Performance Analysis of OFDM System Considering Carrier Frequency Offset in Wireless LAN Channel Environment

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Abstract—In this paper, We analyzes how a synchronization error affects receiving system when using OFDM(Orthogonal Frequency Division Multiplexing) transmission method in wireless LAN channel environment in which we can efficiently transmit wide-band information data. As a performance improvement method, performance distortion can be improved by applying convolution coding. As a result, in OFDM system, we could see that the higher a frequency offset is, the worse performance will be, and we could see that there was performance improvement by applying convolution coding in OFDM system in order to reach (BER=10^{-3}). However, when we use 64QAM (64Quadrature Amplitude Modulation), there was a huge influence between carriers by frequency offset at 0.05, 0.1.

Index Terms—Wireless LAN, OFDM, Frequency Offset, Convolution Coding

I. INTRODUCTION

Recently wireless LAN which is based on the 802.11 standard has spread its domain in the U.S, Europe, England. In Korea, KT and Hanaro have commenced their wireless LAN service and SK telecom has just taken part in wireless LAN market.

IEEE 802.11a, which is currently a standard of high-speed wireless LAN and HiperLAN/2 use wireless frequency 5GHz which is relatively wider than 2.4GHz and OFDM modulation and demodulation method in common[1].

Since OFDM method uses FFT(Fast Fourier Transform) algorithm, it can make the size of circuits smaller and also can vary transmission capacity by changing the number of subcarrier[2].

Besides it has an advantage that by installing a protective section we can completely remove the effect of ISI (Inter-Symbol Interference), which is occurred by delay elements[3].

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However, OFDM system has a weakness that because of subcarrier's narrow band when it comes to frequency offset, it reduces SER (Symbol Error Rate) [4]-[6].

This paper shows how subcarrier frequency offset affects OFDM system and its performance reduction degree as well as performance improvement degree using convolution coding. As a result, we can decide maximum frequency offset in order to satisfy SER performance.

II. OFDM SYSTEM CONSIDERING SUBCARRIER FREQUENCY OFFSET

The model of OFDM which considers subcarrier frequency offset in AWGN(Additive White Gaussain Noise) channel is like the figure 1.

In this paper, we uses QPSK(Quadrature Phase Shift Keying), 16QAM and 64QAM as modulation methods. OFDM signal reduces system performance when orthogonality is corrupted between subcarriers while demodulating. Frequency offset is occurred by the influence of doppler shift.

If receiver generates sine wave $e^{-j2\pi(f_c-\Delta f)t}$ which has a frequency gap from f_c to $-\Delta f$, then baseband OFDM signal is like below. In this case in order to simplify we assumed transmission distortion is inexistent $(H(f)=1)$, in the equation we erased additional noises. We call Δf frequency offset.

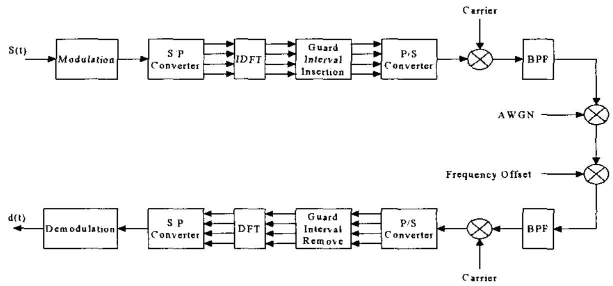

Fig. 1 The model of OFDM system which considers carrier frequency offset.

$$s_B(t) = \sum_{m=-\infty}^{\infty} g(t - mT_s) \sum_{n=0}^{N-1} d(m,n) e^{j2\pi n f_0 (t - mT_s)} e^{j2\pi \Delta f t} \qquad (1)$$

In equation (1), when there's no frequency offset, $e^{j2\pi\Delta ft}$ is multiplied. This signal can be sampled as equation (2).

$$s_B\left(kT_s+\frac{i}{Nf_0}\right)=\sum_{m=-\infty}^{\infty} g\left\{(k-m)T_s+\frac{i}{Nf_0}\right\}e^{j2\pi nf_0\left\{(k-m)T_s\frac{+i}{Nf_0}\right\}}\cdot e^{j2\pi\Delta(kT_s\frac{+i}{Nf_0})}$$
$$=\sum_{n=0}^{N-1} d(k,n)e^{j\frac{2\pi ni}{N}}e^{j2\pi\Delta f(kT_s\frac{+i}{Nf_0})}$$
$$=e^{j2\pi k\Delta fT_s}\sum_{n=0}^{N-1} d(k,n)e^{j\frac{2\pi(n+\alpha)i}{N}} \quad (2)$$

In equation (2), α is a parameter which is expressed by the formula below and the size of frequency offset. We call α regular frequency offset.

$$\alpha = \frac{\Delta f}{f_0} \quad (3)$$

As we can see from equation (4), demodulation $\hat{d}(k,l)$ includes expecting symbol $d(k,l)$ as well as all the subcarrier symbol in the same OFDM symbol, and there can be an interference between carriers.

$$\hat{d}(k,l)=\sum_{i=0}^{N-1}\hat{c}(k,l,n,)d(k,n) \quad (4)$$

$$\hat{c}(k,l,n)=\frac{1}{N}\cdot\frac{\sin\{\pi(n-l+\alpha)\}}{\sin\frac{\pi(n-l+\alpha)}{N}} \quad (5)$$
$$e^{j2\pi k\Delta fT_s}\cdot e^{j\frac{\pi(N-1)(n-l+\alpha)}{N}}$$

A coefficient $\hat{c}(k,l,n)(n\neq l)$ is n'th subcarrier and shows transferred symbol distortion. We can analyze symbol error by using this.

At first, search for a demodulation symbol $\hat{d}(k,l)$'s average power. However, make sure that k, l's symbol demodulation method is same and should be. $E[|\hat{d}(k,l)|^2]=\sigma_d^2$

As we can see from above, demodulation symbol's average power is always same regardless of k and l. This shows that if a regular frequency offset exists, at random symbol different subcarrier's interference frequency and interference is same.

If multipass exists, this doesn't work out. At this point, l'th subcarrier's expecting symbol elements's average power is denoted as equation (6).

$$E\left[\left|\hat{c}(k,l,l)d(k,l)\right|^2\right]=\frac{\sigma_d^2}{N^2}\cdot\frac{\sin^2(\pi\alpha)}{\sin^2\frac{\pi\alpha}{N}} \quad (6)$$

From this, average power $P_I(l)$ of interference elements is denoted by

$$P_I(l)=\sigma_d^2-\frac{\sigma_d^2}{N^2}\cdot\frac{\sin^2(\pi\alpha)}{\sin^2\frac{\pi\alpha}{N}} \quad (7)$$

At this point, we assume that AWGN is added on transmission path and each symbol's average power is $2\sigma_n^2$, l'th subcarrier's expecting SN ratio $\gamma(l)$ is defined by

$$\gamma(l)=\frac{\frac{1}{N^2}\cdot\frac{\sin^2(\pi\alpha)}{\sin^2\frac{\pi\alpha}{N}}}{1-\frac{1}{N^2}\cdot\frac{\sin^2(\pi\alpha)}{\sin^2\frac{\pi\alpha}{N}+(CNR)^{-1}}} \quad (8)$$

It is possible to get symbol errors of each symbol when a frequency offset exists.

Table 1 is system parameters that we consider in this paper.

Table. 1 OFDM system parameter.

Subcarrier number	1024
Subcarrier interval	4KHz
Symbol length	250μs
Guard interval length	31.25μs
Minimum Subcarrier frequency in transmit band	100MHz

III. ANALYZING FIGURES

In this paper, We analyzes performance of OFDM System in which a subcarrier frequency offset exists and shows performance improvement by applying convolution coding.

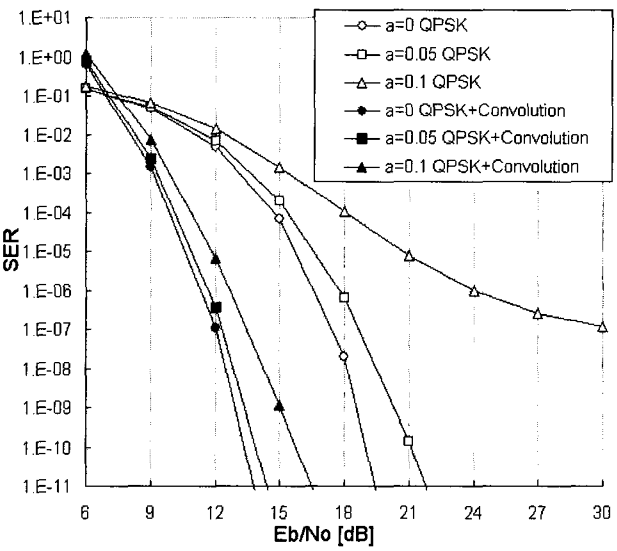

Fig. 2 SER performance of OFDM/QPSK system according to frequency offset.

Fig. 2 analyzes performance of OFDM/QPSK system when 0, 0.05, 0.1 are given as a frequency offset figure. The higher a frequency offset is, the worse the system performance is, and we can see performance improvement by more than 4dB.

In addition, the higher frequency offset is, the better performance improvement is by applying convolution coding.

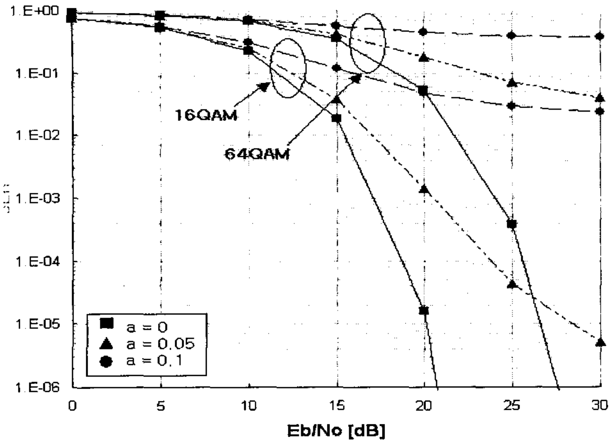

Fig. 3 SER performance of OFDM/MQAM system according to frequency offset in AWGN environment.

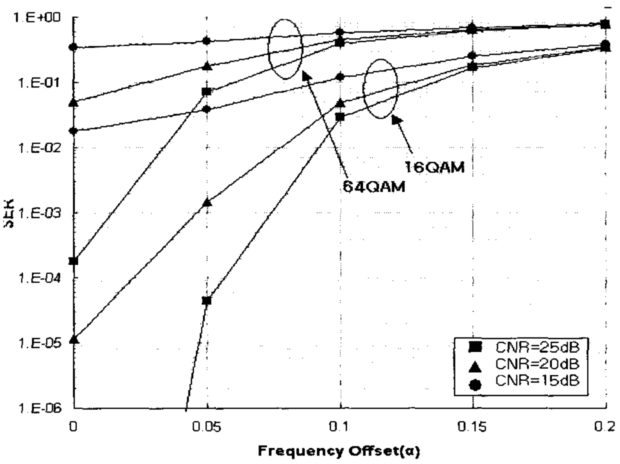

Fig. 4 SER performance of OFDM/MQAM system according to frequency offset (subcarrier=1024).

Fig. 3, 4 analyze OFDM/MQAM system performance according to frequency offset in AWGN environment. From these, we can know OFDM/MQAM system is more sensitive to frequency offset than OFDM/QPSK and OFDM/64QAM can not be satisfactory when we have to reach (BER=10^{-3}). When a frequency offset figure is higher, SER rapidly decreases and more elaborate high frequency synchronization is needed. And we can find out satisfactory and acceptable frequency offset figures.

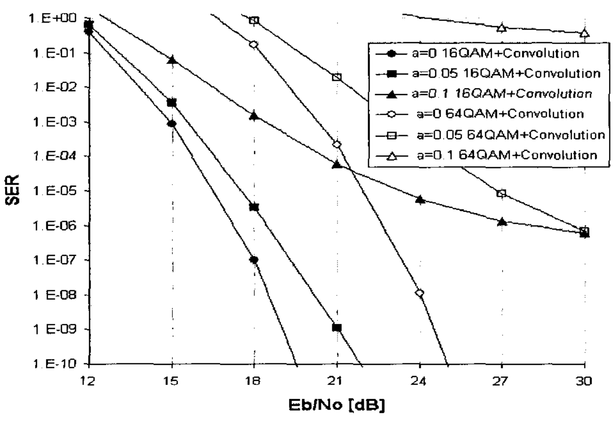

Fig. 5 SER performance of OFDM/MQAM system considering convolution coding.

Fig. 5 analyzes OFDM/MQAM system performance according to frequency offset. When convolution coding is used, we could see performance improvement. However, when frequency offset is set as 0.1 in OFDM/64QAM system, we can hardly see improvement, and when we tried to reach (BER=10^{-3}), we can not meet the conditions of SER.

From this we can see interference by frequency offset between carriers is very important.

IV. CONCLUSION

This paper showed effect of a receiver system when using OFDM transmission method so that we efficiently transmit wide band signal.

In a way, by applying convolution coding, we could improve performance reduction.

As a result, in OFDM/QPSK system the higher a frequency offset is, the better the system performance is, and by applying convolution coding we could see performance improvement more than 4dB. Besides, in OFDM/QPSK system the higher a frequency offset is, the worse the system performance is, and performance reduction is bad even at high SNR.

Lastly, wireless LAN system which aims to reach (BER=10^{-3}) needs additional research because interference effects between carriers is very important by 0.05, 0.1 frequency offset.

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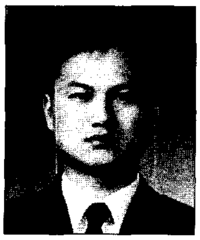

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