The Influence of ADC in Fiber Optic Communication Systems with Maximum-Likelihood Sequence Estimation

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*Abstract:*The influence of analog-to-digital converter (ADC) in fiber optic communication systems with maximum-likelihood sequence estimatio (MLSE) is investigated. We draw the conclusion that the ADC with a 4-bit resolution can achieve the performance we need.

Keywords: ADC, MLSE, chromatic dispersion, inter-symbol interference

1. Introduction

Fiber optic communication systems suffer from chromatic dispersion（CD） which is induced by different wavelength of optical pulse. Chromatic dispersion grows quickly as the data rate increases, and becomes severely at 10Gb/s and beyond [1]. So chromatic dispersion is one of the main obstacles in high data rate long haul fiber optic communication systems since it results in pulse broadening and, hence, inter-symbol interference (ISI) [2]. Maximum-likelihood sequence equalization is a well-known technique to compensate the ISI [3] and can achieve the optimum performance in theory.

The main challenge to the implementation of robust MLSE to mitigate ISI is building a high speed analog–to-digital converter that can meet the high speed fiber optic communication system requirements [4]. So it's important to research the influence of ADCs with different resolutions in the fiber optic transmission system with MLSE and find the resolution which can meet the requirement for fiber optic communication systems.

This paper presents simulation results showing the performance of ADCs in MLSE. The performance is evaluated in terms of receiver power penalty at the bit-error ratio （BER） of 10^{-4} which could be corrected below 10^{-15} using forward-error correction commonly used in fiber optic communication systems [5].

2. Principle Of The MLSE

Different from a simple receiver which decides each bit immediately and individually, in a MLSE, the decision is determined by calculating the transmitted bit stream with the highest probability [6]. That means the probability for all bit combinations for the whole sequence is taken into account and the combination with the highest probability is assumed as the transmitted bit combination [7]. In other words, an MLSE receiver minimizes the probability of the sequence error. In practice, MLSE is used with a very efficient method, the Viterbi algorithm (VA) that significantly reduces the computation effort for searching the most likely transmitted bit combination, given a set of noisy received signals [8].

3. The Influence Of Adc With Different Resolutions

Fig. 1 shows a simplified model of the system under consideration. The bit sequence {an}={a1…an}, (an∈A={0,1}), was transmitted at the rate of 10Gb/s（R_{bit}）. It adopts a binary alphabet (e.g., On-Off Keying (OOK) modulation) to produce ideal nonreturn-to-zero (NRZ) signal. It assumes that the optical transmission impairment was compensated by the optical amplifier, so only the second order CD was considered in the simulation. In the receiver, an additive white Gaussian noise was added after photoelectrical conversion. Then an electric 7th-order Bessel low pass filter with $0.8R_{bit}$ bandwidth was used to simulate the effect of limited bandwidth in the amplifier and photoelectrical detector. The MLSE deals with data from the ADC which converts the analog electrical signal i(t) to a digital signal. The simulation assumes a channel memory of seven symbols which has been proved to be enough for our study.

The main barrier of the MLSE implementation is building a high speed analog-to-digital converter that can meet the fiber

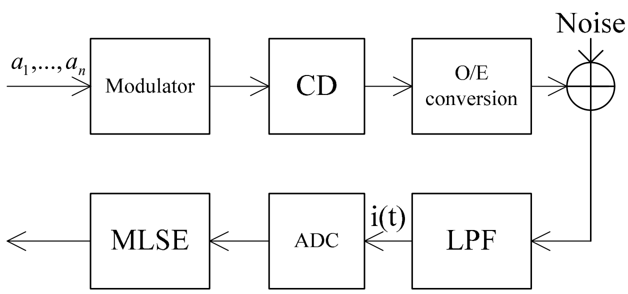

Fig.1. System model in the simulation.

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optic communication system requirements. It's well-known that the resolution of an ADC is directly related to the accuracy of the ADC. However, the power dissipation and the chip area also increase exponentially with the resolution [9]. As a result the complexity and cost will skyrocket. So we must find a balance between them. The uniform quantization was adopted in our simulation study. In Fig. 2, a BER performance comparison between ADCs with different resolutions for fiber optic communication system with a transmission distance of 200km is presented, showing that the performance of a 3-bit ADC is not good enough, while the performance of a 5-bit ADC is as good as that of a ADC with infinite resolution. More important, the difference between a 4-bit ADC and a 5-bit ADC is only 0.4dB in receiver power at a BER of 10^{-4}.

The difference between the 4-bit ADC and the 5-bit ADC has been proved to be small for a fixed transmission distance. But when the distance changes, will the performance difference between the 2 ADC resolutions change sequentially? If so, the implementation of MLSE will be more difficult as different ADC resolution has to be used at different transmission distances. The performance is simulated and compared for different distances with the 4-bit ADC and 5-bit ADC and the result is shown in Fig. 3. From Fig. 3, it is found that the difference between 4-bit and 5-bit ADC resolutions is very small (around 0.4bB in receiver power at a BER of 10^{-4} among a wide range of different transmission distances.

4. Conclusion

In this paper we investigate the influence of ADC with different resolutions in fiber optic communication systems with MLSE for different transmission distances. Simulations of the 4-bit ADC exhibit a good performance that can meet the requirement of fiber optic communication systems.

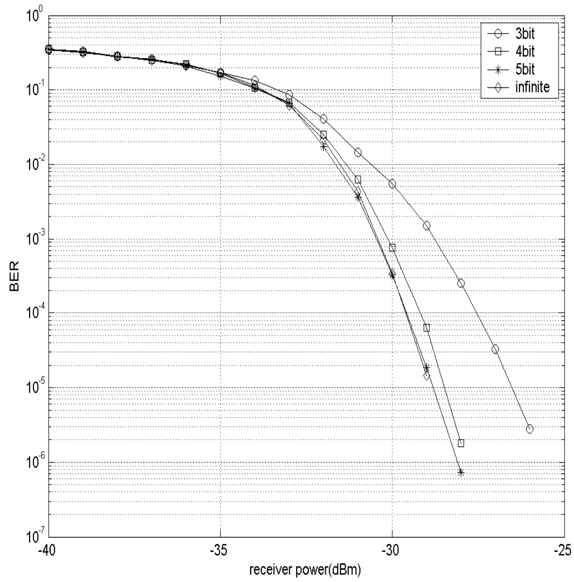

Fig.2. The performance of ADC with different resolutions for MLSE receiver in fiber optic communication systems with a transmission distance of 200km.

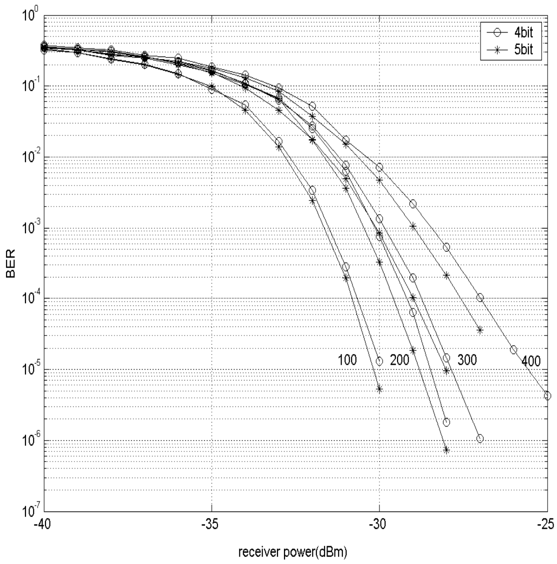

Fig.3. The performance of ADC with different resolution (4-bit & 5-bit) in fiber optic communication systems with MLSE receiver at a transmission distance of 100km, 200km, 300km and 400km

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