Performance Comparison for APRZ on Strongly and Weakly Managed Dispersion Maps for 40 Gb/s WDM Transmission

ABHIJEET SHIRGURKAR, QUN ZHANG, and M. I. HAYEE*
Electrical and Computer Engineering Department, 271 MWAH
University of Minnesota Duluth, 1023 University Drive, Duluth MN 55812, USA

(Received on October 9, 2007)

Abstract – In this short communication, we have explored and compared the performance of Alternate Phase Return-to-Zero (APRZ) modulation format on both strongly and weakly managed dispersion maps with varying path average dispersion values. Our findings show that, as opposed to 0 or 180 deg APRZ, 90 deg APRZ is more efficient for both strongly and weakly managed dispersion maps in minimizing Intra Channel Four-wave Mixing (IFWM) for reliable 40Gb/s transmission.

Keywords: optical fiber communication, wavelength division multiplexing (WDM), modulation format, alternate phase modulation (APRZ)

1. Introduction
Due to their inherent robustness against fiber nonlinearities, regular return-to-zero (RZ) and carrier suppressed return-to-zero (CSRZ) are the most widely used intensity modulation formats for high-speed long-haul wavelength division multiplexed (WDM) transmission systems. CSRZ has an advantage over regular RZ because of its ability to efficiently suppress intra-channel four wave mixing (IFWM) which is an important source of degradation in 40Gb/s transmission [1]. The ability to suppress IFWM in CSRZ is due to alternate phase modulation (APM) of adjacent bits as contrary to regular RZ where all the bits have the same phase. The magnitude of APM in conventional CSRZ is fixed at 180 degrees. Recently, a generalized form of alternate phase modulation scheme for RZ like pulses (APRZ) has been proposed where the magnitude of APM is a free variable and can take any value between 0 and 180 degrees [2]. Recent reports have shown that APRZ with 90 degrees of APM is considered to be optimal for minimizing IFWM for 40 Gb/s transmission in strongly dispersion managed fiber maps using standard single mode fiber (SMF) [3]. However, a large portion of existing fiber infrastructure consists of weakly dispersion managed fiber maps containing various forms of dispersion shifted fiber (DSF) with small dispersion values. Therefore, we have explored APRZ modulation format for 40Gb/s transmission on both strongly and weakly dispersion managed maps with varying path average dispersion values. Our simulations show that APRZ with 90 degrees of APM is efficient in minimizing IFWM for both strongly and weakly dispersion managed fiber maps with varying path average dispersion values.

2. System Model
We have modelled two dispersion maps – one with SMF (D = +17 ps/nm-km) and the other with true wave fiber (TWF: D = +2 ps/nm-km). One span of each dispersion map consists of 100 km of transmission fiber followed by a two-stage EDFA with 19dB and

*Corresponding author’s email: ihayee@d.umn.edu
14dB gains, respectively, to compensate the span losses. There is a dispersion compensating fiber (DCF) between the two EDFA stages for inline dispersion compensation. The length of DCF (D = -85 ps/nm-km) is chosen to have a desired path average dispersion (PAD). At the receiver, dispersion is optimally compensated to maximize eye opening for each PAD value. A PRBS of 256 bits is transmitted through 10 identical spans and a noiseless eye diagram is obtained. The noise of all the amplifiers (NF = 6dB) is added at the receiver to calculate a Q value averaged over all the bits. The data rate is assumed to be 40Gb/s and only single channel simulations are performed as IFWM effect is a dominantly single channel effect.

3. Results and Discussion

We first compare the performance of two dispersion maps (SMF and TWF) for zero PAD by varying the magnitude of APM, the resulting Q’s are shown in Figure 1. As expected, SMF map being strongly dispersion managed map shows a strong dependence on APM and 90 deg turns out to be optimal APM for this map. On the contrary, TWF based map being a weakly dispersion managed map shows very minimal variation with changing APM for zero PAD. We also noticed that APM of other than 0, 90 or 180 deg causes a transfer of energy from each bit to either a preceding or following bit depending upon if APM is more or less than 90 deg. To show this, we plot the modified eye diagrams in Figure 2 by shifting and superimposing two bits simultaneously instead of one bit as in conventional eye diagrams. Figures 2 (a) and (c) show that 45 and 135 deg APM will cause the energy transfer between adjacent bits resulting in more eye closure than it would have been due to IFWM alone. Figures 2 (b) and (d) show no transfer of energy between adjacent bits and also show that 90 deg of APM suppresses ghost pulses resulting from IFWM, more efficiently than 180 deg of APM.

As the next step, we varied the PAD of the two dispersion maps and simulated the APRZ transmission through 10 spans for 0, 90 and 180 deg of APM. The resulting Q vs. PAD is shown in Figures 3 (a) and (b), respectively for SMF and TWF dispersion maps. Figure 3 (a) shows that for SMF dispersion map, APM of 0 or 180 deg performs comparably and Q degrades more than 1.5 dB with PAD changing from -0.5 to +0.5 ps/nm-km. However, with APM of 90 deg, system performs the best and Q remains almost constant to the change in PAD showing robustness of APRZ with APM of 90 deg against IFWM in varying PAD environment. The corresponding results for TWF dispersion map in Figure 3 (b) show that system performance degrades severely in large positive PAD (inline under compensation) region, where 90 deg of APM performs remarkably better and improves the system performance by more than 2 dB. This shows
that APRZ with 90 deg of APM can significantly improve the system performance in weakly managed dispersion map with varying PAD values. The eye diagrams for 0, 90 and 180 deg of APM are shown, respectively, in Figures 4 (a), (b), and (c) for the PAD value of +0.5 ps/nm-km. Figure 4 shows how effectively APRZ with 90 deg of APM suppresses ghost pulses generated as a result of IFWM in TWF dispersion map.

Fig. 3: Q vs. PAD for the disp. maps of (a) SMF and (b) TWF. The curves are for different values of APM.

4. Conclusions

In conclusion, we have analyzed APRZ modulation format on both strongly and weakly managed dispersion maps with varying PAD values. Our findings show that 90 deg of APM is optimal to suppress IFWM for strongly managed dispersion map as well as for weakly managed dispersion map with large positive PAD.

Fig. 4: Eyes after 10 spans of TWF with PAD of +0.5 ps/nm-km for different values of APM.

References

