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Comparative performance study in multiplexed RZDPSK for SMF's with FBG

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Abstract

The Fiber Bragg gratings have emerged as important components in several of light wave applications in the FBG becoming a ubiquitous and necessary element in equipment located throughout the network from the central office to the home. This paper explores comparative performance study with and without using FBG as an external dispersion compensator for sixteen channel return to zero differential phase shift keying modulation operating at 45Gbps per channel with channel spacing of 0.15nm. Simulations are done with various single mode fibers with and without external FBG.Better performance (Q, BER) for dispersion values used in simulation are -58ps/nm, 23ps/nm, and 100ps/nm for FBG's used at receiver channels. It is observed that FBG used with receiver channels support larger communication fiber length, also G655 (NZDSF) fiber shows much better performance as compared with other SMF's tested.

Key Words: FBG, WDM, DCG, DCF, FOM, RZ.

1. Introduction

In currently scenario research is on increasing the capacity of metro and long-haul (LH) ultra dense wavelength-division multiplexing (UDWDM) systems aims at achieving very high spectral efficiency close to 1 b/s/Hz [1].It was accomplished in using highly reduced channel spacing in the order of the bit rate per channel. In such UDWDM systems, the spectra of adjacent channels may overlap significantly if not properly bounded, remarkably increasing the performance degradation caused by linear crosstalk [2]. Forward-error correction (FEC) techniques have been indicated for metro and LH systems [1] to improve the performance or increase the system margin. On the other hand, its use leads to a larger transmitted signal bandwidth, causing greater pre-FEC decoding performance degradation in UDWDM systems due to linear crosstalk .The enormous growth in the demand of bandwidth is pushing the utilization of fiber infrastructures to their limits. The optical fiber communication system is an important part in modern communication networks. Usually, there are three key problems associated with the optical fiber communication system, that is, the transmission loss, dispersion, and the nonlinear effect. The dispersion becomes the major obstacle of improvement of the optical fiber communication system. In order to reduce the effect of dispersion, many fiber structures have been proposed. At first, the zero dispersion point was shifted to wavelength at 1.55 μm to obtain the so-called dispersion-shifted fiber (DSF), but this kind of fiber is not efficient in wavelength division multiplex (WDM) system due to nonlinear effect. The compromise structures considered both the dispersion and nonlinear effect were studied. This kind of fiber is called G.655 fiber [3–6], however, the dispersion is still a problem of G.655 fiber system, especially for long distance and high-speed transmission system and the dispersion compensation is still necessary in G.655 fiber system. Among different dispersion compensation techniques [7, 8], there are two methods which are very useful, one is of using the dispersion compensation fiber (DCF), the other is of using the fiber Bragg grating (FBG) [9]. However, by comparison, the DCF have following disadvantages: first, it is very expensive. Second, EDFA is often necessary to compensate the insertion loss of DCF, and introduce an extra cost. Second, EDFA is often necessary to compensate the insertion loss of DCF, and introduce an extra cost. It has low transmission and insertion losses, and its refractive modulation can be controlled in exposure process easily. The significant discovery of photosensitivity in optical fibers [10] lead to the development of a new class of in-fiber component, called the fiber Bragg grating (FBG). Fiber Bragg gratings are revolutionizing the telecommunications technology due to their intrinsic integration with fibers and the large number of device functionalities that they can facilitate, such as filtering, chromatic dispersion compensation, and optical amplifiers gain flattening. The most distinguishing feature of the FBG is the flexibility that they offer for achieving desired spectral characteristics, due to the broad range of variation in their determining physical parameters [11].Among the different possible methods for achieving chromatic dispersion compensation—the major limitation for today's high speed telecommunication networks—the chirped fiber Bragg grating (FBG), [dispersion compensating grating (DCG)] is a very promising candidate because of its high figure of merit (FOM) [12].The most attractive advantage of using FBG is that the dispersion and dispersion slope can be compensated and matched simultaneously. Now, the dispersion compensation of FBG is considered as the best scheme, and hopefully has wide application foreground. It is shown that generally, the SSB-DCS-RZ formats have poorer *Q*-factor and tolerance to the total residual dispersion but much higher tolerance to the in-line dispersion compensation and intra-channel nonlinear effects than the BL-duo binary formats[13].Previous study were for increase of data rate from 10.7Gbps to 43Gbps WDM system using FBG[14] .Consequently to enhance capacity of the optical communication system in this contribution paper we examine light wave application with FBG we will do study and performance analysis for 45Gb/s/ch return to zero differential phase shift keying multiplexed 720Gb/s (45Gb/sx16) WDM optical transmission link with and without using fiber Braggs Grating (FBG) as an external compensation at receiver end for fiber communication length of 200km with various ITU-T fibers, So that we can search the utility of FBG with receiving channels for better optical performance metrics..

2. Theoretical Consideration

Fiber transmission is more challenging at higher bit rate than at 10Gbit/s. At high bit rate dispersion induces broadening of short pulses propagating in the fiber causes cross talk between adjacent time slots leading to errors when the communication distance increases beyond the dispersion length of the fiber. Actually at very high bit rate transmission fiber non linearity's creates great problem that limits the length of transmission.

Fiber Bragg grating (FBG) is a type of distributed Bragg reflector constructed in a short segment of optical fiber that reflects particular wavelengths of light and transmits all others. This is achieved by adding a periodic variation to the refractive index of the fiber core, which generates a wavelength specific dielectric mirror. A fiber Bragg grating can therefore be used as an inline optical filter to block certain wavelengths, or as a wavelength-specific reflector. The fundamental principle behind the operation of a FBG is Fresnel reflection. Where light traveling between media of different refractive indices may both reflect and refract at the interface. The grating will typically have a sinusoidal refractive index variation over a defined length. The reflected wavelength (λ_B), called the Bragg wavelength, is defined by the relationship,

$$\lambda_B = 2n_e\Lambda$$

Where n_e is the effective refractive index of the grating in the fiber core and Λ is the grating period. The effective refractive index quantifies the velocity of propagating light as compared to its velocity in vacuum. n_e depends not only on the wavelength but also (for multimode waveguides) on the mode in which the light propagates. For this reason, it is also called modal index.

The wavelength spacing between the first minima, or the bandwidth ($\Delta\lambda$), is given by,

$$\Delta\lambda = \left[\frac{2\delta n_0\eta}{\pi}\right]\lambda_B$$

Where δn_0 is the variation in the refractive index ($n_3 - n_2$), and η is the fraction of power in the core.

The peak reflection ($P_B(\lambda_B)$) is approximately given by,

$$P_B(\lambda_B) \approx \tanh^2 \left[\frac{N\eta(V)\delta n_0}{n} \right]$$

The structure of the FBG can vary via the refractive index, or the grating period. The grating period can be uniform or graded, and either localized or distributed in a superstructure. The refractive index has two primary characteristics, the refractive index profile, and the offset. Typically, the refractive index profile can be uniform or apodized, and the refractive index offset is positive or zero. There are six common structures for FBGs are uniform positive-only index change, Gaussian apodized, raised-cosine apodized, chirped, discrete phase shift, and Superstructure. In chirped FBG, different wavelength component involved in a light is reflected at different location and result in different time delay. This property makes FBG useful in dispersion compensation.

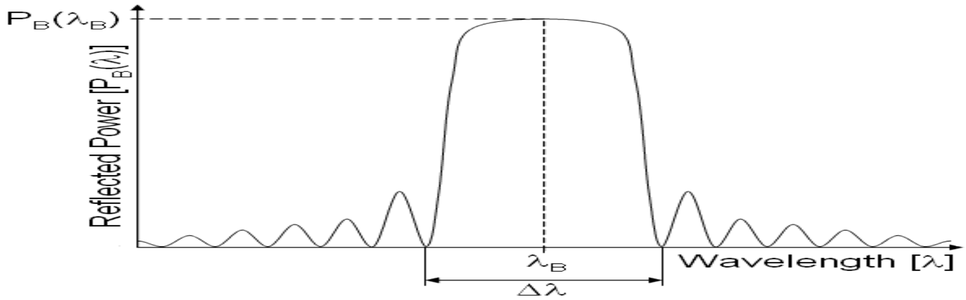

Figure1. FBG reflected power vs. wavelength

3. System details

In it RSoft OptSim software was used which gives us same realization as physical realization of the system. In this simulation return to zero differential phase shift keying modulated WDM system is used. The optical communication model used is 45Gb/s/ch is shown in fig.1, which is used to test performance of different fibers as well as with and without FBG for different channels. Sixteen channel transmitter section is used .The transmitter consists of a PRBS generator, which generates pseudo random bit sequences at the rate of 45Gbit/s with 2^9–1 bits, 39samples per bit. This bit sequence is fed to the RZcoder that produces an electrical RZ coded signal. Electrical low pass Bessel filter with 10 poles -3db B.W and this bit sequence is modulated by optical phase modulator that changes phase of the input optical signal as a function of electrical driving voltage. Multiplexed optical signals are fed into the fiber. Repeater loop consists of short fibers of same type but with opposite dispersion values. The fiber model in OptSim^{TM} takes into account the unidirectional signal flow. Fiber nonlearities, PMD, birefringence are ON and Raman crosstalk is OFF. The parameters are taken according to table-2 and fibers used are according to table-1 for simulation.

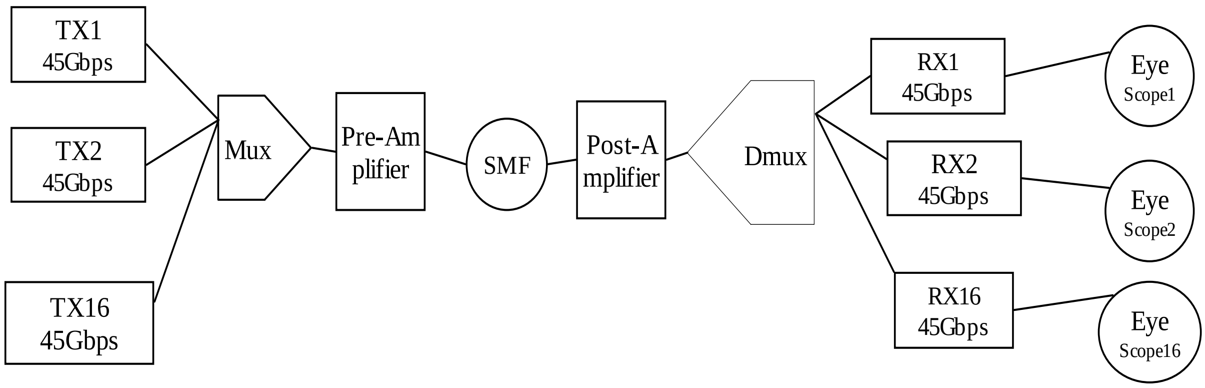

Figure2. 16Chx45Gbps RZDPSK simulation model used

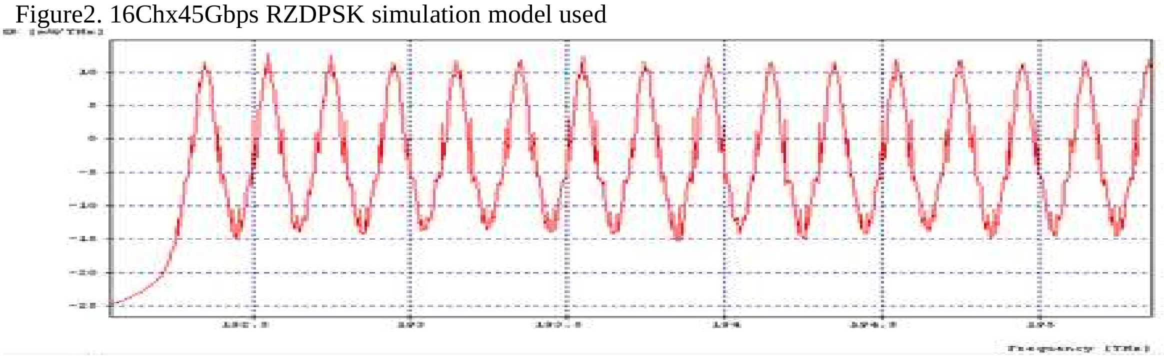

Figure 3. Input optical spectrum of sixteen channel (720Gbps) RZ-DPSK

At the output of the multi stage Lorentzian optical filter and detection is performed by the DPSK receiver. Detection is observed for Three channels(Ch1,Ch8,Ch16) with and without FBG with different fibers observation is taken for three Channels which are operating at receiver1 (192.35THz), receiver8 (193.40THz), receiver16 (195.60THz) with and without grating at receiver end. The all outputs are applied to a visualization tool called Scope. It is an electrical oscilloscope with numerous data processing options, eye display and BER estimation features. Eye diagrams are used to effectively analyze the performance of an optical system. Eye diagrams clearly depict the data handling capacity of an optical transmission system. More the eye open, the more efficient the system. If the eye opening is very wide, there is no crosstalk. Performance degradation will directly affect the eye diagrams which in turn results in reduced eye opening and time jitter at the Edges.

Table1.Transmission fiber characteristics of ITU-T recommended fibers

ITU-T(SMF'S)	**Fiber Names**	**D in Ps/nm/km**	**Effective core area in 10^{-12} m^2**
G.652	AlcatelSMF	16.0	81.7
G.652	yy-CorninSMF28e	-16.0	85.0
G653	DSF(DS_ Anomalous)	2.0	55.0
G.655	NZDSF (Lucent True wave)	4.5	55.0

Table-2

Parameter(unit)	**values**
Ref bit rate(Gb/s)	45
Channel separation(Ghz)	150

Channel frequencies(for 16channels)	192.35 to 195.60
Samples per bit	39
VBS B.W (THZ)	1.3999
Pre amplifier gain(db)	5
FBG dispersion values	-58,23 &100 ps/nm

4. Results and Discussion

In it performance study for 720Gb/s (16x45Gb/s) WDM transmission with 150-GHz channel spacing over 200 km variable length link RZ-DPSK optical communication link using different ITU-T recommended single mode fibers have been tested. Different eye patterns obtained shown in figure (4) to figure (7) and Q vs. length plots for all four fibers has been shown in figure (8-11).Results shows much increase in various losses near around 100kms and optical losses varies for different fibers differently. Now on observing performances Q and eye pattern for different fibers from various results particularly for 100km span of fiber shows that NZDSF (Lucent true wave) fiber has better eye opening and Q in comparison to other fibers tested for performance comparison. DS_Anomalous fiber shows performance good but little poor as compared to Lucent True wave fiber, the other two fibers Corning SMF and Alcatel SMF has shown much poor optical performance for same fiber span length. On increasing communication length for SMF's it is observed that Q value decreases rapidly, BER increases. It is also observed that external FBG compensated receiver channel shows better performance for higher distance of communication and for very short distance of communication the receiver channel without external FBG compensated shows better performance. Different FBG's used at receiver have different dispersion values used for better performance that is for receiver channel 1 FBG is set -58ps/nm, receiver channel8 FBG is set 23ps/nm, receiver channel 16 FBG is set 100ps/nm with WDM optical system operating at 45Gbps/Ch .On comparing for 200km span it is found that NZDSF (Lucent True wave) fiber has shown less BER and better Q , eye pattern in comparison to all other SMF's used for study, also CorningSMF28e shows poor performance compared to other fibers for overall span analysis.

5. Conclusion

The ITU-T recommended fibers are compared for RZDPSK modulation at 45Gb/s/ch by varying span length up to 200km at 45Gb/s/ch .The G652 (yyCorningSMF28e) shows much poor performance as compared to other fibers tested and NZDSF (Lucent True wave fiber) G655 shows better performance (wide eye opening, high Q and lowest BER) in comparison to other fibers for variable length span. FBG is helpful for large distance of communication with optical system operating at such high bit rates as 45Gbps/ch.

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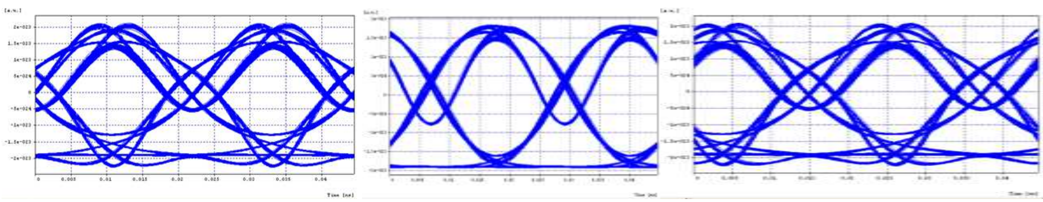

Figure 4. Eye pattern Rx1, Rx8, Rx16 Lucent True wave SMF 200km transmission with FBG

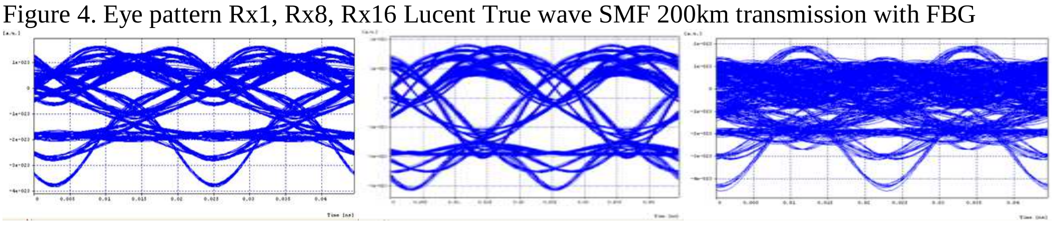

Figure 5. Eye pattern Rx1, Rx8, Rx16 Lucent True wave SMF 200km transmission without FBG

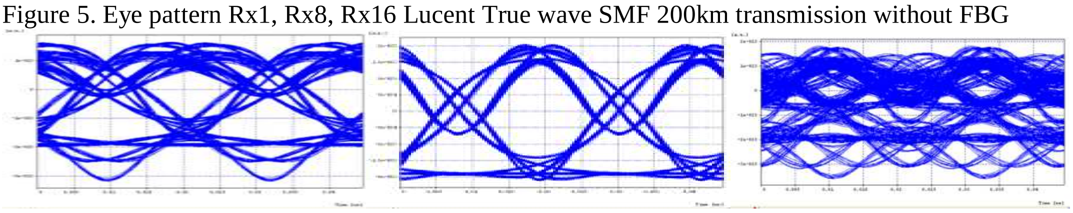

Figure 6.Eye pattern Rx1, Rx8, Rx16 DS_Anomalous SMF 200km transmission with FBG

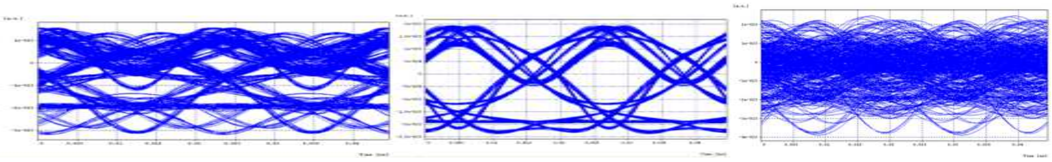

Figure 7. Eye pattern Rx1, Rx8, Rx16 DS_Anomalous SMF 200km transmission without FBG

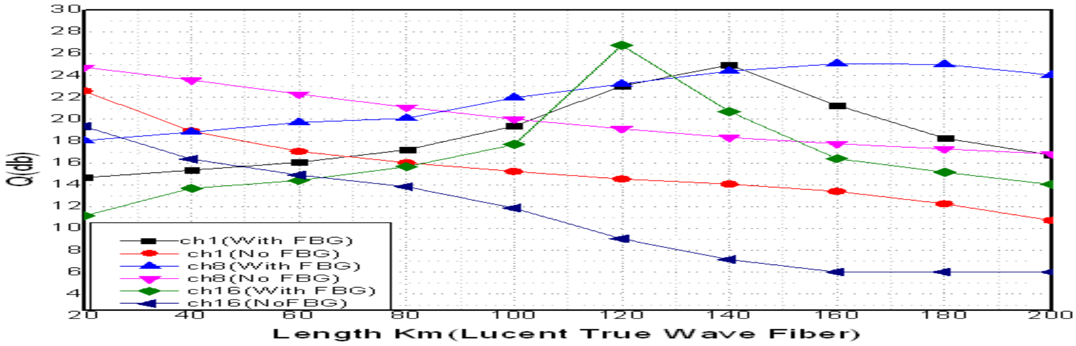

Figure 8.Q vs. Length plot for Lucent True Wave Fiber

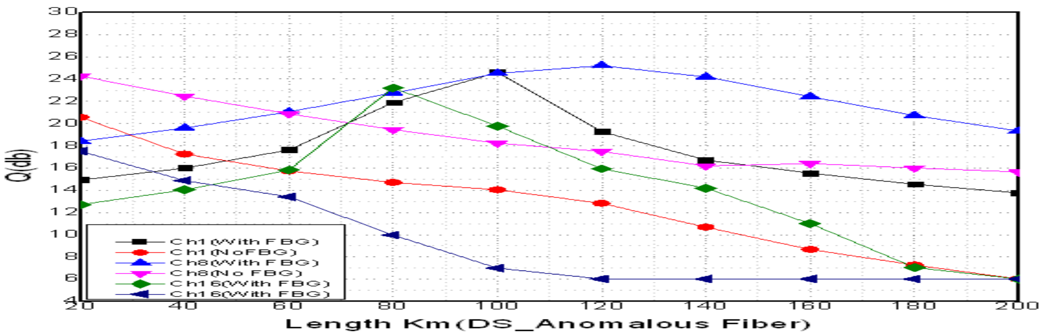

Figure 9.Q vs. Length plot for DS_Anomalous Fiber

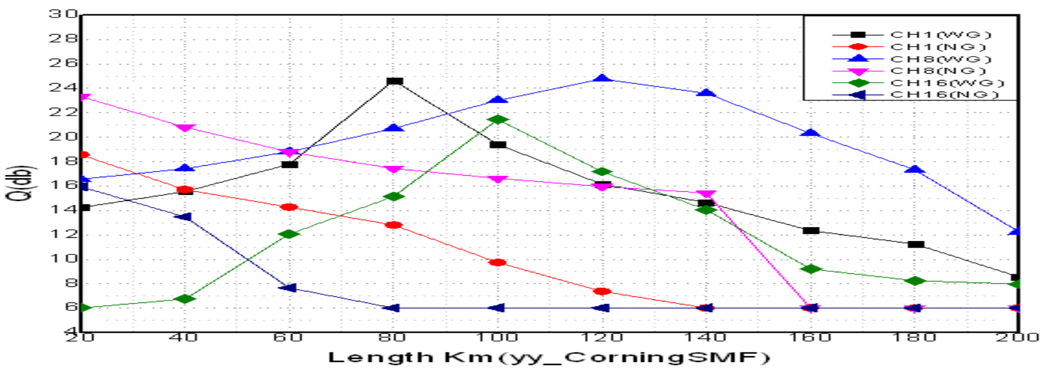

Figure 10.Q vs. Length plot YY_Corning SMF

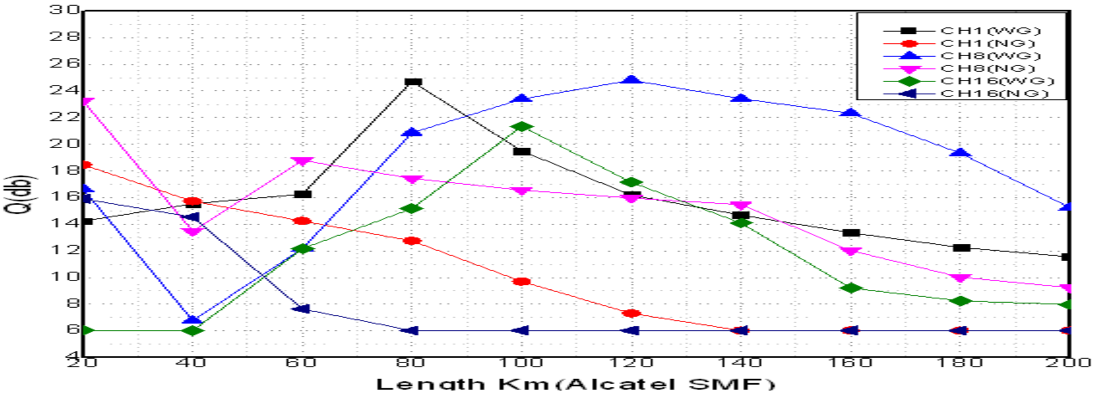

Figure 11.Q vs. Length plot for Alcatel SMF