1320

OPTIMIZATION OF LINEARLY CHIRPED GRATING DISPERSION COMPENSATED SYSTEMS

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ABSTRACT

The optimum design for a 10Gb/s NRZ chirped fibre grating dispersion compensated system operating at 1.55μm over standard fibre is investigated. The study considers self-phase modulation, dispersion, modulator chirp and amplifier noise. Transmission over 1700km of fibre may be achieved by incorporating gratings every 200km and optimising the modulator chirp.

Short running head: *Optimization of grating dispersion compensated systems*

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1. INTRODUCTION

The key factors in the design of ultrahigh speed long span transmission are fibre dispersion, nonlinearity and losses as well as amplifier noise. Fibre loss is suppressed with optical amplifiers, such as the Erbium-doped fibre amplifier (EDFA), operating in the lowest loss region of the fibre (1.55μm). However, in this wavelength range the majority of installed standard fibre has a dispersion of 17ps/(km.nm). Many dispersion equalization techniques such as dispersion compensating fibre, chirped fibre Bragg gratings, midpoint spectral inversion and transmitter prechirp have been proposed to overcome this limitation.

Chirped fibre gratings provide a simple and attractive optical fibre delay, which is polarisation-insensitive, inherently fibre compatible, relatively easy to produce, passive and low-loss. Several experimental and theoretical investigations have shown their potential for dispersion compensation [1-5], but no full analysis of the optimum grating arrangement considering nonlinear effects, amplifier noise and grating bandwidth has been reported. Here we evaluate the impact of Self-Phase Modulation (SPM) in different configurations of dispersion compensated systems. The deterioration caused by the amplifier noise and the limitation of the grating bandwidth are discussed. The effect of the pre-chirp on the data propagation is also studied.

2. SYSTEM DESIGN

An IM/DD 10Gb/s single-channel system is investigated. A 2^7-1 pseudo-random test pattern is employed and the NRZ-format data generated using a push-pull Mach Zehnder modulator with an adjustable chirp. The standard fibre is characterised by a dispersion of 17ps/(nm.km) with dispersion slope of 0.08ps/(nm^2.km), attenuation of 0.2dB/km and non-linear coefficient of 1.31($W.km^{-1}$). Loss of the fibre, grating and circulator(~2dB) are compensated by 6dB noise figure in-line amplifiers. The linearly chirped fibre Bragg grating transfer function is calculated by solving the coupled-mode equations [6]. The grating is designed with a hyperbolic tangent apodisation profile and to give 95% peak reflectivity. At the receiver, the signal is optically filtered by a 40GHz bandwidth Bessel filter, before being detected and electrically filtered by a 7GHz Bessel filter. The eye-opening penalty is evaluated with respect to the back-to-back sensitivity.

2.1 Position of the Grating and Self-phase Modulation

The system layout is illustrated in Fig.1. Each dispersion equalizer enables compensation of ~100km of standard fibre. The length of the grating is 10cm with a 3dB bandwidth of 0.5nm. Three different arrangements of cascaded gratings are considered. Depending on the position of the first grating, we classify them as pre-, mid- or post-system. The grating is designed to slightly undercompensate the dispersion and consequently, the average dispersion is non-zero.

Evaluation of the maximum link length as a function of launch power is shown in Fig.2. At low input powers,the amplifier noise limits transmission whereas for high powers non-linearity is the limitation. Operation of the system relies on the interplay between SPM and group-velocity dispersion (GVD) during the propagation. This can be interpreted by analysing the average dispersion. For the pre-system, because of the negative value of the average dispersion, no modulation instability is taking place to compress the pulses optically and the nonlinearity badly affects the signal. On the contrary, for the mid- and post-system the phenomenon clearly improves the transmission. For launched powers greater than +6dBm, the post-system has a higher dispersion compensating potential compared with the mid-system.

An important concern is to balance the cost and efficiency of the system design. To half the number of circulators and gratings, a 20cm long grating with a 0.5nm bandwidth is considered (see Fig.3). The amplifier spacing is maintained at 100km. Because of the long equalizer spacing (200km), the accumulated amplifier noise affects similarly the mid- and post-system for less than +6dBm input power. Again the post-system scheme was found to be less sensitive to nonlinearity and over 1000km may be reached.The system is degraded compared to gratings every 100km.

2.2 Bandwidth of the Grating

Another important point is the grating bandwidth. The longer the grating, the larger its bandwidth for a given dispersion. An 80cm, 2nm bandwidth grating is able to compensate 200km and has been evaluated for the post-system. The results are plotted in Fig 4. For less than 2dBm average input power, the 80cm grating performance is worse than with 20cm gratings of similar dispersion. This is because the reduced bandwidth of the 20cm gratings acts as in-line filters reducing the amplifier noise. For larger input powers 2dBm to 8dBm, the larger bandwidth, 80cm device gives better performance due to spectral spreading of the data and a fibre span of almost 1400km for less than 1dB eye-closure penalty may be reached.

Transmitter laser wavelength drift is not considered in the present analysis and it may limit the product bitrate-length of the communication system. Efforts are under way to fabricate long and wide bandwidth gratings. Recently linearly chirped gratings up to 400mm in length [7] have been demonstrated. The technique enables the fabrication of arbitrary length gratings in a certain wavelength span.

2.3 Modulator Chirp Parameter

The influence of the modulator chirp with SPM is shown in Fig. 5. The considered set up is the post-system with 20cm long gratings at each 200km. The negative value of the modulator chirp has a beneficial effect on the propagation, while the positive chirp parameter reduces the quality of the transmission. An appropriate chirp parameter can improve by more than 70% the maximum fibre length compared to unchirped transmission for a large range of launched power. The use of a prechirp technique has been shown experimentally [8].

3. CONCLUSION

We have investigated different equalizer spacings and arrangements using linearly-chirped grating dispersion compensators for a single-channel 10Gbit/s NRZ-system operating at 1.55μm over standard fibre. Considering the state-of-art of grating fabrication technology, the best design for 10Gb/s over 1000km is a grating dispersion compensator spacing of 200km and the post configuration. Reducing the equalizer spacing to 100km increases cost, but allows distances up to 1700km to be bridged. Alternatively a negative chirp parameter can increase the fibre span to 1700km.

ACKNOWLEDGEMENTS

K.Ennser acknowledges the Brazilian Council (CNPq) for financial support. This work was partially supported by Pirelli Cavi SpA. The ORC is an EPSRC funded interdisciplinary research centre.

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LIST OF THE CAPTIONS

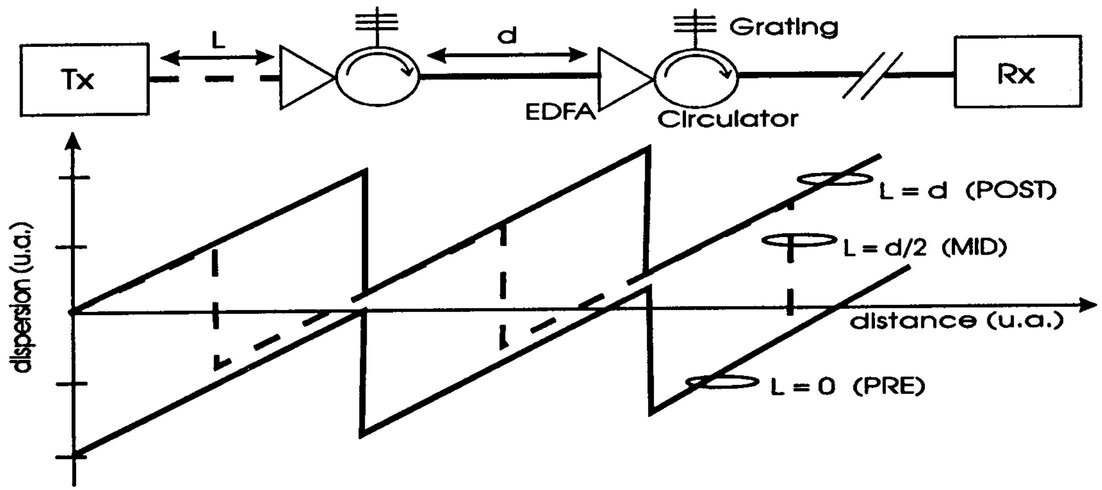
FIG. 1: System layout and dispersion compensating map of three different schemes.

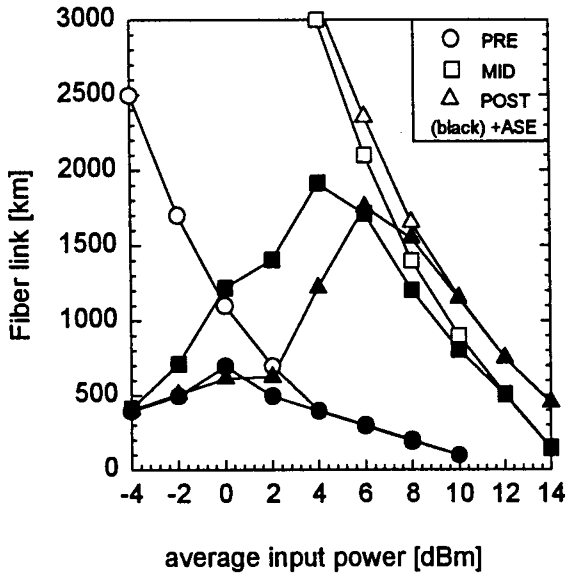
FIG. 2: Maximum fibre length for 1dB eye-opening penalty vs.average fiber-input power for pre-, mid- and post-system with and without amplifier noise (ASE). Equalizer and amplifier spacing is 100km.

FIG. 3: Maximum fibre length for 1dB eye-opening penalty vs. average fibre-input power for pre-, mid- and post-system with and without amplifier noise (ASE). Equalizer and amplifier spacing are 200km and 100km, respectively.

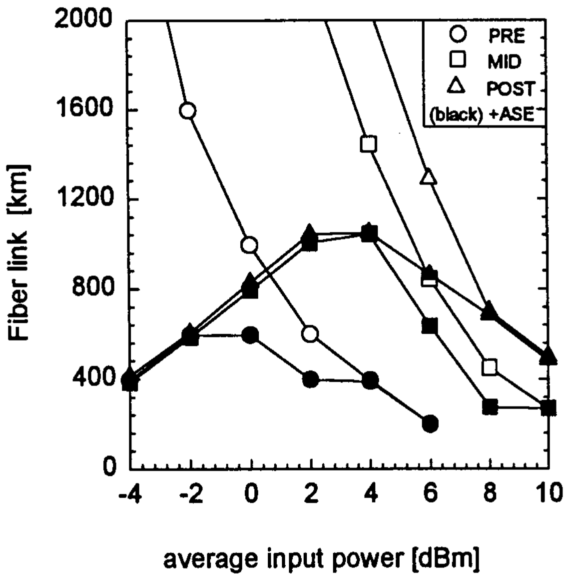
FIG. 4: Maximum fibre length for 1dB eye-opening penalty vs. average fiber-input power for post-system. Grating lengths (Lgr) are 20cm and 80cm with 0.5nm and 2nm bandwidth, respectively.

FIG. 5: Maximum fibre length for 1dB eye-opening penalty vs. average fibre-input power for post-system. Alfa is the modulator chirp parameter.


Tx
L
d
Grating
Rx
EDFA
Circulator
dispersion (u.a.)
L = d (POST)
L = d/2 (MID)
distance (u.a.)
L = 0 (PRE)



PRE
MID
POST
(black) +ASE
Fiber link [km]
3000
2500
2000
1500
1000
500
0
-4
-2
0
2
4
6
8
10
12
14
average input power [dBm]



PRE
MID
POST
(black) +ASE
Fiber link [km]
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1600
1200
800
400
0
-4
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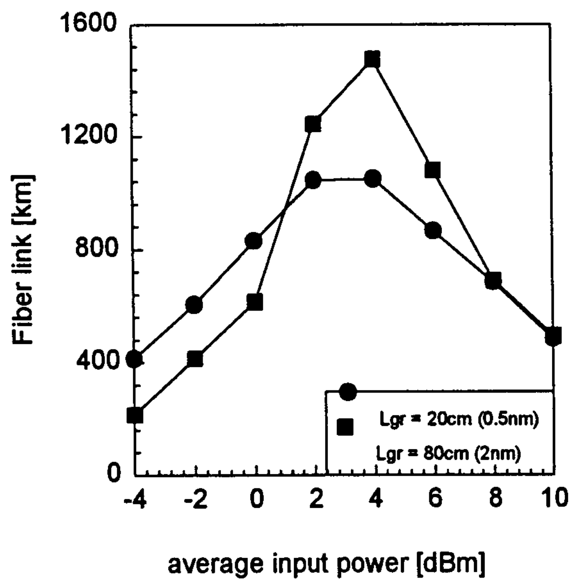
8
10
average input power [dBm]



1600
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0
-4
-2
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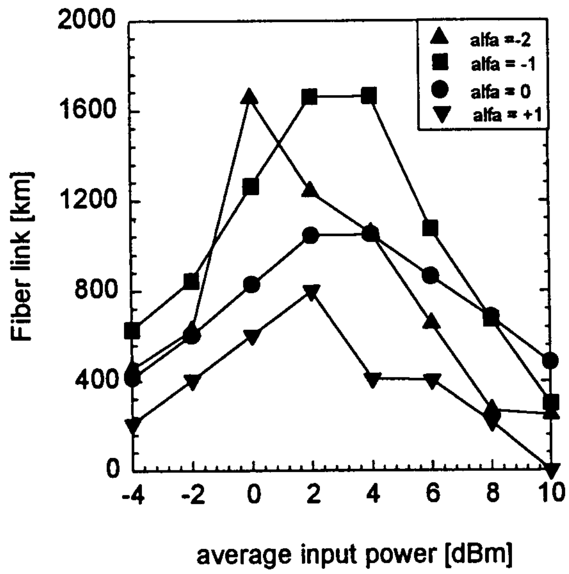
Fiber link [km]
average input power [dBm]
Lgr = 20cm (0.5nm)
Lgr = 80cm (2nm)



2000
1600
1200
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400
0
-4
-2
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2
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6
8
10
Fiber link [km]
average input power [dBm]
alfa =-2
alfa = -1
alfa = 0
alfa = +1