

An Optical WDM Link Simulation at 4·10 Gb/s with the COMSIS Software

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Abstract: The evolution of data transmission using optical fiber media has been accelerated since the advent of technical multiplexing wavelengths (WDM), which helps to achieve bit rates of a few Tb/s transported by a single fiber. In this context, we propose in this work, to make a simulation of a system WDM, at 4·10Gb/s with the COMSIS simulator system. We will interest especially to demultiplexing.

Keywords: Optical fiber, Optical link, COMSIS software, WDM, Demultiplexer, Q-factor.

1 Introduction

The simulators of optical transmission systems bring a precious help for the development of the current systems, for the research and the investigation of the future systems. They so allow to put out the performances of new technologies even before components are available on the market or to investigate the new techniques.

The COMSIS software offers a real possibilities, modeling, simulation and conception of any module of signal processing going from the most elementary device to the complete system of communication [1].

In this aim, we propose in this work, to make a simulation of a system WDM, at 4·10Gb/s. We will interest especially to demultiplexing, we will use a demultiplexer based on Fiber Bragg Grating.

2 Device modeling

Fig. 1 is the block diagram of the optical link that we are going to simulate. The parameters of the modules of the chain of transmission were fired bibliographical references [2, 3, 4].

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The input signal WDM is composed of 4 channels, spaced 100GHz is 0.8nm, in order to limit interference at best, all centered on 1552nm. The multiplex is then modulated to 10Gb/s, then spread to two spans of a Single Mode Fiber which takes into account the effect Kerr, then a fiber compensation and an optical amplifier.

In reception, a demultiplexer based on Fiber Bragg Grating using filters to 40GHz bandwidth is used to separate different channels. The photo-detected signal then passes through a filter low pass Bessel order 5, followed by a circuit decision.

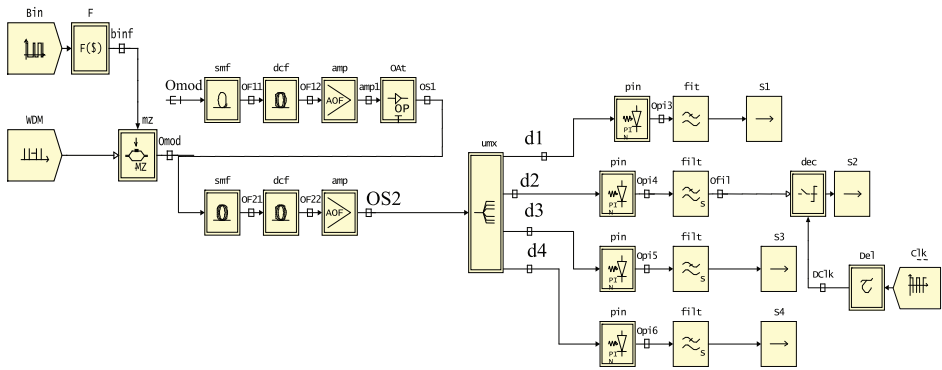


Fig. 1 – WDM transmission system: COMSIS's block diagram.

2.1 Optical fiber

In optical systems the most important passive component is the propagation channel, e.g., the optical fiber. We can write the optical field by introducing a function A , slowly varying, and representing the envelope of the signal as:

$$G(z, t) = A(z, t)e^{j(\omega_0 t - \beta_0 z)}, \quad (1)$$

where: ω_0 is the central frequency and β_0 is the constant propagation.

The generalized propagation equation that describes the propagation of an optical signal in a single-mode fiber is given for the envelope amplitude A by:

$$\frac{\partial A}{\partial z} = -\frac{\alpha}{2} A + \frac{i}{2} \beta_2 \frac{\partial^2 A}{\partial t^2} + \frac{1}{6} \beta_3 \frac{\partial^3 A}{\partial t^3} - i\gamma |A(t)|^2 A - i\xi [S_R(t) \cdot |A(t)|^2] A. \quad (2)$$

This can be written in the form

$$\frac{\partial A}{\partial z} = (D + N)A, \quad (3)$$

where D is a differential operator, which includes the effects of fiber loss through α , chromatic dispersion through β_2 , and dispersion slope through β_3 :

$$D = -\frac{\alpha}{2} + \frac{i}{2}\beta_2 \frac{\partial^2}{\partial t^2} + \frac{1}{6}\beta_3 \frac{\partial^3}{\partial t^3}, \quad (4)$$

where N is a nonlinear operator that takes into account the Kerr and the Raman effects through the nonlinearity coefficient γ and the Raman coefficient ξ :

$$N = -i\gamma |A|^2 - i\xi [S_R(t) \cdot |A|^2], \quad (5)$$

where the asterisk is the symbol for convolution and $S_R(t)$ is the impulse response of the filter simulating the dependence of the Raman gain on the frequency.

The frequency response of this filter is approximated by a Lorentzian:

$$S_R(\Omega) = \frac{1}{\frac{\Omega_R^2 - \Omega^2}{2\Gamma_R \Omega_R} + i \frac{\Omega}{\Omega_R}}, \quad (6)$$

where $\Omega = \omega - \omega_0$, Ω_R is the resonant frequency and Γ_R is the half Raman linewidth.

The split-step Fourier method is used for numerical simulation. The interface of the model allows us to optionally choose the effects that are to be taken into account (Kerr effect, Raman Effect, polarization-mode dispersion) [1, 5, 6].

2.2 Optical Amplifiers

To overcome the power budget limitation in optical transmission systems, we use optical amplifiers. Erbium-doped fiber amplifiers (EDFA's) are now essential devices for many telecommunication applications, and much theoretical research has been done to optimize them [5].

Statistical analysis of the model makes it possible to visualize different curves characteristic of the EDFA such as: Gain, the spectral density of ESA depending on the wavelength, the gain depending on the power of entry, and, the power of the pump, the output power depending on the power of entry, etc. For example, see the curves Figs. 2 and 3.

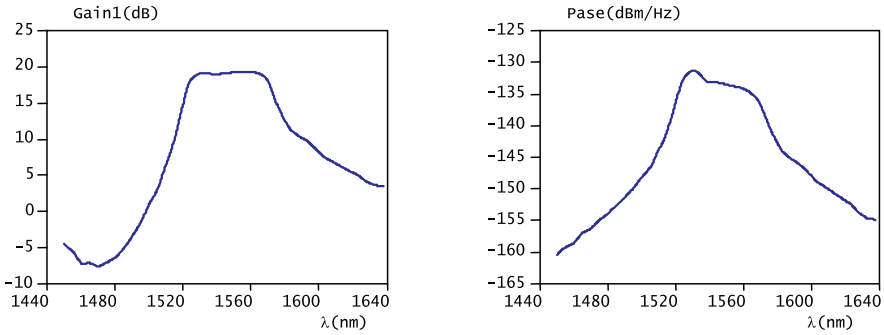


Fig. 2 – Gain spectral and density of ESA depending on the wavelength.

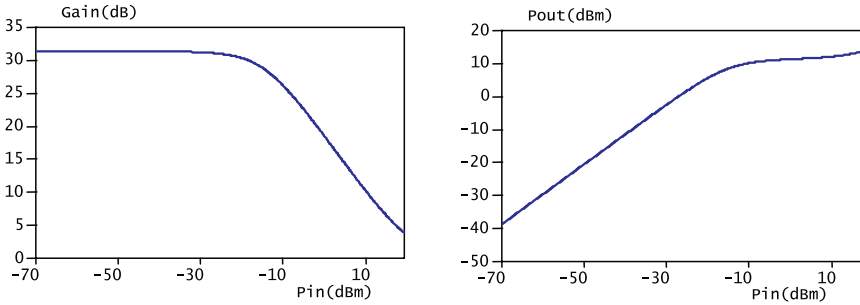


Fig. 3 – Gain and output power depending on the input power.

2.3 Photodetectors

At reception the photodetectors (ideal, PIN, or avalanche photodiodes) are modeled as ideal quadratic detectors (scalar or vectorial) with current fluctuations induced by noise (shot noise, thermal noise). Mathematically, the current fluctuations are modeled as stationary random processes [6].

3 System Performance Assessment

Simulation results are available in digital or graphic forms: time-domain response, power assessment, spectral analysis, bit-error rate, signal-to-noise ratio, or eye diagram.

The eye diagram can be exploited as with a digital oscilloscope. The eye width, height, extinction ratio, crossing position, jitter, and Q factor can be calculated, and estimates of the optimal decision threshold and the bit-error rate are directly given from these values.

3.1 Viewing signals

We will interest on the signals coming out of the amplifier and demultiplexer at the end of highlighting the effect of filtering applied it on the sign; namely:

- reducing the band of integration of noise generated by the ASE optical amplifiers,
- the separation of Channel.

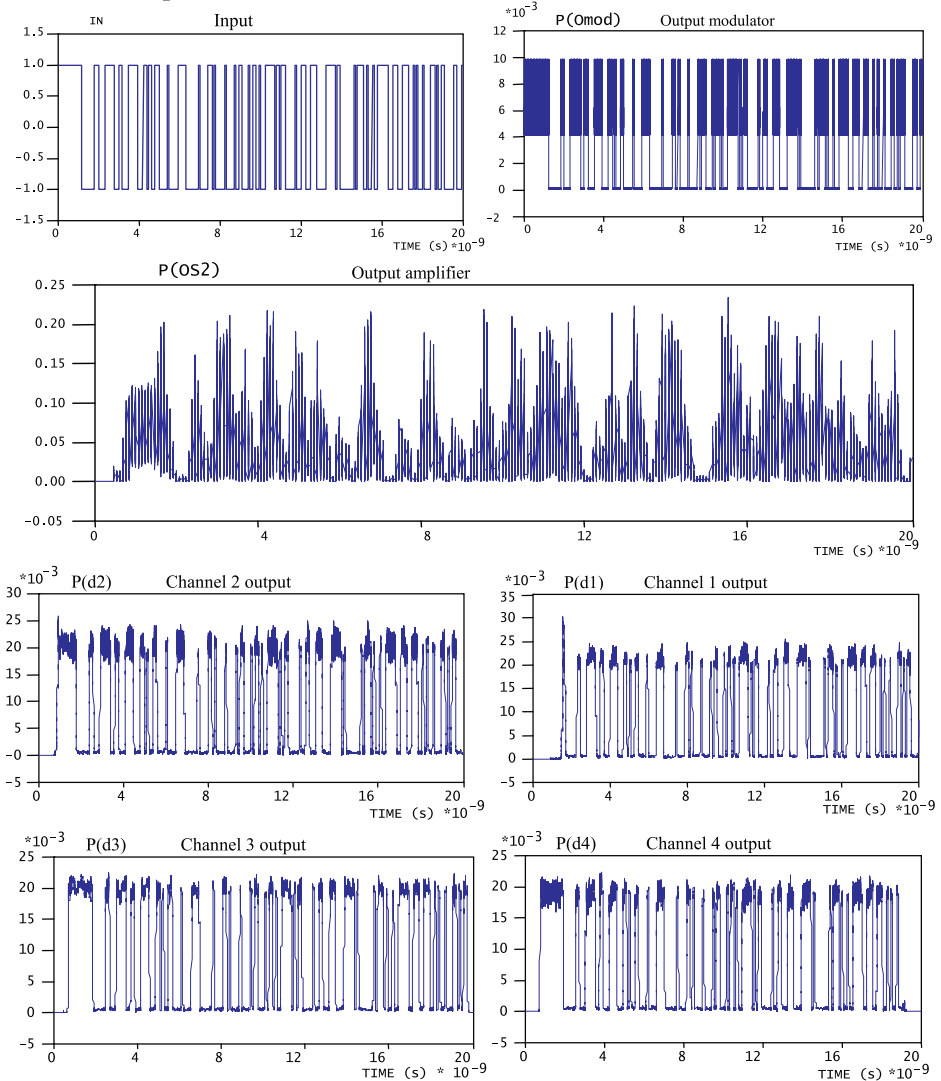


Fig. 4 – Viewing signals.

The Fig. 4 represents the signal at different levels of liaison; at the entrance, then exit modulator, followed by the amplifier and ultimately the signal output of the demultiplexer. Although the signal is reduced output demultiplexer, it has completed its function between the channels and reducing the contribution of noise amplifiers.

The eye diagrams obtained a receipt on 4 channels are represented in Fig. 5.

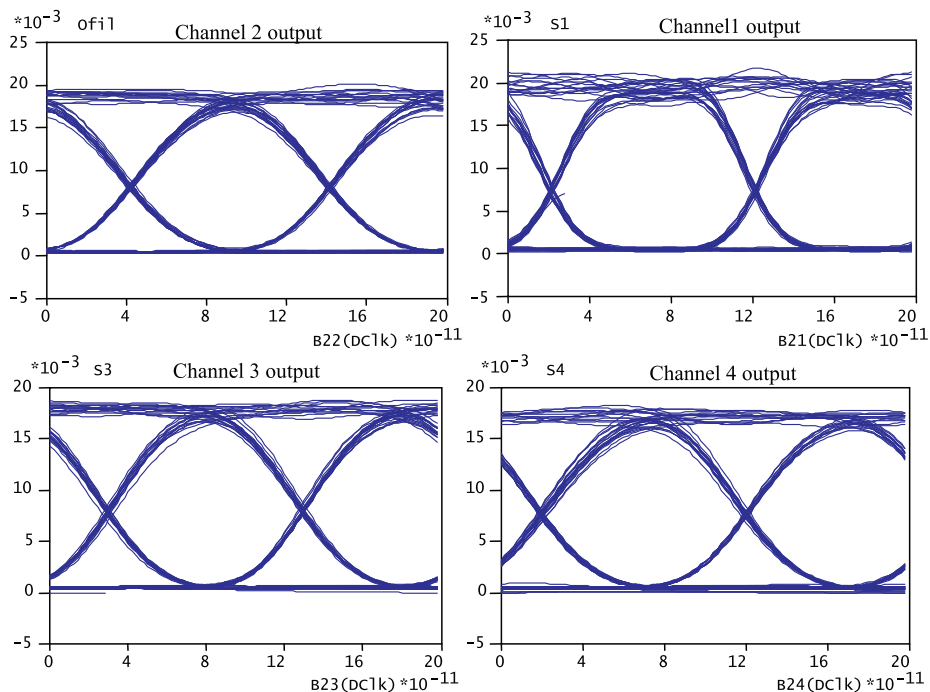


Fig. 5 – The eye diagram in reception channels.

The **Table 1** below summarizes the performance of each of 4 channels in terms of Q calculated from the diagram of the eye in reception. The diagrams of the eye are open which means there is no interference between symbols, therefore fiber compensation plays their role.

Table 1
Performances obtained after 2 spans.

| | |
|---------|-------------|
| Canal 1 | $Q = 14.50$ |
| Canal 2 | $Q = 18.06$ |
| Canal 3 | $Q = 18.00$ |
| Canal 4 | $Q = 16.40$ |

4 Conclusion

We have transmitted data at 40Gb/s capacity over tow spans of Single Mode Fiber, while having an improved tolerance to noise, owing to the demultiplexer based on Fiber Bragg Grating using filters to 40GHz bandwidth.

5 References

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