The Reduction of FWM effects using Duobinary Modulation in a Two-Channel D-WDM System

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Abstract

This papers show that the adoption of a duo binary Modulation scheme reduces the impact of FWM in a DWDM system. The levels of the FWM products are reduced by around 10 dB which will offer a significant performance benefit in digital systems. We have taken into consideration great demand for high data rate & have designed optical fiber system for 40 Gbps.

Keywords*-dispersion shifted fiber (DSF), Dense wavelength division multiplexing (DWDM), Four wave mixing (FWM), Bit error rate (BER).*

1. Introduction

In order to meet the huge capacity demands imposed on the core transmission network by the explosive growth in data communications the number of optical channels in dense-WDM optical networks is being increased. Since the gain bandwidth of EDFAs is limited, these requirements for a very large number of channels means that he channel spacing will have to be small. The current ITU grid specifies 100 GHz channel spacing, but systems are being considered with 50 GHz to 25GHz channel spacing. At these spacing, the non-linear effects of the optical fibre can induce serious system impairments and modulation schemes are now being developed which are robust to both the linear and non-linear behaviour of fibre. Duobinary modulation techniques are known to compress the optical spectrum, thereby facilitating the tighter packing of channels into the EDFA gain window. It has also been reported that the 2- level variant of duo binary signaling [1,2] almost eliminates the impact of SBS since the optical carrier component is suppressed [3]. Four-Wave-Mixing (FWM) is another non linear effect that can limit the performance of WDM systems [4,5]. In this paper, we experimentally demonstrate that a 2-level duo binary modulation format suppresses the FWM non-linear effects in two closely spaced WDM channels. This is particularly prevalent in optical networks employing dispersion shifted fibre (DSF) [6]. To our knowledge, this is the first experimental demonstration of same. The experimental setup is validated using simulation software Optisystem.

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2. Experimental Set up

Two experiments were conducted; one was to determine the level of FWM products in a conventional binary modulated system, and one to determine the level of the FWM products in a 2-level duo binary system. The average launch power was kept as constant as practicable for all of the experiments. The experimental set-up is shown in figure 1. A pattern generator drives the optical transmitter in both experiments. The pattern generator produces a PRBS at a bit rate of 40 Gbit/s. we have used CW LASER 1 which is operating at wavelength 1552nm & given power is 4 mw the optical transmitter generates a modulated optical signal (binary or duobinary depending on the experiment) which is combined with the second unmodulated optical carrier in the 2dB optical combiner. Second CW LASER 2 operating at wavelength 1551nm & given power is 3 mw. An EDFA follows the coupler to increase the launch power into the fibre to +10dBm. The signals are then transported over 25km of DSF operating at close to zero dispersion. DSF is used in this experiment to enable the observation of a significant non-linear effect without

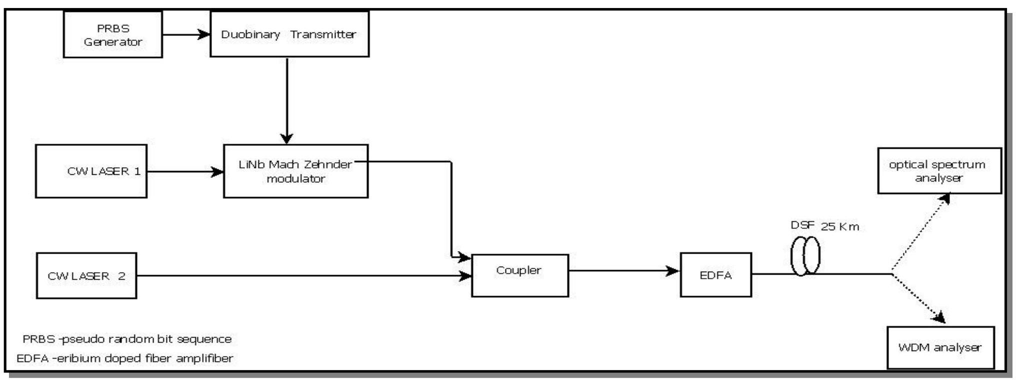

Figure 1. The Experimental setup

requiring a very long fiber span. In this experiment DSF having dispersion factor -0.63ps/nm/km[7].The spectrum after propagation through the DSF is viewed on an optical spectrum analyser (OSA). The duo binary encoder used consisted of a one-bit delay line. The output of the delay line was added to the original signal to generate a zero mean, three-level signal. This signal was amplified and applied to a single drive, balanced Mach-Zehender modulator that was biased at minimum transmission. This generated a two level optical signal which exhibited a π phase shift in the optical field for the two extremes of the three level signals. Since the input data sequence was a PRBS there was no need to include a differential encoding pre coding stage as would be used with random data.

3. Result

With a channel spacing of 1nm the level of the first-order FWM products were measured for both the binary and the duo binary case. Figure 2.1 and 2.2 shows the spectrum plots obtained with the optical spectrum analyzer and Table 1 gives the numerical values of the levels of the four components marked P1 to P4 in the figure. P1, P2 are the carriers and P3, P4 are the FWM products. As in this experiment we have used CW laser 1 which is operating at 1552nm i.e in terms of frequency W_1=193.165243 THz & CW laser 2 operating at 1551nm i.e in terms of frequency W_2= 193.2897 THz. Because of FWM effect we observe two unwanted FWM product at

P3 at $2W_1 - W_2$
P4 at $2W_2 - W_1$

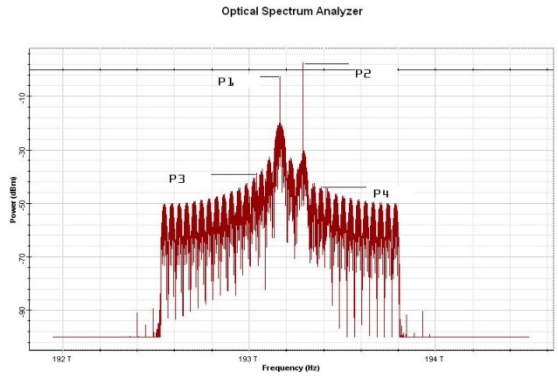

Figure 2.1.Spectral plot at fiber output for binary modulation

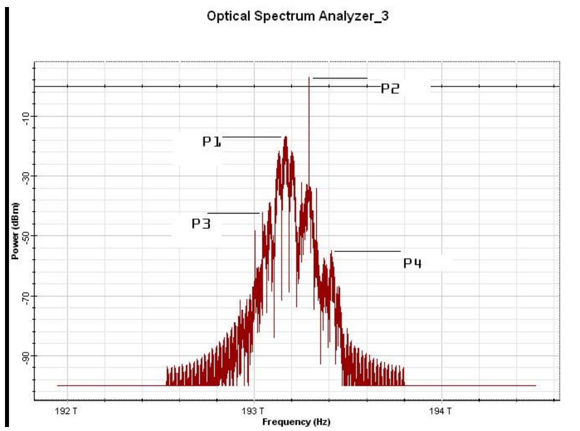

Figure 2.2. Spectral plot at fiber output for duobinary modulation

	P1 (dBm)	P2 (dBm)	P3 (dBm)	P4 (dBm)
Binary	-2.39946	2.7133	-38.6648	- 44.1354
Duobinary	-16.6742	2.98635	-42.5242	-54.539

Table 1: *levels of the optical signals in the binary and duobinary case*

The above results show that duobinary coding suppresses the FWM products by 3.8594dB in the P3 case and 10.4036dB in the P4 case. As a further experiment, the dependency of the suppression of the FWM products on the optical carrier spacing was investigated. The channel spacing was varied from 0.25 nm to 1 nm for both the binary and duo binary cases. The results presented in figure 3 shows how the average level of the FWM products relative to the average levels of the two optical carriers varies over this channel spacing range. As can be seen, the adoption of duobinary gains suppression in FWM product ranging from around 10 dB to around 1 dB, over this range of separations.

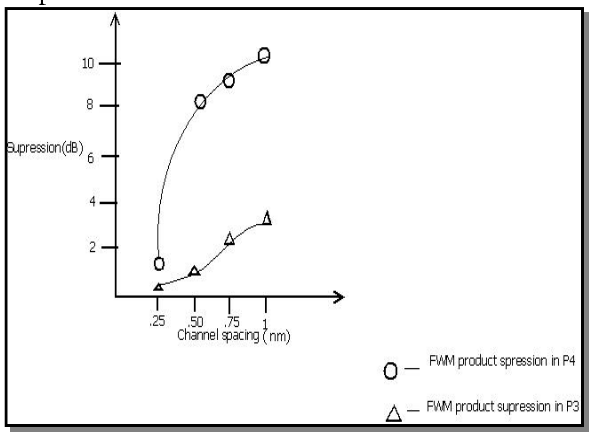

Figure 3. Average suppression of FWM product relative to channel spacing

4. Conclusion

This experiment provides experimental verification that the use of a duobinary encoding scheme can reduce significantly the level of four-wave mixing products. The suppression observed varied from 10dB to 1dB, depending on the channel spacing. The suppression is greater for narrower channel spacing which suggests that as DWDM systems reach higher channel counts duobinary becomes a very attractive encoding method. This is not only because of its narrower spectral width and consequently greater tolerance to dispersion and narrower channel spacing possibilities, but also because of its already proven SBS tolerance, and, as shown in this paper, its tolerance to FWM effects.

5. References

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