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

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Abstract: *In this paper we show that the adoption of a duobinary modulation scheme reduces the impact of FWM in a DWDM system. The levels of the FWM products are reduced by around 3 dB which will offer a significant performance benefit in digital systems.*

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 a 100 GHz channel spacing, but systems are being considered with 50 GHz to 25GHz channel spacing. At these spacings, 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 duobinary signalling [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 duobinary 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 this effect.

2. Experimental Set-up

Two experiments were conducted: one 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 duobinary 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.

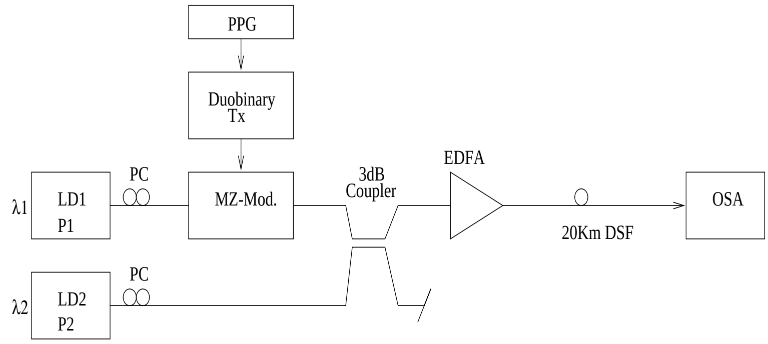


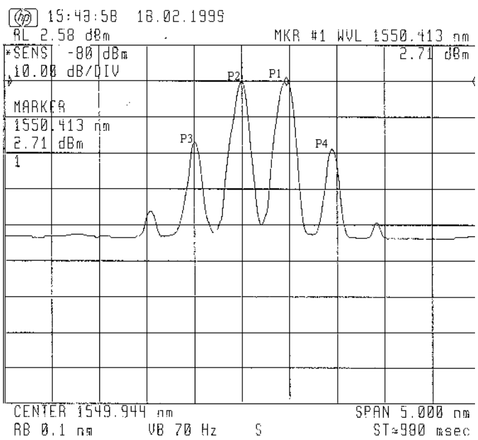
Figure 1: The experimental set-up

A pattern generator drives the optical transmitter in both experiments. The pattern generator produces a PRBS of length of 2^{31}-1 at a bit rate of 2.5Gbit/s. 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 3dB optical combiner. An EDFA follows the coupler to increase the launch power into the fibre to +11dBm. The signals are then transported over 20km 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 requiring a very long fibre span. The spectrum after propagation through the DSF is viewed on an optical spectrum analyser (OSA).

The duobinary 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-Zehnder 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 signal. Since the input data sequence was a PRBS there was no need to include a differential encoding precoding stage as would be used with random data.

3. Results

With a channel spacing of 50GHz the level of the first-order FWM products were measured for both the binary and the duobinary case. Figure 2 shows the spectrum plots obtained with the optical spectrum analyser 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.



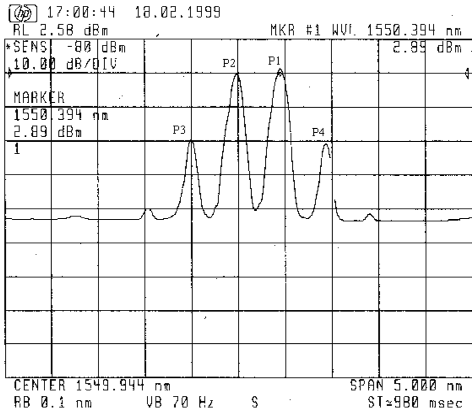


Figure 2: Spectral plots at fibre output – top is for binary modulation, bottom is for duobinary modulation

	P1 (dBm)	P2 (dBm)	P3 (dBm)	P4 (dBm)
Binary	2.71	2.41	-13.88	-15.77
Duobinary	2.89	2.66	-17.16	-18.21

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 3.78dB in the P3 case and 2.44dB 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 43GHz to 125.4GHz for both the binary and duobinary cases. The results presented in figure 3 show 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 a suppression in FWM product ranging from around 3 dB to around 1 dB, over this range of separations.

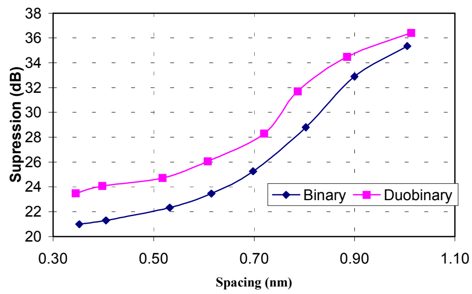


Figure 3: Average supression of FWM products relative to average data channels .

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 3dB 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.

Acknowledgements

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