Improvement and Optimization of OFDM System Performance

Xiaoyan Huang[1], Rong Zhou [1,a]

[1] Chengdu University of Information Technology, Chengdu, 610225, China

[a] email: yyq@cuit.edu.cn

Keywords: OFDM System; BER Enhancement; SNR

Abstract. This paper introduces the basic principles of OFDM system, simulates and discusses the inter-symbol interference and other issues caused by Gauss noise comprehensively simulates and analyzes the QPSK modulation technique using Matlab. This paper obtains the BER performance curve within a certain SNR by simulation.

Introduction

OFDM (Orthogonal Frequency Division Multiplexing) is a special multi-carrier transmission scheme, it combines digital modulation, digital signal processing, multi-carrier transmission technologies, and now it is the highest spectral efficiency of communication system with the advantages of fast transmission speed, anti-multipath interference ability [1]. Currently, OFDM technology is widely used in the digital audio broadcasting (DAB), terrestrial digital video broadcasting (DVB-T), wireless LAN and other fields.

The basic principle of OFDM is to distribute the transmitted high speed data to numbers of sub-channels flow which has relatively low transmission rates through the serial-parallel conversion [2]. The symbol period of each sub-channel will be relatively increased, which will make the value of symbol period larger than the multipath delay, this can reduce the impact of time diffuse caused by the wireless channel multipath delay spread on the system. In addition, as the OFDM signals make full use of the time-frequency orthogonal which allow the N sub-channels spectrum have a 1/2 overlap, and the spectral efficiency is nearly doubled compared to single-carrier serial systems, it can be achieved by the digital signal processing (DSP) technology - Fast Fourier Transform (FFT) without the Comb filters easily[3].

OFDM modulation and demodulation system

Principle of OFDM modulation and demodulation system

Orthogonal frequency division multiplexing is based on the principle of the frequency division multiplexing (FDM), and the subcarriers use the sine or cosine function set which is orthogonal to each other, and it satisfies equation (2.1).

$$\frac{1}{T}\int_0^T \exp(j\omega_n t)\cdot\exp(-j\omega_m t)\,dt = \begin{cases} 1, & m = n \\ 0, & m \neq n \end{cases} \quad (2.1)$$

Suppose the N symbols d (0), d (1), d (2), ..., d (n-1), d (n) transmitted in a period [0, T] are complex, this complex sequence will modulate the N subcarriers to complete the frequency division multiplexing after going through the serial-parallel converter[4]. One OFDM symbol comprises a plurality of synthesized signal of the modulated subcarriers, where each sub-carrier is modulated by phase shift keying (PSK) or quadrature amplitude modulation (QAM) modulation symbols.

$$S(t) = Re\left\{\sum_{t=0}^{N-1} d(n)\exp(jw_n t)\right\} = \sum_{n=0}^{N-1}\left[a(n)\cos 2\pi f_n t + b(n)\sin 2\pi f_n t\right] \quad (2.2)$$

Where T is the OFDM symbol period, and it is the period of the symbol witch goes through the data encoder.

At the receiver, we divide the input signal into N branches, and the N subcarriers are used to

mixing and integral respectively to recover the N sub-signals, and then after the parallel-serial conversion and conventional QAM (or QPSK) demodulation the data can be restored[5]. Since the orthogonally of the sub-carriers, the mixer and the integration circuit can separate each sub-channel effectively, as the following equation shows:

$$d(m) = \int_0^{T_s} \sum_{n=0}^{M-1} d(n) \exp(j\omega_n t) \exp(-j\omega_m t) dt$$

$$= \sum_{n=0}^{M-1} d(n) \int_0^{T_s} \sum_{n=0}^{M-1} \exp[j(\omega_n - \omega_m)t]$$

$$(2.3)$$

The FFT / IFFT in OFDM system

After discrete, s (t) can be shown as:

$$S(mT_s) = \sum_{N=0}^{N-1} \left[a(n) \cos 2\pi f_n (mT_s) + b(n) \sin 2\pi f_n (mT_s) \right] \quad 0 \le m < N \quad (2.4)$$

Let these components go though the low-pass filter at the time Δt, which means to do the D/A conversion, and then we can recover the original analog signal S (t). Putting it into the upper discreted equation, we can get:

$$S(m) = \text{Re} \left\{ \sum_{n=0}^{N-1} \left[a(n) + jb(n) \right] e^{\frac{j2\pi mn}{N}} \right\} \quad m = 0, 1, 2, \cdots, N-1 \quad (2.5)$$

The component in the brace is the inverse discrete Fourier transform IDFT of the sequence. Obviously, IDFT can be used to achieve the OFDM system, taking the real part of the output of IDFT, and then after the D/A conversion and reconstruction (smoothing) filter ,we can restore the original analog signal S(t), it can be send into the channel to transmit after the up-conversion. Since only the real part of the output of IDFT is transmitted, we do the sampling at the receiver, and the 2N-point DFT to recover the original data.

BER performance simulations in different channel environments

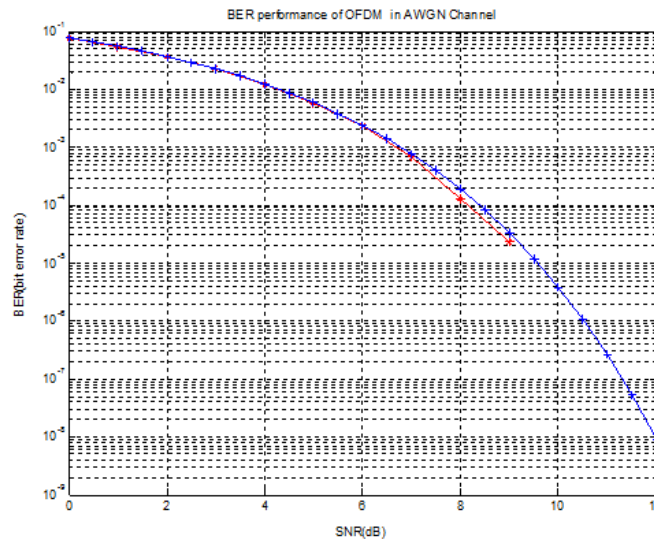**BER performance with the additive white Gauss noise interference**

Fig 3.1 BER performance with the additive white Gauss noise interference

As it is shown in Fig 3.1, we use the blue line indicate by + to represent the BER of theoretical analysis, its curve is generated by the Qfunct function, by the knowledge learned on Communication Theory courses we can get the theoretical BER formula of the QPSK modulation system with additive white Gauss noise interference. Short curve in Fig 3.1 is the actual simulation BER, from the figure we can see, the two curves are basically consistent, which shows that, the BER performance of the QPSK modulation OFDM system is consistent with the BER performance

of the original QPSK modulation system, which means that IFFT and FFT transform do not change the BER performance of system.

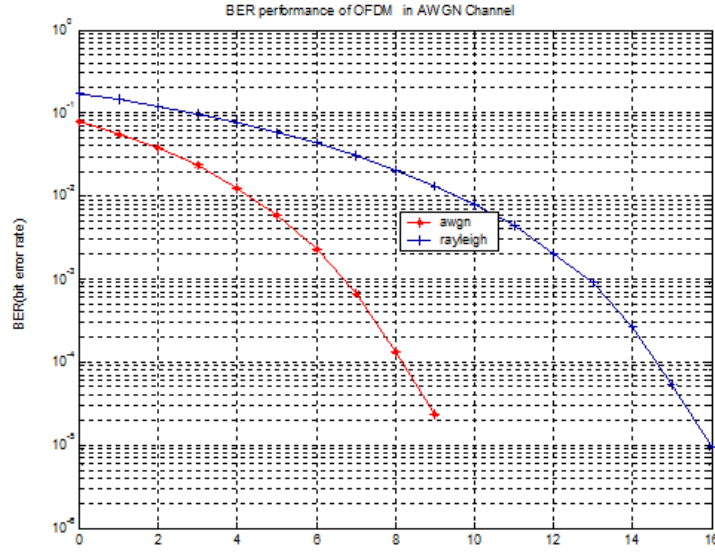**BER performance comparison with multipath interference**

Fig 3.2 BER performance with multipath interference

The line below shown in Fig 3.2 indicates the BER performance of system with OFDM modulation under multipath interference, and the upper line represents the BER performance of system without OFDM modulation under multipath interference As can be seen from the figure that, OFDM modulation can reduce the impact of multipath interference, and improve the BER performance.

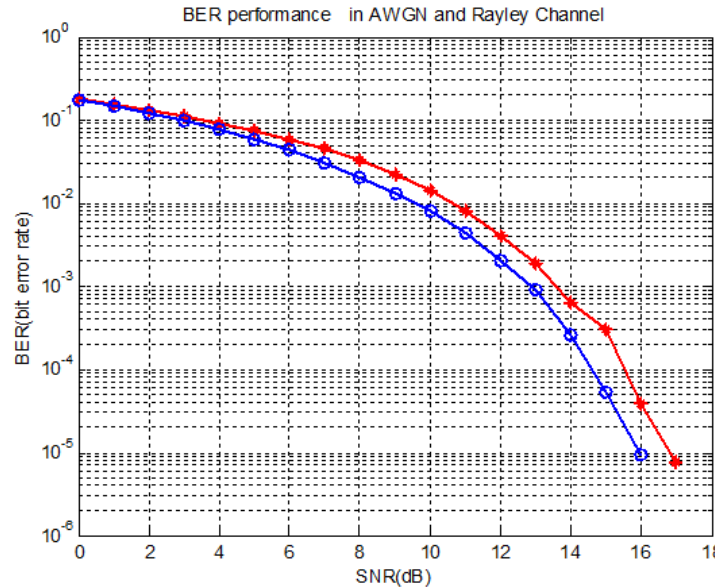**BER performance with additive white Gauss noise and multipath interference**

Fig 3.3 BER performance with additive white Gauss noise and multipath interference

As it is shown in Fig 3.3, we use the blue line (upper) indicated by + to show the system BER performance under the case of multiple-path fading, and we use we use the red line (below) indicated by * to show the system BER performance under additive white Gauss noise. As can be seen from the figure that, the BER performance under multipath interference is much worse than the BER performance under the additive white Gauss noise interference, this is mainly due to the inter-symbol interference caused by the multipath delay which influence the BER performance of the system.

Conclusions

Based on the analysis of the OFDM technology principle, this paper uses MATLAB to achieve the simulation of sending, channel transmission and receiving of the OFDM transmission system. In addition, this paper has analyzed the BER performance under different channel environments and the BER performance under different modes of the system realization way. The results show that the OFDM system can reduce the impact of multipath interference, and improve the BER performance of system.

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