Barisal University Journal Part 1, Vol. 4(1):105-114(2017) ISSN 2411-247X

PERFORMANCE ANALYSIS OF BCH ERROR CORRECTION CODE IN HIGH BANDWIDTH 40GB/S FIBER OPTIC CHANNEL

Rahat Hossain Faisal[1]

[1]Department of Computer Science and Engineering, University of Barisal
Barisal 8200, Bangladesh

Abstract

Optical fiber communication has grown rapidly over the last couple of decades. Due to different fiber-optic phenomena like attenuation, nonlinear effects and dispersion effects, error can be introduced easily during transmission. There are different forward error correction techniques for error free information at the receiver. Among the different codes, the most impressive results can be obtained by using RS, BCH, Turbo and LDPC codes. In this paper we have experimented the error correction performance of BCH code, for ultralong-distance 40 Gb/s based SMF-linked system, assuming the AWGN model.

***Keywords*:** AWGN, OOK, RZDPSK, BCH CODE, BER, SMF OPTICAL FIBER

Introduction

Many forms of communication systems have appeared over the years, from earliest civilization to the present day. The basic motivations behind each new form were either to improve the transmission fidelity, to increase the data rate so that more information could be sent, or to increase the transmission distance between relay stations. But at present we look for the systems which combine all of these to meet our present and future demand (Keiser, 2000). Comparing the present situation with that of a couple of years ago, it is found that the expectations of needs for and dimensions of data communication have increased greatly. Fiber-optic communication systems are found to be the most suitable and reliable way to meet present and future needs for fast and huge data communication among long distance relay stations.

Corresponding author's e-mail: rhfaisal@gmail.com

BCH Code

BCH (Bose, Ray-Chaudhuri, Hocquenghem) is a suitable and more specifically error correcting code. A BCH code is a multilevel, cyclic, error-correcting, variable-length digital code used to correct multiple random error patterns. BCH codes may also be used with multilevel phase-shift keying whenever the number of levels is a prime number or a power of a prime number (Justesen and Hoholdt, 2004).

A. Performance Analysis

A BCH (s, t) code is constructed over the Galois Field GF (2^S). It can correct up to t bits out of the block of n = $2^S - 1$ bits. The minimum distance is 2t+1 and the code length n is $2^S - 1$. The rate of the code can only be found after finding the generator polynomial $g(x)$. It is then found that $m = n - \deg[g(x)]$, where $\deg[g(x)]$ is the degree of the generator polynomial and the code rate is then $r = m/n$ (Peterson and Weldon, 1972; Gabla *et al*., 1992; Berrou and Glavieux, 1996; Vucetic and Yuan, 2000; Pretzel, 1992; MacKey, 2003).

B Performance of Selected BCH Codes

The performance comparison of different BCH codes is shown below to identify the performance of BCH (11, 11) (Peterson and Weldon, 1972; Gabla *et al*., 1992; Berrou and Glavieux, 1996; Vucetic and Yuan, 2000; Pretzel, 1992; MacKey, 2003):

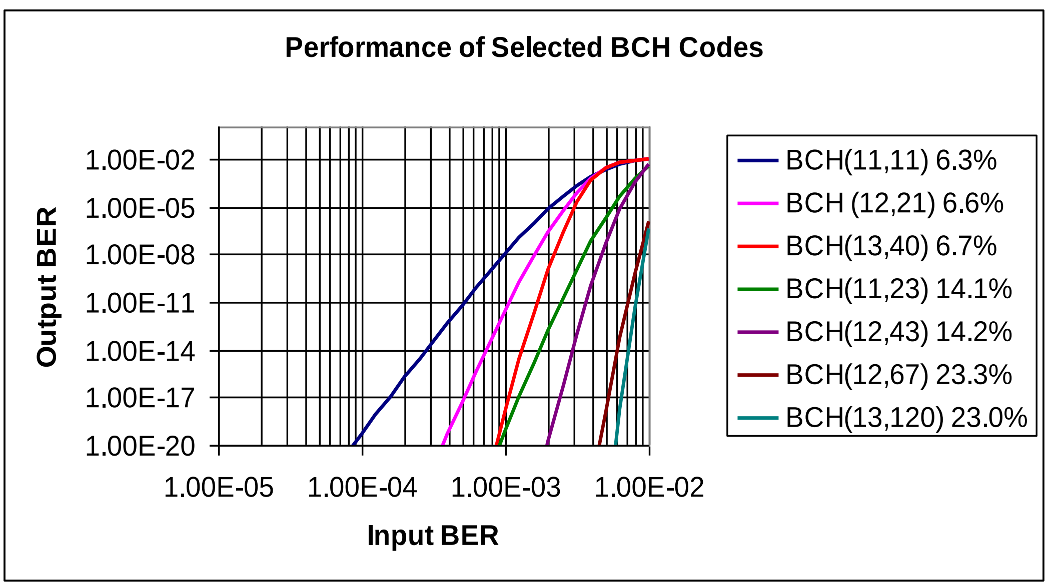

Fig. 1. Performance comparison among different BCH codes

C. Performance Analysis of BCH (11,11) code:

- ❖ Code Length, n = 2^{11} – 1=2047 bits.
- ❖ The minimum distance is (2*11+1) = 23
- ❖ It can correct up to t = 11 bits per block.
- ❖ Degree of the generator polynomial is 121
- ❖ m = n – deg[g(x)] = 1926
- ❖ Code rate r = m/n = 1926/2047 = 94%
- ❖ Coding Overhead = (deg[g(x)] /1926)*100=6.28%

Simulation Model

Now the aim of this research paper is to analyze the performances of BCH (11, 11) code to represent its suitability to use for high bit rate (40 Gb/s) optical fiber transmission systems to ensure error free transmission.

I have used the Cray XD1 system to simulate the performance of the code. I have used 40 Gbit/s transmission system and SMF fiber. Due to the performance limitation of OOK modulation format RZDPSK modulation format is used to do research to find its suitability for longer distance reliable transmission. EDFA noise figure is 4.5 dB. The length of the Span of our system is 170 km.

Since OOK modulation format does not give as good a performance for long distance transmission as RZDPSK does, we realized both the modulation formats at long distance to show the performance comparison among them. To find the performance comparison both BER and Q-factor is used. Due to the performance limitation of OOK, RZDPSK modulation format is used for further/longer distance. We have experimented with different powers and different bandwidths to find the optimal situation for long haul (3400km) optical communication systems using OOK modulation format. 40Gbit/s system is found to be the optimal at launch power around 1 dBm; that is the system operates better for OOK modulation format at this BW and Power combination (Q-factor is highest & BER is lowest).

For our further experiment on OOK modulation format we have chosen 40Gbit/s transmission systems at Power = 1 dBm. But for RZDPSK modulation format at 40Gbit/s transmission we have found launch power -2 dBm to be the optimum. To find the longest distance up to which the system will support reliable transmission we have realized BER after transmission varying the transmission distance (using RZDPSK modulation format).

Two possible signal levels in binary digital communication systems may have a different average noise associated with it. This means that there are essentially two discrete signal-to-noise ratios (SNR_{OH}, SNR_{OL}), which are associated with the two possible signal levels. To calculate the overall probability of bit error, we need to consider both the signal-to-noise ratios. Q-factor is a convenient measure of overall system quality to combine these two SNRs into a single quantity (Maxim, 2000).

Bit error ratio (BER), is determined by two factors: (1) the standard deviations of the noise (σ_L and σ_H) and (2) the voltage difference between v_L and v_H. For the special case when σL = σH, the threshold is halfway between the low and high levels. That is, γ = (v_L - v_H)/2. But, generally when $\sigma_L \neq \sigma_H$, the optimum threshold for minimum BER will be higher or lower than (v_L - v_H)/2.

Let's consider SNR_{OH} and SNR_{OL} are the optical SNRs for the high and low levels. The optimum threshold level, γ_{opt}, is the threshold level that results in the lowest probability of bit error. If the optimum threshold level is set, we may achieve the same probability of bit error for both the cases of a high signal transmission and a low signal transmission. This means the special condition of γ_{opt}, $SNR_{OH} = SNR_{OL}$, which leads to the following definition of the Q-factor (Maxim, 2000) and (Bergano *et al*., 1993):

$$Q = \frac{V_H - \gamma_{opt}}{\sigma_H} = \frac{\gamma_{opt} - V_L}{\sigma_L} \qquad (1)$$

From the above equation we get,

$$\gamma_{opt} = \frac{V_H\,\sigma_L + V_L\,\sigma_H}{\sigma_L + \sigma_H} \qquad (2)$$

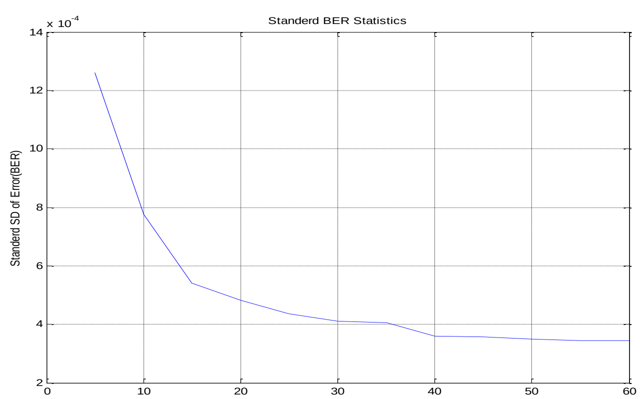

Fig. 2. Number of runs for stable statistics

From the above two equation we can write,

$$Q = \frac{V_H - V_L}{\sigma_L + \sigma_H} \qquad (3)$$

We can convert the expression for Q to equivalent terms of current or optical power by multiplying the individual terms in the above equation by resistance, impedance, or responsivity.

The Scheme of the one period:

For the experiment SMF (Standard Monomode Fibre) fibre link is used. DCF (dispersion compensating fibre) has used to compensate the dispersion of SMF fibre. EDFA noise figure is 4.5 dB. The length of the SMF Span was 170 km. The used scheme of the one period is as follows:

SMF (85 km) + EDFA1 + DCF (15 km) + EDFA2 + DCF (15km) + EDFA 2 + SMF (85 km) + EDFA1

Simulation Result

For the system, I have experimented and found that if an experiment is repeated for around 30 times it will give a reasonable and stable statistics (Fig.2). So for our further experiment we have used Number of Run = 30. Performance of OOK Modulation Format within the experimented fiber spans is shown graphically in the following Fig.3 to Fig.4.

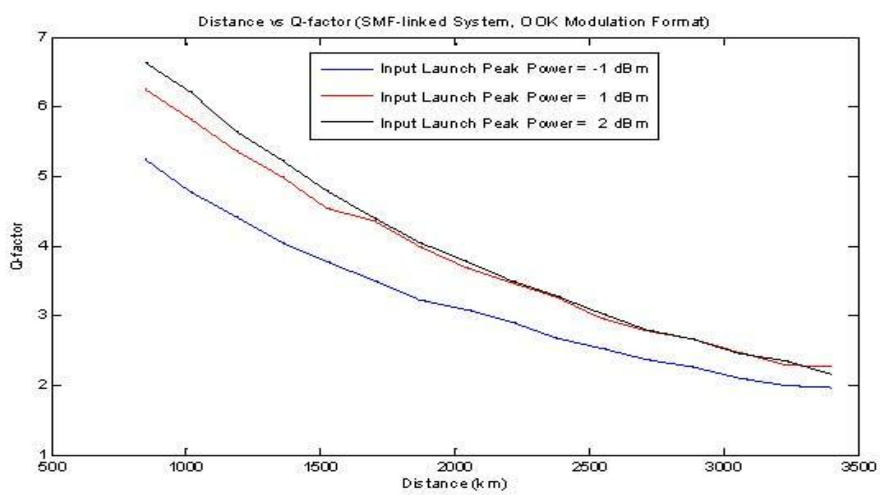

Fig. 3. Transmission distance vs Q-factor (OOK)

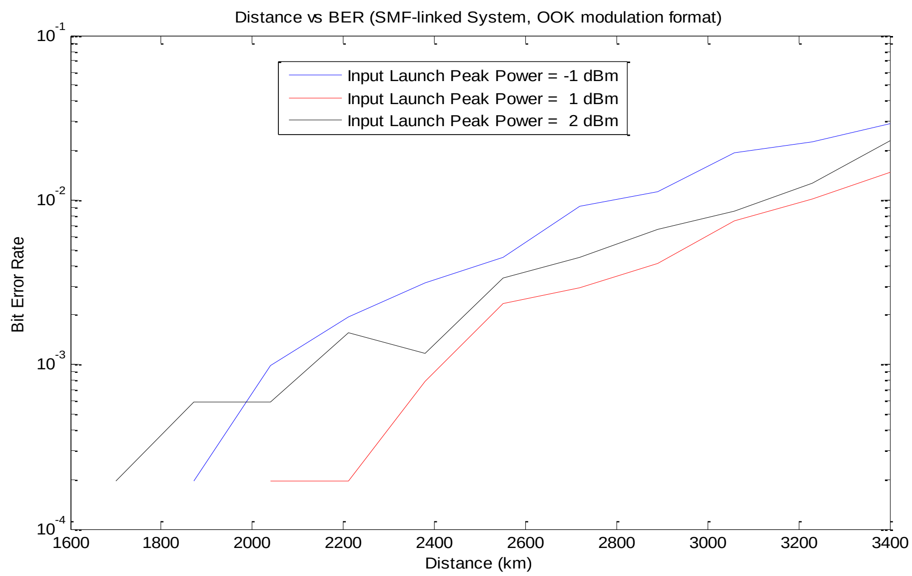

Fig. 4. Transmission distance vs BER (OOK)

Similarly, the Performance of RZDPSK Modulation Format is shown graphically in the following figures (through Fig. 5 to Fig. 6)

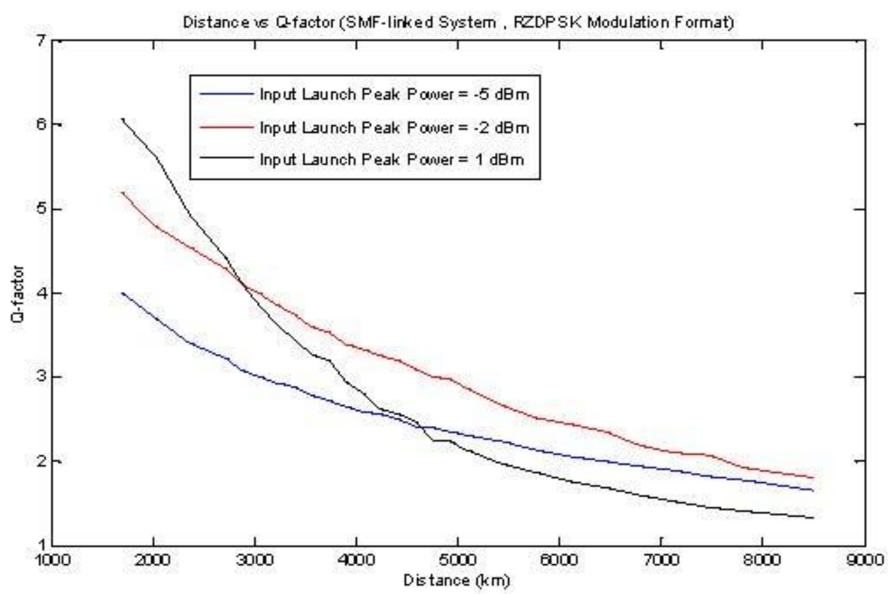

Fig. 5. Transmission distance vs Q-factor (RZDPSK)

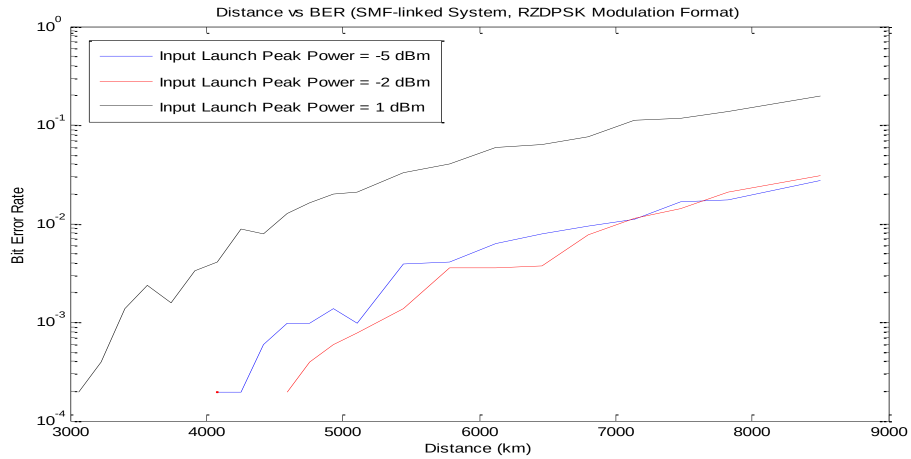

Fig. 6. Transmission distance vs BER (RZDPSK)

For reliable transmission we need Q-factor = 3 and BER should be around 10^{-3}. From above experiments/figures we can come to a conclusion that for SMF-linked system and using OOK modulation format we may achieve reliable transmission up to around 2000 km, and for RZDPSK modulation format up to around 5500 km.

A. Performance Analysis at 1700 km

BER performance and coding gain for BCH (11, 11) at a distance of 1700 km is shown in the following figures-

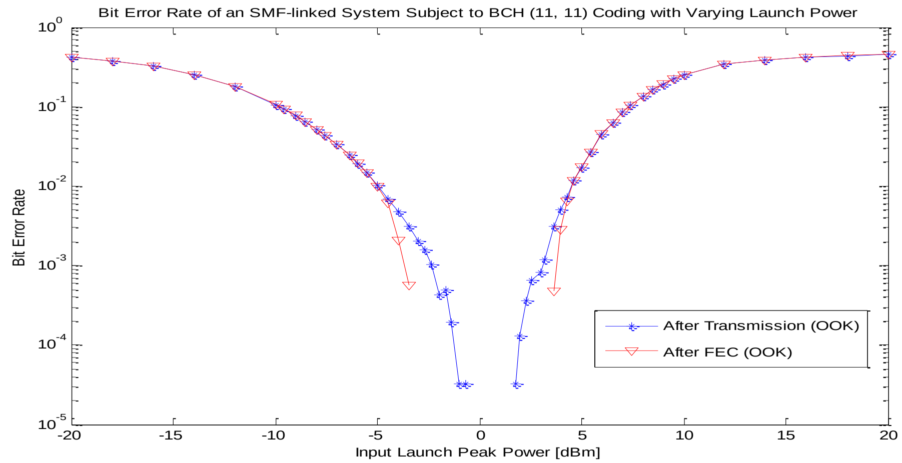

Fig. 7. Bit rate for an SMF-linked system subjected to BCH (11, 11) coding with different lunch power.

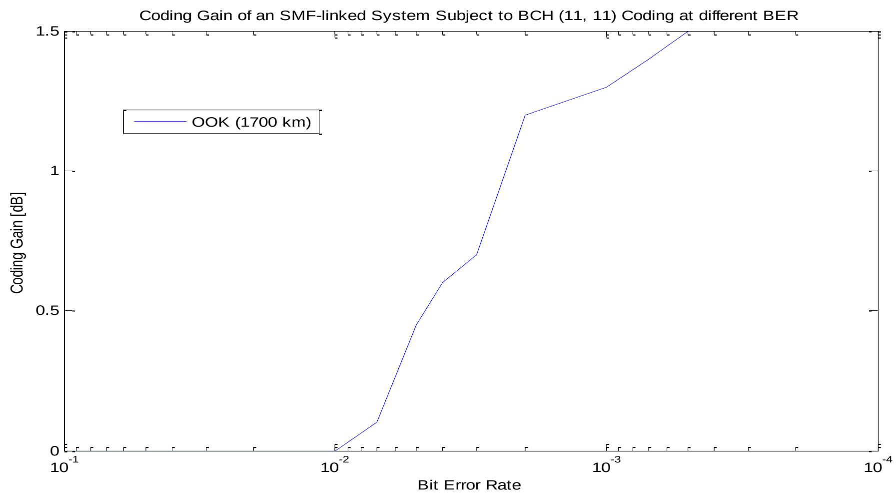

Fig. 8. Coding gain for an SMF-linked system subjected to BCH (11, 11) coding at different BER considering OOK modulation format.

B. Performance Analysis at 3400 km

BER performance and coding gain for BCH (11,11) at a distance of 3400 km is shown in the following figures:

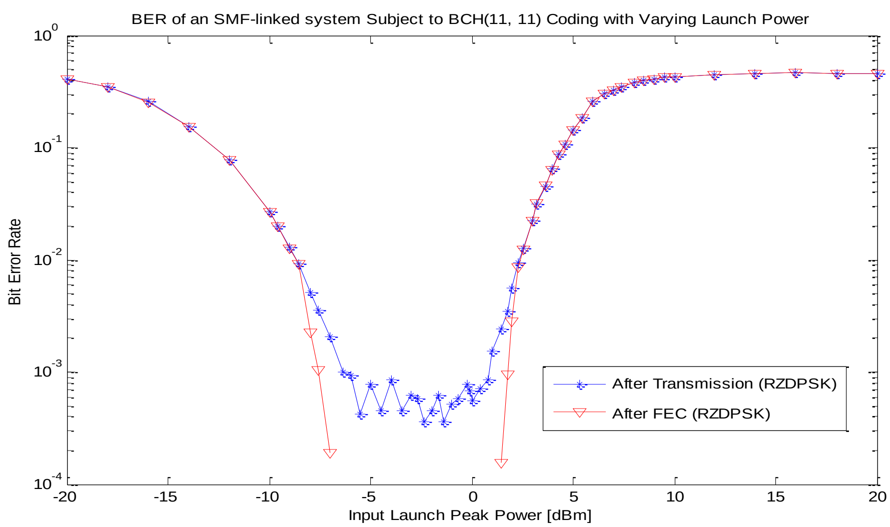

Fig. 9. Bit rate for an SMF-linked system subjected to BCH (11, 11) coding with different lunch power

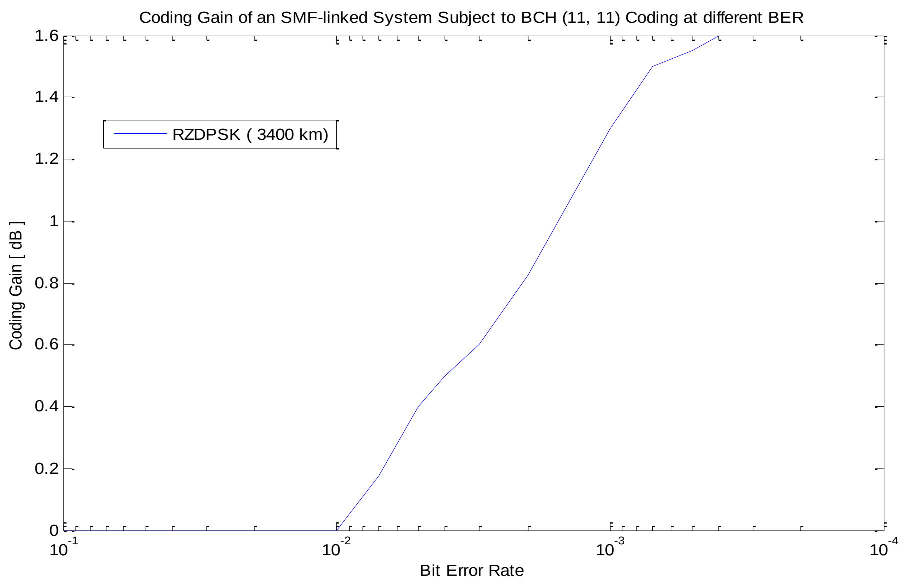

Fig. 10. Coding gain for an SMF-linked system subjected to BCH (11, 11) coding at different BER considering RZDPSK modulation format.

Conclusion

From the above experimental result it is clear to us that the BCH (11, 11) code can correct significant number of errors for long optical fibre transmission distance. To show the results of our experiments we have drawn the BER performance graphs of the FEC code and the coding gain of corresponding FEC code for different transmission distance. Using OOK modulation format we have achieved satisfactory transmission performance up to around 1700 km. On the other hand, using RZDPSK modulation format we have achieved more satisfactory transmission performance than OOK. The performance comparison is as follows:

Code	Modulation format	Distance	Coding gain
BCH (11, 11)	OOK	1700 km	1.3 dB
BCH (11, 11)	RZDPSK	3400 km	1.3 dB

References

Bergano, N. S., Kerfoot, F. W. and Davidson, C. R. 1993. Margin measurements in optical amplifier systems. *IEEE Photonics Technology Letter*. **5**:304-306.

Berrou, C. and Glavieux, A. 1996. Near optimum error correcting coding and decoding. *IEEE Trans. Comm*. **44**:1261- 1271.

Gabla, P. M., Pamart, J. L., Uhel, R., Leclerc, E., Frorud, J. O., Ollivier, F. X., and Borderieux, S. 1992. 401 km, 622 Mb/s and 357 km, 2.488 Gb/s IMJDD repeaterless transmission experiments using Erbium-Doped Fiber amplifiers and error correcting code. IEEE Phot. *Tech Lett*. **4**:1148-1151.

Justesen, J. and Hoholdt, T. 2004. A course in error-correcting codes. European Mathematical Society. Helsinki, Finland.

Keiser, G. 2000. Optical Fibre Communications. Third Edition, McGrawHill, London.

MacKay, D. J. C. 2003. Information Theory, Inference, and Learning Algorithms. Cambridge University Press, London.

Maxim. MAXIM High-frequency/ fibre communication group. 4hfan902.doc. 02/27/02. Optical signal-to-noise ratio and the Q-factor in the fibre optic communication systems.

Peterson, W. W., and Weldon, Jr. E. J. 1972. Error-Correcting Codes. MIT Press, Cambridge USA.

Pretzel, O. 1992. Error-Correcting Codes and Finite Fields. Clarendon Press, Oxford. Vucetic, B. and Yuan, J. 2000. Turbo Codes. Kluwer Academic Publishers, The Netherlands.