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A Study on QoS Improvement using MIMO-OFDM Technique

T. Kannan[1], T. Krishnakumar[2], M. Karthikeyan[3] and K. Selvakumar[4]

[1]Bharath University, Chennai – 600073, Tamil Nadu, India; kannabbran@gmail.com
[2]Strategy and Planning, BIHER, Chennai – 600073, Tamil Nadu, India; foryoukk@yahoo.com
[3]Tamil Nadu College of Engineering, India; mkarthikn@rediffmail.com
[4]SRM University, Chennai – 603203, Tamil Nadu, India; selvakse@gmail.com

Abstract

Objectives: This paper elucidates the analytical study of the diversity schemes and the channel estimation techniques. **Methods/Analysis:** The future generation wireless communication systems require high speed data connection with lower bandwidth usage and high QoS with minimal system complexity. So, Multiple-Input Multiple-Output (MIMO) is one of the best and suitable solutions for future wireless system demands and not disturbing the bandwidth. MIMO offers spatial multiplexing and diversity gains. **Findings:** The combination of Orthogonal Frequency Division Multiplex (OFDM) with MIMO enables the users to get the advantages of both OFDM and MIMO and Spatial multiplexing concept is used in this system to increasing the spectral efficiency of a system. The signal fading is caused by destructive interference. **Novelty/ Improvement:** To improve the signal quality, we can use the different diversity schemes and channel estimation techniques and discussed in this paper detail.

Keywords: Channel Estimation, Diversity Gain, MIMO, Multiplexing, OFDM

1. Introduction

Among many wireless local area network transmission techniques, *Orthogonal Frequency Division Multiplex* (OFDM) serves but suitable for high data rate[1,2]. The parameter diversity gain plays a vital role in data transmission. Here it improves the diversity gain of OFDM combined with Multiple-Input Multiple-Output (MIMO)[3] and hence the capacity of system is also improved on time varying multipath fading[4] channel. MIMO has multiple transmitting and receiving antennas. Since it is important to minimize the hardware complexity at receiver side. MIMO-OFDM decodes frequency selective channel into collection of frequency flat sub channel[5].

The Inter Symbol Interference (ISI) is drawback in wireless transmission. It is minimized by introducing guard band or by minimizing the bandwidth of sub channel, results in increasing sub carriers. Since introducing the guard band causes power loss and bandwidth expansion, and reducing the bandwidth of sub channel is the suitable method for minimizing ISI[6].

The MIMO-OFDM implementation was reviewed in[7,8]. The most difficult issues in OFDM namely time and frequency synchronization, peak-to-mean power ratio and on mitigating the effects of the frequency selective fading channels are addressed by research articles. Also in OFDM[9] system design, channel estimation and equalization is also addressed recently.

Normally channel estimation is one of the fundamental issues. The channel frequency response or impulse response is derived often based on training sequence or pilot symbols, but it is also possible to utilize non-pilot aided method like blind equalizer algorithms. If the channel is not estimated, then it is necessary to utilize non coherent detection which leads to power loss of three to four dB compared to coherent detection. The basic task of equalizer is to compensate the channel influence. Thus compensation also requires the estimation of the channel.

*Author for correspondence

Hence channel estimation plays a vital role in MIMO-OFDM. QoS improvement using diversity schemes are discussed here.

2. Diversity Schemes

'Diversity schemes are used to improve the system performance and channel capacity by combating the effect of fading. The main idea of diversity is to send multiple replicas of the message signal to the receiver. The receiver receives N number of copies of the independently faded message signal from the transmitter, where N is the number of channels. For a particular time, the some of the received signals were not be affected much by fading and this concept improves the quality of reception. Here redundancy is introduced to maximize the diversity gain or to minimize the bit error rate.

The diversity schemes are classified as follows:

- Time (temporal) diversity
- Frequency diversity
- Spatial diversity

A. Time Diversity

In time diversity, the same information symbol is frequently transmitted at sufficiently separated time periods. This makes the same information symbol to fade with different channels. This scheme may affect the spectral efficiency of the system.

B. Frequency Diversity

In frequency diversity, the same information symbol is frequently transmitted at sufficiently separated frequency bands. This makes the same information symbol to fade with different channels. This requires additional bandwidth and causes the loss in spectral efficiency.

C. Spatial Diversity

Instead of using single transmitting and receiving antenna, multiple antennas are used at both transmitter and receiver. The minimum spacing between the antennas is maintained to λ/2 meters, where λ represents wavelength. It has been proved that this minimum separation ensures independent fading at each antenna. Because of the larger size of BS, MIMO is easily employable at the transmitter side. The conventional spatial diversity schemes are shown in Figure 1.

In receive diversity schemes; multiple antennas are deployed at the receiver (Rx) to receive different faded copies of transmitted information signal. Measurement of SNR at every antenna for every symbol period consumes

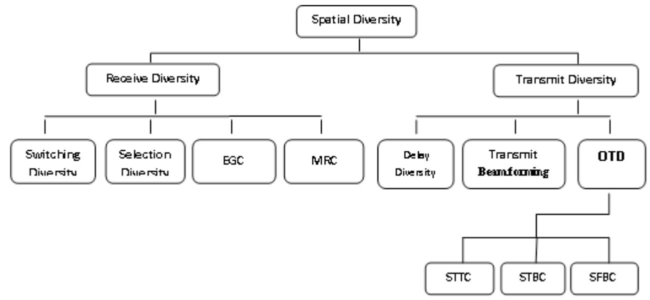

Figure 1. Conventional spatial diversity schemes

lot of energy in selection diversity. Switching diversity is easy for implementation and consumes less energy when compared to selection diversity. The major disadvantage is switching will not occur until the present receiving antenna's signal quality goes below the threshold even though other antennas have better channel conditions. In Equal Gain Combining (EGC) only the phase effect of the channel is compensated. To compensate both magnitude and phase effect of the channel, the other receive diversity scheme called Maximal Ratio Combining (MRC) is used. Here all receiver antennas are connected to the receiver at any time. All the received signals are weighted and coherently combined at the receiver which improves the system performance. This scheme gives greater resistance to fading. The SNR after MRC becomes,

$$SNR = \frac{\|\boldsymbol{h}\|^2 E}{\sigma_w^2} \quad (1)$$

where $\|\boldsymbol{h}\|^2 = |\boldsymbol{h}^{1,1}|^2 + |\boldsymbol{h}^{2,1}|^2 + \cdots + |\boldsymbol{h}^{N_R,1}|^2$ (2)

Where N_R is the number of receiving antennas and in $\boldsymbol{h}^{i,j}$ the superscript i and j indicates receiver and transmitter antenna indices respectively. From (2), it is very clear that MRC offers a diversity gain of NR. In Single-Input and Single-Output (SISO) case, there will be only one channel. If the channel is poor, the *Signal-to-Noise Ratio* (SNR) also becomes poor. In cellular communication the receiver is usually Rx. Actually the Rx station is a smaller size, so due to this it is not possible to place a multiple antennas with the distance λ/2 and which makes MRC inefficient.

Placing multiple antennas at the transmitter i.e. BS is possible because of the larger size of the BS. Transmit diversity based on pre-coding needs accurate channel information at the transmitter side. Assume a modulated symbol X is transmitted through NT transmitting antennas. Before transmission it is pre-coded using a weight vector as,

$$\begin{bmatrix} \frac{h^{1,1^*}}{\|h\|} \\ \frac{h^{1,2^*}}{\|h\|} \\ \vdots \\ \frac{h^{1,N_T^*}}{\|h\|} \end{bmatrix} X \begin{bmatrix} \frac{h^{1,1^*}}{\|h\|} \\ \frac{h^{1,2^*}}{\|h\|} \\ \vdots \\ \frac{h^{1,N_T^*}}{\|h\|} \end{bmatrix} X \qquad (3)$$

It is proved that the SNR obtained by MRC and transmit diversity based on precoding schemes are same. In transmit diversity system, the channel information to be clear and accurate in the transmitter side, but it is impossible for every time. So, the channel estimation error and channel information feedback delay makes transmit diversity scheme with pre-coding inefficient.

Mr. Alamouti proposed a transmit diversity scheme for (2Tx,1Rx) system with flat fading channels. This scheme does not require the channel information at the transmitter side. It offers performance almost similar to MRC and transmit diversity with pre-coding with a loss of 3 dB. This scheme was later generalized by Tarokh for multiple transmitting antennas[10]. It is named as Space Time Block Codes (STBC). STBC is most popular diversity scheme adopted for Universal Mobile Telecommunication Standard (UMTS). There are some other codes called Space Time Trellis Codes (STTC) which also offers spatial and time diversities. The decoding complexity increases along with the modulation order, code length and state number[11]. Because of low decoding complexity and full diversity gain STBC is often preferred for flat fading channels. Like STBC, SFBC is also preferred for the transmission.

3. Channel Estimation

According to channel estimation, the piliot cells have been arranged in various patterns in means of interpolation and channel estimation on data carriers and channel estimation on data carriers and channel estimation tracking, where piliot cells are transmitted with data cells which is used for data transmission.

Channel Estimation for OFDM[12] uplink has time variant multipath fading, multi access interference and ISI which constitute major pairing error. Channel estimation is a crucial part of a multi user receiver[13]. When the load is increases, the least square algorithm is suffered by slow convergence. So calling the random variable *R*, it will have a probability density function.

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega} \qquad (4)$$

Where the variable $\Omega = E(R^2)$

For Rayleigh fading[14] with a vertical receive antenna with equal sensitivity in all directions[15],

$$S(\vartheta) = \frac{1}{\pi f_d \sqrt{1 - \left(\frac{\vartheta}{f_d}\right)^2}} \qquad (5)$$

Where ϑ is the frequency shift relative to the carrier frequency. This equation is only valid for values of ϑ between $\pm f_d$, the spectrum is minimized to zero outside this frequency range.

Input signal to time domain is given by the equation

$$x(n) = IDFT\{X(k)\} \qquad (6)$$

where $n = 0,1,2 \ldots . N-1$

Guard interval has been given by

$$x_f(n) = \begin{cases} x(N+n), & n = -N_g, N_g+1, \ldots . -1 \\ x(n), & n = 0,1,2, \ldots \ldots . N-1 \end{cases} \qquad (7)$$

The received signal is given by

$$y_f = x_f(n) \otimes \boldsymbol{h}(n) + w(n) \qquad (8)$$

where h(n) is channel impulse response and w(n) is white Gaussian noise.

Guard removal is done by

$$y(n) = y_f(n) \qquad n = 0,1,2, \ldots \ldots . N-1 \qquad (9)$$

Output signal from frequency domain is given by

$$Y(k) = DFT\{y(n)\} \qquad k = 0,1,2, \ldots \ldots N-1 \qquad (10)$$

Output signal consists of Transmitted signal, Inter symbol Interference and white Gaussian noise and can be denoted as

$$Y(k) = X(k)H(k) + I(k) + W(k) \quad k = 0,1,2,.N-1 \qquad (11)$$

Finally Estimated Channel Response or System Response can be written as

$$X_e(k) = \frac{Y(k)}{H_e(k)} \quad k = 0,1,2 \ldots \ldots \ldots . N-1 \qquad (12)$$

The consecutive binary values are generated from the source and then it is modulated with different modulated schemes (eg. PSK, BPSK, QPSK, etc,.). After that the modulated signal is converted as OFDM signal and transmitted through the Add White Gaussian Noise (AWGN) channel. So the signal is received in the receiver then demodulated using demodulator and error is observed. Then, this calculated value is the bit error rate.

4. Conclusion and Future Work

In this paper we have studied about the different diversity schemes and the channel estimation, which is useful in minimizing the bit error rate and it results in the increasing the throughput. So, the channel can be clearly estimated and the fading is minimized through the MIMO-OFDM technique. Hence this method can be considered for improving the system performance and there is an enhancement in the error performance for the MIMO-OFDM mobile multimedia communication systems with QoS constraints.

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