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A primitive review on: Optimal dispersion compensation and technique

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Abstract

The performance of digital communication system like the optical fibre system is depends on bit error rate (BER). However MC simulation to optical fibre communication system is the low BER required for such system.

Dispersion compensation (DC) has been used for several years and it is one of the essential techniques that make 40Gb\s and higher rate fibre optic transmission possible.

Keywords: BER, MC and DC.

Introduction

Optical fibre Sensors comprise a light source Optical fibre, external transducer and photo detector. They sense by detaching the modulation of one or more of the properties of light that is guided inside the fibre intensity, wavelength or Polarization for instance. That produce a direct fashion by external Perturbation which caused by Physical parameter to be measured. This is inferred from changes detected due to the property of light.

The fibre optic communication systems evolves from 10 Gb/s to 40Gb/s, the nonlinear interaction between pulses introduces significant ISI. In this chapter, we study how to achieve better system performance by optimizing the dispersion compensation scheme of a system. We also show the variation of optimal dispersion compensation with the different system and device parameters.

Dispersion compensation (DC) or dispersion management has been studied and used for several years and it is one of the essential techniques that make 40 Gb/s and higher rate fibre-optic transmission possible. Much research has been done on the fabrication of better dispersion compensation devices and schemes and on the effect of dispersion compensation on the system performance. However, there still exist important questions not yet answered for 40 Gb/s systems due to the complexity of such systems.

Tradition

A schematic of the systems that is shown in Fig. 1. The transmitter sends out an on-off keying (OOK) intensity-modulated pulse train with the specified pulse shape. After the optical signal has propagated through multiple identical fibre spans with the addition of optical amplifier noise, an optical low-pass filter (LPF) is used to cut the noise level before the signal and the noise enter the photo-detector, which is simply modelled as a perfect square-law detector in this chapter. After the electrical signal from the photo-detector passes through an electrical low-pass filter and is sampled, a threshold device decides whether a 0 or 1 is sent based on the samples. The receiver is assumed to be synchronized and the samples are taken at the bit centre.

In Fig. 1, bi-end dispersion compensation with both pre- and post-dispersion compensation is used within each span. The pre- and post-dispersion compensators are modelled as linear devices with transfer functions exp $(j\varepsilon\beta_2 L\omega^2/2)$ and exp $(j(1-\varepsilon)\beta_2 L\omega^2/2)$ respectively, where β_2 is the second-order dispersion of the fibre and L is the span length, that is, the fibre second-order dispersion $(-j\beta_2 L\omega^2/2)$ is perfectly compensated by the pre- and post-dispersion compensation within each span. The parameter ε represents the percentage of fibre dispersion Compensated by the pre-DC and we call it the normalized pre-DC value.

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A lumped optical amplifier provides linear gain to compensate for the fibre transmission loss within each span while introducing amplified spontaneous emission (ASE) noise. The ASE noise is modelled as wide-band complex white Gaussian noise with power spectral density $\Psi_0 = (G-1)\ NF\times h\nu$. $G=\exp(\alpha L)$ is the amplifier gain for the signal power with α as the fibre attenuation factor, h is Planck's constant, υ is the optical carrier frequency and NF is the optical amplifier noise figure. The noise introduced by the different optical amplifiers are assumed to be independent. Note that other types of loss like connection loss and coupling loss have been neglected in this work. The system parameters are kept the same from span to span in our study. To find the optimal DC, we vary ε from 0 to 1 to achieve the best system performance as indicated by the lowest BER.

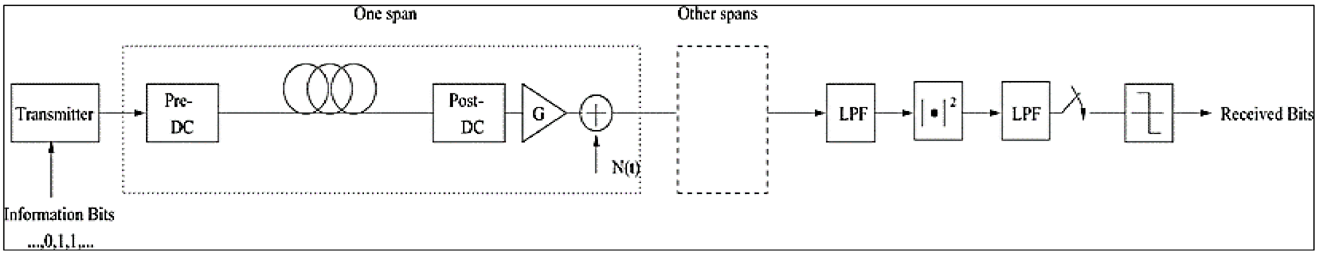

Fig 1: Simplified system models for multi-span system with bi-end dispersion compensation. DC is the dispersion compensator. G is the optical amplifier. LPF stands for low-pass filter

To characterize the performance of an optical fibre communication system, in this work we use BER analysis based on a bit-sequenced Gaussian approximation of the receiver statistics as a compromise between accuracy and computational complexity. Note that the conventional Gaussian approximation is not suitable for 40 Gb/s systems where the system performance might be seriously degraded by ISI from two main sources: the ISI from nonlinear interaction between pulses and the ISI from signal filtering. To take into account the ISI, we introduce a bit-sequenced Gaussian approximation with a bit sequence of variable length K; we write the Gaussian approximated PDF's for the detector samples when bit b_0=0 and 1 are send as

$$f_Y(y|b_0=0) = \frac{1}{2^{K-1}} \sum_{\tilde{b}_j \in \{0,1\}^{K-1}} \mathcal{N}(m(b_0=0,\tilde{b}_j), \sigma^2(b_0=0,\tilde{b}_j)), \quad (1)$$

$$f_Y(y|b_0=1) = \frac{1}{2^{K-1}} \sum_{\tilde{b}_j \in \{0,1\}^{K-1}} \mathcal{N}(m(b_0=1,\tilde{b}_j), \sigma^2(b_0=1,\tilde{b}_j)) \quad (2)$$

where the interference from K–1 neighbouring pulses are considered. The two PDF's are defined the same as in the Application section

$$BER = \frac{1}{2}P(y>T|b_0=0) + \frac{1}{2}P(y<T|b_0=1) \quad (3)$$

$$= \frac{1}{2^K} \sum_{\tilde{b}_j \in \{0,1\}^{K-1}} \mathrm{Q}\left(\frac{T-m(b_0=0,\tilde{b}_j)}{\sigma(b_0=0,\tilde{b}_j)}\right) + \mathrm{Q}\left(\frac{m(b_0=1,\tilde{b}_j)-T}{\sigma(b_0=1,\tilde{b}_j)}\right) \quad (4)$$

where Q(x) is the Gaussian tail integral function. Note that the approximated BER from the conventional Q-factor is very close to the BER from an optimal receiver with a Gaussian approximation based on a single bit.

Technology

Interferometry fibre-Optic Sensing systems have become important tools for oil and gas exploitation, perimeter security and wind detection. The optical fibre typically acts as a long continuous sensor that is highly sensitive to acoustic perturbations from the surroundings. The small influences induced by the environment cause a change of the optical path length in the fibre; when interrogated by coherent laser light and recombined with unperturbed reference light from the laser source itself on a Photo detector, an acoustic finger print is produce by means of data. This finger print provide detailed information about the event at a fixed location along the fibre. With the help of perimeter surveillance fibre Optic systems use algorithms to discriminate background noise that can arise from such sources as rain droplets, so that alarm are triggered only by relevant and potentially critical events.

NKT photonics has been manufacturing low noise, single-frequency fibre lasers since 1997 for global research Integrators and the space and defence Industries. This type of fibre Laser is so-called Distributed-feedback DFB. Design and is essentially a short and robust laser activity. The high value and the L elatively long length of the DFB cavity combined with long radiative life times of rare earth ions in silica which provide for fundamental ally low values of phase noise and spectral line width.

Conclusion

In this Article, I have reviewed the effects of different device parameters on the optimal DC for a 40 Gb/s bi-end dispersion compensated optical fibre communication system up to 40 spans.

We start by checking the accuracy of BER computation based on Gaussian approximation with variable bit length where we have found that the conventional Q-factor is not accurate enough for a 40 Gb/s system due to the large ISI associated with such systems. Instead, we use the bit-sequenced Gaussian approximation with 5-bits where the ISI from the 4 neighbouring pulses are taken into account.

Different noise models are also checked in this chapter. Both the noise model neglecting noise nonlinear interaction with the signal and the noise model where the noise is propagating through the fibre with CW signal are found to be inaccurate for 40 Gb/s systems even though they require much less computation time. Full simulation by the SSF method with multiple realization of the ASE noise is adopted in this work.

The study also shows some unexpected result. An optical filter with higher-order does not necessarily give the best system BER performance (at least for Gaussian pulses). The reason for this unexpected behaviour need to be studied and the result might have significant impact on system.

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