Chromatic Dispersion Compensation by MLSE Equalizer with Diverse Reception

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Abstract

We present a concept of improving MLSE by diverse reception. Simulation results show CD tolerance of 42.7G NRZ-OOK system is 382 ps/nm at 3 dB OSNR penalty

Introduction

Electric dispersion compensation (EDC) is a promising technique to combat residual chromatic dispersion (CD) in modern optical transmission systems and networks [1-4]. Compared with CD compensation by traditional dispersion compensating fibre (DCF), EDC is more flexible, cheaper and more compact. However, in an intensity modulation-direct detection (IM-DD) system the photo diode ignores phase information of the optical signal, which makes the receiver essentially nonlinear. Therefore EDC techniques in optical systems are not as effective as those in wireless or electrical cable systems even if maximum likelihood sequence estimation (MLSE) is used.

In this paper, we propose a concept of diverse reception MLSE, namely DR-MLSE. The DR-MLSE uses optical band pass filter (OBPF) to bring part of the phase information of the optical signal to intensity domain so that the MLSE equalizer after the photo diodes can acquire more information from the optical signal. The concept is validated by simulation in which the DR-MLSE is used to compensate residual CD in 42.7G bit/s non-return-to-zero on-off keying (NRZ-OOK) system.

Configuration of the DR-MLSE

Fig. 1 shows schematic of the proposed DR-MLSE. In the equalizer, the incoming optical signal is first split into two branches. In each branch, the optical signal is filtered by OBPF and photo detected, respectively. Then a MLSE equalizer works with the samples from the two branches. The reason for performance enhancement of MLSE by diverse reception is that

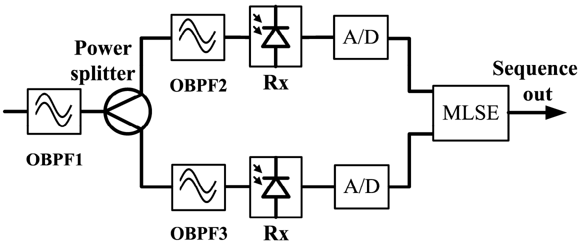

Figure 1: Schematic of the DR-MLSE

OBPF2 and OBPF3 convert part of the phase information of the optical signal to intensity domain and therefore the phase information can be partly detected by the photo detectors. The receiver thus becomes relatively more “linear” so that the MLSE equalizer achieves better performance.

Simulation setup

In our simulation, we consider a 42.7G bit/s NRZ-OOK system in which residual CD is not fully compensated. Fibre nonlinearity is not considered here. All the OBPFs have a second order super-Gaussian characteristic. The bandwidth of OBPF1 for emulating wavelength division multiplexing (WDM) demultiplexer is 100GHz. The electric circuits in the optical receivers have a fifth order Bessel characteristic and their bandwidth is set to 30 GHz. Although theoretically the DR-MLSE will perform better if we increase the number of the branches, only two branches are considered here. OBPF2 and OBPF3 with the same bandwidth are detuned symmetrically from the centre frequency of the optical signal. The DR-MLSE takes one sample from each branch for every bit. And the conventional MLSE for comparison takes two samples in each bit interval. Both of them have 4 states. The difference between the DR-MLSE and the conventional MLSE is that they take samples in different ways and thus the complexities of their MLSE modules are exactly the same.

Results and discussion

Fig. 2 shows the required optical signal to noise ratio (OSNR) to achieve bit-error rate (BER) of 10^{-3} for the DR-MLSE with the detuning frequency of OBPF2 and OBPF3. The bandwidth of OBPF2 and OBPF3 has been optimized to 0.6 times the bit-rate at 300 ps/nm residual CD. We can see that the performance of the DR-MLSE is poor with a detuning frequency approaching zero. This is because when the detuning frequency is equal to zero, the DR-MLSE will degenerate to the conventional MLSE with one sample per bit. The difference between the acquired information from the two branches widens with the

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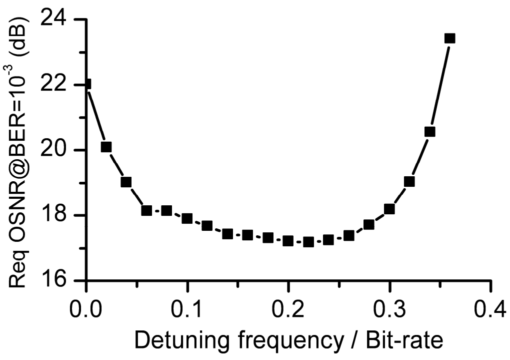

Figure 2: Required OSNR with detuning frequency of OBPF2 and OBPF3 at 300ps/nm residual CD

detuning frequency, leading to reduced OSNR requirement. However, when the detuning frequency is greater than 0.3 times the bit-rate, the required OSNR begins to rise again. Note that at this turning point, the detuning frequency is half of the bandwidth of OBPF2 and OBPF3, which means the centre frequency of the optical signal is at the edges of the OBPFs. So when the detuning frequency continues to rise, important information near the centre frequency of the optical signal will be lost. Therefore the required OSNR rises accordingly. Since the optimum bandwidth is less than the bandwidth of the signal, this narrow filtering does bring about penalty when the residual CD is zero or small.

Fig. 3 shows required OSNR with residual CD for different types of receivers. In the DR-MLSE receiver, the bandwidth of OBPF2 and OBPF3 is 0.6 times the bit-rate, and their detuning frequency is 0.21 times the bit-rate. We can see that without equalization the required OSNR rises rapidly as the residual CD increases and the residual CD tolerance at 3 dB OSNR penalty is 65 ps/nm. As for the receiver with conventional MLSE equalizer, there is slight performance improvement when the residual CD is zero. This is probably because even without residual CD, there is still small inter symbol interference (ISI)

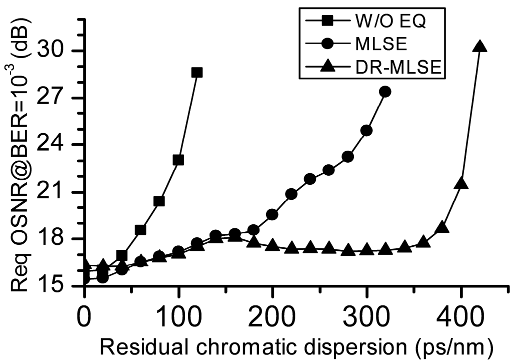

Figure 3: Required OSNR with residual chromatic dispersion for different receivers

from filtering in the electric circuits of the receiver. When the residual CD increases, the required OSNR rises much slower, and the residual CD tolerance increases to 188 ps/nm. We can see from the triangle line that compared with the conventional MLSE receiver, the DR-MLSE receiver has a 0.9 dB OSNR penalty at zero residual CD. This is because the bandwidth of the OBPFs for diverse reception is optimized by achieving minimum required OSNR at 300 ps/nm residual CD, and the bandwidth is narrow thus the OBPFs bring about ISI. However, the required OSNR rises slower than that of the conventional MLSE receiver as the residual CD increases, and the performance of the DR-MLSE receiver is clearly better than that of the conventional MLSE receiver after the residual CD exceeds 160 ps/nm. The residual CD tolerance extends to 382 ps/nm. In practical applications, we can compromise between the OSNR penalty at zero residual CD and the residual CD tolerance by adjusting the bandwidth and the detuning of the OBPFs in the DR-MLSE.

Conclusions

We have proposed the concept of DR-MLSE to enhance the performance of conventional MLSE equalizers by diverse reception, which is realized by splitting the optical signal into two branches and optically filtering them before photo detection, respectively. We numerically demonstrate that when the 4-state DR-MLSE is applied in 42.7G bit/s NRZ-OOK systems in which CD is not fully compensated, tolerance of residual CD increases to 382 ps/nm at 3 dB OSNR penalty, while that of the conventional 4-state MLSE is 188 ps/nm. Although narrow filtering in the DR-MLSE brings about OSNR penalty when the residual CD is zero or small, we can compromise it with residual CD tolerance by adjusting the bandwidth and the detuning of the OBPFs for diverse reception.

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