國 立 交 通 大 學

資訊科學與工程研究所

碩 士 論 文

兩徑通道引起之深衰落
正交分頻多工系統影響研究

Compensation for
Deep Fading Effect of Two-Ray Channel
in OFDM System

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Compensation for Deep Fading Effect of Two-Ray Channel in OFDM System

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摘要

本論文提出了一個在不改變傳送端規格下，在接收端解決深衰落的方法。由於正交分頻多工系統是於多工載波傳送，因此當遇到選擇性衰落的通道時，效能會明顯下降。當傳送訊號通過兩徑通道所產生的深衰落效應時，被深衰落的資料將完全消失，以至於接收端無法正確的把資料解回。

本論文使用一種虛擬通道法，接收端在時域先處理訊號，然後經過快速傅麗葉轉換後，處理被深衰落的訊號。此方法可以在傳送規格 3/4、64QAM 下，在 36 分貝收斂。

Abstract

This paper proposes a method in Rx for deep-fading channel with no variation Tx. Because of OFDM system is multicarrier modulation. Therefore, the performance is affected by selective fading. When the transmitted signal through pass the deep fading channel. The deep fading data will lose after FFT.

This paper of contribution is resolved the deep-fading channel in Rx with no variation Tx. The performance is convergent on 36dB with the data rate 3/4 and 64QAM.

Acknowledgement

I would like to thank my advisors, Dr. Terng-Yin Hsu, for advice, guidance and constant care. To my dear isIP Lab. members, this work would not have been possible without your support. You make me feel free and comfortable. Always be grateful to my family, your unconditional love encourages me all the time.

Sincerely, Shao-Ying Yeh

August 2009

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Chapter 1
Introduction

As the wireless communication is widely applied, serious effect occur in some environment. A special channel called two-ray channel reveals when transmit signals by two paths between transmitter and receiver occurs to.

There is a simple idea in [1]. The idea is precoding OFDM system. In Tx, the signal is precoded before transmitted. And [2] enhance [1]'s method, the ideal is zero-padding in Tx. Insert zero-value in GI(Guard Interval) for equalizer in time-domain. The two methods are result of good performance. But IEEE 802.1 series are not used.

In this paper of contribution is only resolved two-ray channel in Rx by the specification of IEEE, the Tx is not varied. The occasion two-ray channel is introduced in section 1.1. And section 1.2 describes the deep fading effect induced by two-ray channel. Finally, section 1.3 show how OFDM system is crashed by two-ray channel

1.1 Two-ray Channel

In wireless communication, the signal in TX transmitted through channel and received in RX. If RX receives the two signals which delay n_0 apart and have the same attenuation, then the channel we describe is the two-ray channel, as shown in Figure 1-1.

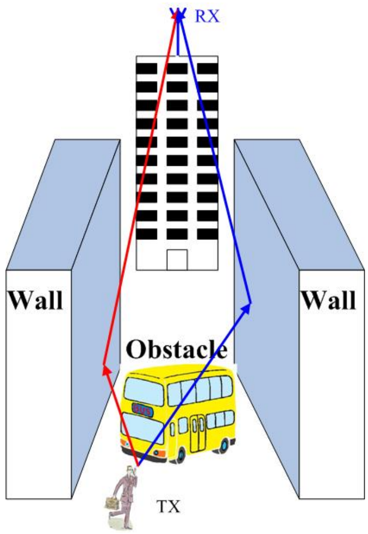

Figure 1-1 Two-ray channel

1.2 Deep Fading Effect

In this paper, we define the deep fading effect which is some approximating zero or zero values on channel frequency response. And the approximating zero or zero values on channel frequency response are defined deep fading points.

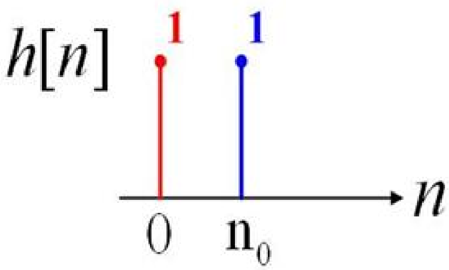

Figure 1-2 Two-ray channel impulse response

The two-ray channel of CIR (channel impulse response) is shown in Figure 1-2, and the mathematic is expressed as:

$$h[n] = \delta[n] + \delta[n - n_0] \tag{1.1}$$

Now, we transfer the CIR to CFR (channel frequency response) by FFT, shown as Figure 1-3. Observation, there is some deep fading points over spectrum.

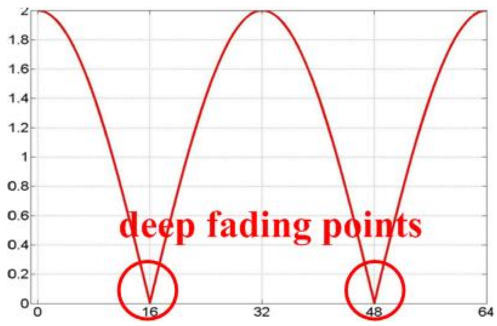

Figure 1-3 Two-ray channel frequency response, $H[k]$

1.2.1 OFDM System

The OFDM systems may be severely distortion by two-ray channel. Because of the OFDM (Orthogonal Frequency-Division Multiplexing) is one of multicarrier modulation and equalization in frequency domain.

In general, the bit-stream data is modulated to tones, transmitted data $S[k]$. In Rx, the transmitted signal through pass to channel, $H[K]$, and add AWGN, $N[k]$, the received signal is $Y[k]$. Because of attenuation of the channel on every tone should be compensated. Therefore, the equalizer compensate for the attenuation to the estimated data $S'[k]$. Above description is in frequency domain, and express as:

$$\begin{aligned} Y[k] &= H[k]S[k] + N[k] \\ \Rightarrow S'[k] &= \frac{Y[k]}{H[k]} \\ &= S[k] + \frac{N[k]}{H[k]} \end{aligned} \tag{1.2}$$

For example, Figure 1-4 show the Tx which transmitted data are all ones tones in frequency, and this signals which through pass to two-ray channel, Figure 1-3 , is received in Rx, shown in Figure 1-5. And then we equalize the received signal, shown in Figure 1-6. There is two distorted points by noise enhance. Conclusion, the distorted tones are deteriorated on deep fading points.

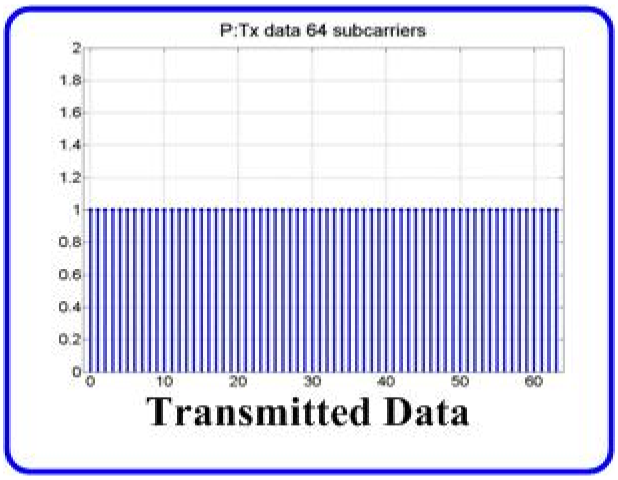

Figure 1-4 Transmitted Data, $S[k]$

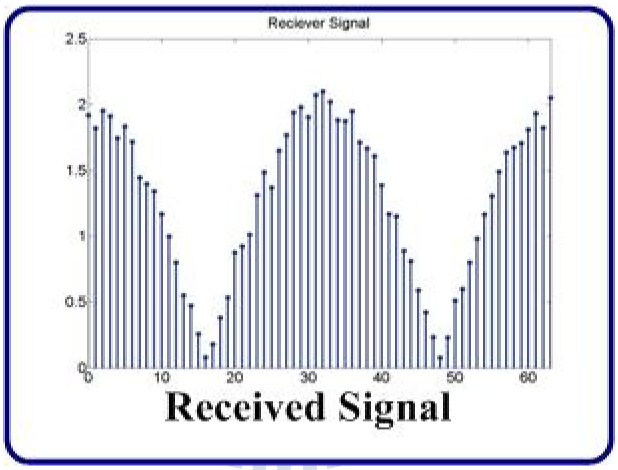

Figure 1-5 Received Signal, $Y[k]$

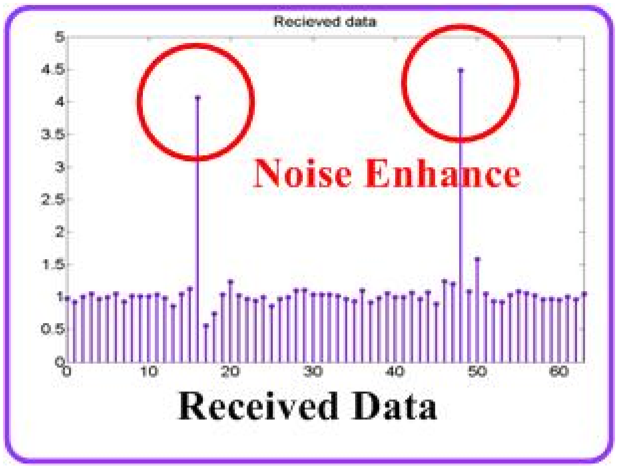

Figure 1-6 Received Data, $S'[k]$

Chapter 2
System platform

2.1 IEEE 802.11a PHY Specification

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation that achieves high data rate and combat multi-path fading in wireless networks. The main concept of OFDM is to divide available channel into several orthogonal sub-channels. All of the sub-channels are transmitted simultaneously, thus achieve a high spectral efficiency. Furthermore, individual data is carried on each sub-carrier, and this is the reason the equalizer can be implemented with low complexity in frequency domain.

2.1.1 Transmitter

The transmitter block diagram of OFDM specified in IEEE 802.11a proposal is shown as Figure 2-1. The source data is first scrambled to prevent a succession of zeros or ones, and then it is encoded by convolutional encoder, which is used as Forward Error Correction (FEC). The FEC-encoded bit stream is punctured in order to support four coding rates, 1/2, 2/3, 3/4 and 5/6.

The interleaver changes the order of bits to prevent burst error. Then the interleaved sequence of bit is modulated (to complex constellation points), there are four kinds of modulations, BPSK, QPSK, 16-QAM and 64-QAM.

There are 64 frequency entries for each IFFT, or 64 sub-carriers in each OFDM symbol. 52 of them are data carriers, 4 of them are pilot carriers and the rest 8 are null carriers. Finally, the time domain signals appended to the Guard Interval (GI) of 1/4 symbol length, are transmitted by RF modules.

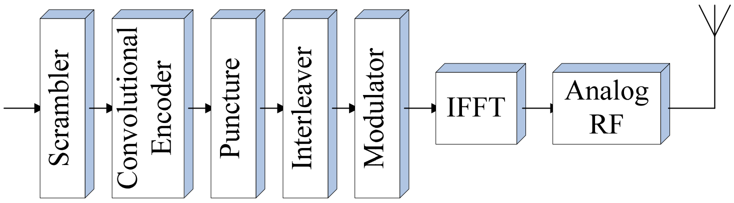

Figure 2-1 IEEE 802.11a transmitter

2.1.2 Receiver

The receiver block diagram is shown as Figure 2-2. Signals received from the RF modules are first synchronized to recognize each OFDM symbol. Each OFDM symbol is transformed to frequency domain by the Fast Fourier Transform (FFT). If the OFDM symbol belongs to long preamble (described in section 2.1.3), then it is used for channel estimation. Otherwise, it belongs to payload and is decoded by equalizer, which needs the CFR information estimated by the channel estimation block.

After separated by equalizer, the data carriers are demodulated to bit-level stream. Then these bit-level data stream is de-interleaved. Finally, the data stream is decoded by FEC which includes de-puncturing, Viterbi decoder and de-scrambler.

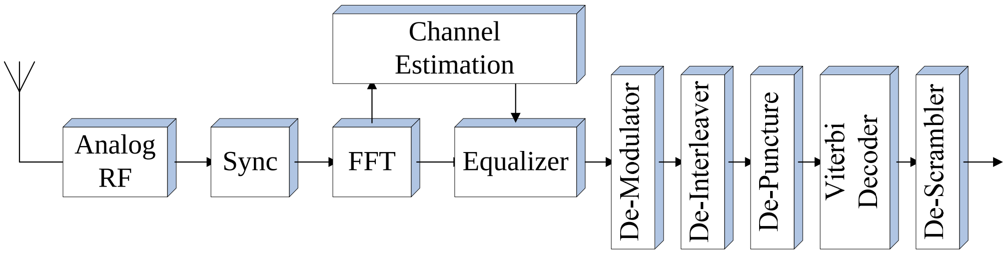

Figure 2-2 IEEE 802.11a receiver

2.1.3 Packet Format

The packet format fields are shown as Figure 2-3. The OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols, and each of transmitted time is $0.8\mu s$ .The t_1 to t_7 are used to signal detection, AGC(Automatic Gain Control) and, diversity selection. The other, t_7 to t_{10}, are used to timing synchronize and coarse frequency offset estimation.

The T_1 and T_2 denote long training symbols, and each of transmitted time is $3.2\mu s$ .The long training symbols are used to Channel estimation and fine frequency offset estimation. The total training length is $16\mu s$. In this paper, the key points are the format of long training symbol.

The PLCP preamble is followed by SIGNAL field and DATA, which data rate (RATE) and PSDU length (LENGTH) of information in SIGNAL field.

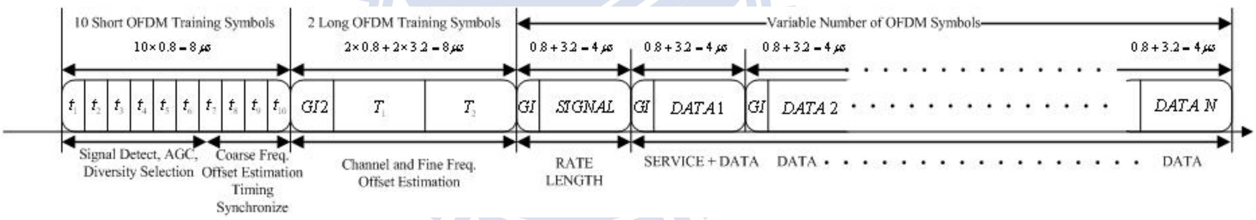

Figure 2-3 IEEE 802.11a packet format

2.2 Two-ray Channel Model

In this section, our two-ray channel model of CIR and CFR is shown in Figure 2-4. It is two comparable pulses which are delayed 2 units apart in CIR, and there is two deep fading points on index 16 and 48 in CFR. It is the simplest two-ray channel model, but it still crashes the original system, IEEE 802.11a.

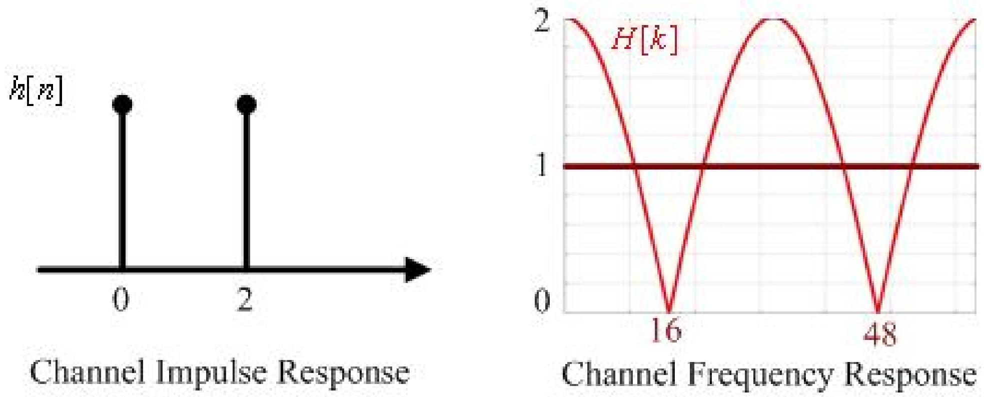

Figure 2-5 Two-ray channel model

Figure 2-5 show carrier error rate in two-ray channel model. We can observe although SNR approximate 60dB, there is two errors, highlight in figure, on spectrum,

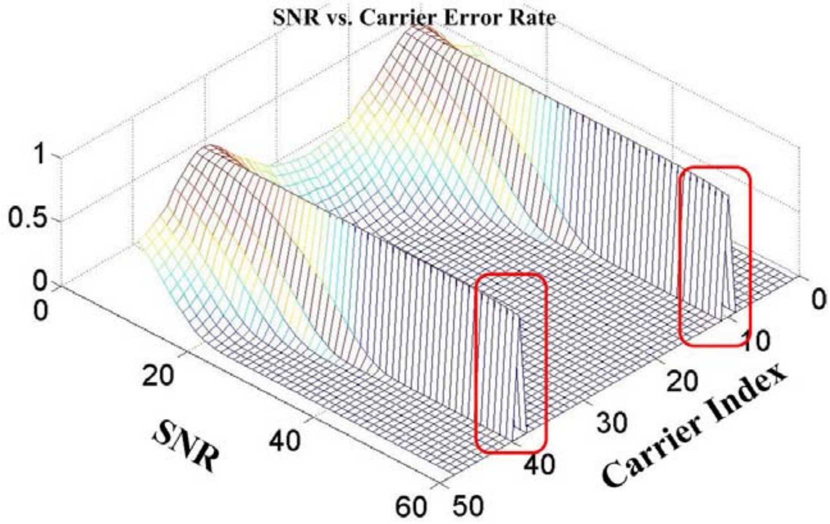

Figure 2-6 Carrier error rate

Chapter 3
The proposed algorithm

3.1 Pseudo Channel Block Diagram

The pseudo channel block diagram show in Figure 3-1.

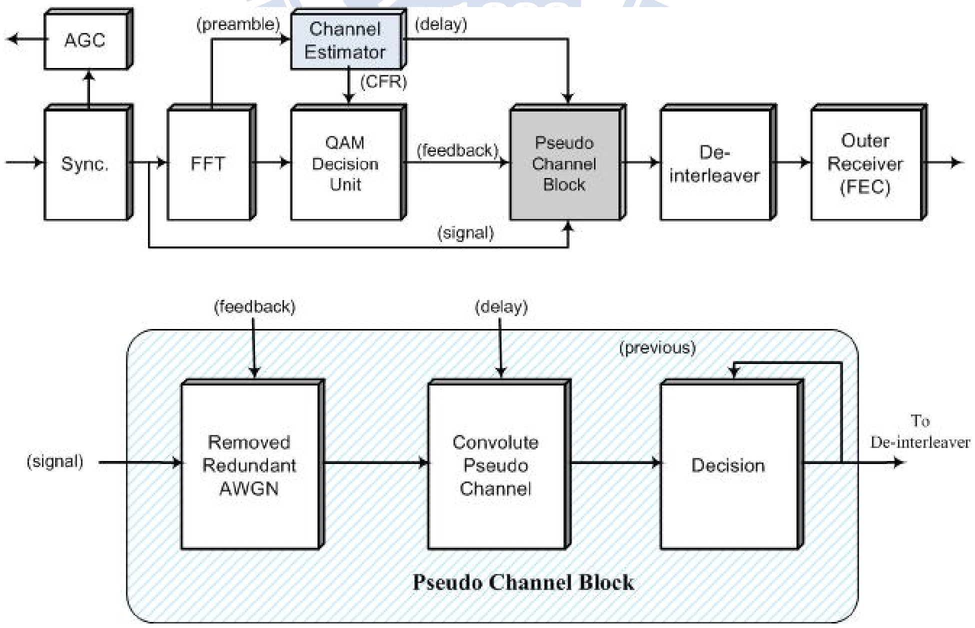

Figure 3-1 Block Diagram

In Rx, we can class the tones into two categories, one is deep-fading tones, and another is non-deep-fading tones. After the "Sync."(synchronize), if received signal is preamble, then input the data to "Channel Estimator" for estimating CFR, and then feed CFR into "Pseudo Channel Block". In this paper, the channel model is fixed, and we assume the channel estimation is accuracy.

Else if the signal is payload, then we resolve the non-deep-fading tones at first by equalizer, "QAM Decision Unit", and feedback resolved data to "Pseudo Channel Block". The remainder, deep-fading tones, is resolved by "Pseudo Channel Block".

3.2 Pseudo Channel Algorithm Process

In Figure 3-1 below, pseudo channel process have three steps. The first step is removed redundant AWGN. The second step is convolute pseudo channel. Final step is decision.

Before discuss the process, we have use a simple example for understanding the algorithm easily. In Figure 3-2, we transmit $p(t)$ and follow $d(t)$ in Tx. Because of we focus the deep-fading tones, so the index 16, 48 are discussed in the example. Therefore, we only descript the process by index 16. Figure 3-2 below, $X_{16}(t)$ is the 16th carrier in OFDM system and P_{16}, D_{16} are the transmitted data.

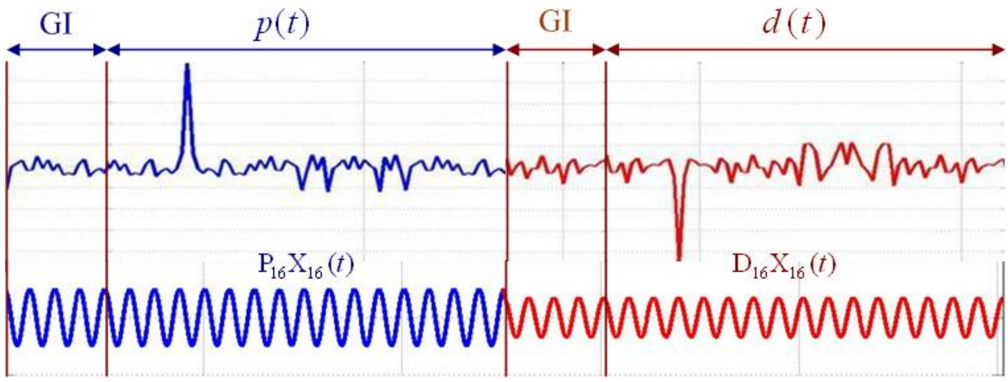

Figure 3-2 A sample of transmitted signal and index 16 of signal

Figure 2-5 show the two-ray channel we focus in this paper. When the 16th carrier through pass the two-ray channel, it is effected that first path and second path delay 2 units and is added AWGN (Additive White Gaussian Noise). Figure 3-3 show effected signal by two-ray channel. In Rx, the received signal is shown in Figure 3-3 below, $r_{16}(t)$. Formal expression is shown as:

$$y[n] = h[n] * s[n] + w[n] \tag{3.1}$$

$s[n]$ is the transmitted signal. $y[n]$ is the received signal. The two-ray channel, $h[n]$, we defined in section 2.2. $w[n]$ is AWGN. And the notation '*' means convolution.

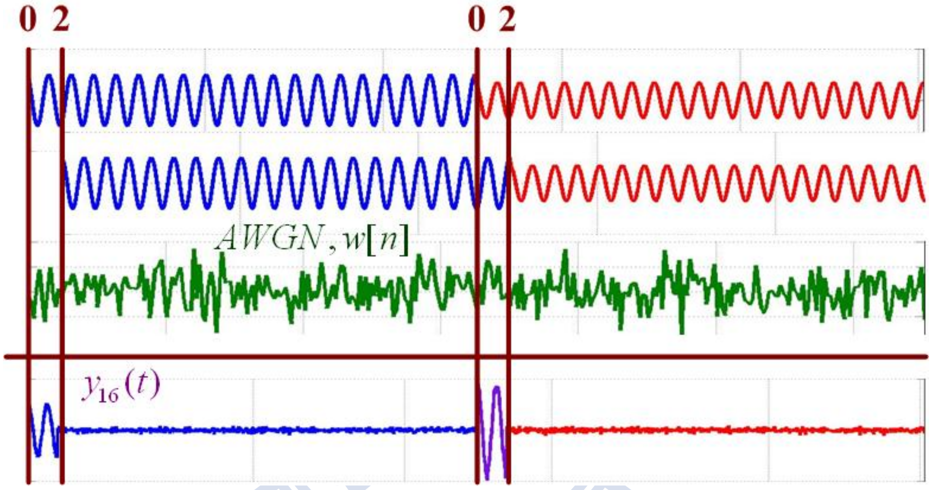

Figure 3-3 A sample of received signal on index 16, $y_{16}(t)$

Observation, there is no signal power about transmitted data after 2 unit time and it is only AWGN. By the general OFDM system, we get a interval signal after GI (Guard Interval) which is only AWGN in the 16th carrier. Therefore, there is noise enhance on index 16 in two-ray channel.

3.2.1 Removed Redundant AWGN

In Figure 3-3 below, the redundant AWGN of the received signal is replaced by zeros, shown in Figure 3-4. But the previous signal should leave the deep-fading data by feedback signal, non-deep-fading data. And express as:

$$w''[n] = w[n] \times \sum_{j=0}^{k} (\delta[n-80j] + \delta[n-1-80j] + \delta[n-2-80j]) \tag{3.2}$$

$$y'[n] = h[n] * s[n] + w''[n]$$

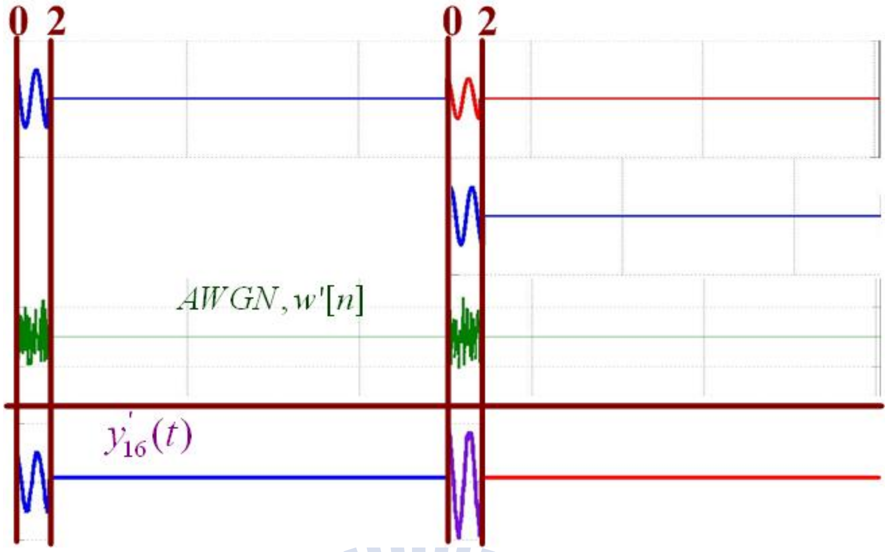

Figure 3-4 Removed redundant AWGN after 2 unit time

3.2.2 Convolute Pseudo Channel

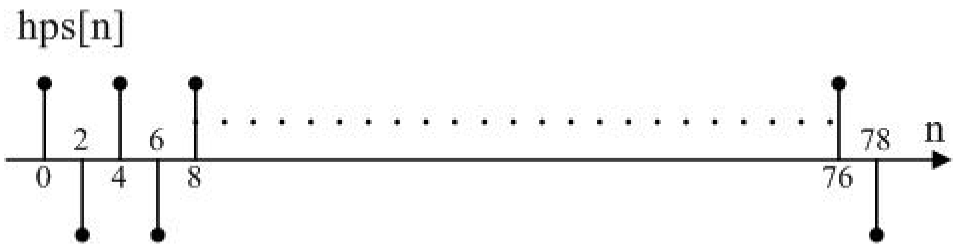

Figure 3-5 Pseudo channel impulse response

At the first, we define pseudo channel for the two-ray channel. Figure 3-5 show the pseudo channel and express as:

$$hps[n] = \sum_{i=0}^{39} (-1)^i \delta[n-2i] \tag{3.3}$$

If we convolute two-ray channel and pseudo channel, we can find the result which is delay apart one symbol length. Shown in Figure 3-6 and express as:

$$
\begin{aligned}
& hps[n]*h[n] \\
&= (\sum_{i=0}^{39}(-1)^i\,\delta[n-2i])*(\delta[n]+\delta[n-2]) \\
&= \delta[n]-\delta[n-80]
\end{aligned} \tag{3.4}
$$

Figure 3-6 Convolute two-ray channel and pseudo channel

Now, convolute the receiver signal and pseudo channel, shown in Figure 3-7. And the expression is followed as:

$$
\begin{aligned}
y''[n] &= y'[n]*hps[n] \\
&= s[n]*(h[n]*hps[n])+w_0[n] \\
&= s[n]-s[n-80]+w_0[n] \\
&= s[n]-p[n]+w_0[n]
\end{aligned} \tag{3.5}
$$

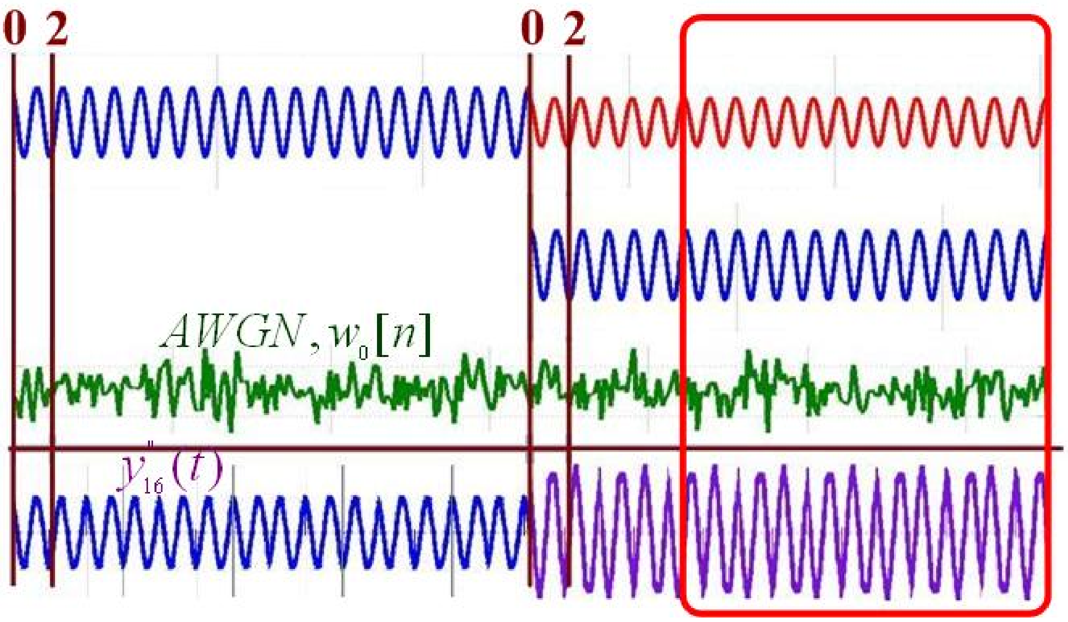

Figure 3-7 Convolute the receiver signal and pseudo channel

3.2.3 Decision

In Figure 3-7, the rectangle show reconstruction of signal which is deep-fading by two-ray channel. Therefore, we can decision the deep-fading signal after convolution pseudo channel. The first, we transfer $y''[n]$ by FFT and express as:

$$Y''[k] = S[k] - P[k] + W_0[k] \tag{3.6}$$

Then, estimate the data we resolve by previous data, $P[k]$. Express as:

$$S'[k] = Y''[k] + P[k] = S[k] + W_0[k] \tag{3.7}$$

3.2.4 Noise Enhance

Observation, if we don't execute the first step, removed redundant AWGN. The result is also Equation 3.7. But Figure 3-8 show the noise enhance on deep-fading point, 16 and 48.

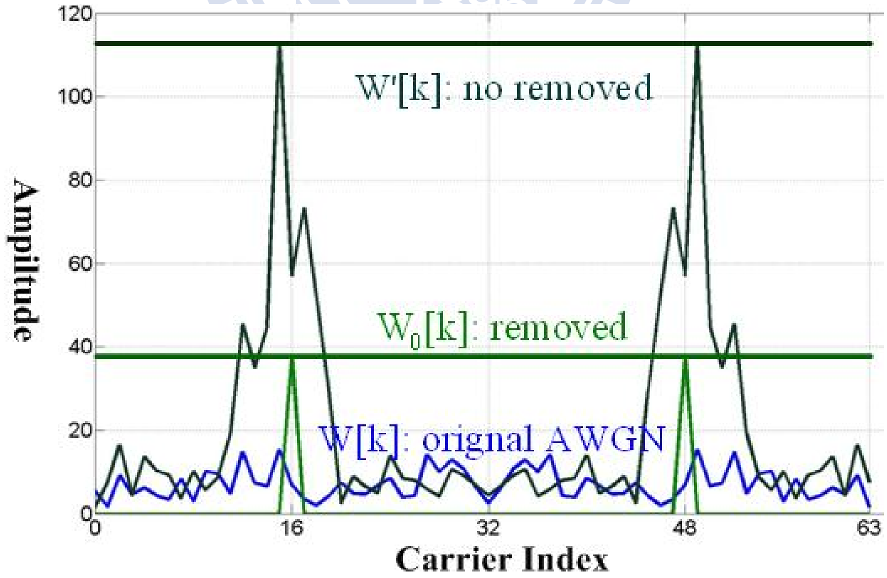

Figure 3-8 Compare no removed and removed AWGN

Chapter 4
Simulation results

In this chapter, to evaluate the pseudo channel algorithm, a typical OFDM system based on IEEE802.11a Wireless LANs, TGn Sync Proposal Technical Specification is used as the reference design platform. The performance of proposed algorithm is simulated under two-ray channel which we defined in section 2.2 with Additive White Gaussian Noise (AWGN).

In the simulations, the source data of transmitted length is 1024 Bytes and use the coding rate of 3/4 and modulation of 64-QAM. Follow as Table 4-1

Parameter	**Value**
System Platform	IEEE 802.11a
Modulation	64-QAM
Coding rate	3/4
PSDU length	1024 Bytes
Carrier frequency	2.4 GHz
Bandwidth	20 MHz
Symbol rate	250 KHz
IFFT/FFT period	3.2 μs
GI duration	0.8 μs
Approx. packet duration	200 μs

Table 4-1 Simulation environment

In Figure 4-1, the no algorithm method is divergence, and only the pseudo channel algorithm is convergence on 51dB. Additional removed redundant AWGN is convergence on 36dB, it gain 15dB. Figure 4-2 shows the SNR vs. BER. Figure 4-3 shows the SNR vs. PER.

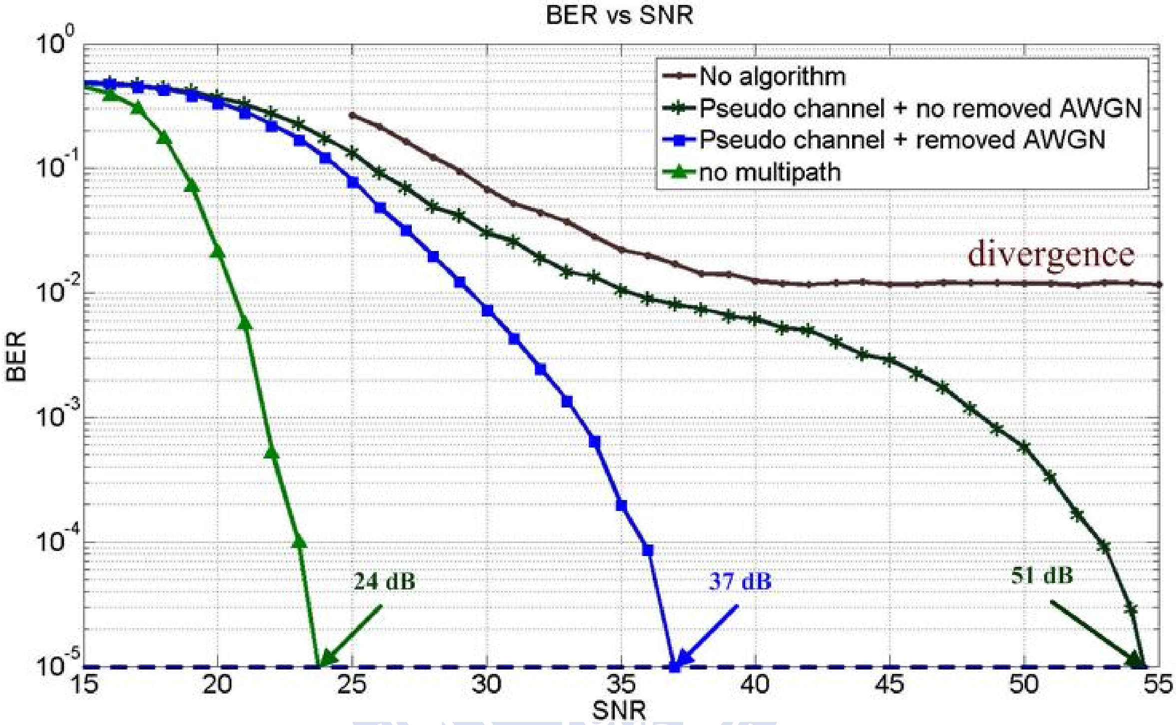

Figure 4-2 BER vs. SNR

And the SNR vs. CER by pseudo channel algorithm with removed redundant AWGN on every carrier is shown in Figure 4-5. The influenced carrier decrease on about 30dB, and it convergent on 36dB. In Figure 4-6, CER which no algorithm is 0.98 on 36dB. And the pseudo channel with removed redundant AWGN of CER is 0.68. To observe, the expected value is good to 0.68 on deep fading carriers, and the FEC enable to decode.

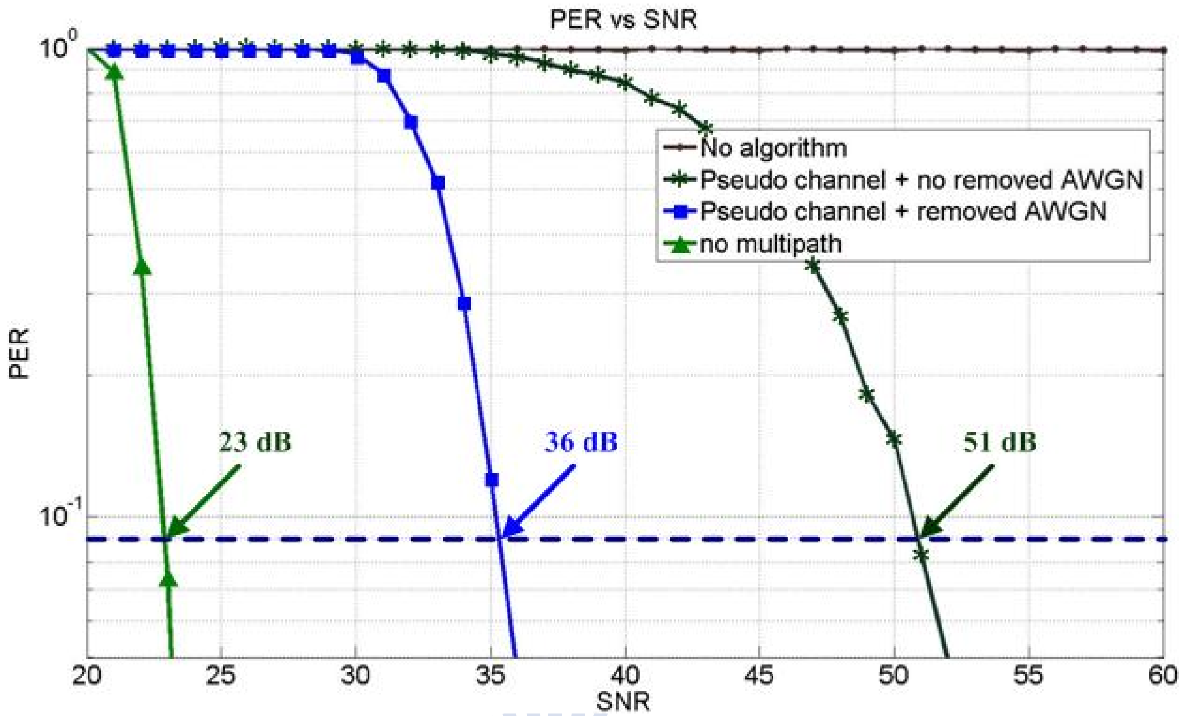

Figure 4-3 PER vs. SNR

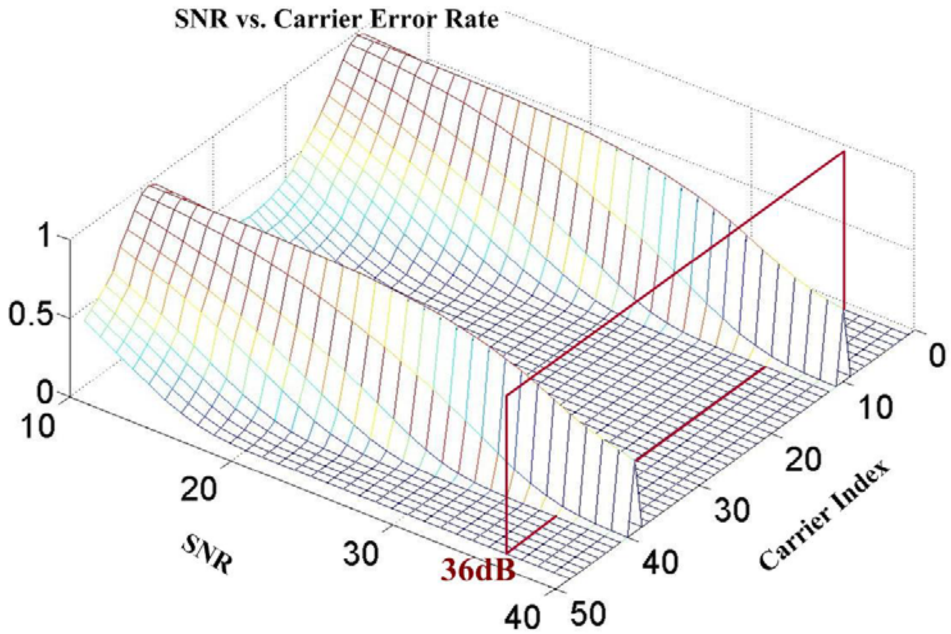

Figure 4-4 SNR vs. CER by pseudo channel algorithm

with removed redundant AWGN

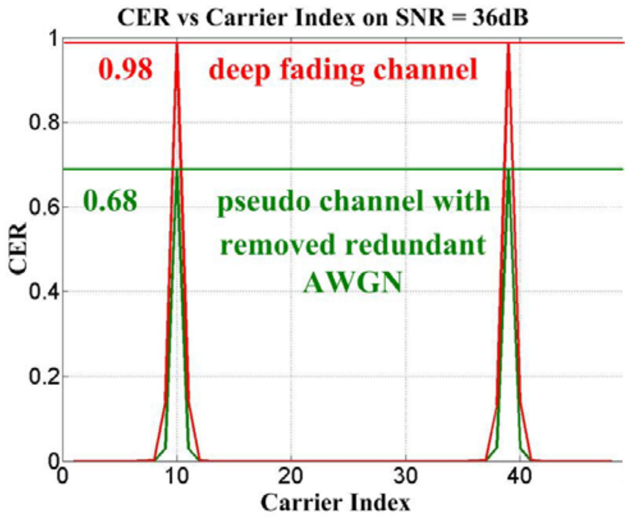

Figure 4-5 SNR vs. CER on 36dB by pseudo channel algorithm with removed redundant AWGN

Chapter 5
Conclusion and Future Work

5.1.1 Conclusion

This thesis proposes a pseudo channel method. The deep fading carrier is fading by resonance phenomenon in two-ray channel. It is all zero value by sum of peak and trough. And then, the ADC in receiver sample zeros on deep fading carriers.

Therefore, find the remaining energy of deep fading carriers is main ideal of the algorithm. And we find the GI have the remaining energy, but complex with previous data. The feedback mechanism should be used for cancelling previous data.

Although, it works to reconstruct the deep fading carriers, but the noise enhance is a big problem. Because of total energy in GI is less than one FFT length. The SNR loss occurs.

The removed redundant AWGN is proposed for gain SNR. And the performance gain 15dB against no removing. But there is still 23dB gap.

A common sense is up sample in ADC, and it get more non-zero values in GI on deep fading carrier.

5.1.2 Future Work

The next study is enhancing performance by MIMO-OFDM system. It is simple idea that the number of received antenna will gain the same number time of performance. But the preliminary studying find it is better than the idea. Because of the STBC is a diversity which changes the channel type. Therefore, the deep fading effect in two-ray channel is destroyed and the noise enhance don’t occur or less.

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