Research on Multi-carrier System Based on Index Modulation

Dong Wang, Jie Yang(✉), and Bing Zhao

Electronic and Communication Engineering, Heilongjiang University, No. 74 Xuefu Road, Harbin, People's Republic of China
guitaryang@126.com

Abstract. Multi-carrier modulation technology can improve spectrum efficiency in limited spectrum resources by modulating data to low speed parallel multiple subcarriers, and can provide reliable data transmission in an effective frequency band. As a member of multicarrier modulation, orthogonal Frequency Division Multiplexing (OFDM) can resist certain channel fading, but it has the disadvantages of low energy efficiency and spectral efficiency, sensitive to carrier frequency offset and high out-of-band radiation. In order to solve this problem, scholars have further explored in the field of multicarrier modulation, and proposed OFDM technology based on index modulation (OFDM-IM) and filter bank multicarrier technology (FBMC). Compared with OFDM, although the complexity of OFDM-IM and FBMC is improved, OFDM-IM has higher energy efficiency. The on-demand adjustment between system bit error rate (BER) performance and spectral efficiency can be realized by configuring the number of active subcarriers in each subcarrier group. FBMC has higher spectral efficiency, can resist a certain carrier frequency offset, and the out-of-band attenuation is greatly reduced. Therefore, the research on OFDM-IM has very important theoretical significance and application value.

Keywords: Multicarrier modulation technology · Index modulation · Orthogonal frequency division multiplexing technology

1 Introduction

As the key technology of 4G, OFDM can realize high speed data transmission, high spectrum efficiency, good anti-noise, anti-frequency selective fading and anti-multipath interference ability. However, it is more sensitive to frequency offset, such as the frequency offset caused by the Doppler effect of the signal during transmission, or the frequency deviation between the carrier frequency of the transmitted signal and the frequency generated by the local oscillator of the receiver. Will destroy the orthogonality between the subcarriers of OFDM signals, and then bring about ICI to affect the performance of the system [1]. In addition, when the phase of multiple sub-signals is the same, the instantaneous power of superimposed signal is much higher than the average power, which leads to higher PAPR, and reduces the efficiency of transmitter power amplifier [2]. Inspired by SM, frequency index modulation technology emerges as the times require. Index modulation OFDM technology not only transmits

Q. Liang et al. (Eds.): CSPS 2019, LNEE 571, pp. 1887–1891, 2020
https://doi.org/10.1007/978-981-13-9409-6_228

information by sending symbols, but also carries information by using activated subcarrier serial number compared with traditional OFDM, it can not only bring larger bit error rate (bit error rate BER) performance gain and higher energy efficiency [3]. Moreover, because the number of activated subcarriers is smaller than the total number of subcarriers, it also has a prominent contribution to reducing PAPR and ICI, thus improving the overall performance of OFDM system, which is one of the main technologies of 5G network [4].

2 Design and Analysis of OFDM-IM Model

The OFDM transmitter block diagram is shown in Fig. 1. In a OFDM-IM block, when m-bit information is input to the system transmitter, these information bits are equally divided into g groups, each group containing P bits, that is p = m/g. The P bits of each group are mapped to a OFDM-IM subblock of length n, where n = N/G, N is the subcarrier number of the system. The mapping here is not only on modulation symbols, but also on subcarrier positions used to transmit information. Inspired by the idea of SM, redundant bits are transmitted through the set of subcarrier positions. As shown in the figure, k of the n subcarriers of each subblock are used to transmit data, The first p of each group of P-bit information is used to select the position of the k subcarrier to be used for the transmission information [5]. Although part of the subcarrier does not transmit information, we use the subcarrier position to carry information bits to make up for this loss, so compared with the traditional OFDM system, the number of bits transmitted per OFDM block in OFDM-IM is not less or much.

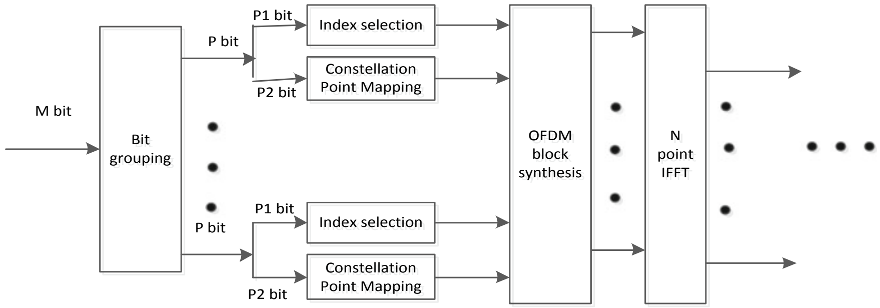

Fig. 1. OFDM transmitter block diagram

3 Comparative Analysis of Simulation

In this section, the BER simulation of OFDM-IM system is carried out, and the performance of traditional OFDM, OFDM-IM system is compared. The main parameters of the simulation are as follows: the total number of subcarriers N = 128, the number of paths V = 16 of the Riley fading channel, and the length of the cyclic prefix L = 32.

All the simulation schemes are carried out under the known channel state information at the receiver.

Figure 2 shows the simulation results of OFDM-IM system and traditional OFDM system using 4-QAM modulation respectively. The OFDM-IM system uses two different activation modes: n = 8, k = 4, k = 8, k = 6. Where in the spectrum efficiency of the "OFDM-IM (n = 8, k = 4), 4-QAM" simulation scheme is 1.75 bps/Hz.

The spectrum efficiency of the other simulation schemes is 2 bps/Hz. It can be seen from the figure that the BER performance of OFDM-IM system with 4-QAM modulation is better than that of traditional OFDM system at medium and high signal-to-noise ratio (SNR). In addition, at medium and high signal-to-noise ratio (SNR), the OFDM-IM system configured in k = 4 activation mode will have a performance gain of about 3 dB compared with n = 8, and the OFDM-IM system in k = 6 activation mode will have about 3 dB performance gain. This is because C(8, 4) > C(8, 6), so the OFDM-IM system with n = 8, k = 4 activation mode can carry more index bits, and this part of the bits has a lower probability of error at medium to high SNR.

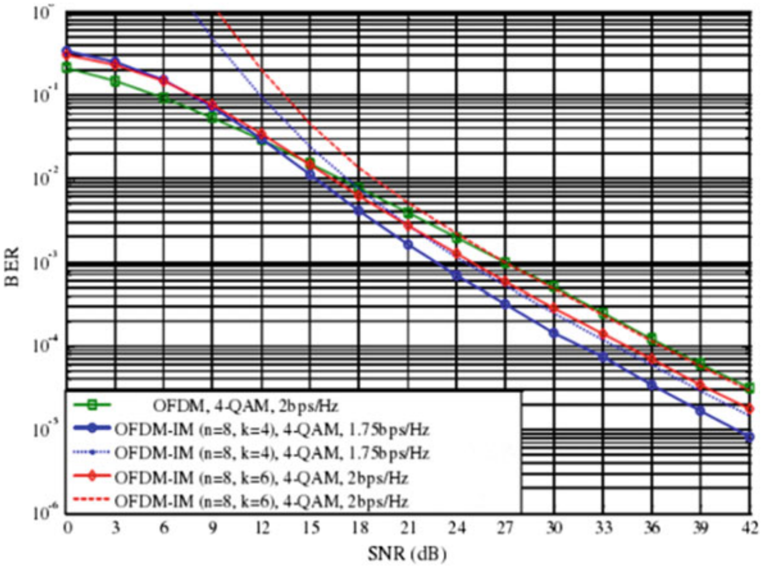

Fig. 2. Simulation results of 4-QAM modulation

Figure 3 shows the simulation results of OFDM-IM system and traditional OFDM system using BPSK modulation respectively. In the figure, the OFDM-IM system uses two different activation modes: n = 4, k = 2, k = 8, k = 4. Among them, the spectral efficiency of the simulation scheme of "OFDM-IM (n = 8, k = 4), BPSK" is 1.25 bps/Hz. The spectrum efficiency of the other simulation schemes is 1 bps/Hz. It can be seen from the figure that the BER performance of the OFDM-IM system is about 6 dB higher than that of the traditional OFDM system when the bit error rate is in the order of 10 to 4 under the activation mode of n = 4 and k = 2. The significant improvement of BER performance is due to the low error probability of index bits carried by the index combination of activated subcarriers in OFDM-IM system at medium and high signal-to-noise ratio (SNR). When the transmission power of OFDM-IM is the same as that of traditional OFDM-IM system, the transmission power of single subcarrier in OFDM-IM system will be larger than that of single subcarrier in traditional OFDM system. In addition, for the two different activation mode configurations of OFDM-IM system, with the increase of signal-to-noise ratio (SNR), the BER theoretical value curve of the system matches the simulation curve more and more.

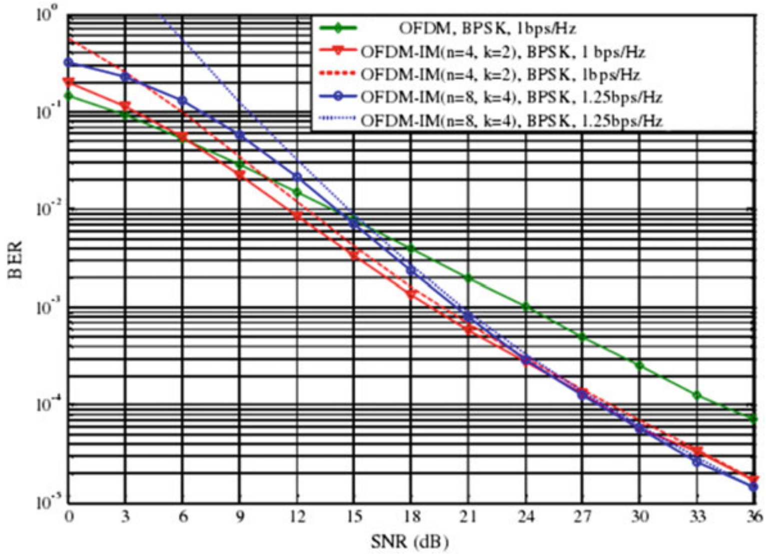

Fig. 3. Simulation results using BPSK modulation

4 Concluding Remarks

In this paper, through the modeling and analysis of OFDM system and OFDM-IM system, it can be found that carrier serial number modulation OFDM-IM is a new physical layer transmission technology, which can obtain better spectral efficiency and BER performance while retaining the advantages of traditional OFDM. There are still many shortcomings, there is still a lot of room for improvement of the algorithm, and MIMO technology is one of the core technologies of the next generation mobile wireless communication, which can be combined with it as the focus of research.

References

1. Basar E, Aygolu U, Panayirci E et al (2013) Orthogonal frequency division multiplexing with index modulation. IEEE Trans Signal Process 61:36–49
2. Ye S, Blum RS, Cimini LJ (2006) Adaptive OFDM systems with imperfect channel state information. IEEE Trans Wirel Commun 5:1276–1536
3. Ntouni G, Kapinas V, Karagiannidis G (2017) On the optimal tone spacing for mitigation in OFDM-IM systems. IEEE Commun Lett 21:1019–1022
4. Wen M, Zhang Y, Li J et al (2016) Equiprobable subcarrier activation method for OFDM with index modulation. IEEE Commun Lett 20:2386–2389
5. Zhang H, Yang LL, Hanzo L (2016) Compressed sensing improves the performance of subcarrier index-modulation assisted OFDM. IEEE Access 4:7859–7873