1300

PHASE-ENCODED DUOBINARY TRANSMISSION OVER NON-DISPERSION SHIFTED FIBRE LINKS EMPLOYING CHIRPED GRATING DISPERSION COMPENSATORS

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ABSTRACT

High-bit-rate (10Gbit/s, 1.55µm) phase-encoded duobinary transmission over non-dispersion shifted fibre links employing chirped grating dispersion compensators is analysed. A reduced sensitivity to optical nonlinearities allows increased transmission powers and thus distance, 1700km compared to 1000km for the conventional NRZ-format. In addition for typical links around 700km an increased dispersion margin is observed, equivalent to ±60km compared with ±25km for the NRZ format.

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Introduction: Dispersion compensating chirped fibre Bragg gratings are attractive to overcome the limitation of long-haul and high-bit-rate transmission over non-dispersion shifted fibre [1, 2]. In addition, the phase-shifted signalling has been pointed out as a simple technique to bridge the chromatic dispersion limit [4, 5]. The advantages of this 2-level duobinary scheme are that no decoder is needed and a conventional binary IM/DD receiver can be used.

By incorporating phase-shifted duobinary coding, it is possible to increase further the performance of dispersion compensated systems, 10Gb/s transmission up to 700km of standard single mode fibre has been experimentally demonstrated with a grating compensator [3].

In this paper, we compare the impact of self-phase modulation, amplifier noise and dispersion on the performance of dispersion compensated 10Gbit/s systems employing either the binary or phase-encoded duobinary transmission format. The duobinary scheme shows an increased transmission performance and greater dispersion margin than conventional binary format.

System Model: The duobinary transmitter model is shown in Fig. 1. The phase of the wave is coded generating a 2-level intensity duobinary signal. This ideal duobinary scheme does not show any advantage [6], however, by overfiltering the data the energy of the '1' is maintained through propagation thus reducing both the dispersion effect and sensitivity to fibre nonlinearity. Binary coding is simulated by removing the duobinary encoder and changing the filter bandwidth to 10GHz. The inclusion of a narrowband filter (<10GHz) in the binary encoder shows only a slight improvement and is not considered here.

The optically amplified link is made up of 100km sections of fibre with 1700ps/(nm.km) dispersion and 0.2dB/km loss. The effect of nonlinearity for different positions of identical gratings has been studied numerically using the split-step Fourier method. Best performance was obtained when the dispersion is compensated by incorporating a grating every 200km with the first grating at 200km. This is because we are taking advantage of the interplay between dispersion and nonlinearity. The gratings are 20cm long and designed with a hyperbolic tangent apodisation profile to give a dispersion of 3400ps/nm, 95% reflectivity and 3dB-bandwidth of 0.5nm. The combined losses of the grating and circulator (~2dB) are compensated by increased gain in the appropriate amplifiers.

System Evaluation and discussion: The impact of self-phase modulation for binary and duobinary coding is compared in figure 2. In order to understand the effect of nonlinearity and amplifier noise the performance of the binary system with different amplifier noise figures is shown. For low powers (<~2dBm) maximum distances are limited by amplifier noise with binary and duobinary being comparable for the same noise figure. Whereas for high transmission powers (>~4dBm) the maximum distance is limited by nonlinearity and is independent of amplifier noise. Approximately 2dBm higher transmission power can be employed with duobinary transmission thus allowing an increased maximum link length of 1700km compared to 1000km for binary transmission with 6dB noise figure amplifiers.

Figure 3a investigates the eye-opening (EO) penalty versus average launch transmission power for a link of 700km. In each case the last grating at 600km is optimised. It can be seen that the duobinary system is more robust against noise and nonlinearity and increases the dynamic range for 1dB EO-penalty from ~8 to ~11dBm. Figure 3b shows the sensitivity to link-length. The average transmission power is 4dBm and the gratings optimised for 700km. For less than 1dB EO-penalty and binary transmission the link must be matched to ~±25km whereas for duobinary transmission a window of ~±60km is facilitated. This increased margin may be very significant in switched networks.

Conclusion: By using a simple phase-shifted duobinary coding technique the linearly-chirped fibre grating dispersion compensated system has increased noise immunity, bit-rate-length-product and flexibility in design. For a 10Gb/s transmission system and grating compensators each 200km, an improvement of 70% of transmission length of standard fibre has been shown compared with the conventional NRZ binary signal.

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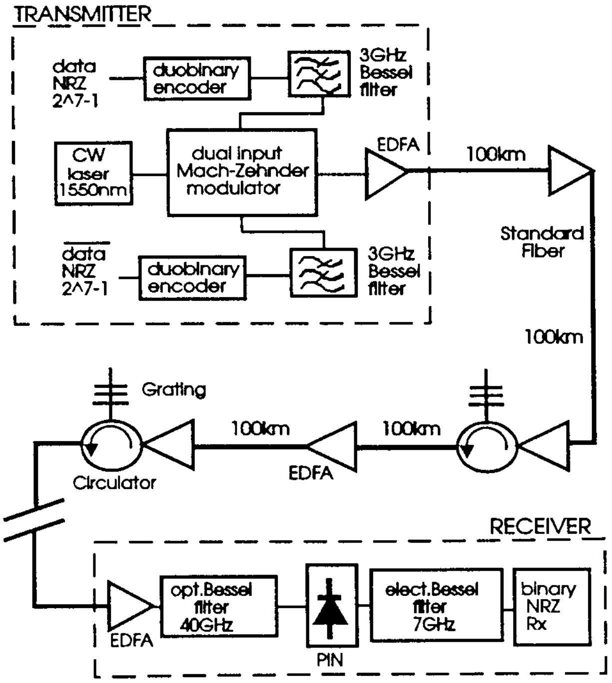
LIST OF THE CAPTIONS

Figure 1: System configuration of 10Gb/s digital transmission over non-dispersion shifted fibre. EDFA: erbium-doped fibre amplifier with 6dB noise figure.

Figure 2: Maximum fibre length for 1dB eye-opening penalty vs. average fibre input power for 10Gb/s transmission of binary and phase-encoded duobinary coding. NF : Noise figure of the optical amplifier.

Figure 3: Comparison of the performance of a binary and a phase-encoded duobinary 700km dispersion compensated standard fibre link. (a) Eye-opening penalty vs. average fibre input power and (b) eye-opening penalty vs. fibre length for 4dBm average input power.


TRANSMITTER
data
NRZ
2^7-1
duobinary encoder
3GHz Bessel filter
CW laser 1550nm
dual input Mach-Zehnder modulator
EDFA
100km
Standard Fiber
data
NRZ
2^7-1
duobinary encoder
3GHz Bessel filter
100km
Grating
100km
100km
Circulator
EDFA
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EDFA
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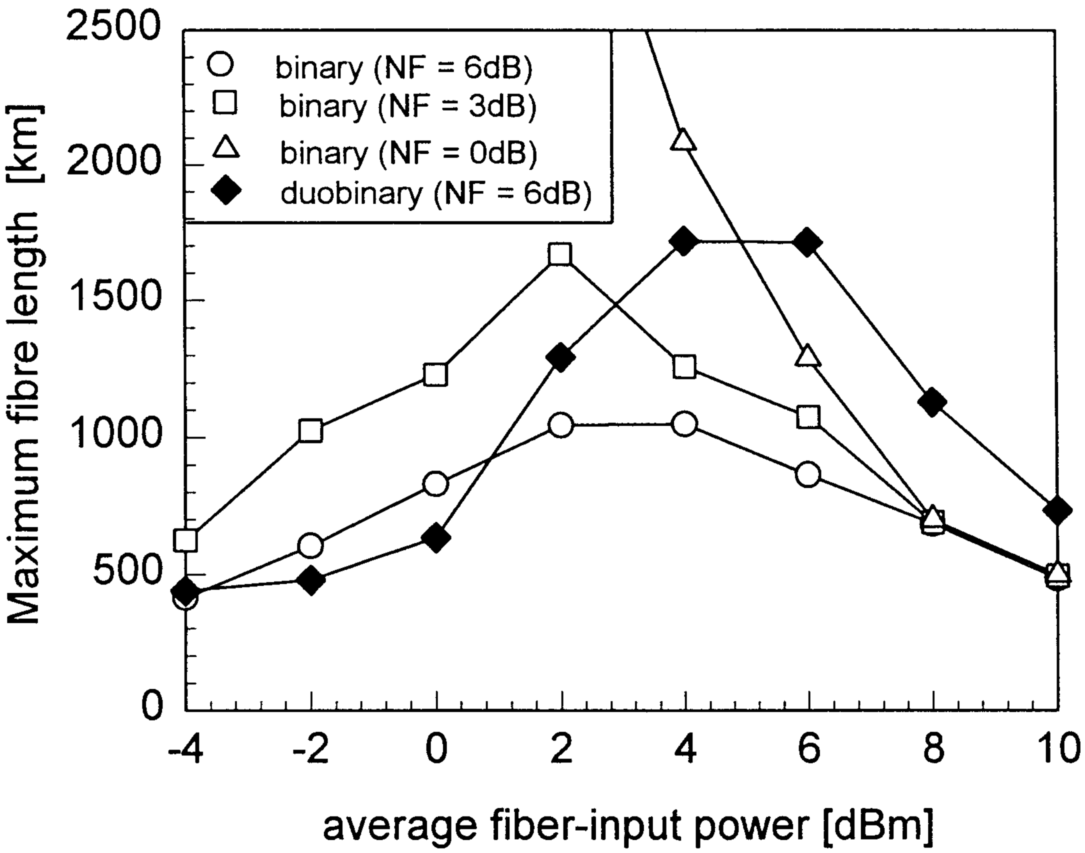
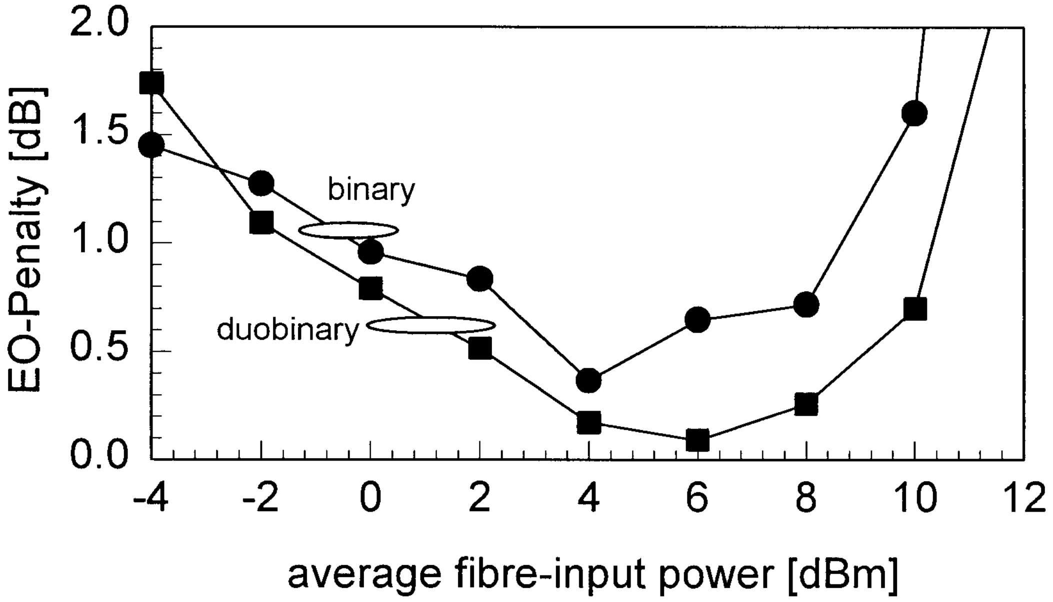
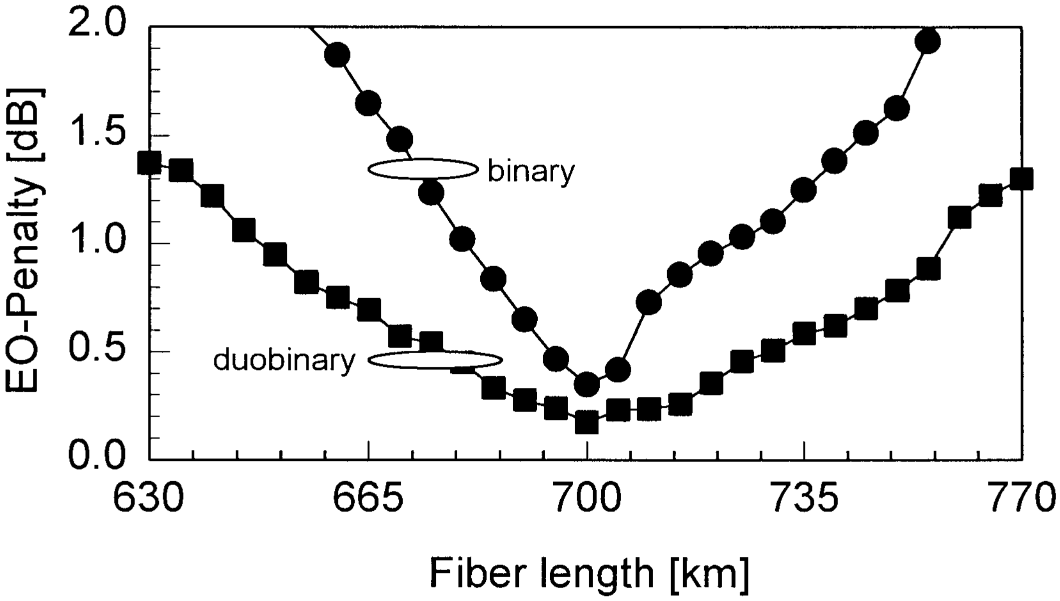
PIN
elect.Bessel filter 7GHz
binary NRZ Rx



2500
2000
1500
1000
500
0
Maximum fibre length [km]
○ binary (NF = 6dB)
□ binary (NF = 3dB)
△ binary (NF = 0dB)
◆ duobinary (NF = 6dB)
-4
-2
0
2
4
6
8
10
average fiber-input power [dBm]



EO-Penalty [dB]
2.0
1.5
1.0
0.5
0.0
binary
duobinary
-4
-2
0
2
4
6
8
10
12
average fibre-input power [dBm]



EO-Penalty [dB]
2.0
1.5
1.0
0.5
0.0
binary
duobinary
630
665
700
735
770
Fiber length [km]