

BER Performance Improvement in Multipath Fading Environment Using Combined Equalizer and Diversity Techniques

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Abstract — The wireless communication is impaired by the multipath fading characteristics and therefore creates the problems in proper reception. Therefore the knowledge of the channel and the type of fading is most important in designing the receiver. 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 equalizer and Zero forcing equalizers are used to provide the optimum solution and compensate for Inter-Symbol error. As the BER performance of equalizers is variable in multipath fading channel therefore we have combined Equal Gain combining and Maximal Ratio Combining Diversity techniques, and find that Maximal Ratio combining techniques is able to fight with Co-Channel interference and Inter-symbol interference problem. The above approaches have resulted in big improvement in BER performance.

Key Words — OFDM, Equalizer, Diversity, QAM.

I. INTRODUCTION

The radio channels in mobile radio systems are usually multipath fading channels, which are causing intersymbol interference in the received signal. To remove intersymbol interference from the signal, much kind of equalizers and diversity algorithm can be used. The wireless radio channel can be parameterized as a combination of paths, each characterized by a delay and complex amplitude. The amplitudes show fast temporal variations due to the mobility of terminals while the delays are almost constant over a large number of orthogonal frequency division multiplexing (OFDM) symbols. A possible approach is that of explicitly estimating and tracking the delay [1]. It is well known that the wireless channel causes an arbitrary time dispersion, attenuation, and phase shift in the received signal. The use of OFDM is to mitigate the effect of time dispersion. The function of channel estimation is to form an estimate of the amplitude and phase shift caused by the wireless channel and allows subsequent symbol demodulation.

OFDM is a special case of multicarrier transmission and it can accommodate high data rate requirement of multimedia based wireless systems. Since channel estimation is an integral part of OFDM systems. As a combination of MIMO-OFDM systems promises higher data rates. OFDM divides the available spectrum into a number of overlapping but orthogonal narrowband sub channels, and hence

converts a frequency selective channel into a non frequency selective channel [2].

II. OFDM (ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING)

OFDM is a multicarrier system uses Discrete Fourier Transform/ Fast Fourier Transform and $\frac{\sin x}{x}$ spectra for subcarriers. OFDM is becoming widely applied in wireless communications systems due to its high rate transmission capability with high bandwidth efficiency and its robustness with regard to multipath fading and delay [4]. Available bandwidth is divided into very many narrow bands for example 2000-8000 hz for digital TV and 48 hz for hiperlan2 and data is transmitted in parallel on these bands. OFDM method is so popular for new broadband systems are subject to multipath transmission.

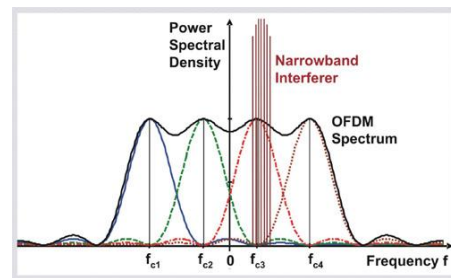


Fig. 1.

OFDM is a combination of modulation and multiplexing. Modulation means a mapping of the information on changes in the carrier phase, frequency or amplitude or combination. Multiplexing means a method of sharing a bandwidth with other independent data channels. OFDM is a special case of FDM. In OFDM the signal itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier.

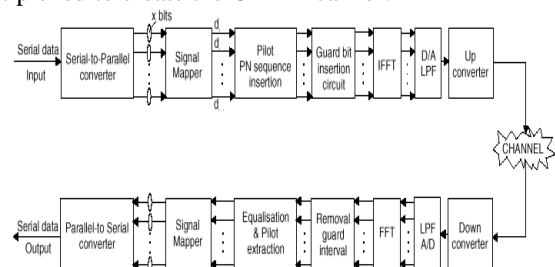


Fig. 2. Block diagram of an OFDM system using FFT, pilot PN sequence and a guard bit insertion FFT is written as



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

W_N be the complex-valued phase factor

$$W_N = e^{-j2\pi/N}$$

Thus, $X(k)$ becomes

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

Similarly IFFT is written as,

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

III. QUADRATURE AMPLITUDE MODULATION (QAM)

QAM is more efficient in terms of bandwidth than either FSK or QPSK, but it is also more susceptible to noise. The disadvantage of DSB signals which is occupy twice the bandwidth required for the baseband can be overcome by transmitting two DSB signals using carriers of the same frequency but in phase quadrature [5].

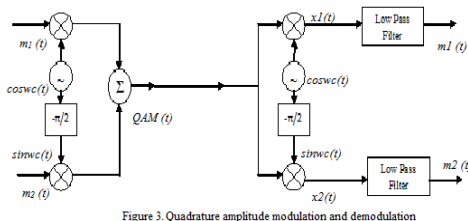


Figure 3. Quadrature amplitude modulation and demodulation

In this figure, the boxes labeled $-\pi/2$ are phase shifters, which delay the phase of an input sinusoid by $-\pi/2$ rad. If the two baseband signals to be transmitted are $m_1(t)$ and $m_2(t)$, the corresponding QAM signal $\phi_{QAM}(t)$, the sum of the two DSB-modulated signals is

$$\phi_{QAM}(t) = m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c(t) \quad \dots (4)$$

Both modulated signals occupy the same band. Yet two baseband signals can be separated at the receiver by synchronous detection using two local carriers in phase quadrature.

$$x_1(t) = 2\phi_{QAM}(t)\cos\omega_c(t)$$

$$x_1(t) = 2[m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c(t)]\cos\omega_c(t) \quad \dots (5)$$

$$x_1(t) = m_1(t) - m_1(t)\cos2\omega_c t + m_2(t)\sin2\omega_c(t) \quad \dots (6)$$

The last two terms are suppressed by the low-pass filter, yielding the desired output $m_1(t)$. Similarly, the output of the lower receiver branch can be shown to be $m_2(t)$. This scheme is known as quadrature amplitude modulation (QAM). Thus, two baseband signals, each of bandwidth B Hz, can be transmitted simultaneously over a bandwidth 2B by using DSB transmission and Quadrature multiplexing.

IV. EQUALIZER

Theoretically, an equalizer [6] should have a frequency characteristic that is the inverse of that of the transmission medium. This will restore higher frequency components and eliminate pulse dispersion. Unfortunately, this also increases the received channel noise by boosting its high-frequency components. For digital signals, however, complete equalization is really not necessary, because a detector has to make relatively simple decisions- such as whether the pulse is positive or negative.

4.1 Zero Forcing equalizer (ZF)

It is really not necessary to eliminate or minimize ISI with neighboring pulses for all t. all that is needed is to eliminate or minimize interference with neighboring pulses at their respective sampling instants only, because the decision is based only on sample values. This can be accomplished by the transversal-filter equalizer encountered earlier, which forces the equalizer output pulse to have zero values at the sampling instants. In other words, the equalizer output pulses should satisfy the Nyquists criterion or the controlled ISI criterion.



Figure 4. Block diagram of channel with zero-forcing equalizer

$$C(z)F(z) = 1$$

$$C(z) = \frac{1}{F(z)} \quad \dots (7)$$

4.2 Least Mean Squared Error Equalizer (LMSE)

Another approach to equalization, the least mean squared error method, does not try to force the pulse samples to zero at 2N points. Instead the mean of the squared errors over a set of output samples is minimized [7].

The prediction error is given by

$$e_k = d_k - \hat{d}_k = x_k - \hat{d}_k \quad \dots (8)$$

$$e_k = x_k - y_k^T W_k \quad \dots (9)$$

W_k is a weight vector

To compute the mean square error $|e_k|^2$ at time instant k.

$$|e_k|^2 = x_k^2 + W_k^T y_k y_k^T W_k - 2x_k y_k^T W_k \quad \dots (10)$$

Taking the expected value of $|e_k|^2$ over k yields

$$E|e_k|^2 = E[x_k^2] + W_k^T E[y_k y_k^T] W_k - 2E[x_k y_k^T] W_k \quad \dots (11)$$

W_k filter weights are not included in the time average since, for convenience, it is assumed that they have converged to the optimum value and are not varying with time.

V. DIVERSITY

Diversity techniques [8] are based on the notion that errors occur in reception when the channel attenuation is large, i.e. when the channel is in a deep fade. If we can supply to the receiver several replicas of the same information signal transmitted over independently fading channels, the probability that all the signal components will fade simultaneously is reduced considerably.

5.1 Maximal Ratio Combining (MRC)

In telecommunications, maximal-ratio combining [9] is a method of diversity combining in which: (a) the signals from each channel are added together, (b) the gain of each channel is made proportional to the rms signal level and inversely proportional to the mean square noise level in that channel. (c) different proportionality constants are used for each channel. It is also known as ratio-squared combining and predetection combining. Maximal-ratio-combining is the optimum combiner for independent AWGN channels. In this method, the diversity branches are weighted for maximum SNR as can be seen in Figure 5 [9].

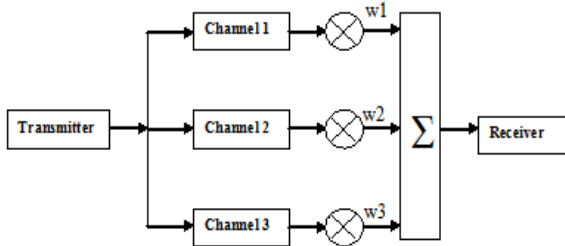


Figure 5. Block diagram of Maximal Ratio Combining

The Combiner output is given by

$$y(t) = \sum_{i=0}^{M-1} w_i r_i(t) \quad \dots\dots\dots (12)$$

The SNR of the combined signal is

$$\Gamma = \frac{\sum_{i=0}^{M-1} A_i^2 E_b}{N_0} \quad \dots\dots\dots (13)$$

5.2 Equal-Gain Combining Diversity (EGC)

Various techniques are known to combine the signals from multiple diversity branches. In Equal Gain Combining, [10] each signal branch weighted with the same factor, irrespective of the signal amplitude. However, co-phasing of all signals is needed to avoid signal cancellation. In figure 5 each branch signal is rotated by $e^{-j\theta_i}$, all branch signals are then added.

The Combiner output is given by

$$y(t) = \sum_{i=0}^{M-1} e^{-j\theta_i} r_i(t) \quad \dots\dots\dots (14)$$

The SNR of the combined signal is

$$\Gamma = \frac{(\sum_{i=0}^{M-1} A_i)^2 E_b}{MN_0} \quad \dots\dots\dots (15)$$

VI. RESULTS

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.

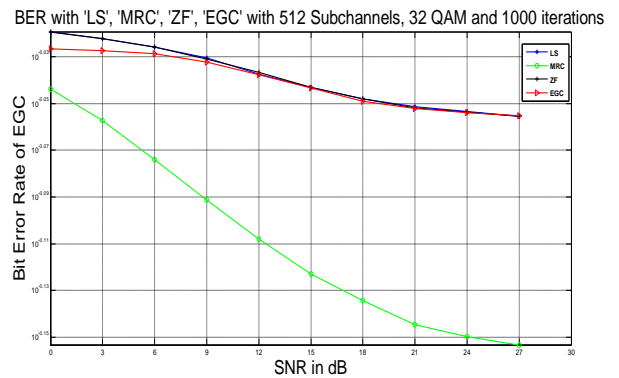


Fig. 1.

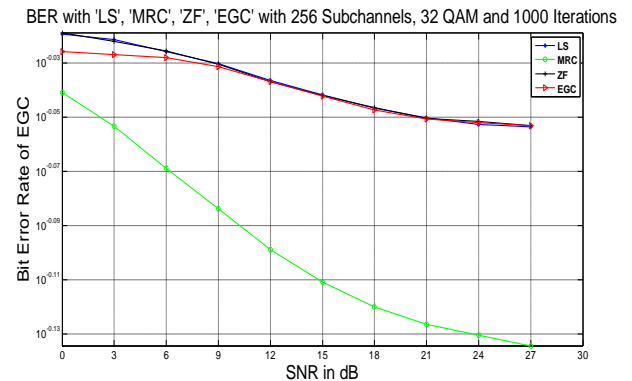


Fig. 2.

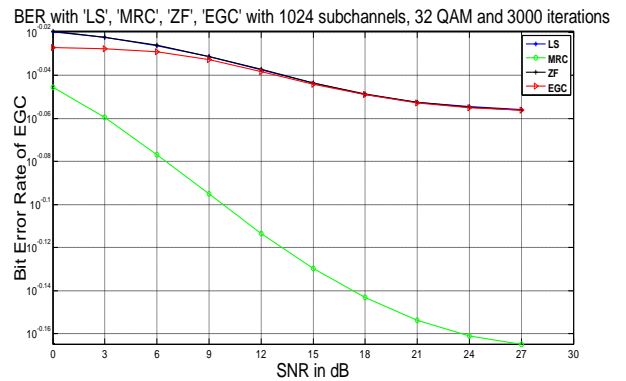


Fig. 3.

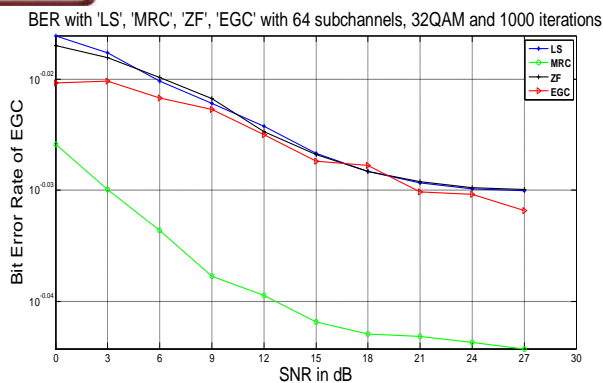


Fig. 4.

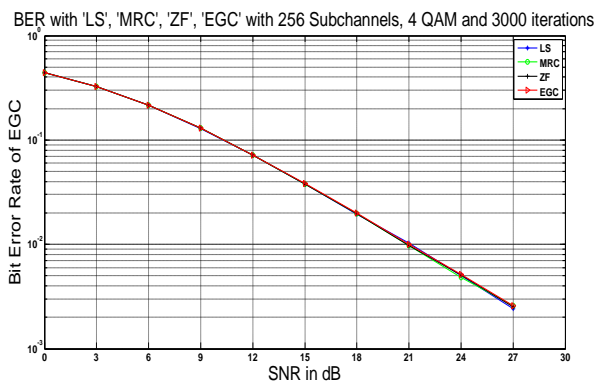


Fig. 8.

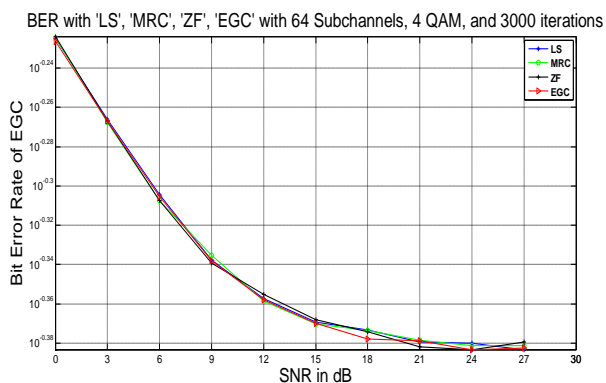


Fig. 5.

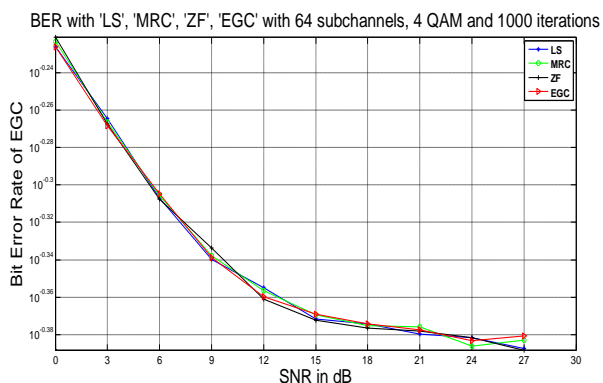


Fig. 6.

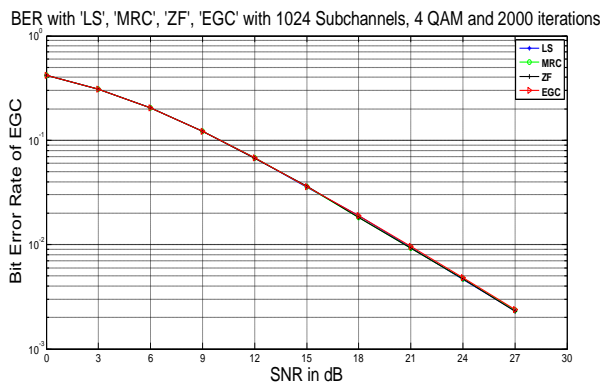


Fig. 7.

VII. CONCLUSION

In this paper we have considered the maximum number equals 3000. We have also considered varying number of subchannels. The wireless communication without the channel estimation results in high errors. Therefore channel estimation is important to know the parameters of the channel and also to get the knowledge of affecting parameters. Without the channel estimation we can not find the proper knowledge of the channel and impairments.

If we look at the simulation result with 1024 subchannels 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 more better results compared to 256 and 512 subchannel conditions. Figure no.7, shows the effect of the

different equalizers and diversity techniques with the 2000 iterations and 1024 subchannels. Here we find the results in the range of 0.1 to 0.001. But not a good difference is seen here.

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 more number of iterations and with the higher number of subchannels results can be improved but at the cast of high simulation time. Finally with 1000 iterations we have better performance of used algorithms and MRC is very much able to show expected results and with less complexity in achieving the better BER performance.

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