Channel Estimation in Multipath fading Environment using Combined Equalizer and Diversity Techniques

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Abstract - The channel estimation has become very vast field due to different types of interference present in wireless channel and in equipments. In this thesis, estimation algorithms for digital communications systems in the presence of Additive White Gaussian noise and Multipath environment are explored and their performance is investigated. In particular, least square Error and Zero forcing equalizers are used to provide the optimum solution and compensate for Inter-Symbol error. As the BER performance of equalizers in variable in multipath fading channel therefore we have combined Equal Gain combining and Maximal Ratio Combing Diversity techniques, and searched that Maximal Ratio combining techniques is able to fight with Co-Channel interference and Inter-symbol interference problem.

Keywords: - OFDM, Equalizer, Diversity, QAM

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1 INTRODUCTION

Wireless communication [1] systems require signal processing techniques that improve the link performance in hostile mobile radio environments. Complex channel estimation i.e. estimation of channel gain, which includes phase and amplitude. Equalization, diversity and channel coding are three techniques which can be used independently or in tandem to improve received signal quality and link performance over small scale times and distances. In flat fading environment, estimation of the channel using trained sequence of the data has been studied and implemented in [2]. Then pilot data of some required percentage of data length is inserted into the source data. It is used to estimate the random phase shift of the fading channel and train the decision to adjust the received signal with phase recover. So, finally phase estimation using training symbol is implemented in flat fading environment. The radio channels in mobile radio systems are usually multipath fading channel, which are causing intersymbol interference (ISI) and intercarrier interference (ICI) in the received signal. To remove ISI and ICI from the signal many kind of equalizers and diversity algorithms can be used. Detection algorithms based on trellis search like Least square error (LSE) and Zero forcing (ZF) algorithms for equalization[3] and Maximal ratio combining (MRC) and Equal gain combining (EGC) for diversity techniques[4] offer a good receiver performance, but still often not much computation. Therefore, these algorithms are currently quite popular. Channel estimation in frequency selective has different approach then compared with flat fading environment.

Semi analytical method to evaluate BER of quadrature amplitude modulation (QAM) and additive noise where pilot assisted linear channel estimation and channel equalization. A novel channel estimation scheme for OFDMA uplink packet transmissions over doubly selective channels was suggested in [5].

2 OFDM

OFDM is a spectrally efficient modulation technique [6]. It is conveniently implemented using IFFT and FFT operation. There are very fast and efficient implementation of the FFT and IFFT, which is the big reason of the popularity of OFDM. It handles frequency selective channels well when combined with error correction coding. In other words OFDM is frequency division multiplexing of multicarriers which are orthogonal to each other i.e. they are placed exactly at the nulls in the modulation spectra of each other. In OFDM data is divided into several parallel data streams or sub-channels, one for each sub carrier which are orthogonal to each other although they overlap spectrally. Each subcarrier is modulated with a conventional modulation scheme (QAM or QPSK) at a low symbol rate, maintaining total data rates similar to conventional single carrier modulation schemes in the same bandwidth.

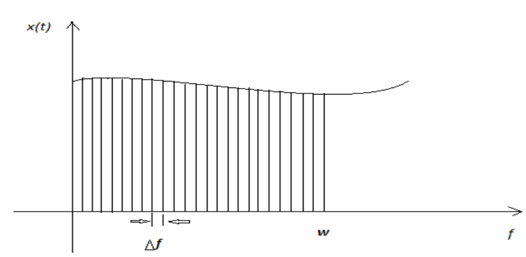

Figure 1 Subdivision of the channel bandwidth W into narrowband sub channels of equal width Δf

The advantages of OFDM include its robustness to narrowband cochannel interference. High spectral efficiency and its low sensitivity to time synchronization errors.

Besides these advantages it has some disadvantages like its complexity and sensitive to Doppler shift and frequency synchronization problems. OFDM requires a more linear power amplifier.

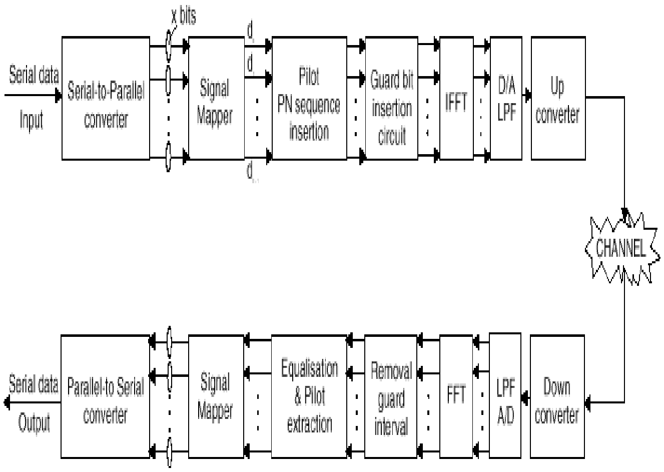

Figure 2 Block diagram of OFDM transmitter and receiver

FFT is written as

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-j2\pi kn/N} \quad ,0 \le k \le N- \quad \text{... (1)}$$

W_N be the complex-valued phase factor

$$W_N = e^{-j2}$$

Thus, X (k) becomes

$$X(k) = \sum_{n=0}^{N-1} x(n) W_N^{nk} \quad ,0 \le k \le N- \quad \text{... (2)}$$

Similarly IFFT is written as,

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} X(k) W_N^{-nk} \quad ,0 \le n \le N- \ldots (3)$$

3 EQUALIZERS

Equalization is the process of adjusting the balance between frequency components within an electronic signal. The circuit or equipment used to achieve equalization is called Equalizer [7]. Equalization compensates for ISI created by multipath within time dispersive channels. If the modulation bandwidth exceeds the coherence bandwidth of the radio channel, ISI occurs and modulation pulses are spread in time into adjacent symbols. 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 known and time varying. So, an adaptive equalizer compensates for an unknown and time varying channel, it requires a specific algorithms to update equalizer coefficients and track the channel variations, we use zero forcing (ZF) algorithm and least square error (LSE) algorithm.

3.1 Zero Forcing Algorithms:

In a zero forcing equalizer, the equalizer coefficients Cn are chosen to force the samples of the combined channel and equalizer impulse response to zero at all. For a channel with frequency response F(f) the ZF equalizer $C(f) = \frac{1}{F(f)}$. Thus the combination of channel and equalizer gives a flat frequency response and linear phase must satisfy Nyquists criterion.

$$F(f)C(f) = 1 \ , \ |f| < \frac{1}{2T} \quad \text{.... (4)}$$

Zero Forcing equalizer has the disadvantage that the inverse filter may excessively amplify noise at frequencies where the folded channel spectrum has high attenuation.

3.2 Least Mean Square Algorithms:

A more robust equalizer is the LMS equalizer where the criterion used is the minimization of the MSE between the desired equalizer output and the actual equalizer output. Define the input signal to the equalizer as a vector yk.

Mean Square Error is

$$E|e_k|^2 = E[x_k^2] + W_k^T E[y_k y_k^T] W_k - 2E[x_k y_k^T] \quad \ldots (5)$$

Equalization can be used to any signal processing operation that minimizes intersymbol interference (ISI). Since the mobile fading channel is random and time varying, equalizer must track the time varying characteristics of the mobile channel and thus are called adaptive equalizer.

4 DIVERSITY

In telecommunication, a diversity scheme refers to a method for improving the reliability of a message signal by using two or more communication channel with different characteristics. Diversity plays an important role in combating fading and co-channel interference and avoiding error bursts. It is based on the fact that individual channels experience different levels of fading and interference. Multiple version of the same signal may be transmitted and/or received and combined in the receiver. Diversity technique may exploit the multipath propagation, resulting in a diversity gain, often measured in decibels.

Diversity combining is the technique applied to combine the multiple received signals of a diversity reception device into a single improved signal. Various diversity combining techniques can be distinguished.

4.1 Equal Gain Combining (EGC):

All the received signals are summed coherently. With two receive antennas, the BER with equal gain combining is

$$P_e = \frac{1}{2}\left[1 - \frac{\sqrt{E_b/N_O\left(\frac{E_b}{N_O}+2\right)}}{\frac{E_b}{N_O}+1}\right] \quad .... (6)$$

The effective $\frac{E_b}{N_0}$ with EGC is

$$E(\gamma_i) = \frac{E_b}{N_O}\frac{1}{N}\left[N + N(N-1)\frac{\pi}{4}\right] \quad .... (7)$$

4.2 Maximal Ratio Combining (MRC):

It is often used in large phased array systems. The received signals are weighted with respect to their SNR and then summed. The resulting SNR yield $\sum_{k-1}^{N}(\mathrm{SNR})_k$ where $(\mathrm{SNR})_k$ is SNR of the received signal k.

Given that the effective bit energy to noise ratio with maximal ratio combining is γ, the total bit error rate is the integral of the conditional BER integrated over all possible values of γ.

$$P_e = \int_0^{\infty}\frac{1}{2}erfc(\sqrt{\gamma})\frac{1}{(N-1)!(E_b/N_O)^N}\gamma^{N-1}e^{\frac{-\gamma}{(E_b/N_O)}}d\gamma \quad . (8)$$

The effective $\frac{E_b}{N_0}$ with MRC is

$$\gamma_i = \frac{|h_i|^2 E_b}{N_O} \quad ... (9)$$

5 QAM

Quadrature amplitude amplitude (QAM) conveys two digital bit streams by changing the amplitudes of two carrier waves using amplitude shift keying. These two sinusoidal waves are out of phase with each other by 90 degrees.

The in-phase signal (the I-signal, e.g., cosine waveform) and a quadrature phase signal (the Q-signal, e.g., sine waveform) are amplitude modulated with a finite number of amplitudes and summed, resulting a combination of phase shift keying and amplitude shift keying.

The QAM equation is represented as follow in equation

$$s(t) = A_c\sqrt{\frac{2}{T}}\cos(\theta(t))\cos(2\pi f_c t) - A_c\sqrt{\frac{2}{T}}\sin(\theta(t))\sin(2\pi f_c t)$$

Where $\theta = \frac{2\pi}{M}$ .... (10)

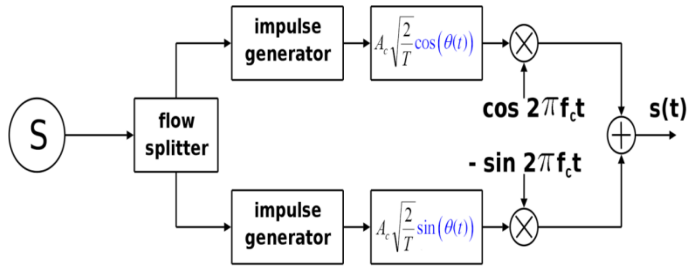

Figure 3 QAM modulator

For a 4-QAM signal, we have M = 4, so we have 4 symbols representing a two bit word. Therefore, for M = 16 and 64, we have 16 symbols representing a four bit word and 64 symbols representing a six bit word respectively.

The bit error probability p_e for M-ary QAM is expressed in equation is

M-ary QAM

$$p_e \approx 4\left(1-\frac{1}{\sqrt{M}}\right).T.\sqrt{\frac{3}{M-1}.\frac{E}{No}} \quad ... (11)$$

6 RESULT

If we set the simulation environment for the OFDM based wireless modulation, then we get the variable performance for equalizers as well as for diversity techniques.

The following results have been obtained with the considered combinations.

Figure 1, shows the effect of 256 OFDM subchannels, 4 QAM with 1000 number of iterations.

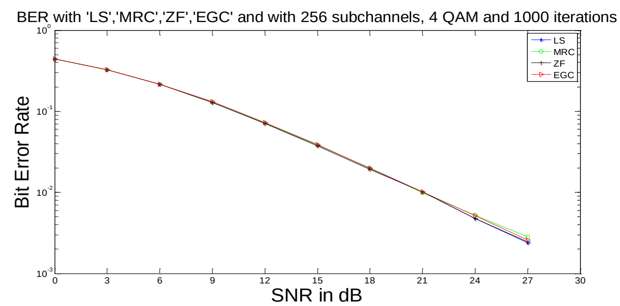

Figure 1.

SNR in db	Bit Error Rate (BER)			
	LSE	MRC	ZF	EGC
0	0.4428	0.4419	0.4427	0.4413
3	0.3274	0.3251	0.326	0.3261
6	0.2169	0.2129	0.216	0.2164
9	0.1295	0.1303	0.1293	0.128
12	0.07232	0.07127	0.07129	0.07243
15	0.03764	0.03817	0.0374	0.03802
18	0.01908	0.02022	0.02006	0.0202

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21	0.01	0.01014	0.01015	0.0104
24	0.004996	0.00517	0.00504	0.005371
27	0.002598	0.002652	0.002759	0.002478

Figure 2, shows the effect of 1024 OFDM subchannels, 4 QAM with 1000 number of iterations.

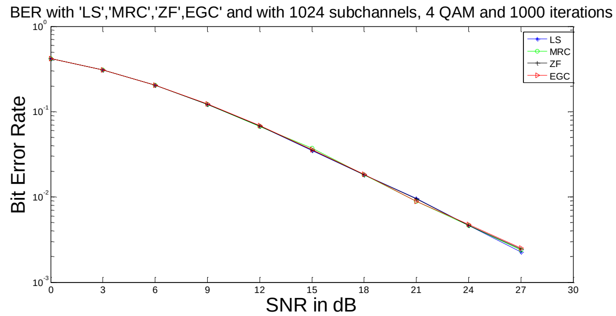

Figure 2

SNR in db	Bit Error Rate (BER)			
	LSE	MRC	ZF	EGC
0	0.4181	0.4182	0.4191	0.4178
3	0.3081	0.3084	0.3077	0.3088
6	0.2033	0.2043	0.2047	0.2024
9	0.122	0.1215	0.1221	0.1223
12	0.0687	0.0663	0.0688	0.06694
15	0.0362	0.03601	0.03602	0.0357
18	0.01845	0.01839	0.01869	0.01836
21	0.009338	0.009385	0.009499	0.00946
24	0.004613	0.00473	0.004795	0.004741
27	0.002357	0.002438	0.002385	0.002478

Figure 3, shows the effect of 512 OFDM subchannels, 32 QAM with 1000 number of iterations.

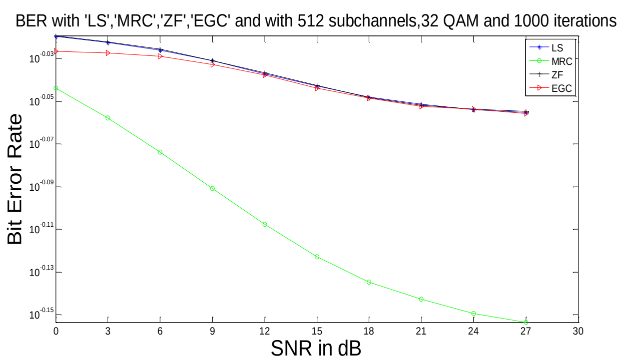

Figure 3

SNR in db	Bit Error Rate (BER)			
	LSE	MRC	ZF	EGC
0	0.9563	0.9044	0.9567	0.9409
3	0.9499	0.8765	0.9502	0.9356
6	0.9418	0.844	0.9419	0.9285
9	0.9311	0.8109	0.9316	0.917
12	0.9183	0.7798	0.9181	0.9047
15	0.907	0.7544	0.9047	0.8949
18	0.8952	0.7327	0.8955	0.8872
21	0.8876	0.7182	0.8878	0.8833
24	0.8834	0.7081	0.8826	0.8805
27	0.8811	0.702	0.8803	0.8793

Figure 4, shows the effect of 1024 OFDM subchannels, 32 QAM with 1000 number of iterations.

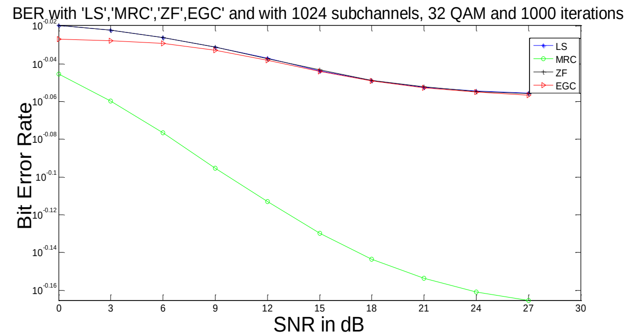

Figure 4

SNR in db	Bit Error Rate (BER)			
	LSE	MRC	ZF	EGC
0	0.9558	0.9009	0.9558	0.9396
3	0.9499	0.872	0.9497	0.9386
6	0.9416	0.8383	0.9419	0.9356
9	0.9304	0.8036	0.9308	0.927
12	0.9181	0.7705	0.9177	0.9159
15	0.9045	0.7416	0.9047	0.9035
18	0.894	0.7204	0.8938	0.8924
21	0.8865	0.7023	0.8867	0.886
24	0.8822	0.6912	0.8822	0.8803
27	0.8794	0.6848	0.8794	0.8789

7 Conclusion

The wireless communication without the channel estimation results in high errors. Therefore channel estimation is most important to know the parameters of the channel and also to get the knowledge of affecting parameters.

If we look at the simulation result with 1024 sub channels and 1000 iterations, we find that the BER curve is becoming linear and therefore with high number of subcarriers and with 1000 iterations we get better results compared to 256 and 512 sub channel conditions.

One thing is clear here that with lower order QAM modulation techniques results are not much comparative, but results in bunching like the optimum performers.

Only the change between performances can be seen with lower number of subcarriers and with 1000 iterations.

Therefore we conclude with this assumption that with 1000 iterations we have better performance of used algorithms and MRC is very much able to show expected results.

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