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Performance Analysis of OFDM 60GHz System and SC-FDE 60GHz System

Xueyan Han[1], Jingjing Wang[1,a] , Wei Shi[1,b] and Xinli Dong[2]

[1]School of Information Science & Technology, Qingdao University of Science & Technology, Qingdao, Shandong Province, China
[2]Qingdao Branch, China United Network Communications Corporation, China

Abstract. In this paper, the performance of 60GHz wireless communication system with SC and OFDM is studied, the models of OFDM 60GHz system and SC 60GHz frequency domain equalization (SC-FDE) system are established, and the bit error rate (BER) performance of OFDM 60GHz system and SC-FDE 60GHz system in 802.15.3c channels is compared. The simulation results show that SC-FDE 60GHz system has a slight advantage over OFDM system in line-of-sight (LOS) channels, while OFDM 60GHz system has a slight advantage over SC-FDE system in non-line-of-sight (NLOS) channels. For 60GHz system, OFDM 60GHz system has a slight advantage over SC-FDE system in overcoming multipath fading, but the performance of both is close whether in the LOS or NLOS case.

1 Introduction

Currently, the high-speed interface, such as high definition multimedia interface (HDMI), Gigabit wireless local area networks(WLAN) and wireless personal area networks, have a more and more urgent requirement for Gbps-class wireless transmission technology. However, the current popular wireless high-speed communications technology, such as Ultra Broadband (UWB) wireless communication technology, generally only provides a data transfer rate of hundreds of megabits per second. 60GHz wireless communication technology has emerged. Because of several GHz wideband spectrum, up to 10W transmit power, and low-cost CMOS devices[1][2][3], it is the first choice in short distance wireless communication technologies.

At present, the study of 60GHz wireless communication physical layer for domestic and foreign research institutions and scholars mostly focus on SC-FDE and OFDM modulation. In the case of gigabit-speed transmission, the time-domain equalizer is complex. To solve this problem, [4-6] proposed SC-FDE modulation. SC-FDE can be viewed as OFDM linear precoding in special cases. The output of the receiver equalizer is inserted to compensate for linear precoding brought by the FFT matrix at the transmitter. This is the SC-FDE system. SC-FDE system has a low complexity of frequency-domain multipath channel equalizer, which is similar to OFDM. However, in the actual wireless systems, both show some different characteristics. Because of IFFT precoding at the transmitter, SC-FDE has less PAPR than OFDM. In addition, the computational complexity required for both the transmitter and receiver are different, in OFDM systems, both the transmitter and receiver should execute FFT or IFFT operations. In the SC-FDE system, the transmitter does not need to execute FFT / IFFT operations, while at the receiver, it need to perform two times of FFT / IFFT operations.

Because of OFDM system with high spectrum efficiency, which can help to achieve high-speed communications, OFDM and SC-FDE are two powerful candidate technologies that can realize gigabit transmission throughput. In 802.15.3c [7] and 802.11ad [8], both standards are chosen as the physical layer transmission modulation.802.15.3c standard divides 60GHz band into four channels band. The standard defines three physical layer technology, namely High Speed Interface (HSI) physical layer, Audio and Visual (AV) physical layer and SC physical layer, the first two kinds are based on OFDM modulation, SC physical layer uses SC-FDE modulation. The paper uses HSI and SC over 802.15.3c standards for an example, the performance of OFDM 60GHz and SC-FDE system are studied and simulated.

The remaining part of the paper is organized as follows: Section 2 analyze the 60GHz system with OFDM modulation, and conducts Monte Carlo simulations in LOS and NLOS scenes over 802.15.3c channel model; In Section 3, the 60GHz system with SC-FDE is analyzed, and compares bit error rate (BER) performance with 60GHz system with OFDM modulation; Concluding remarks are given in Section 4.

* Corresponding author: [a]*kathy1003@163.com* & [b]*shiwei6670595@126.com*

2. The 60ghz System With Ofdm Modulation

2.1.The 60GHz system model based on OFDM modulation

The 60GHz system model with OFDM modulation [9] is shown in Figure 1. The specific process is as follows: after LDPC channel coding, interleaving and constellation mapping, the frequency domain signal d(n) obtain the data symbols transmitted in N subcarriers, denoted as X (k) (k = 0, 1, 2, ..., N-1). After IFFT, the time domain signal x (n), n = 0, 1, 2 ..., N-1 is obtained.

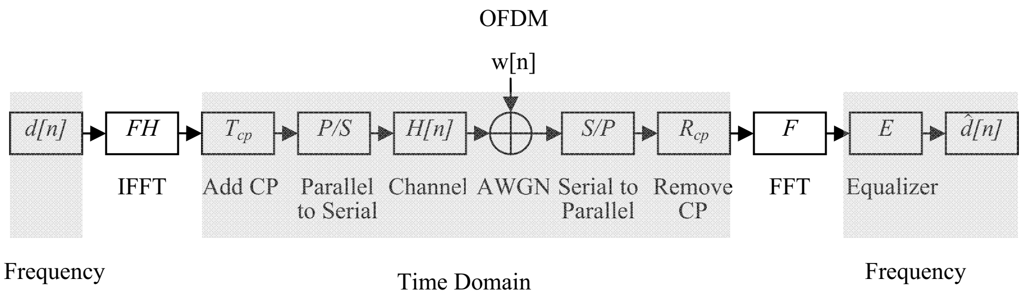


Figure 1. OFDM 60GHz system model.

$$x(n) = IFFT\{X(k)\} = \frac{1}{N}\sum_{k=0}^{N-1} X(k)\exp(j2\pi kn/N) \quad (1)$$

Then the Guard Interval (GI) is added to x(n)[10]. GI length, denoted by TGI, is greater than the maximum delay spread of the wireless channel. The original symbol is used to cycle and expand by GI generally as the Cyclic Prefix, and by this way Inter-Carrier Interference (ICI) is suppressed, Inter-Symbol Interference (ISI) is eliminated, while the linear convolution of the channel and signal is transferred to cyclic convolution. After adding CP, the signal sequence is denoted as $x_f(n)$

$$x_f(n) = \begin{cases} x(N+n) & n = -N_{GI}, -N_{GI}+1, \ldots, -1 \\ x(n) & n = 0, 1, \ldots, N-1 \end{cases} \quad (2)$$

where NGI is the length of CP.

The signal $x_f(n)$ transmitted by the antenna, goes through 60GHz channel, then the received signal $y_f(n)$ is obtained. $y_f(n)$ is given as

$$y_f(n) = x_f(n) * h(n) + w(n) \quad (3)$$

where h(n) is the sampling sequence of actual channel impulse response, w (n) is the sample sequence of additiv e white Gaussian noise with zero mean, the sampling rate is same with that of input data X (k). By removing CP fro m the received signal $y_f(n)$, $y(n)$ is obtained,

$$y(n) = y_f(n), \quad n = 0, 1, \ldots, N-1 \quad (4)$$

After FFT transform, we can obtain

$$Y(k) = FFT\{y(n)\} = \sum_{n=0}^{N-1} y(n)\cdot\exp(-j2\pi kn/N), \quad K = 0, 1, \ldots N-1 \quad (5)$$

$H(k) = FFT\{h(n)\}$ is the frequency domain representation of h(n), $W(k) = FFT\{W(n)\}$ is the frequency domain representation of w(n), then we obtain

$$Y(k) = X(k)H(k) + W(k), \quad k = 0, 1, \ldots, N-1 \quad (6)$$

After equalizing, data is through modulation constellation de-mapping, de-interleaving, channel coding translation, and finally get the decision data $\hat{d}(n)$.

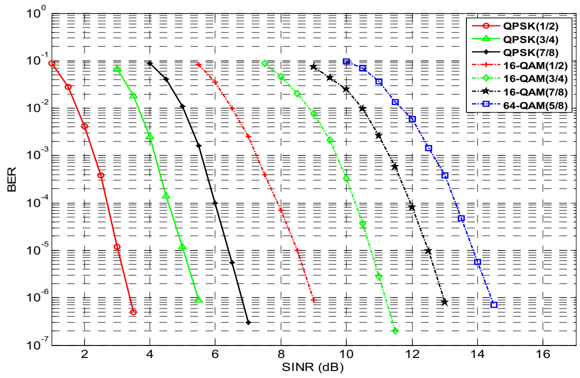
2.2. The performance simulation of OFDM 60GHz system

This section chooses HSI physical layer with 802.15.3c channel to study OFDM 60GHz system. The number of subcarriers is 512,low density parity check (LDPC) is used, BPSK, QPSK, and 16-QAM modulation modes can be chosen, 12 kinds of transmission rates of modulation and coding scheme (MCS) are provided. Table 1 lists the parameters of modulation and coding schemes.

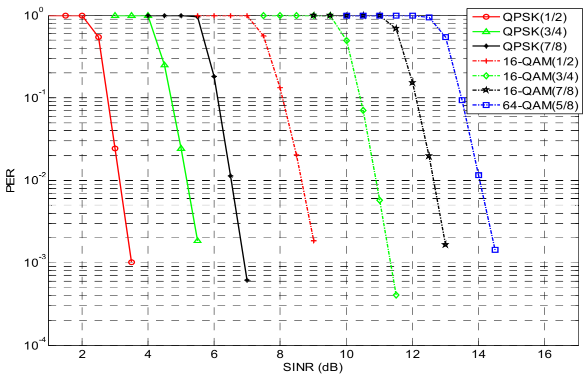
LOS CM1.3 and NLOS CM2.3 channel are selected to simulate, and investigate bit error rate, package error rate of OFDM 60GHz system with different modulation and coding schemes. Each package contains 1Kbit information. MMSE equalization is used.

Table 1. HSI physical layer parameters of different modulation and coding modes.

MCS number	Data rate (Mb/s)	Modulation	Sprea -ding factor	Coding rate
1	1540	QPSK	1	1/2
2	2310	QPSK	1	3/4
3	2695	QPSK	1	7/8
4	3080	16-QAM	1	1/2
5	4620	16-QAM	1	3/4
6	5390	16-QAM	1	7/8
7	5775	64-QAM	1	5/8



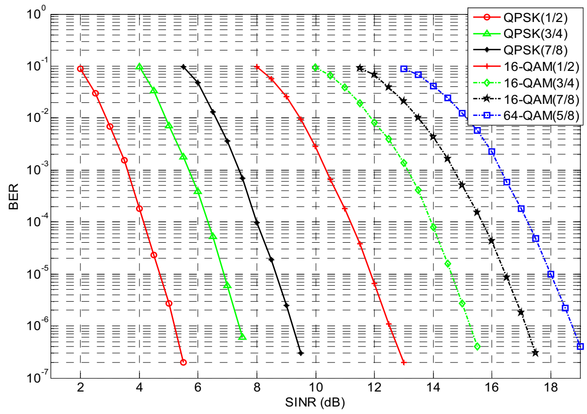
a) The BER performance simulation



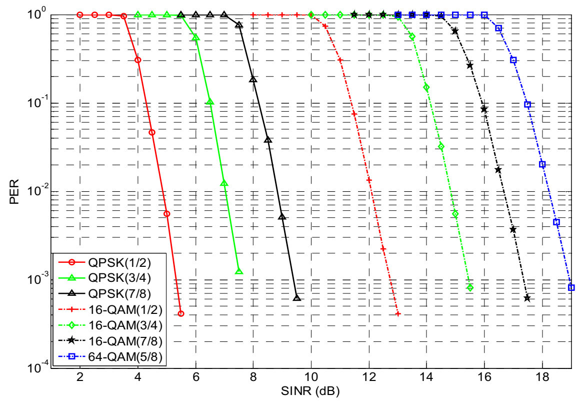
b) The PER performance simulation

Figure 2. The BER and PER performance simulation under 802.15.3c CM1.3 channel

From Figure 2 and 3, under different physical layers MCS schemes, i.e., transmission rates are 1540Mb/s, 2310Mb/s, 2695Mb/s, 3080Mb/s, 4620Mb/s, 5390Mb/s, 5775Mb/s, the SINR required for the reliable transmission with bit error rate of 10^{-6} under LOS CM1.3 channel of order are 3.3dB, 5.4dB, 6.8dB, 9.0 dB, 11.1dB, 12.9dB and 14.4dB. The SINR required for the reliable transmission with bit error rate of 10^{-6} under NLOS CM2.3 channel are 5.1dB, 7.2dB, 9.1dB, 12.6dB, 15.2dB, 17.1dB and 18.7dB. As can be seen from the simulation, in the same modulation scheme, as the coding rate increases, the bit error rate performance will deteriorate correspondingly. In order to obtain higher transmission rates, a higher SINR requirements. In whatever rate transmission, with the same SINR, the package rate and bit error rate performance of OFDM 60GHz system under LOS channel has better performance than that of OFDM 60GHz system under NLOS channel. Comparing Figure2 (a) and Figure 3 (a), we can find that, with the increasing of coding rate and modulation order, to obtain the same error rate, the SINR difference between NLOS channel and LOS channel is growing.



a) The BER performance simulation



b) The PER performance simulation

Figure 3. The BER and PER performance simulation under 802.15.3c CM2.3 channel.

3. The 60ghz System With Sc-Fde Modulation

3.1. The 60GHz system model based on SC-FDE modulation

The 60GHz system model employing SC-FDE[11] is depicted in Figure 4 which moves the IFFT module, in transmitting end of OFDM system, to the receiving end. The same with the OFDM 60GHz system is that its equilibrium is also happened in frequency domain, so it is similar to the structure of the OFDM 60GHz system model.

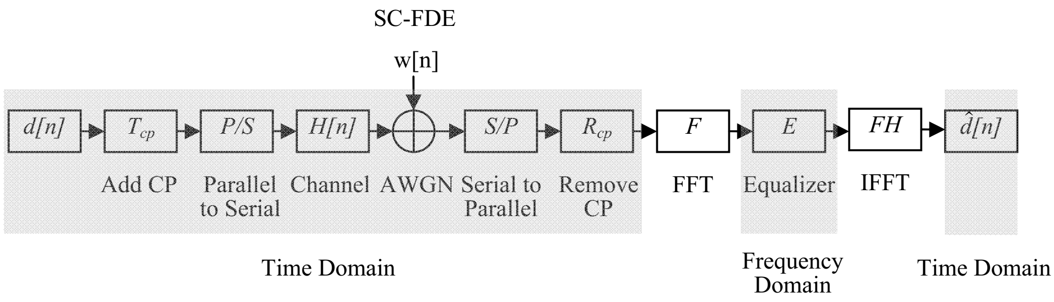


Figure 4. SC-FDE 60GHz system model.

3.2. The performance simulation and comparison of SC-FDE 60GHz and OFDM system

The study is conducted under 802.15.3c SC physical layer. When the pilot length is 64, the data transmission rate is1.54Gb/s - 4.62Gb/s. The sub-block length is 512. Low Density Parity Check Code (LDPC) and Reed-Solomon code (RS) are used. BPSK, QPSK, and 16-QAM modulation modes can be chosen. The constellation mapping takes $\pi/2$ phase shifting scheme. The modulation and coding scheme (MCS) can provide 13 kinds of transmission rate. Table 2 shows the parameters selection using the LDPC code.

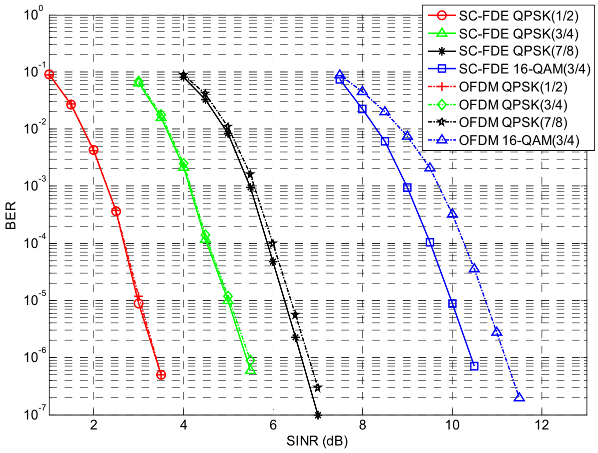
Table 2. Parameter selection of modulation and coding scheme under SC physical layer.

MCS Number	Data transmission rate /(Mb/s) when pilot length=0	Data transmission rate/(Mb/s) when pilot length=64	Modulation scheme	Spreading factor	Coding rate
7	1760	1540	$\pi/2$ QPSK	1	LDPC(672,336) R=1/2
8	2640	2310	$\pi/2$ QPSK	1	LDPC(672,504) R=3/4
9	3080	2695	$\pi/2$ QPSK	1	LDPC(672,588) R=7/8
13	5280	4620	$\pi/2$ -16QAM	1	LDPC(672,504) R=3/4

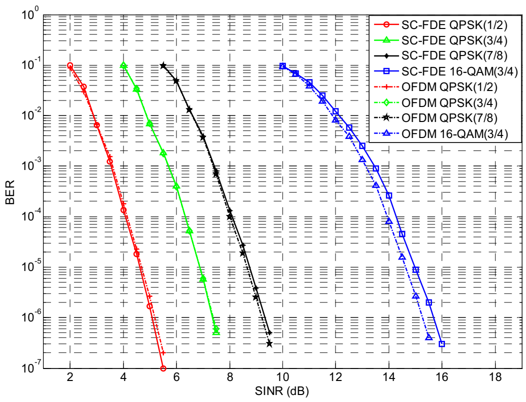
From Table 1 and Table 2, we can obtain that, when the pilot length is 64, the data transmission rates of SC MCS7、8、9、13 are the same with that of HSI MCS1、2、3、5.Using the MCS in Table 1 and Table 2, under the same data transmission rates, we compare the BER performance of SC-FDE and OFDM over 802.15.3c channels.

From Figure 5(a), we can see that the performance of SC-FDE 60GHz system is close to that of OFDM 60GHz system in LOS channels. With he increasing of coding rate and modulation order, the performance of SC-FDE 60GHz system has advantage over that of OFDM 60GHz system. This can be observed when SNR is large, but the advantage is small. When BER is 10^{-6} even with 16QAM high order modulation and high coding rate, the gap between them is less than 1dB. SC-FDE 60GHz system has a slight advantage in the high-speed transmission in LOS channels, but the performance of OFDM 60GHz system can be compared with that of SC-FDE system.

Figure 5(b) shows that, the performance of OFDM 60GHz system is better than that of SC-FDE 60GHz system in NLOS channels when SNR is low and QPSK (1/2LDPC) is used, and with the increasement of SNR, the performance of SC-FDE 60GHz system is slightly better than that of OFDM 60GHz system. When QPSK (3/4 LDPC) and QPSK (7/8 LDPC) are used, the performance of SC-FDE system is close to that of OFDM system. When 16QAM (3/4 LDPC) is used, the performance of OFDM system has a slight advantage over that of SC-FDE system, and the gap between them is less than 0.5dB when BER is 10-6. By comparing Figure 5, we can obtain that, SC-FDE has a slight advantage over OFDM 60GHz system in LOS channels, OFDM 60GHz system has a slight advantage over SC-FDE 60GHz system in NLOS channels. It shows that OFDM 60GHz system has a slight advantage in overcoming multipath fading, but the performance of both is close whether in the LOS or NLOS case.



a)The BER performance simulation in CM1.3



b)The BER performance simulation in CM2.3

Figure 5. The BER performance comparison of SC-FDE 60GHz system and OFDM 60GHz system under 802.15.3c CM1.3 and CM2.3 channel.

4. Conclusions

The system models of OFDM 60GHz and SC-FDE 60GHz are established respectively, and their principle are elaborated. Physical layer communication scheme under 802.15.3c standard is analyzed, and the BER performance of OFDM 60GHz system and SC-FDE system in 802.15.3c channels is compared and simulated respectively based on 802.15.3c standard and channel model. The simulation results show that, SC-FDE has a slight advantage over OFDM in LOS channels, while OFDM has a slight advantage over SC-FDE in NLOS channels. For 60GHz system, OFDM has a slight advantage over SC-FDE in overcoming multipath fading, but the performance of both is close whether in the LOS or NLOS case.

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