Performance of MIMO-OFDM System Based on Channel Estimation for IEEE 802.11n

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Abstract IEEE 802.11n is considered as the current development of standard communication WLAN IEEE 802.11 providing the increase throughput relatively standard to IEEE802.11a/g. The increase of various transmission channel in the wireless communication makes the antenna receiver work harder as the noise and fading happen in the channel. A certain method is needed to predict the channel description between the transmitter and receiver for standard communication WLAN IEEE802.11n. This research does an estimated channel simulation using minimum mean square error (MMSE) method on the MIMO-OFDM system in scheme antennas 2 × 2 and 2 × 4. The rectangular shaping on the time domain is used as channel model approach. The operation of system is stated into impulse responses sent from Tx transmitter antenna to Rx receiver output from the channel estimated output. The computer simulation program shows that the estimated channel works well on the antenna schemes 2 × 2 and 2 × 4.

1 Introduction

In the development of communication system, the need of users in quick access for information is getting higher. To provide the users' demand and increase the system operation, reliable wireless communication system is designed by combining orthogonal frequency-division multiplexing (OFDM) modulation combined with

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system multiple-input multiple-output (MIMO) of which it becomes an important engineering development in WLAN communication appropriate to IEEE 802.11n standard [1].

The increase of various wireless communication channel makes the receiver antenna work harder because the noise and fading get high in the channel itself. Therefore, it needs an estimated method which can be used for making prediction and getting information about channel condition between the transmitter and receiver. The channel estimation system using OFDM pilot comb type with algorithm MMSE [2] results in channel impulse response compared between Rician and Rayleigh channel. The use of pilot comb type channel produces better channel response impulse than the use of block pilot type. However the algorithm MMSE for estimating the real channel condition is applied only on the OFDM system of which the signal quality received by OFDM receiver is rather low. Therefore the channel estimation produced is not so good and needs to combine with MMSE algorithm in interpolated channel. The previous research [3] discusses comprehensively about the block and comb pilot types for channel estimators. The channel estimation using block pilot type is done with and without equalizer decision feedback. Meanwhile, the comb pilot type is done by using pilot frequency method and channel intrusion on data frequency. The comparison on each parameter shows that pilot comb type with algorithm minim mean-square (MMSE) combined with low-pass interpolation shows the best result among all parameters being used. When the doppler value is low, the decrease operation can be ignored though the result of estimated channel using comb type with low-pass interpolation gives good influence for increasing doppler frequency. Another paper using estimation on MIMO-OFDM system [4] discusses the intrusion on the pilot channel on the changing time environment. The method uses a number of L-path channel models for estimating the path complex amplitude (CA) and calculate carrier frequency offset, while the data recovery is done by using equalizer QR. When it is compared to conventional method, the output fading shows better Doppler value 0,1. In this research, estimation is done on the channel of MIMO-OFDM System with schemes 2 × 2, 2 × 4 according to communication standard WLAN IEEE 802.11n. The system MIMO-OFDM gives more advantages such as the deletion of inter-symbol interference (ISI) and inter-carrier interference (ICI) that are caused by multipath channel. Moreover, it can strengthen the received signal on the OFDM system because the use of more than one antenna is good on both the transmitter and receiver.

2 WLAN IEEE 802.11n

WLAN IEEE 802.11n is the current development of WLAN IEEE 802.11 (a/b/g/n) which continuously gets development and improvement in its throughput. WLAN IEEE 802.11n [1] has been applied into a system having many transmitting and receiving antennas with multiple carrier modulation well known as

MIMO-OFDM. WLAN IEEE 802.11n can support the need of users through qualified video streaming that is good for some users at the same time (video conference in one WLAN network) and consistently produces high throughput (gigabyte). Besides, it can improve its Quality of Service (QoS) that is relatively better than its similarly standard WLAN. According to MIMO-OFDM system, standard WLAN IEEE 802.11n is capable to provide more rate data throughput than the original data rate that is from 54 Mb/s up to 600 Mb/s.

2.1 *MIMO-OFDM for WLAN IEEE 802.11n*

MIMO-OFDM in this research uses antenna schemes 2 × 2 and 2 × 4, such as follows in Fig. 1. On the transmission side, series of symbols on frequency domain are put in parallel and modulated with 16-QAM. After that, the block IFFT is added with zero padding symbol with IFFT sizes and the series of symbols are penetrated with one pilot symbol on as many as each subcarrier so that the IFFT output produces symbols with time domain the subcarrier being used. On the transmission site, the series of frequency symbols are inserted in parallel and they are modulated with 16-QAM modulation. Then, the IFFT block is added with zero padding symbols according to IFFT size being used and these series of symbols are penetrated with a symbol of pilot on each subcarrier so the IFFT output produces symbols with time domain as many as subcarriers being used. Next, 25 % of IFFT size is inserted with guard interval of cyclic prefix (CP) in the series of symbols to disappear ISI and ICI. The series of symbols are then ordered and transmitted

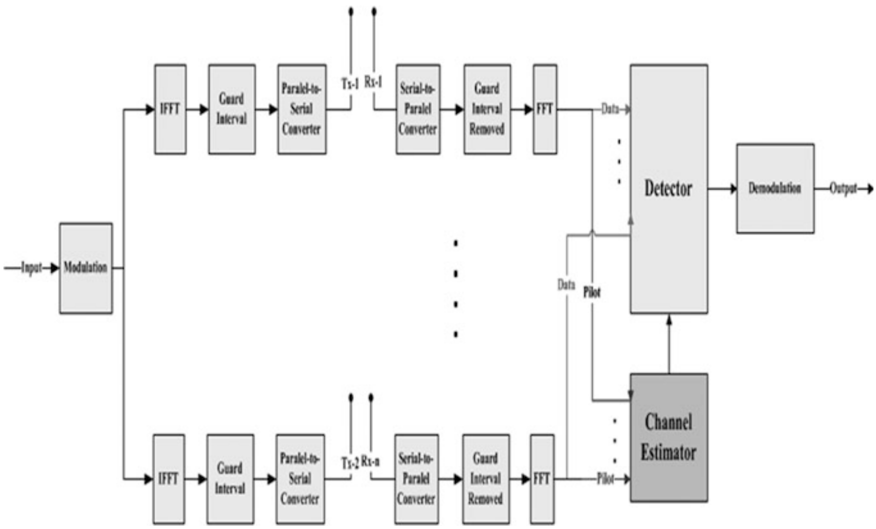

Fig. 1 Block diagram of MIMO-OFDM systems with channel estimation

through the multipath channel. The series of symbols are distributed as Rayleigh and Gaussian and received by an antenna. The series of symbols on the time domain are made parallel and pass through deleting CP block of which the process is done by FFT block. The output of FFT block is the form of pilot and symbol series. The symbol series are accepted by a detector and the series of pilot are managed by an estimator channel block. The output of estimator channel is proceed by a detector altogether with the received symbols. The series of symbols created by the detector are modulated with 16-QAM modulation and symbol output is obtained together with the input on the receiver site. The series of symbols produced by the detector are modulated with 16-QAM and this result in a symbol output that is the same with the input symbol on the receiver side.

2.2 Channel Estimation

On the receiver, the signal is generally made distortion by the channel so that, in order to get back the signal sent, channel estimation and compensation by the receiver must be done. Generally, the signal data can be used to make channel estimation. Some aspects that need consideration in channel estimation are for examples the work expectation, complexion in calculation, the changing of channel time, and so on [5]. In simple way, the channel estimation method together with Minimum Square Error (MMSE) is shown in the block diagram such as on Fig. 2 [7].

Based on Fig. 2, the value of mean square error (MSE) on the estimated channel H is inserted on the following equation.

$$J\left(\widehat{H}\right) = E\left\{\|e\|^2\right\} = E\left\{\left\|H - \widehat{H}\right\|^2\right\} \tag{1}$$

The purpose of MMSE estimation is to get better estimated value; on the other hand, it is intended to choose the most appropriate weight W value. So the Eq. (1) needs to be nominated. And by implementing the orthogonal characteristics on the vector error e = H − H, the equation can be written as follows (2):

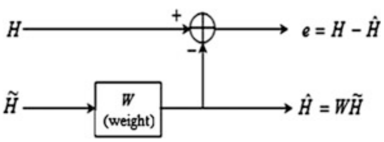

Fig. 2 Channel estimation using MMSE technique

$$\begin{aligned} \left\{e\widehat{H}^{H}\right\} &= E\left\{\left(H - \widehat{H}\right)\widehat{H}^{H}\right\} \\ &= E\left\{\left(H - W\widehat{H}\right)\widehat{H}^{H}\right\} \end{aligned} \tag{2}$$

2.3 The Design of Channel Estimation on MIMO-OFDM System of WLAN IEEE 802.11n

From Fig. 1 channel estimation can be designed we design. This section explains about the approach of channel model that is used so that MMSE method can be processed. This research uses channel model approach that is in rectangular shaping filter for Rayleigh fading channel [6]. The rectangular shaping equation on the time domain is shown as follows (4):

$$p_r(\tau) = \begin{matrix} 1; & 0 \le \tau \le T_1 \\ 0; & otherwise \end{matrix} \tag{4}$$

Note: T1 shows the root-mean-squared delay spread. To get shaping rectangular on frequency domain the equation is derived as follows:

$$\begin{aligned} R_p\left(\Delta_f\right) &= \int_{-\infty}^{\infty} p_r(\tau)e^{-j2\pi\Delta_f\tau}d\tau \\ &= \int_{0}^{T_1} \tau e^{-j2\pi\Delta_f\tau}d\tau \\ &= T_1 e^{-j\pi\Delta_f T_1}\frac{sin\left(\pi\Delta_f T_1\right)}{\pi\Delta_f T_1} \end{aligned} \tag{5}$$

Afterward the Eq. (5) is used to get the matrix covarian such as on the following Eq. (4).

3 Results

This research uses symbols that are transmitted by using 16-QAM modulation. Pilot sequences are insulated by using High Throughtput Long Training Field (HTLTF) basing on IEEE 802.11n on frequency 20 MHz. Other parameters are shown on Table 1.

Table 1 Parameter systems

Part	Parameter	Value
Transmitter	Pilot sequens	HTLTF
	Modulation scheme	16-QAM
	Number of sub-carrier	56
	FFT-size	64
	Dimension of antenna	2 × 2, 2 × 4
	Length of *guard interval*	¼
Channel model	Rayleigh fading	2– *rays*
	Channel model Approximated	Rectangular shaping
Receiver	Channel estimation algorithm	MMSE

3.1 Performance System Testing

3.1.1 Channel Estimation Results

This section shows the results from the output simulation program based on channel estimation design on MIMO-OFDM system using Rayleigh fading channel. The results of simulation is the real and imaginary response impulse values for each antenna schemes that are used in the system as seen from Fig. 3. To save space we only show a few figure. The system with 2 transmitters and 2 receivers gives estimation result that is shown from Fig. 3. The comparison between ideal channel estimation result and ideal channel shows difference error value shown by the error value curve in Fig. 4 for channels h11 in the system with 2 antenna receivers. Each figure states the error value in the real and imaginary subcarrier on each channel. The star curve shows the real error and the other show the error for imaginary. The axis Y shows subcarrier and axis X shows error value on each subcarrier.

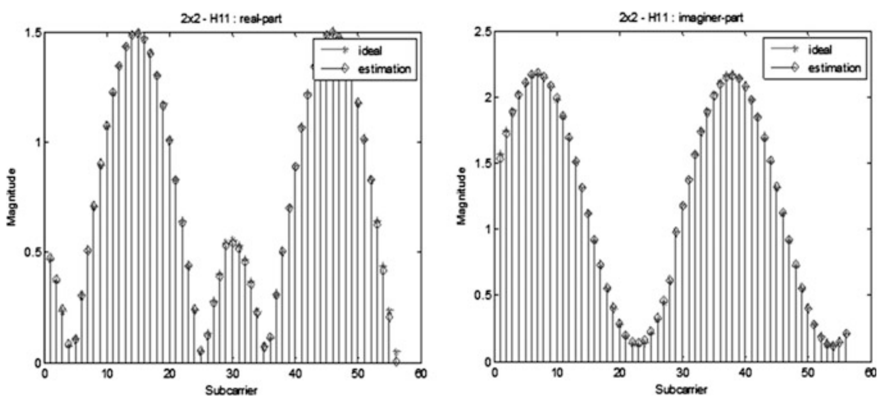

Fig. 3 Estimated channel for real part of MIMO-OFDM 2 × 2 from Tx-1 to Rx-1

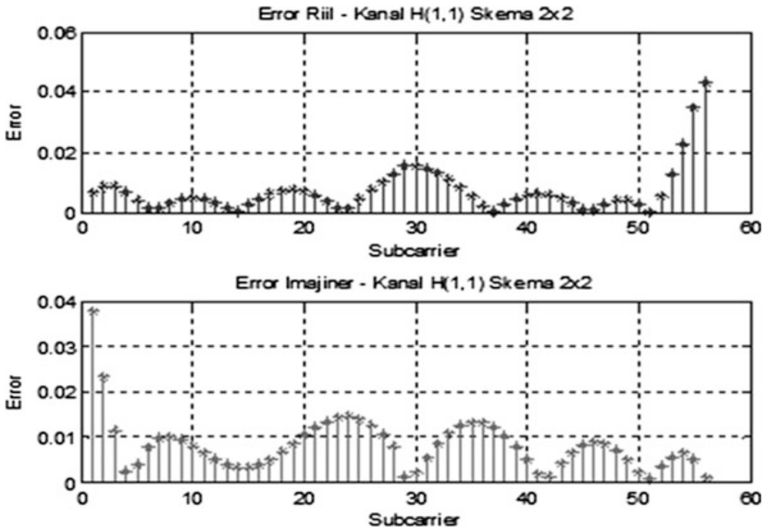

Fig. 4 Deviation/error of real-imaginary parts for channel $h_{1,1}$ of MIMO-OFDM 2 × 2 schemes

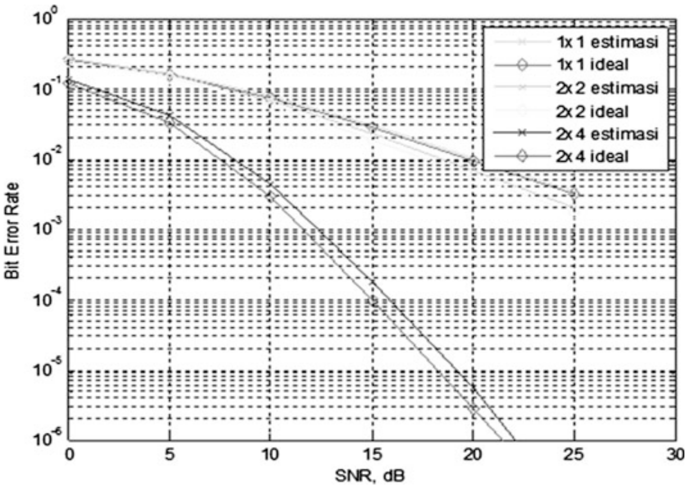

Fig. 5 BER vs SNR of Performance of MIMO-OFDM systems with and without channel estimation for 2 × 2 and 2 × 4 schemes

3.1.2 Bit Error Rate

Figure 5 shows the system SISO-OFDM performance having antenna dimension 1 × 1, system MIMO-OFDM 2 × 2, and system MIMO-OFDM 2 × 4.

4 Discussion

In the wireless communication, signal propagation between the transmitter and receiver passes various different channels. The various channels mark the environment condition of which the multipath continuously changes. The existence of multipath makes the strength of receiving signals different on the receivers. For this reason, MIMO-OFFDM is applied for data transmission on a multipath channel model that is the distribution of Rayleigh fading. Besides, the approach of Additive White Gaussian Noise (AWGN) channel model is also tested by giving disturbance of which the white noise is increased by using Gaussian distribution. On this research, a block estimator channel is added on the MIMO-OFDM system receiver with both antenna schemes 2 × 2 and 2 × 4. The simulation results show that the estimation channel output is shown by series of red dots; while the ideal channel condition is stated with impulse respose in blue color for each real and imagery values. The estimated dot position is not widely different from impulse response ideal channel on both the system scheme with 2 and 4 receivers. The receiver working operation is not influenced by the work of channel estimator however, the operation is still able to estimate exactly the channel condition for each scheme antennas. The different antenna dimension influences on the result of working system on curve BER functioning SNR. The bigger the antenna dimension is, the better system performance it will be. The betterment is marked with the lower value results for BER and SNR shown on Fig. 5.

5 Conclusion

On MIMO-OFDM system with channel estimation technique on Rayleigh channel, it is concluded that estimator channel with antenna schemes 2 × 2 and 2 × 4 can work well because the result shows that the real and imaginary channel response impulse is estimated to have closer response impulse to the ideal channel. When the channel is compared with system MIMO-OFDM having 2 antenna receivers, the MIMO-OFDM system with 4 antenna receivers gives advantage 7.2 dB without channel estimation technique, and 7.5 dB with channel estimation.

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