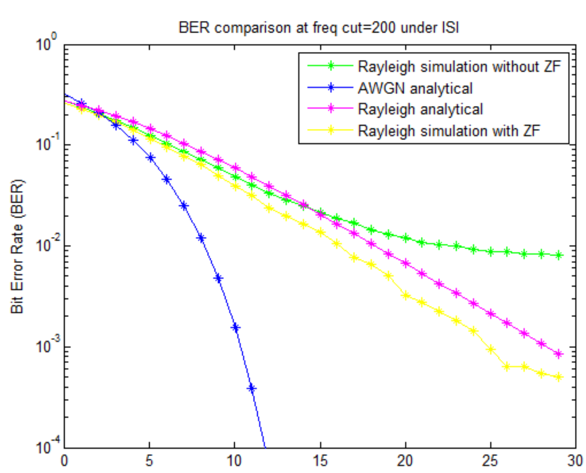

Fig: BER comparison by setting the ISI co-efficient freqcut=200

Similarly for freq cut=600, the figure shown below shows that both the graphs (with and without applying ZF effect) are approximately coincides with each other

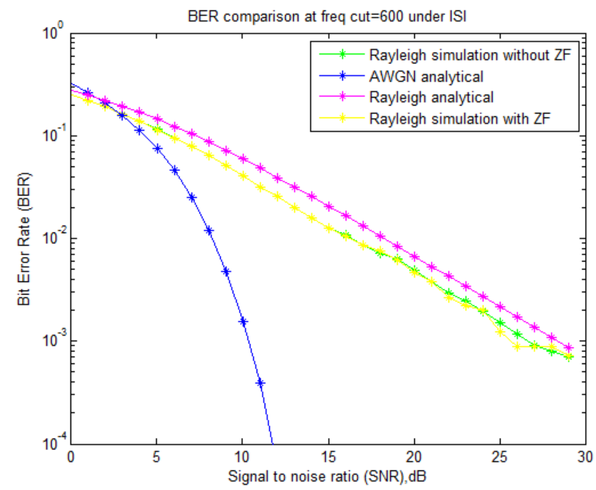

Fig: BER comparison by setting the ISI co-efficient freqcut=600

The above results of all the figures shows us that graph of BER v/s SNR for both the cases (with and without applying ZF effect) shows the same result at the zero ISI effect. From this theory, it has been concluded that the ISI affects the bit-error-rate just like the noise and the zero-forcing equalizer is much useful for mitigating the effect of the bit error rate introduced by ISI. The other equalizers like MMSE and RLS etc do not usually eliminate the ISI effect completely but instead minimizes the total power of noise

5. Conclusion

From the above mentioned simulations, we can conclude that the effect of ISI can be decreased (mitigated) using a specialized equalizing technique called Zero-forcing. The above Figures shows that the effect of ISI causes an increase of Bit Error Rate. By applying the Zero-Forcing equalizer, the bit error rate is decreased.

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