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Performance of FSO-OFDM based on BCH code

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Abstract. As contrasted with the traditional OOK (on-off key) system, FSO-OFDM system can resist the atmospheric scattering and improve the spectrum utilization rate effectively. Due to the instability of the atmospheric channel, the system will be affected by various factors, and resulting in a high BER. BCH code has a good error correcting ability, particularly in the short-length and medium-length code, and its performance is close to the theoretical value. It not only can check the burst errors but also can correct the random errors. Therefore, the BCH code is applied to the system to reduce the system BER. At last, the semi-physical simulation has been conducted with MATLAB. The simulation results show that when the BER is 10-2, the performance of OFDM is superior 4dB compared with OOK. In different weather conditions (extension rain, advection fog, dust days), when the BER is 10-5, the performance of BCH (255,191) channel coding is superior 4~5dB compared with uncoded system. All in all, OFDM technology and BCH code can reduce the system BER

Key words: Free Space Orthogonal (FSO); Orthogonal Frequency Division Multiplexing (OFDM); BCH code

1 Introduction

Free space optical communication can transfer information by optical signals in the space directly. Due to the Free Space Optical communication has the advantages of low cost, flexible networking, convenient installation and dispense with frequency permission, it has become a major technology in the present information technologies[1-2]. As the channel is atmosphere channel the signals have to experience atmospheric scattering effects causing by dust, raindrop and fog drop, which result in severe fading of the power of the optical signal[3]. In references , it pointed out that the FSO-OFDM technology not only could resist the effects of light scattering, but also improve the velocity without increasing the bandwidth. BCH code has a good error correcting ability, particularly in the short-length and medium-length code, and its performance is close to the theoretical value. It not only can check the burst errors but also can correct the random errors[4-6]. Therefore, the BCH code is applied to the system to reduce the system BER.

2 The Model of the FSO-OFDM

The basic principle of FSO-OFDM is divided the channel into many sub channels through the use of multiple sub carriers. The signal through serial parallel conversion to modulate the subcarrier respectively.

2.1 The Model of OFDM

The FSO-OFDM system was formed by transmitting part and receiving part.

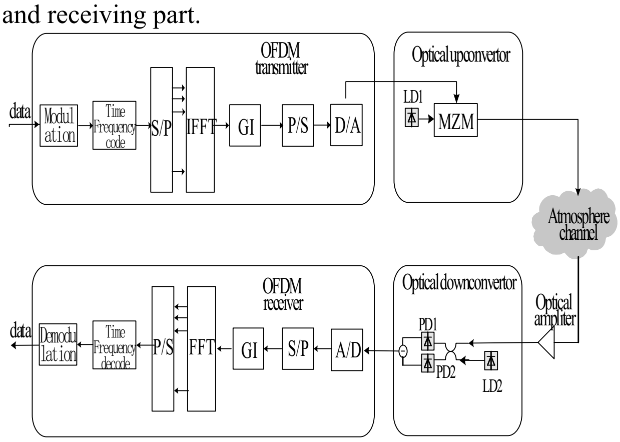

Figure 1. signal model

The baseband OFDM signal format is:

$$S(t)=\frac{1}{N}\sum_{i=1}^{\infty}\sum_{k=1}^{N}X_{i,k}\,e^{j2\pi f_k t} \qquad (1)$$
$$f_k=(k-1)/T_s$$

in the formula : f_k represents carrier frequency. $X_{i,k}$ represents sub-carrier signal.

$$f_k = f_0 + n\Delta f \qquad (2)$$

in the formula : Δf represents the sub-carrier interval; f_0 represents practical emission carrier frequency. T is the symbol period. $\Delta f=\frac{1}{T}$ .Generally every N sub-carriers make up an OFDM signal.

We need spectrum shift the base-band OFDM signals to the intermediate frequency f_{LO1}, and the intermediate frequency signal can be expressed as formula (3).

$$S_{IF}(t) = \frac{1}{N}\exp(j2\pi f_{LO1}t)\sum_{i=1}^{\infty}\sum_{k=1}^{N} X_{i,k}\exp(j2\pi f_k t) \tag{3}$$

Take one OFDM symbol as an example, the real part of the signal is shown as:

$$\begin{aligned} S_{OFDM}(t) &= \mathrm{Re}[S_{IF}(t)] \\ &= \frac{1}{N}\left[\sum_{K=1}^{N}\mathrm{Re}(X_{i,k})\cos(2\pi(f_k+f_{LO1})t) - \sum_{K=1}^{N}\mathrm{Im}(X_{i,k})\sin(2\pi(f_k+f_{LO1})t)\right] \end{aligned} \tag{4}$$

Euler's formula shows that the real part of the intermediate frequency signal has contained the phase components and the orthogonal components of the signal X_k. Therefore, the format of the ith OFDM symbol's kth sub-carrier is $S_{OFDM}(i,k)\big|_{i=1:\infty,\,k=1:N}$ 。

2.2 The Model of Atmospheric Scattering Channel

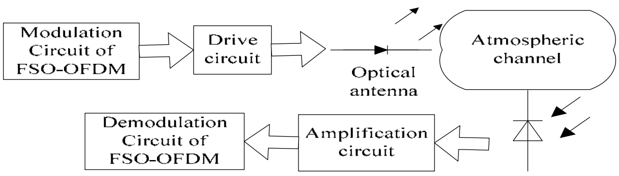

Figure 2. The channel model

FSO-OFDM communication system in this paper is a point to point communication system. the signals will be effected by atmospheric scattering caused by dust, frog, rain, etc, which will make the optical signal intensity was significantly attenuated. According to the Bougure rule, the power of the light with optical power I_0 after through the transmitter substance with h distance can be written as[1-3]:

$$\begin{aligned} I(\varepsilon) &= I_0(\varepsilon)\exp\left[-\int_0^h \sigma(\varepsilon)dh\right] \\ &= I_0(\varepsilon)\exp[-\sigma(\varepsilon)h] \end{aligned} \tag{5}$$

in the formula : $\sigma(\varepsilon)$ represents attenuation coefficient, ε is frequency parameter.

3 The Principle of BCH Coding and Decoding

3.1 BCH coding

Let the input signal polynomial is

$$I(x) = I_0 + I_1 x + \Lambda + I_{k-1}x^{k-1} \tag{6}$$

The check polynomial is

$$P(x) = P_0 + P_1 x + \Lambda + P_{n-k-1}x^{n-k-1} \tag{7}$$

From the generator polynomial $g(\mathrm{x})$ we can get $\mathrm{P(x)}$: $\mathrm{P(x)} = X^{2t}I(\mathrm{x})(\mathrm{mod(x)})$

the polynomial of generational chip can be written as : $\mathrm{C(x)} = X^{2t}I(\mathrm{x}) + \mathrm{P(x)}$

3.2 BCH Decoding

Let $W(\mathrm{x}) = \mathrm{r}_0 + \mathrm{r}_1 x + \cdots + \mathrm{r}_{n-1}x^{n-1}$ is the receiving code, we can get the adjoin polynomial from the receiving code :

$$\mathrm{S(x)} = s_0 + s_1 + \cdots + s_{2t-1}x^{2t-1} \tag{8}$$

From formula (8) we can calculate the error locator polynomial $\sigma(\mathrm{x})$ and error polynomial $\mathrm{R(x)}$. We can get error pattern from the second step. Finally, we will recover the correct code $\mathrm{C(x)}$ by subtract error pattern from receiving group.

4 Simulation Experiment

In this paper, we conduct a simulation on the system's BER on different weather condition by Monte Carlo method, and set the simulation parameters as follows: 10^6 OFDM symbols, the laser wavelength $\lambda = 1.064\mu m$, the number of subcarriers $N = 64$, the laser-band corresponds to the refractive index of the rain medium $m = 1.178 - i \times 0.071$, transmission distance is 1km, adopting MPSK.

The system performance in the extend rain days which average rainfall is 25mm is shown in figure 3. After BCH coding the system's performance improved about 2.5dB than the original performance when the BER is 10^{-3} and improved about 5dB than the original performance when the BER is 10^{-5}.

The system performance under advection fog which average visibility is 600m is shown in figure 4. After BCH coding the system's performance improved about 2dB than the original performance when the BER is 10^{-3} and improved about 4.5dB than the original performance when the BER is 10^{-5}.

The system performance under dust condition which average visibility is 2500-3000m is shown in figure 5. After BCH coding the system's performance improved about 2dB than the original performance when the BER is 10^{-3} and improved about 5dB than the original performance when the BER is 10^{-5}.

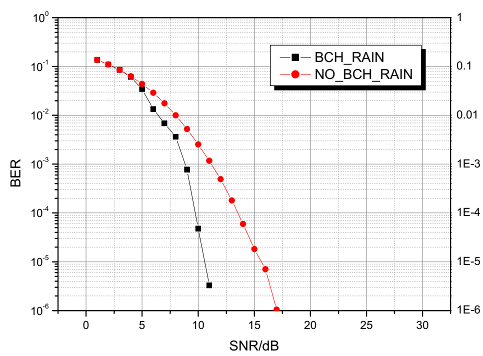

Figure 3. the BER under extend rain conditions

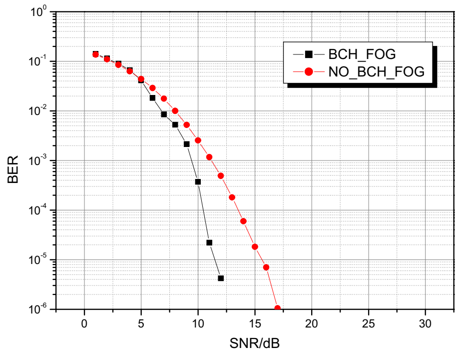

Figure 4. the BER under advection fog conditions

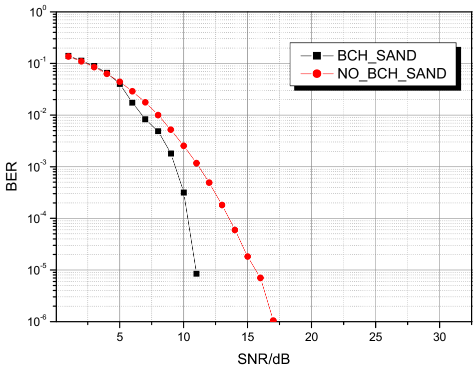

Figure 5. the BER under dust conditions

5 Conclusion

In this paper, the OFDM technique was introduced into FSO system so as to establish the FSO-OFDM system model, and the system error performance of FSO-OFDM was analyzed under the scattering channel condition. Meanwhile, according to the simulation results the performance of the FSO-OFDM system is better than the OOK system under the lower SNR condition, and the system with BCH coding technique is better than the system without channel coding technique.

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