# *High bit rate optical communications: Limitations and perspectives*

by S.Guizani[1], Habib Hamam[2], Y. Bouslimani[2] and A. Cheriti[1]
[1]Université du Québec à Trois Rivières, QC
[2]Université de Moncton, Fredricton, NB

### Abstract

Motivated by the world's growing need for communication bandwidth, progress is constantly being reported in building newer optical fibers that are capable of handling the rapid increase in traffic. However, building an optical fiber link is a major investment, one that is very expensive to replace. For example, the optical fiber cables that were installed during the early 80's consist of millions of kilometers of "standard" single-mode fiber (SSMF) around the globe. Since old optical fibers cannot be easily replaced with newer ones, innovative methods of exploiting the available bandwidth are crucial. Even today, standard single-mode fibers are substantially cheaper than the more advanced ones. The present document illustrates the constraint of the need to increase the fiber based transmission bit rate without being obliged to undertake significant infrastructural changes.

### Sommaire

Motivé par le besoin mondial croissant en termes de bande passante de communication, un progrès continu est rapporté dans le domaine de la mise en œuvre de nouvelles fibres optiques permettant de faire face à l'augmentation rapide du trafic. Cependant, établir un réseau de fibres optiques est un investissement important. Par conséquent, il n'est rentable de remplacer ce réseau. Par exemple, les câbles à fibres optiques qui ont été installés pendant au début les années 80s comportent des millions de kilomètres de fibres standard monomodes (SSMF) autour du globe. Du fait que les vieilles fibres optiques ne sont pas rentablement remplaçables par des nouvelles, des méthodes innovatrices d'exploiter la bande passante existante sont primordiales. Jusqu'à présent, la fibre monomode standard est significativement moins chère que les nouveaux produits. Le présent document illustre la contrainte de la nécessité d'augmenter le débit binaire fourni par la fibre sans être obligé d'entreprendre des changements d'infrastructure importants.

## 1.0 Background

The goal of an optical fiber communication system is to transmit the maximum number of bits per second over the maximum possible distance with the fewest errors. A typical digital fiber optic link is depicted in Figure 1.

Electrical data signals are converted to optical signals via a modulator. A "1" is transmitted as a pulse of light while a "0" has no light output. This modulation is referred to as the "ON-OFF keying" and has three formats as shown in Figure 2.

The NRZ format is the most commonly used since it requires less bandwidth. It is worth noting that the RZ format has the advantage to allow easier implementation of time recovery in case of long sequences of "1's".

The number of "1's" and "0's" transmitted per second determines the speed of the link (bit rate). Glass optical fibers have a wide transmission window over which a number of optical signal channels may be transmitted simultaneously by wavelength division multiplexing (WDM).

The power of all the channels combined is boosted by an optical amplifier before being launched into an optical fiber. The launched power generally compensates for the fiber transmission loss of a given fiber stage (span). After each span, the signals are amplified by an optical line amplifier (e.g., Erbium doped fiber amplifier), or by a repeater. Since the transmission fiber is a dispersive medium, implying that pulses spread as they travel through the fiber, some form of dispersion compensation is applied at each repeater stage. At the receiving end of the link, the WDM optical signal is de-multiplexed. Each channel is optically pre-amplified and then detected by an optical-to-electrical (O/E) converter (e.g., a photodiode). A decision circuit identifies the "1's" and "0's" in the signal. An optical filter can be inserted before the O/E converter to filter out amplifier noise.

## 2.0 Limitation factors

The need for high-speed data transmission has enhanced the use of optical communication systems, which have experienced a rapid evolution during the last decade. New system concepts including dense wavelength division multiplexing (DWDM) and optical time division multiplexing (OTDM) have multiplied the transmission capacity of an optical fiber. Especially WDM provides a straightforward way to upgrade the capacity of the existing fiber lines. Even though the above advancement, there is a major impairment that restricts the achievement

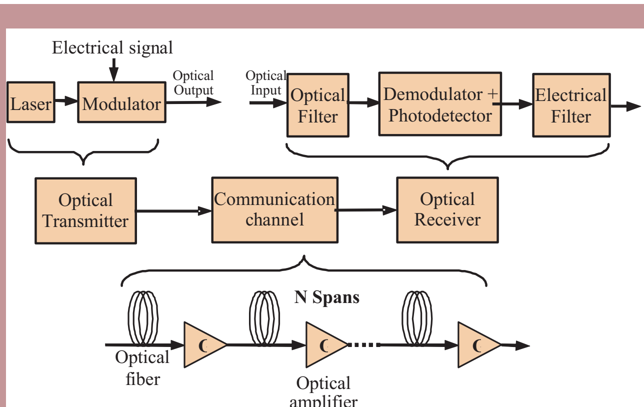



**Figure 1: A typical digital fiber optic link**

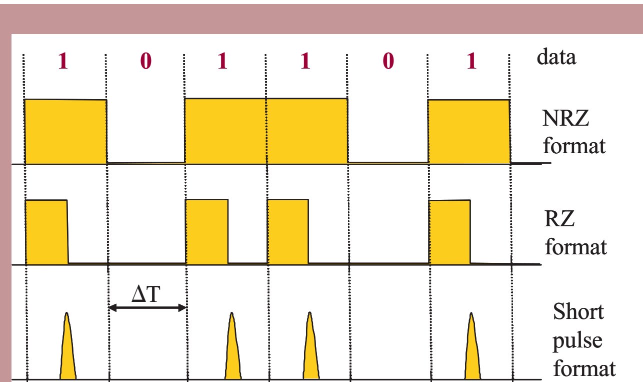



**Figure 2: RZ, NRZ and pulse format, T: bit interval**

of higher bit rates with standard single mode fiber is chromatic dispersion. This is particularly problematic for systems operating in the 1550 nm band, where the chromatic dispersion limit decreases rapidly in inverse proportion to the square of the bit rate. Chromatic dispersion (CD) and polarization-mode dispersion (PMD) can cause the creation of Inter-Symbol Interference (ISI) which is a major obstacle to reliable high speed data transmission over optical fibers. As both CD and PMD originate in the optical domain, the most effective compensation schemes use optical equalization. Nonetheless, electrical equalization schemes are also being widely considered because they offer several potential advantages, including compactness, flexibility and low cost.

Moreover, non-linear effects arise when the pulse is shorter such as the case of moving from 10 to 40Gbit/s. Thus, we face a major limitation factors for high bit rate transmission: dispersion and the presence of nonlinear effects. It is very desirable to make both factors cancel one another. In this spirit, some researches lead to what is referred to as the “solitons”. Initially, these special forms of optical signals are designed to balance the chromatic dispersion and the Kerr nonlinearity of the fiber.

## 3.0 Fiber Impairment

### 3.1 Attenuation

Attenuation in fiber occurs due to absorption, scattering and radiative losses of the optical energy. Absorption losses are caused by atomic defects in the glass composition, intrinsic absorption by atomic resonance of fiber material and extrinsic absorption by the atomic resonance of external particles (like OH ion) in the fiber. Scattering losses in fiber arise from microscopic variations in the material density and from structural inhomogeneities. There are four kinds of scattering losses in optical fibers namely Rayleigh, Mie, Brillouin and Raman scattering. Radiative losses occur in an optical fiber at bends and curves because of evanescent modes generated.

### 3.2 Signal distortion

#### 3.2.1 GVD / PMD

Dispersion has two major forms: chromatic and polarization mode (Figure 3). The former (Figure 3b) is the phenomenon by which different frequencies travel through a fiber with different group velocities, while the latter (Figure 3a) represents a velocity difference between the two orthogonal electric field components inside the fiber. Unlike Polarization Mode Dispersion (PMD), chromatic dispersion or Group Velocity Dispersion (GVD) increases linearly with the fiber length. The GVD is governed by material properties (the dependence of the fiber material refractive index on the light frequency) and waveguide dispersion (wherein Maxwell’s equations yield different $\beta$’s for different frequencies depending upon the fiber dimensions). It is quantified by a Dispersion Parameter, $D(\lambda)$, which measures the time delay introduced between light at different wavelengths while propagating through a fiber with a length $L$ ($\tau_{delay} = D(\lambda)\, \Delta\lambda L$, where $D$ =17 ps/nm-km in the 1550 nm communication window). PMD on the other hand is caused by the removal of circular symmetry in a fiber due to external factors like temperature, mechanical stress etc. It is a random process and hence the group delay it produces ($\tau_{PMD}$) is proportional to the square root of the propagation distance. The fraction of the total power contained in one of the polarizations ($\gamma$) basically governs how bad the PMD is. The overall effect of both GVD (Figure 4) and PMD is the broadening of pulses propagating through the fiber and this result in Inter-Symbol Interference (ISI) [1] as pointed out in Figure 4. Indeed, what we presented in Figure 3, is not the actual signal. In reality it deals with the envelope of the transmitted pulses. However, the actual signal looks like what we point out in Figure 4. ISI leads to closing of the eye at the output that in turn causes higher bit error rates and increases input power requirements.

#### 3.2.2 Non linear optical effects

The refractive index of silica has a weak dependence on the optical intensity $I$ (optical power per effective area in the fiber) and is given by: $n = n_0 + n_2 I = n_0 + n_2 P/A_{eff}$ where $n_0$ is the normal refractive index of the fiber material, n2 is the nonlinear index coefficient, P is the optical power and $A_{eff}$ is the effective cross-sectional area of the fiber. In silica, the value of $n_2$ ranges from 2.2 to 3.4 x$10^{-8}$ $\mu m^2/W$. This nonlinearity in the refractive index is known as Kerr nonlinearity, and results in a carrier-induced phase modulation of the propagating signal, called the Kerr effect. It can cause self-phase modulation (SPM), cross-phase modulation (XPM) and four-wave mixing (FWM).

*3.2.2.1 Self-Phase Modulation (SPM):* Because the local refractive index is a function of the optical intensity of the propagating signal, the mode propagation constant becomes dependent on the optical intensity also. The power dependent propagation constant, $\beta$, can be written as $\beta = \beta + \gamma P$, where $\beta$ is the mode propagation constant which is derived by assuming a constant refractive constant. The nonlinear coefficient $\gamma$ is defined by $2\pi n_2/(A_{eff}\lambda)$. Since this nonlinear phase modulation is self induced, the nonlinear phenomenon responsible for it is called SPM. As phase fluctuations translate into frequency fluctuations, SPM causes frequency chirping of the optical pulses, which presents a source of error.

*3.2.2.2 Cross-Phase Modulation (XPM):* In WDM systems, where several optical channels are transmitted simultaneously inside an optical fiber, the nonlinear phase shift for a specific channel depends not only on the power of that channel but also on the power of the other channels. Moreover, the phase shift varies from bit to bit, depending on the bit pattern of the neighboring channels. This nonlinear phenomenon is known as XPM. Like SPM, XPM may lead to erroneous reception of the transmitted bits sequence.

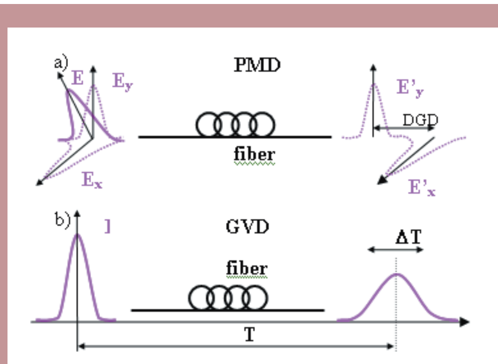
*3.2.2.3 Four-Wave Mixing (FWM):* FWM is a third order nonlinearity in silica fibers, caused by the third order nonlinear susceptibility of silica. FWM resembles inter modulation distortion in electrical systems. If three optical fields with carrier frequencies $f_1$, $f_2$, and $f_3$ are propagating simultaneously in a fiber, the fiber nonlinearity causes them to mix, producing a fourth inter modulation term that is related to the other frequencies by the relation $f_4 = f_1 \pm f_2 \pm f_3$. FWM is an additional source of ISI.

## 4.0 Electronic Dispersion Compensation

### 4.1 Pre-compensation

Pre-compensation schemes are based on the idea of modifying the characteristics of the input pulses at the transmitter before being launched

**Figure 3: a) PMD: Polarisation mode Dispersion, DGD: Differential Group Delay, E: input field, E’: output field, Ex: x-component of the field, b) GVD: Group Velocity Dispersion.**



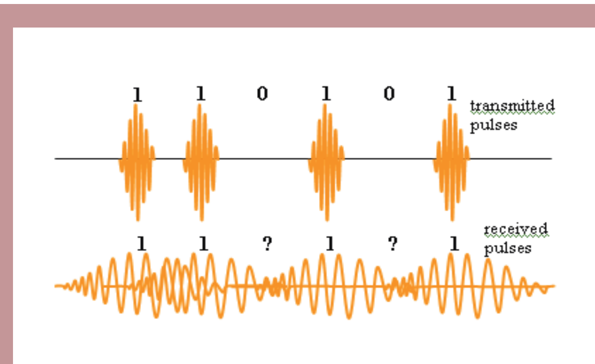




**Figure 4: The overall effect of both GVD and PMD.**

into the optical fiber so that the dispersion negates the applied pre-compensation and an undistorted signal results at the receiver.

### 4.1.1 Alternative coding techniques

Instead of using the conventional On-Off Keying (OOK) to modulate the light signal, several other modulation schemes have been developed that offer a substantial increase in the transmission distance. In one approach, referred to as dispersion-supported transmission, the frequency shift keying (FSK) format is used for modulating the light signal [2]. The FSK signal is generated by switching the laser wavelength by a constant amount $\Delta\gamma$ between '1' and '0' bits without changing the amplitude of the modulated signal. Due to chromatic dispersion, the two wavelengths travel at different speeds inside the fiber. As a result, the chromatic dispersion converts the FM signal into a three-level signal that can be decoded in the receiver. The wavelength shift is chosen so that the time delay, $\Delta t$, between the '1' and '0' bits is equal to one-bit duration.

Another approach for increasing the reach of the system depends on utilizing modulation formats that further reduce the bandwidth of the optical signal, as compared to the standard OOK technique. One such approach makes use of duobinary coding, which reduces the signal bandwidth by approximately 50%. In their simplest form, duobinary signals are created by low pass filtering of the electrical signal to reduce its bandwidth, while generating controlled inter symbol interference. Since the detrimental effect of the chromatic dispersion depends on the signal bandwidth, the system reach can be improved substantially [3-7]. Experimental results have shown that 10 Gb/s duobinary-coded systems, operating in the 1550 nm band can have a reach in excess of 200 km, as compared to the 80 km limit of conventional OOK systems [3]. Combining duobinary coding with prechirping increases the system reach even further. In [4], a distance of 277 km has been achieved using that technique. An additional advantage of duobinary coding is its reduced sensitivity to higher order PMD which is a direct result of their reduced bandwidth.

### 4.1.2 Prechirping Techniques

Prechirping is the process of appropriately phase modulating the light carrier in order to compensate for the pulse width broadening that would otherwise result from the chromatic dispersion of the optical fiber. In the 1550 nm band, conventional optical fibers suffer from anomalous dispersion; that is, longer wavelengths have a lower group velocity than shorter wavelengths. In this case, the spreading of the bit into adjacent slots can be delayed by making the light in the leading edge of the pulse of longer-than-average wavelength and that in the trailing edge of the bit to be of shorter-than-average wavelength (Figure 5). As a result, the pulse initially becomes narrower as it travels along the fiber, which means that the allowable transmission length for a system with prechirp is greater than that of a system with an ideal external modulator. However, further transmission causes the pulses to broaden again and intersymbol interference results.

Several techniques have been proposed to prechirp the transmitted signal. One simple way is to add phase modulation by the use of an unbalanced Mach-Zehnder amplitude modulator. However, this technique achieves only modest gains [8]. Another method is to frequency modulate the laser to provide chirp in the optical signal that is entering an external modulator [9]. With this technique, the experiments in [10] demonstrated a penalty-free 10 Gb/s NRZ transmission over 100 km of SSMF at 1550 nm.

## 4.2 Post-compensation Techniques

### 4.2.1 Error Correction

For high-speed optical fiber communication, the data transmission reliability can be degraded by some or all of the system impairments, mentioned earlier, resulting in a quality of service that is lower than that demanded by the system specifications. In this case, the transport protocol of the network can be manipulated to compensate for the loss in performance. The two common schemes for improving the reliability of the system are automatic repeat request (ARQ) and forward error correction (FEC). The ARQ scheme is based on using a feedback channel between the receiver and the transmitter to request a message retransmission in case errors are detected. Since each retransmission adds at least one round trip time of delay, ARQ may not be adequate for applications that require low latency. FEC avoids the shortcomings of ARQ which makes it more suitable for high-speed optical networks that require short delays.

For FEC techniques, redundant information is transmitted along with the original data. The redundant information is used to check the integrity of the transmitted data and correct the received errors. Typically, the overhead that is added to the transmitted data is kept small, so that the FEC scheme does not require much additional bandwidth, and thus, remains efficient.

Although FEC does not compensate for ISI by itself, it can be used to complement other dispersion compensation techniques. In [5], polarization scrambling was combined with FEC and electronic equalization in the receiver so as to mitigate the PMD. The idea is to accelerate the PMD dynamics by polarization scrambling so that the bad PMD constellations can affect only a limited number of bits per FEC frame. Then, these few errors can be corrected by the FEC scheme.

### 4.2.2 Electrical Equalization

Although the term equalization derives from linear filter theory, it now applies to any scheme aimed at compensating for the effects of a dispersive channel. Equalizers are classified into three general types [14]. One is based on the maximum-likelihood sequence estimation (MLSE) criterion which provides the best performance. The second type is based on the use of linear filters with adjustable coefficients. The third type uses the previously detected symbols to subtract the ISI in the present symbol being detected; thus, the name decision-feedback equalizer (DFE).

*4.2.2.1 Maximum Likelihood Sequence Estimation (MLSE)*

MLSE is the optimum detection technique. It is based on the correlation of a complete distorted signal sequence with estimates of all the possible sequences over many time slots. The selection of the sequence with the maximum correlation, usually done with the Viterbi algorithm, determines the decision for the actual bit. The Viterbi algorithm has the disadvantage of imposing a heavy computational burden. Indeed, the MLSE has a computational complexity that grows exponentially with the length of the channel time dispersion. If the size of the symbol alphabet is M and the channel dispersion spans L symbols, the Viterbi algorithm computes ML+1 for each newly received symbol. However, for many channels of practical interest, this kind of computational complexity is prohibitively expensive to implement. Instead, one can resort to much simpler, although suboptimum, equalizers such as linear transversal equalizers and decision-feedback equalizers.

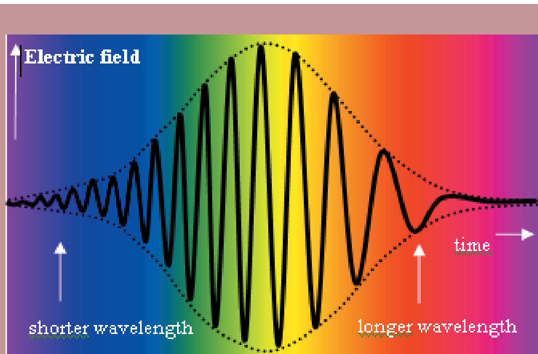



**Figure 5: A negatively chirped Gaussian pulse: The instantaneous frequency decreases with time.**

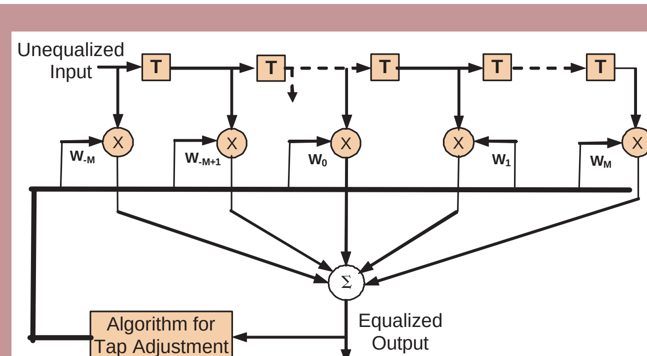



**Figure 6: Linear Transversal Equalizer**

*4.2.2.2 Linear Equalization*

The most widely used linear filter for equalization is the transversal (tapped delay line), depicted in Figure 6. Usually, the input signal is assumed to be sampled at T-intervals, where T is the symbol period. Thus, the commonly used name, T-spaced transversal equalizer.

The peak distortion criterion based method and the more recent one based on the mean square error (MSE) criterion are the two popular methods using linear equalization. In the peak distortion criterion, the transversal filter frequency response is adjusted to approximate the inverse of the channel frequency response. The resulting filter is commonly referred to as the zero-forcing equalizer. However, this filter has a serious drawback. If the channel contains a spectral null in its frequency response, the linear zero forcing equalizer attempts to compensate for this by introducing an infinite gain at that frequency. This compensates for the channel distortion at the expense of enhancing the additive noise and poor performance results.

For the MSE criterion based method, the taps of the equalizer are adjusted to minimize the mean square value of the error signal which is the difference between the correct symbol and the output of the equalizer. The main difference between the MSE criterion and the peak distortion criterion is that the noise at the input of the equalizer is also considered to avoid any excessive noise enhancement. As a consequence, the MSE criterion attempts to achieve a compromise between the cancellation of the ISI and noise enhancement.

*4.2.2.3 Decision-Feedback Equalization*

Unfortunately, linear equalizers in not very efficient for channels suffering from serious ISI. The decision-feedback equalizer (DFE), which is the most popular nonlinear equalizer for severe fading channels, requires a lower computational effort. As depicted in Figure 7, it consists of two filters, a feedforward (FF) filter, and a feedback (FB) filter. The FF filter is identical to the linear transversal equalizer; usually, a FSE is used. The FB filter has, as its input, the sequence of decisions on previously detected symbols. Functionally, the FB filter is used to remove that part of the ISI from the present estimate caused by previously detected symbols. Typically, the MSE criterion is used for the optimization of the equalizer coefficients. The performance characteristics of the DFE are summarized as follows [6]:

- The feedback section does not exhibit any noise enhancement, since it operates on noise-free decisions.
- The combined impulse response of the channel and the FF section can have nonzero samples following the main pulse; that is, the FF equalizer does not need to approximate the inverse of the channel characteristics, and so avoids excessive noise enhancement and sensitivity to the sampler phase.
- Since the feedback section operates on symbol decisions, the feedback section taps are baud-spaced.
- The required number of feedback taps equals the channel's maximum delay spread. However, when an incorrect decision is fed back, the DFE output reflects this error for the next few symbols, because the incorrect decision traverses the feedback delay line. As a result, there is a greater likelihood of more incorrect decisions following the first one, i.e., error propagation. Fortunately, the error propagation in a DFE is usually not catastrophic. Under typical channel conditions, errors occur in short bursts that degrade the performance only slightly.

## 5.0 Solitonic transmission

The techniques covered above are limited to the compensation of dispersion. Given that dispersion is not the only source of ISI, nonlinearity should be taken into account in high bit rate communications. Instead of handling nonlinearity alone as the case of predispersation, it is more convenient to eliminate or at least to reduce both effects at once. The idea consists of mutually balancing the effects of dispersion and nonlinearity [7].

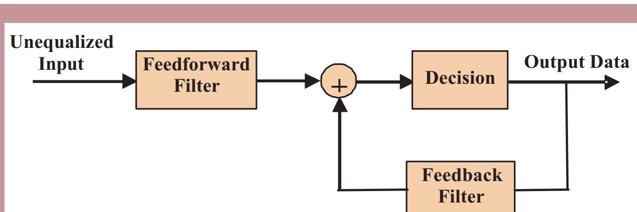



**Figure 7: DFE structure**

Solitons are understood as arising from a balancing of the chromatic dispersion and the Kerr nonlinearity of the fiber [7]. While solitonic transmission presents a very attractive technique for providing high-speed long-distance communication, there are some serious difficulties to overcome before reaching the commercialization stage of amplified solitonic systems. The Gordon-Hauss effect is one of these problems. It is induced by the mixing of the signal and the Amplified Spontaneous Emission (ASE) noise generated by the Erbium-Doped Fiber Amplifiers (EDFAs). We recall that this amplifier is used to balance the attenuation inherent to solitonic communication systems. During propagation, signal mixing and ASE noise distort the soliton shape and lead to timing jitter. As a consequence, the Bit Error Rate or Ratio (BER) is increased. The BER is defined as the ratio of the number of erroneous bits received to the total number of bits transmitted.

## 6.0 Discussion

Although equalization is very well known in lower rate communication systems, its potential in Gb/s optical communication has not been fully exploited yet. The main obstacle lies in the very high speed implementation requirements which limit the available options for implementation. The effectiveness of linear equalizers, which are the simplest and most amenable to high speed implementation, is limited by the fact that direct detection receivers convert the distortion that results from chromatic dispersion, which is linear in the optical domain, into a nonlinear distortion that is difficult to cancel. Although nonlinear techniques such as decision feedback equalizers and maximum likelihood sequence estimation can substantially improve the dispersion-limited reach, their implementation remains the main challenge at high data rates.

Duobinary modulation, principally driven by its advantage of the reduced bandwidth, compared to conventional NRZ OOK modulation, and the ability to use a conventional direct detection receiver. In principle, electrical pre-equalization can also be applied to other modulation formats for potential improvements, albeit at the cost of more complex transmitters and receivers.

All these techniques do not handle nonlinear effects, which are serious sources of errors in the framework of high bit rate communications. Besides, solitonic transmission is a totally different compensation technique, that is in theory largely more powerful than the previously mentioned techniques. The power of the latter lies in its ability of making two sources of signal distortion, namely dispersion and nonlinear effects to cancel each other. The major drawback of this technique is the technological difficulty of implementing soliton like pulses. As technologies progress, it would be possible to implement the solitonic transmission compensation with ease, leading to a blooming of high bit rate communications.

## 7.0 References


[1]. J H Winters, R D Gitlin, "Electrical Signal Processing Techniques in Long-Haul Fiber-Optic Systems", IEEE Transactions on Communications, Vol 38, No. 9, pp 1439-1453. 1990

[2]. K. Morito, R. Sahara, K. Sato, and Y. Kotaki, "Penalty-free 10 Gb/s NRZ transmission over 100 km of standard fiber at 1.55 □m with a blue-chirp modulator integrated DFB laser," IEEE Photon. Technol. Lett., vol. 8, no. 3, pp. 431-433, Mar. 1996.

[3]. W. Kaiser, G. Mohs, T.Wuth, R. Neuhauser, W. Rosenkranz, and C. Glingener, "225 km repeaterless 10 Gb/s transmission over uncompensated SSMF using duobinary modulation and Raman amplification," in Proc. 14th Annual Meeting of the IEEE Lasers and Electro-Optics Society (LEOS'01), vol. 1, 2001, pp. 155-156.

[4]. M. Wichers, W. Kaiser, T. Wuth, and W. Rosenkranz, "10 Gb/s chirped duobinary transmission (CDBT) over 277 km of uncompensated standard single mode fibre," in Proc. 4th International Conference on Transparent Optical Networks (ICTON'02), vol. 1, 2002, pp. 34-37.

[5]. B. Wedding and C. N. Haslach, "Enhanced PMD mitigation by polarization scrambling and forward error correction," in Proc. Optical Fiber Communication Conference and Exhibit (OFC'01), 2001, pp. WAA1-1 - WAA1-3.

[6]. John Proakis, "Digital Communications", McGraw Hill, 1995.

[7]. G.P Agrawal, "Nonlinear Fiber Optics", 3rd ed., Academic Press, San Diego, Ca, 2001

[8]. A. H. Gnauck, S. K. Korotky, J. J. Veselka, J. Nagel, C. T. Kemmerer, W. J. Minford, and D. T. Moser, "Dispersion penalty reduction using an optical modulator with adjustable chirp," IEEE Photon. Technol. Lett., vol. 3, no. 10, pp. 916-918, Oct. 1991.

[9]. N. Henmi, T. Saito, and T. Ishida, "Prechirp technique as a linear dispersion compensation for ultrahigh-speed long-span intensity modulation directed detection optical communication systems," J. Lightwave Technol., vol. 12, no. 10, pp. 1706-1719, Oct. 1994.

[10]. K. Morito, R. Sahara, K. Sato, and Y. Kotaki, "Penalty-free 10 Gb/s NRZ transmission over 100 km of standard fiber at 1.55 m with a blue-chirp modulator integrated DFB laser," IEEE Photon. Technol. Lett., vol. 8, no. 3, pp. 431-433, Mar. 1996.

## *About the authors*

**Sghaier Guizani** Obtained B. Eng and M.Sc in Electrical Engineering from SUNY at Binghamton, NY in 1990 and North Carolina State University in 1992 respectively. Worked with Alcatel Data Network from 1993 to 1998 in Software Development. Joined Nortel Networks, Ottawa, Canada in 1999 to 2002 where he joined the ASIC Group. Working toward his PhD in the Fiber Optic Dispersion Compensation technique in Trois Rivières, QC, Canada.

**Habib Hamam** obtained the B.Eng. and M.Sc. degrees in information processing from the Technical University of Munich, Germany 1988 and 1992, and the Ph.D degree in telecommunications from Université de Rennes I jointly with the France Telecom Graduate School of Brittany, France 1995. He also obtained in 2004 a postdoctoral diploma in "Habilitation of Conducting Research in Signal Processing and Telecommunications" from Université de Rennes I. He is currently an associate Professor in the Department of Electrical Engineering at the Université de Moncton. He is a registered professional engineer in New-Brunswick. He is an associate editor of the IEEE Canadian Review. His research interests are in optical telecommunications, diffraction, fiber components, optics of the eye, biomedical engineering and E-Learning.

**Yassine Bouslimani** received an Engineering degree specialized in Electronics from Batna University (Algeria) in 1994, a D.E.A. degree in Instrumentation and Control from the INSA (Institut National des Sciences Appliquées) of Rouen (France) in 1995 and a Ph.D. degree in Optoelectronics from Rouen University (France) in 1999. Since July 2000, he is a Professor of Electrical Engineering at the Faculty of Engineering of Moncton University (Canada). Between 1998 and 2000, he was at the Department of electrical and computer engineering (IUT- GEII) of Rouen University in France as an ATER (Research and teaching Attached). He is a member of IEEE and OSA. He is a registered professional engineer in the province of New Brunswick).

**Ahmed Cheriti** received the B.S.degree in electrical engineering and the M.S. degree in power electronics from the Université Du Québec, Trois-Rivières, Québec, Canada, and the Ph.D. degree in electrical engineering from école Polytechnique, Montréal, Canada, in 1985, 1987 and 1993, respectively. Since 1992, he has been working as a professor in power electronics at the University of Quebec at Trois-Rivières. His research fields include ac drives, dc to dc converters and soft commutated inverters. Dr. Cheriti is a Registered Professional Engineer in the Province of Québec.

## *Highlights from IEEE Canada Region 7 Spring Meeting in Saskatoon, May 2005*

Various **IEEE Canadian Foundation Awards** were presented to Section Chairs to take back to their members.

(left to right): Maike Miller (Ottawa), Lawrence Whitby (S. Alberta), Andrew Kostiuk (N. Saskatchewan), Bill Kennedy (President IEEE Canada) Bob Alden (President IEEE Canadian Foundation), Jim Dunfield (Kingston), Keith Brown (Northern Canada Section), Kostas Plataniotis(Toronto) and Ani Gole (Winnipeg).

President Bill Kennedy acknowledges work done by members of the **IEEE Canada Audit Committee.**

(left to right): Bill Kennedy, Danny Wong, Gerard Dunphy, Kash Husain and Vijay Bhargava.