The Study of Adaptive Modulation Algorithms in OFDM System

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Abstract. The adaptive modulation techniques is widely used in orthogonal frequency division multiplexing (OFDM) system, this technique can not only improve the utilization efficiency of spectrum, but also the bit error rate performance of system can be significantly improved. Adaptive modulation algorithm is important part in achieving performance improvement, this paper introduces three adaptive bit and power modulation algorithms based on the different allocation principle, and through simulation the paper can comparatively analyze the performance of different algorithms.

Keywords: OFDM, adaptive performance, modulation, algorithms.

1 Introduction

Frequency band is the most valuable resources in wireless communication, along with people has rapid demand to the wireless data services, but how to realize the maximal data transmission rate in the limited bandwidth, that is to say how to realize maximal utilization efficiency of frequency band, it becomes the research focus of mobile communication. Due to adaptive technology has strong advantage in increasing data transmission rate and utilization rate of spectrum, thus it becomes the key technology in the current and future mobile communication system.

2 OFDM Principle

The OFDM technology is different from the FDM technology, its basic principle: the high speed data stream pass the transform of tandem and parallel connection, and the data stream be assigned to the several sub-channels that its transmission rate is relatively low; last the data stream can transmit in the channel. Because of the symbol period of each channel increase relatively, so it can lessen the impact that the multi-path time delay spread of the wireless channel have affection on the system. and also the protection interval is inserted between the OFDM symbols, and let the protection interval is greater than the maximum delay spread of wireless channel, thus can

D.-S. Huang et al. (Eds.): ICIC 2013, LNCS 7995, pp. 339–345, 2013.

maximally eliminate ISI produced by the multi-path interference, generally using cyclic prefix as guard interval, which can be avoided the ICI produced by multi-path channel interference. The basic block diagram of OFDM system is shown in Fig.1.[1-3]

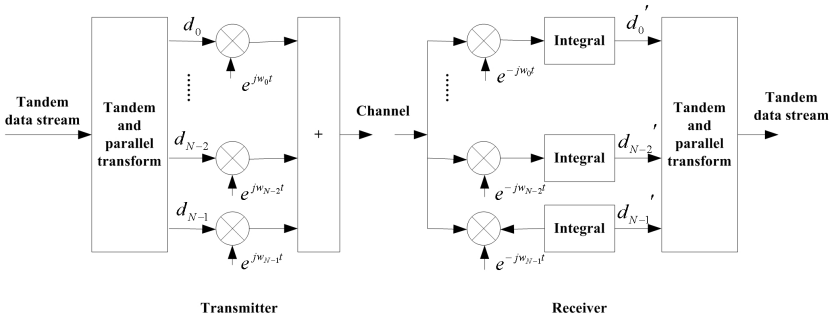

Fig. 1. Block diagram of the basic principles of OFDM system

From the diagram we can see: in the transmitter of OFDM system, the basic principle is that the input data transform N sub-channels data through tandem and parallel connection transform, then each orthogonal sub-carrier respectively modulated correspondingly and stacking synthetic output together. In the receiver of OFDM system, after each sub-carrier respectively mixing and integrating we will get various data, and output the original data through serial conversion. The fundamental idea of the OFDM technology is that the serial high speed data stream change into the parallel low speed data streams through the tandem and parallel transform, the key point is to ensure the orthogonal performance of each sub-carrier.

3 Adaptive OFDM Principle

The equivalent base-band of adaptive OFDM system model is shown in Fig.2. Its basic principle is summarized as follows: first, the receiving end obtains the channel state information through the channel estimator; according to the built-in algorithm and channel state information from the channel estimator, the adaptive bit and power divider sets appropriate modulation parameters for each sub-carrier, (including two parts of the modulation mode and sending power), and these parameters are putted into the transmitting end through dedicated channel; according to the modulation parameters, the tandem-parallel converter of sending end allocates corresponding bits for every sub-carrier, then the modulator completes base-band modulation of each sub-carrier; the output data of each modulator added into the channel and transmitted to receiving end through the fast IFFT converter, parallel / tandem converter, adding cyclic prefix, the receiving end process the inverse operation comparing to the sending end, then the final data is outputted.[4-7]

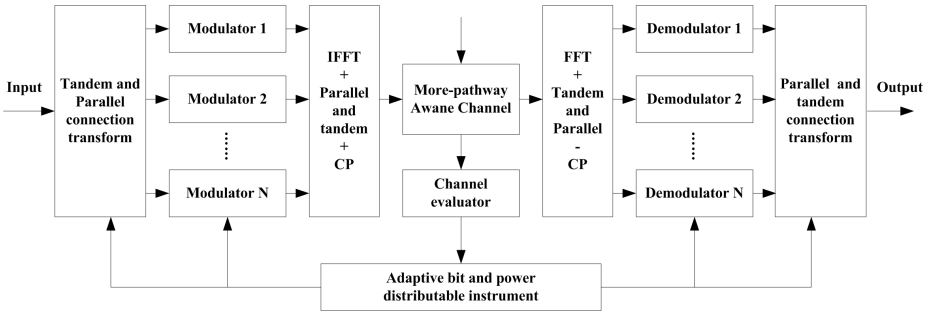

Fig. 2. Base-band model diagram of adaptive OFDM system

From the above principles, in order to the whole system can obtain good performance, the key parts are the channel estimator, adaptive bit and power distributor, when the channel state information of the channel estimator is more accurate, the performance of adaptive bit and power divider is more better.

4 Adaptive Modulation Algorithms

The performance of adaptive OFDM system, the key two parts are the channel estimator, adaptive bit and power distributor, and the adaptive algorithms of two parts are the core parts, this paper presents three different adaptive bit and power optimum modulation algorithms based on three different allocation principles: the Hughes-Hartogs algorithm based on minimum power, the Chow algorithm based on maximal system capacity and the Fischer algorithm based on minimal error rate. And this paper also presents improvement that the complexity of Hughes-Hartogs algorithm and the performance of Fischer algorithm.[8-13]

4.1 Hughes-Hartogs Algorithm

The Hughes-Hartogs algorithm is an adaptive bit and power allocation algorithm that applied to the OFDM system or multi-carrier system, it first used in downlink high speed data transmission of xDSL cable system. This algorithm is based on the channel gain, its basic idea: the bit initial value sets to 0 in each sub channel, and then all unallocated bits are allocated to the corresponding sub-channel. Each allocation, first the algorithm find the increase of 1 bit, and the minimal sub-channel needing to increase power, then the bit number of sub-channel is increased 1. So cycling, until all of the bits are dispensed, the required power of each sub-channel final calculated.

The Hughes-Hartogs algorithm can achieve the optimal bit and power allocation results, but require additional search and sorting, the computational complexity is great. Especially when the sub channel number is more, the Hughes-Hartogs algorithm is very slow.

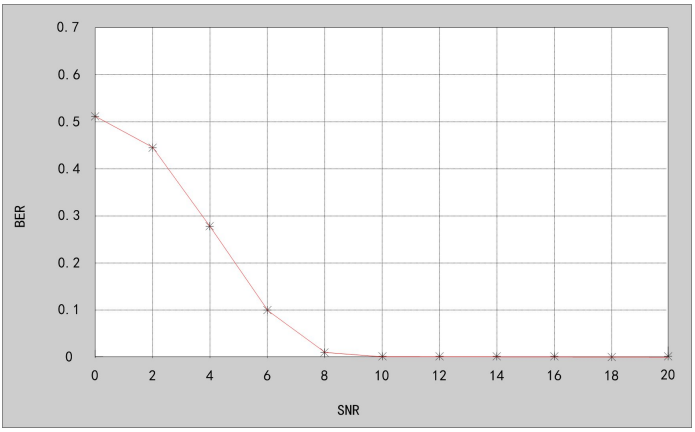

Fig. 3. BER curves of Hughes-Hartogs algorithm

Fig.3 shows that the Hughes-Hartogs algorithm based on minimal power distribution maintains good system performance, it can be said to be a classic algorithms, but its complexity is very high, the calculation amounts is large, because calculation time is too long so that the algorithm cannot get good application in the actual system. Due to the Hughes-Hartogs algorithm has such shortcomings, the algorithm can be improved, the improved Hughes-Hartogs algorithm can reduce allocation complexity within the premise that the performance maintains in the allowable range, and it can overcome shortcomings.

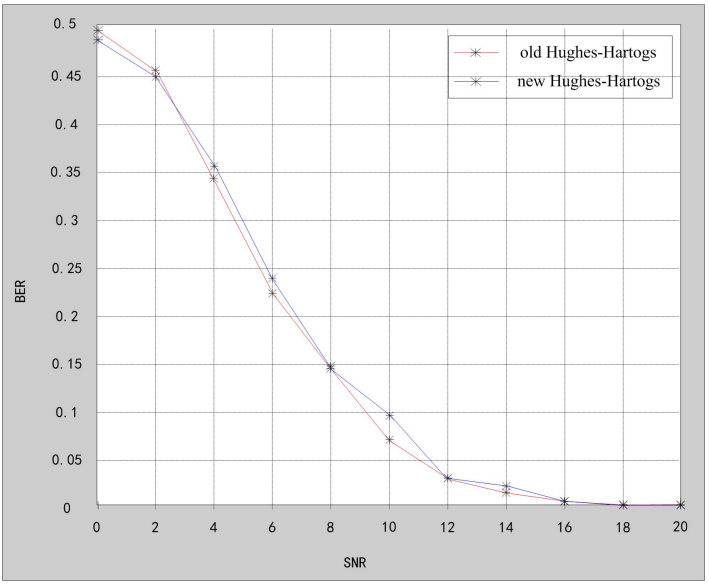

Fig. 4. BER curves of improved Hughes-Hartogs algorithm

The system BER simulation curve as shown in Fig.4, the BER curves shows that: the improved adaptive modulation bit allocation algorithm has not very big influence on the bit error rate (BER) performance of the system, when the SNR value is same; the improved adaptive algorithm reduces about one order of magnitude comparing to the original algorithm.

4.2 Chow Algorithm

Comparing to the Hughes-Hartogs allocation algorithm, the Chow algorithm greatly reduces the complexity of the algorithm, improves the speed of the bit allocation, and the adaptive modulation can be used in high speed data transmission. The Chow algorithm allocates bit based on the channel capacity of sub-channel. Its optimization criterion makes that the system spectrum efficiency achieves best under the condition maintaining the target bit error rate (BER). The algorithm uses an iterative process, gradually allocates bit, also makes the system margin gradually increased, until the entire bit allocated.

4.3 Fischer Algorithm

The Fischer algorithm is an improved algorithm based on the Chow algorithm. Comparing to the Chow algorithm, the basis of the Fischer algorithm bit allocation is not the channel capacity, its design goal is the bit error rate (BER) minimum. Its optimization criterion is that the bit error rate (BER) of the system achieves optimal performance under the premise of maintaining the constant transmission rate and the total transmission power.

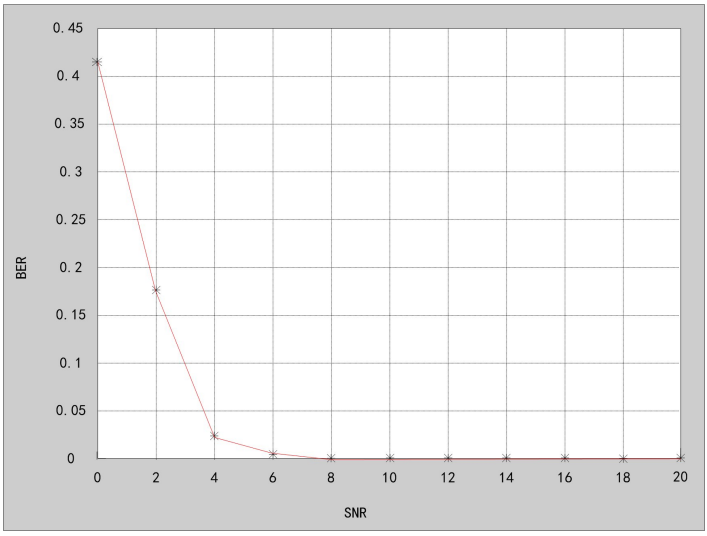

Fig. 5. BER curves of Fischer algorithm

Fig.5 shows that this OFDM adaptive modulation algorithm based on the minimum bit error rate (BER) principle can meet the requirements in system performance, from the comparison of figure 3 and Fig.5, the BER performance of the Fischer algorithm is better than the Hughes-Hartogs algorithm based on the minimum power allocation principle. So the Fischer algorithm is applied to the businesses that bit error rate (BER) demanding is high, such as data transmission, multimedia services and so on, and it has been adapted in xDSL system. This algorithm also has some shortcomings, the shortcomings can be improved, the improved Fischer power allocation algorithm directly distribute power according to the quantized scale bits, so as it can reduce the quantization error of the power allocation, and get better performance of allocation affection than the original algorithm.

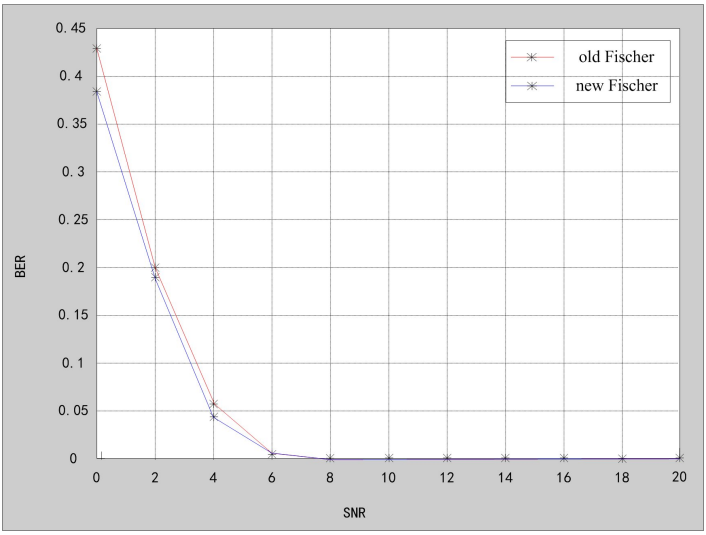

Fig. 6. BER curves of improved Fischer algorithms

Fig.6 shows, when the SNR value is same, the error rate of this improved power allocation algorithm is reduced somewhat than the original algorithm, in low SNR environment the error rate probably drop about 0.03.

5 Conclusions

This paper introduces three adaptive modulation algorithms based on different optimal criterion, then the Fischer algorithm and the Hughes-Hartogs algorithm also is improved, from the simulation results we can see the respective improvement results of different algorithms, the complexity of the improved Hughes-Hartogs algorithm is better than the original algorithm, but the performance is reduced slightly, so that it is possible in the actual application. The performance of the improved Fischer algorithm is improved than the original algorithm, and the system bit error rate is further reduced.

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