Improved dispersion tolerance of duobinary optical transmission considering the influence of duobinary filters and optical input power

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Abstract

We consider the efficiency of dispersion compensation to optical duobinary transmission. Considering dispersion compensation of one span we study the influence of transmitter configuration and optical input power to the dispersion tolerance.

Introduction

Several works have shown the benefits of duobinary optical transmission in relation to broadening the transmission distance and increasing the channel efficiency [1, 2]. The intention of duobinary coding is decreasing the optical channel bandwidth to reduce the chromatic dispersion and the distortion of the signal [3]. Furthermore dispersion and self-phase modulation (SPM) limits can be overcome by dispersion management using dispersion compensating fibres (DCF). Several dispersion management schemes for binary transmission have been studied so far [4-7].

In this paper, we will study the influence of dispersion compensation to optical duobinary transmission.

We will study one span and its dispersion compensation. That way we will consider the influence of the duobinary transmitter configuration and the optical input power to the dispersion tolerance after one span.

Simulation model

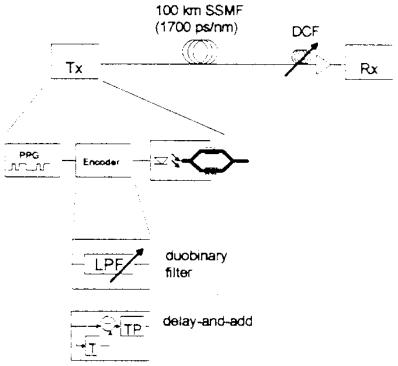

Figure 1: Simulation model

The system model consists of a transmitter, one span and a receiver. The transmitter is an ideal chirp-free Mach-Zehnder modulator in push-pull configuration. It is fully driven by a duobinary or binary signal generating either an AM-PSK duobinary or an IM binary optical signal respectively [8]. The span consists of 100km SSMF followed by dispersion compensating fibre (DCF). The data rate is 10Gb/s. The standard single mode fibre (SSFM) is characterised by an attenuation constant α=0.2dB/km, dispersion D=17ps/(nm·km) at λ=1550nm and nonlinearity coefficient $\gamma=1,62\cdot10^{-3}(Wm)^{-1}$. The DCF is simulated in the linear regime with attenuation constant α=0.5dB/km and dispersion D=-80ps/(nm·km). The receiver consists of a pin diode followed by an electrical filter, that

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is a Butterworth filter, 2nd order, 7GHz bandwidth. The required OSNR at the receiver is set to 25dB at 0.1nm bandwidth. The criterion for specifying the dispersion tolerance is a Q factor larger or equal to 10.

Simulations and results

Influence of duobinary filter:
A duobinary signal can be generated either by a delay-and-add device followed by a band limiting lowpass filter or by an analog duobinary lowpass filter. An analog duobinary filter approximates the transfer function of the main lobe of an ideal bandlimited duobinary filter, which is cosine shaped. That means the spectrum decays to zero smoothly. These characteristics of the transfer function can be realised closely by physically realizable lowpass filters. Therefore using an analog duobinary filter means less effort to realize a duobinary transmitter compared to a delay-and-add device and a lowpass filter with a steep slope.

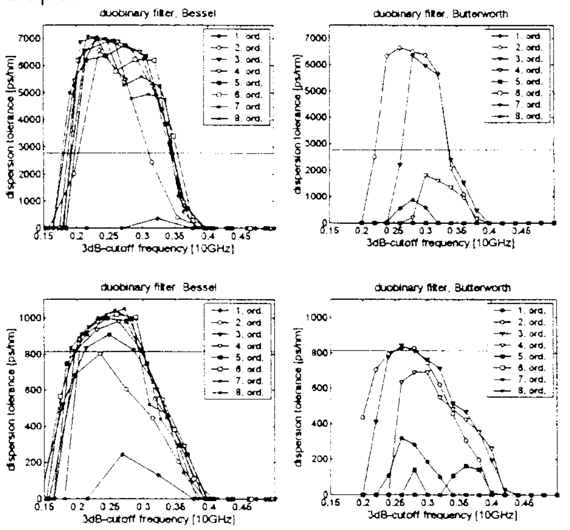

Figure 2: Dispersion tolerance after 100km SSMF varying duobinary filter types, cutoff frequency and order. Left top: duobinary Bessel filters, linear SSMF. Right top: duobinary Butterworth filters, linear SSMF. Left bottom: duobinary Bessel filters, nonlinear SSMF. Right bottom: duobinary Butterworth filters, nonlinear SSMF. The horizontal line is the dispersion tolerance of binary transmission for comparison.

We consider the influence of the filter characteristics to a simple dispersion compensated system. The simulation model consists of a duobinary transmitter, 100km SSMF in the linear regime followed by dispersion compensated fibre of various length. The dispersion tolerance is the range of DCF length, that fulfils the condition $Q \geq 10$. We have considered Butterworth lowpass filters and Bessel lowpass filters for their applicability to generate a duobinary optical signal with maximum dispersion tolerance after 100km SSMF. Their order and cutoff frequency have been varied. The dispersion tolerance of different transmitter configurations are shown in figure 2.

Considering the dispersion tolerance after one span it shows that duobinary transmission more than doubles the dispersion tolerance. Bessel filters are more tolerant to varying the cutoff frequency and order, because of their smoothly decaying slope and linear phase, that is more similar to the ideal duobinary cosine-shaped spectrum. Only Butterworth filters with less order are useful. Otherwise their slope is to steep. The maximum dispersion tolerance is 7080ps/nm in contrast to 2780ps/nm using binary transmission. That means an improvement of more than 150%. The optimized filter is a Bessel filter 7th order with 2.2 GHz cutoff frequency. Figure 2 shows the dispersion tolerance for 18dBm optical input power, too. The SSMF is in the nonlinear regime and the benefit of SPM is not considered. The DCF is still simulated in the linear regime. The characteristics of the curves are the very similar, but the improvement of duobinary transmission in relation to binary transmission is less. The maximum dispersion tolerance is 1050 ps/nm in contrast to 814ps/nm using binary transmission. That means an improvement of 29%. The optimized filter is a Bessel filter 7th order with 2.7 GHz cutoff frequency.

Influence of optical input power:
The dispersion tolerance after 100km SSMF related to optical input power is shown in figure 3. The SSMF is in the nonlinear regime followed by linear simulated DCF. The duobinary filter is a Bessel filter 7th order with 2.2 GHz cutoff frequency.

However the benefit of duobinary transmission in contrast to binary transmission decreases, but still exists, according to increasing optical input power. Considering this effect in the frequency domain we have simulated and measured the power density spectrum after 100km SSMF. The spectrum is widened related to increasing optical input power. We have simulated the power density spectrum of the optical field after 100km duobinary and binary transmission. The bandwidths B90, B95 and B99, that means 90%, 95% and 99% of the power are inside these bandwidth, respectively, are shown in figure 4.

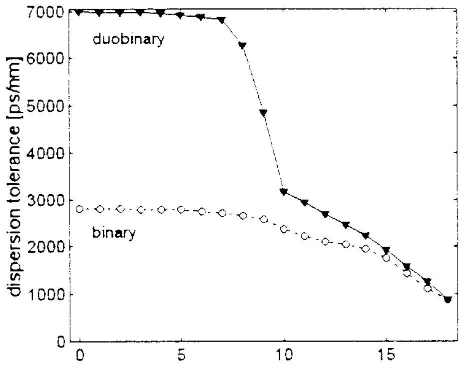

Figure 3: Dispersion tolerance related to optical input power after 100km SSMF.

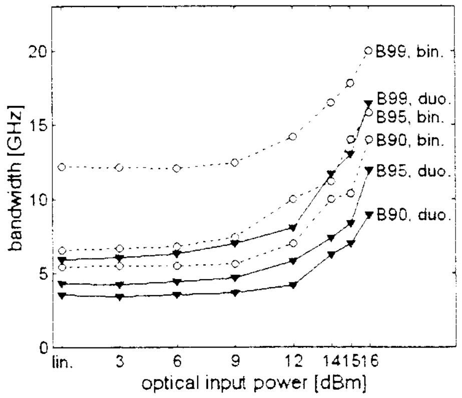

Figure 4: Bandwidth B90, B95 and B99 of the optical field related to optical input power after 100km binary and duobinary transmission, respectively.

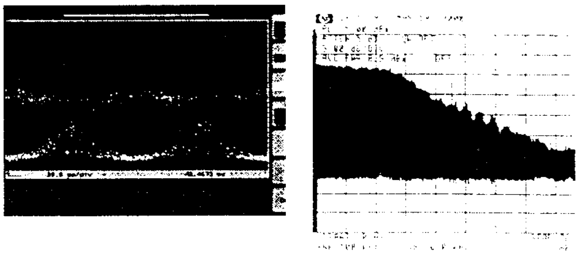

Figure 5: Eye diagram (left) and power density spectrum (right) of duobinary transmission over 100km SSFM with 0dBm optical input power

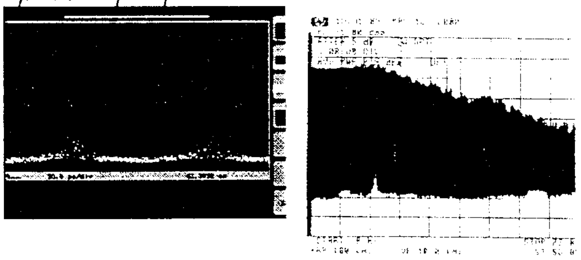

Figure 6: Eye diagram (left) and power density spectrum (right) of duobinary transmission over 100km SSFM with 15dBm optical input power

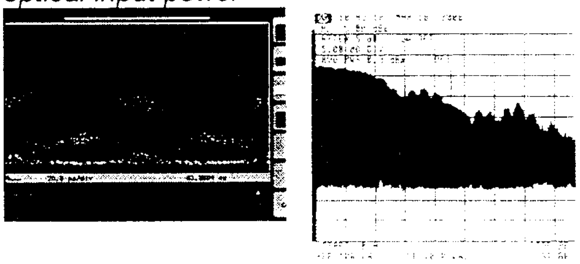

Figure 7: Eye diagram (left) and power density spectrum (right) of binary transmission over 100km SSFM with 0dBm optical input power

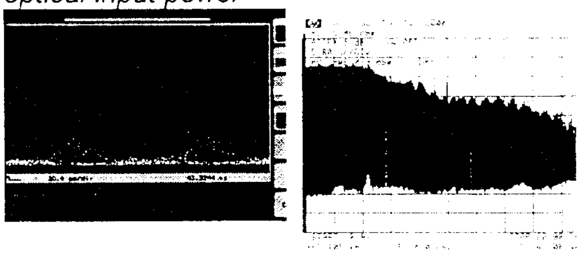

Figure 8: Eye diagram (left) and power density spectrum (right) of binary transmission over 100km SSFM with 15dBm optical input power

The spectral widening is shown in figure 5-8, that shows the spectrum of duobinary and binary transmission after 100km SSMF in linear and nonlinear regime. Although the bandwidth of the duobinary signal is still narrower than of the binary signal the broadening of duobinary is more distinct. B99 of duobinary is less than 50% in the linear regime and it increases to 82% with 16dBm optical input power. The widening of the duobinary spectrum increases more than the binary one and its dispersion tolerance decreases more, too.

Transmission in the linear regime means the spectrum is only phase distorted, therefore the bandwidth is nearly the same. The nonlinear transmission results in increasing bandwidth. This kind of distortion cannot be reversed by DCF in the linear regime, which only reverses the phase distortion.

Conclusion

Duobinary transmission with optimized duobinary filters increases the dispersion tolerance after 100km SSMF up to 150% compared to binary transmission. The spectral bandwidth after 100km SSMF of duobinary transmission widens relatively more with increasing optical input power. This effect decreases according to increasing the optical input power. These results were found by simulations and verified by measurements.

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