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Use of Fibers in Long Distance Telecommunication DWDM Systems

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Abstract—**This paper compares the performances of DWDM system with 04 channels and 10Gb/s per channel with a channel spacing of 50 GHz using a conventional single mode fibre (SMF) or non zero dispersion shifted fiber (NZDSF). NZDSF concern three types of fibers: TeraLight fiber, TrueWave fiber and Corning fiber. For this, a simulation of DWDM system is performed using OptSim software. Chromatic dispersion compensation and non linear phenomenon in the fiber (SPM, XPM Raman SRS) are also included in the simulation. The performances in terms of EYE DIAGRAM and BER are presented to illustrate the limitation transmission for each type of fiber.**

Index Terms— **Laser, DWDM, Chromatique Dispersion, Non Linear Effects, SPM, XPM, SMF and NZDSF**

I. INTRODUCTION

GROWING demand for higher speed internet services is the primary driver for network operators to upgrade to higher data rate in the metro and long haul systems. This increasing demand for capacity has led to propos dense wavelength division multiplexing (DWDM) [1] transmission systems and to choose which type of optical fibers could support very high bit-rates [2].

The WDM technique corresponds to the scheme in which the capacity of a light wave system is enhanced by employing multiple optical [6] carriers at different wavelengths. Each carrier is modulated independently using different electrical bit streams that are transmitted over the same fiber. The output of several transmitters is combined using a multiplexer. The multiplexed signal is launched into the fiber link for transmission to its destination where a demultiplexer separates individual channels and sends each channel to its own receiver. WDM has the potential for exploiting the large bandwidth offered by optical fiber [6].

II. NONLINEAR EFFECTS IN OPTICAL FIBERS

When optical signals propagate inside the optical fiber, both dispersive and non linear optical effects influence their shape and spectrum. Optical fiber nonlinearities can lead to interferences, distortion and excess attenuation of the optical fiber, resulting in performance degradation. The refractive index of any material can be described as [3]:

$$n = n_L + n_{NL} I \qquad \text{(I)}$$

where I is the optical intensity of the field, n_L and n_{NL} are the linear and nonlinear refractive indices respectively. The numerical value of n_{NL} varies from 2.2 ~3.4×10^{-20} m^2/W. The nonlinear coefficient of the fiber γ ($1/m^{-1}W^{-1}$) is defined by [4]:

$$\gamma = \frac{2\pi n_{NL}}{\lambda A_{eff}} \qquad \text{(II)}$$

where A_{eff} (m^2) is the effective area of the fiber and λ(m) is the wavelength.

The tendency of the optical fiber to distort an optical signal transmitted through it is known as chromatic dispersion.The chromatic dispersion parameter D is commonly described in terms of β_2 according to [4]:

$$D = \frac{-2\pi c}{\lambda^2}\beta_2 \qquad \text{(III)}$$

This equation is typically used as a measure of the chromatic dispersion D and is expressed in units of ps/km-nm. The parameter β_2, in units of ps^2/km, represents dispersion of the groupe velocity and its responsible for pulse broadening during propagation inside a fiber.

The major nonlinear phenomenon affecting the performance of an optical system is SPM (Self Phase Modulation) [5] and XPM [7] (Cross Phase modulation). SPM is a manifestation of the intensity dependence of the refractive index in non linear optical fiber, a phenomenon that leads to spectral broadening of optical pulse. XPM effect occurs only in multichannel (wavelength multiplexing) systems. Intensity variations in one pulse alter the phase of a signal in another channel via the non linear refractive index of the fiber. This leads to spectral broadening which may cause severe pulse distortion as in SPM.

III. COMMUNICATION SYSTEM

An optical communication system consists of transmitter, communication channel and receiver.

A. Transmitter

The role of optical transmitter is to convert the electrical signal into optical form. It consists of optical source, an electrical pulse generator and an optical modulator. Mach-Zender external modulator model was used in system design.

The structure is shown in Figure 1.

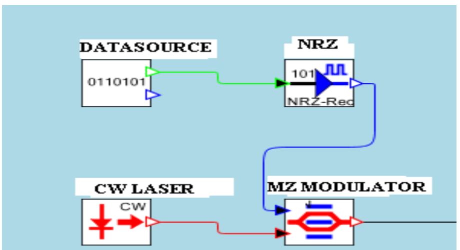


Figure 1: Structure of optical transmitter

B. Communication Channel

There are three major classifications of single –mode optical fiber in use in today's telecommunications networks. They are specified by the International Telecommunication Union (ITU) as G.652 conventional single mode fiber, G.653 dispersion- shifted fiber (DSF) and G.655 non –zero dispersion-shifted fiber NZ-DSF) [8].

The primary way to differentiate between fiber types is by their chromatic dispersion.

Other critical parameters of optical fiber that impact on network performance are attenuation, polarisation mode dispersion PMD and effective area A_{eff}. PMD occurs when the two orthogonal polarizations of an optical pulse travel with a different velocity. The A_{eff} of a fiber is loosely defined as the light- carrying region of the fiber. It is a critical characteristic for determining the amount of optical power that can be launched into a fiber before non-linear effects limit the transmission speed an the distance.

In optical fiber, after a long haul the signal intensity was greatly attenuated. The EDFA [9] was added to compensate for the linear loss. EDFA was also added to compensate linear loss after the DCF (dispersion compensating fiber). The linear chromatic dispersion restricts the transmission of high speed signal on the 1550nm optical fiber. Therefore the DCF was used for compensating their dispersion performance to according [4]:

$$L_1D_1+ L_2D_2=0 \qquad \text{(IV)}$$

Where L_1 (km) is the fiber length, L_2 (km) the fiber compensating length, D_1 and D_2 (ps/km.nm) are respectively the dispersion parameters of the used fiber and the DCF fiber.

From above, in the design of communication channel, the parameters of SMF, Teralight, TrueWave, CorningLeaf and DCF will be corresponding in Table I.

TABLE I: PARAMETERS OF FIBERS

	SMF	Tera light	True Wave	Corning Leaf	DCF
Attenuation (dB/km)	0.2	0.25	0.22	0.2	0.5
Dispersion (ps/nm.km)	16	08	04	O4	-80
Non linearity coefficient ($w^{-1}km^{-1}$)	1.32	1.67	2.02	1.46	4.6

C. Receiver

The role of optical receiver is to convert the optical signal into electrical form. It is composed of the photoelectric detector preamplifier and filters.

The structure is shown in Figure 2.

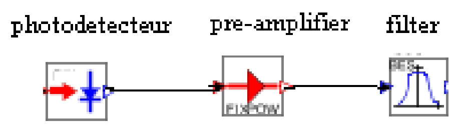


Figure 2: Structure of optical receiver

D. Experiment Description

A point to point link is performed in this simulation as shown in Figure 3.

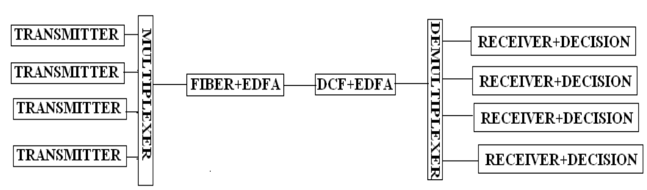


Figure 3: Block diagram of the simulated system

In transmitter (O4) four optical wavelengths are generated with the channel spacing of 50 GHz, which are externally modulated using NRZ format. These four modulated signals are multiplexed and sent to the transmission fiber , amplified by a 15 dB erbium doped fiber amplifier (EDFA) and compensated by a DCF(Dispersion compensated Fiber).

In the receiver, the signal is démultipléxed before electrical conversion and processing.

The launched power into the fiber is -3.46 dBm for each channel. The noise figure for the EDFA is 4dB. PMD and the non-linear phenomena SPM and XPM and Raman effects are taken into in account.

Figure 4 and Figure 5 show the time domain and the frequency domain.

The used wavelengths are 1551.92, 1552.32, 1552.73, and 1553.13(nm).

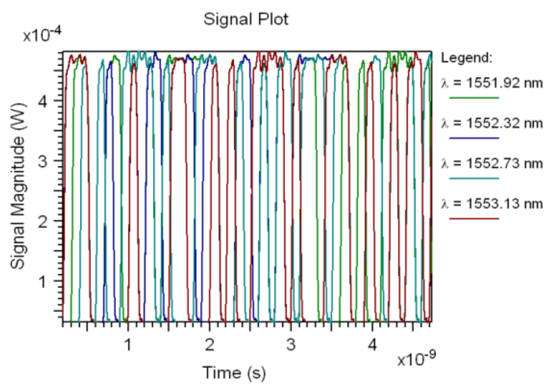


Figure 4: Optical time domain

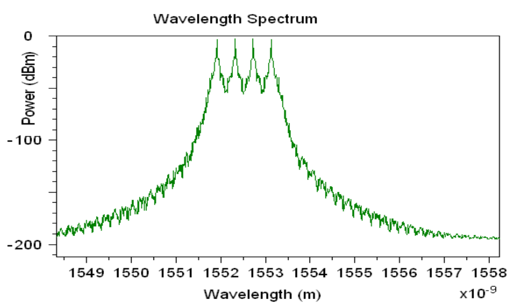


Figure 5: Optical frequency Domain

IV. RESULTS

We present above in different tables all simulation results obtained with SMf, Tera Light, True Wave and Corning Leaf fiber. These simulations are performed without both SPM and XPM and with both SPM and XPM. The parameter of interest is the maximale distance reached corresponding to critical BER (Bit Error Time) of 10^{-9}.

The figure also shows eye diagram with different distances for each type of fiber.

A. SMF Fiber

TABLE II: THE SPM AND XPM INFLUENCE ON THE MAXIMALE DISTANCE

	Without SPM and XPM	With SPM and XPM
BER	10^{-9}	10^{-9}
Maximale Distance(km)	780	480

Distance (km)	120	240	480
BER	10^{-28}	10^{-19}	10^{-9}

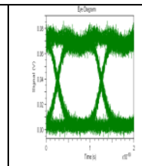
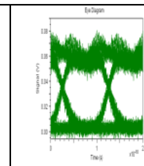
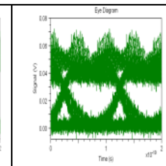
EYE DIAGRAM			

Figure 6: The eye diagram for different distances with non linear effects

B. Tera Light Fiber

TABLE III: THE SPM AND XPM INFLUENCE ON THE MAXIMALE DISTANCE

	Without SPM and XPM	With SPM and XPM
BER	10^{-9}	10^{-9}
Maximale Distance(km)	720	600

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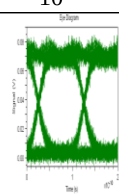
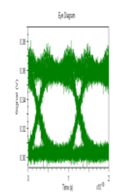
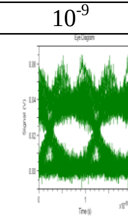
Distance (km)	110	220	600
BER	10^{-31}	10^{-21}	10^{-9}
Eye Diagram			

Figure 7: The eye diagram for different distances with non linear effects

C. True Wave fiber

TABLE IV: THE SPM AND XPM INFLUENCE ON THE MAXIMALE DISTANCE

	Without SPM and XPM	With SPM and XPM
BER	10^{-9}	10^{-9}
Maximale Distance(km)	780	720

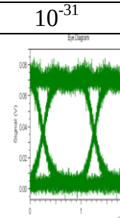
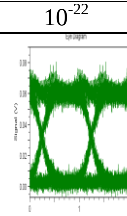
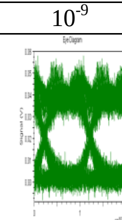
Distance (km)	130	260	700
BER	10^{-31}	10^{-22}	10^{-9}
Eye Diagram			

Figure 8: The eye diagram for different distances with non linear effect

D. Corning Leaf fiber

TABLE V: THE SPM AND XPM INFLUENCE ON THE MAXIMALE DISTANCE

	Without SPM and XPM	With SPM and XPM
BER	10^{-9}	10^{-9}
Maximale Distance(km)	2000	1000

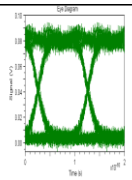
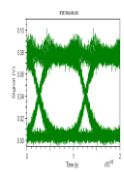
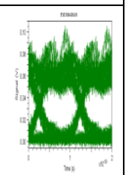
Distance (km)	140	280	1000
BER	10^{-39}	10^{-33}	10^{-9}
Eye Diagram			

Figure 9: The eye diagram for different distances with non linear effects

V. CONCLUSION

As seen in the tables, the transmission distances are reduced for all types of fibers when using SPM and XPM. In this simulation, the best result taken into account linear phenomena are obtained with CorningLeaf fiber. We can consider that the CorningLeaf fiber is very suitable for long haul distances. In this case the distance of 1000KM is reached and the corresponding BER is 10^{-9} bit/s.We also obtained good results with TeraLight and TrueWave fiber. The distance of 600km and 700km are respectively reached without distortions and the corresponding BER is 10^{-9} bit/s for each one. These fibers can be used in metropolitan optical systems. For SMF, high dispersion combined with non linear effects limit the extension of a linkup to 480km and the corresponding BER is 10^{-9} Bit/s. At 10 Gbit/s in DWDM [10] system with NRZ format SMF fiber still in use today but to intensively increase the capacity, 40Gbit/s DWDM systems with a channel spacing of 50 Ghz using advanced modulation formats and Corning Leaf fiber must be investigated.

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