PERFORMANCE ENHANCEMENT OF 32 CHANNEL LONG HAUL DWDM SOLITON LINK USING ELECTRONIC DISPERSION COMPENSATION

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ABSTRACT

In this paper, electronic dispersion compensation (EDC) based on minimum mean square error optimization has been employed to improve the performance of 32 channel, Terabit capacity, long haul DWDM optical soliton link. Symmetrical optical dispersion compensation has been used to negate the accumulated dispersion in the fiber span using DCF and mid span OPC mitigates the FWM power by introducing destructive interference between the first and second halves of the fiber optic link. It is observed that EDC significantly reduce BER by $10^{-20}$ and improved $Q$ by 2 dB, thus resulting in improved eye opening and considerably reduced inter-symbol interference.

KEY WORDS: DWDM, EDC, FWM, MLSE, MMSE

INTRODUCTION

With the explosive growth of information technology, ultra-high bit rate communication systems are becoming more popular. Optical transmission using a short optical pulse train is a fundamental technology for achieving a high-speed and long-distance global network. It is an appropriate approach to utilize a portion of the huge bandwidth of single mode optical fibers. Optical solitons are high intensity, short optical pulses which are most suitable for data transmission as they can circumvent the problem of pulse broadening due to fiber dispersion by nonlinear pulse propagation [1]. Optical soliton balances the anomalous group velocity dispersion with the fiber nonlinearity self-phase modulation, thus maintains its waveform over long distances. Dispersion management is a powerful technique for enhancing the performance of a soliton transmission system [2], [3]. The performance of WDM soliton system is strongly affected by fiber dispersion especially in long haul communication links. The dispersion tolerance in an optical transmission system tends to be proportional to the inverse square of the bit rate of the optical channel. A variety of methods have been used to compensate chromatic dispersion. Beyond 40 Gb/s not only the impact of dispersion is more stringent, but the circuit challenges are also severe [4]. Currently optical dispersion compensation (ODC) is mainly based on dispersion compensating fiber (DCF) modules [5]. Though DCF is an effective method to negate the accumulated dispersion but it lacks adaptability. Electronic dispersion compensation uses the past decisions to correct the error at the decision threshold and thus helps the equalizer in compensating the inter-symbol interference. For this reason the EDC is being widely used in the most modern receivers. As EDC mitigates the optical signal distortion in electrical domain after detection in a photo receiver, the amount of compensation can be changed rapidly, simply by adjusting the parameters of the compensation algorithm and no physical changes are required to be made in optical link [6,7]. The two most widely applied algorithms for EDC are maximum likelihood sequence estimation (MLSE) and minimum mean square error optimization (MMSE). MLSE is a digital signal processing approach that operates on a sequence of bits rather than on a single bit at a time. It attempts to find the sequence of digital data that is statistically most likely to have generated the detected optical signal. MLSE performance has been
It is shown that MLSE is effective in the presence of self-phase modulation (SPM) alone, but is largely ineffective with both SPM and cross-phase modulation [9]. However, MMSE algorithm is more suitable for high bit-rate long haul optical communication links in the presence of non linear impairments. Next generation high capacity long haul communication systems are likely to see the convergence of optical dispersion compensation and electronic dispersion compensation for optimal performance.

The goal of this paper is to improve the performance of 32 channel, Terabit capacity, long haul DWDM optical soliton link by employing electronic dispersion compensation.

**SYSTEM DESCRIPTION**

Fig. 1 shows 32 channel DWDM soliton link. Each channel consists of pseudorandom generator, electrical generator, mode locked laser and an external modulator. The input pulse of 60 Gb/s is generated by Mode-Locked Laser and has a “sech” shape with 4.1666 ps pulse width. The pulse peak power corresponds to N=1 soliton and is set to 12 mW per channel. These 32 optical soliton channels occupying bandwidth of 12.8 nm from $\lambda=1543.6$ – 1556.4nm and having narrow inter-channel spacing of 0.4 nm are multiplexed using 32:1 multiplexer and this combined optical soliton signal is
launched into a fiber having 30 re-circulating loops, where each loop consists of two symmetrical spans of 10 km DCF and 40 km SMF, followed by EDFA for loss compensation making total long haul link length as 3000Km. Single mode fibers in a loop have a dispersion coefficient of 90 s/m$^3$ and attenuation of 0.25 dB/km. At receiver end signal is de-multiplexed and original signal is retrieved in the receivers by employing photo-detector and Bessel filter. MMSE based electronic dispersion compensation has been employed to balance the dispersion effect in electrical domain i.e. after the receiver. Measuring instruments viz. Signal analyzers, Spectrum analyzers, Eye diagram analyzers and BER Testers have been employed to gauge the link’s performance. The system has been modeled on the basis of ITU G.692 standard.

Optical Dispersion Compensation

In the considered 32 channel DWDM long haul soliton link, symmetrical dispersion compensation has been employed to negate the accumulated dispersion. Accumulated dispersion after each 40 Km SMF span is 3600 s/m$^3$km which is compensated by adding 10 km DCF having dispersion co-efficient of -360 s/m$^3$ and attenuation of 0.5 dB/km. Mid span OPC has been employed to suppressed the FWM penalty. Overall loss of 30dB over each span of 100 km is compensated by EDFA. Performance of the modeled soliton link is gauged on the basis of Eye opening, BER and $Q^2$ (dB).

Performance Enhancement Using Electronic Dispersion Compensation

In section 2.1 the performance of the proposed link with application of Optical Dispersion Compensation has been considered. Even after Optical Dispersion compensation, significant inter symbol interference (ISI) is observed in the signal after the photo receiver which limits the performance and reach of the system. Electronic Dispersion Compensation (EDC) is an effective tool to negate the dispersion in electrical domain. As shown in figure 1, MMSE based EDC is applied after the receiver to further enhance the performance of the system. EDC technique used is based on feed forward equalization (FFE) and decision feedback equalization (DFE). Using digital signal processing, the performance of FFE/DFE has been optimized on the basis of feed forward and feed backward taps. Four feed forward taps and three feed backward taps have been used to obtain optimized performance.

RESULTS AND DISCUSSIONS

The output has been obtained on the sample basis from higher wavelength channel, central wavelength channel and lower wavelength channel in order to check the optimal functioning of the system over entire wavelength range. The eye patterns of received signal before EDC and after EDC corresponding to $\lambda_1=1552.20$ nm, $\lambda_{16}=1550$ nm and $\lambda_{32}=1546$ nm are shown in Fig. 2(a-c), 3(a–c) and corresponding BER and $Q^2$ (dB) values obtained before and after EDC are tabulated in Table 1.

Fig. 2: Eye Patterns of Received Signal Before EDC Corresponding to (A) $\lambda=1552.20$ Nm (B) $\lambda=1550$ nm and (C) $\lambda=1546$ nm
Fig. 3. Eye Patterns of Received Signal After EDC Corresponding to (A) $\lambda = 1552.20$ nm (B) $\lambda = 1550$ nm and (C) $\lambda = 1546$ nm

Table 1: Performance Parameters of Received Signal before and after EDC

<table>
<thead>
<tr>
<th>Wavelength/Parameter</th>
<th>$\lambda = 1556.40$ nm</th>
<th>$\lambda = 1550$ nm</th>
<th>$\lambda = 1543.6$ nm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before EDC</td>
<td>After EDC</td>
<td>Before EDC</td>
</tr>
<tr>
<td>BER</td>
<td>$3.19 \times 10^{-14}$</td>
<td>$5.30 \times 10^{-21}$</td>
<td>$5.90 \times 10^{-16}$</td>
</tr>
<tr>
<td>$Q^2$ (dB)</td>
<td>17.50</td>
<td>19.59</td>
<td>18.06</td>
</tr>
</tbody>
</table>

CONCLUSIONS

In this paper, performance enhancement of 32 channel, Terabit capacity, long haul DWDM optical soliton link by using MMSE based electronics dispersion compensation technique has been illustrated. Application of EDC resulted in improved eye opening and reduced inter-symbol interference. Considerable reduction in BER of the order of $10^{-7}$ and corresponding enhancement in $Q^2$ (dB) up to 2 dB was observed.

REFERENCES

5. Atsushi Kodama, Akira Mizutori and Masafumi Koga, “Cancellation of Four-Wave Mixing Light by Carrier Phase $\pi$-Shift in Phase-Locked Multi-Carrier Transmission”, 9th International Conference on Optical Internet (COIN), 2010.

