Pulsed laser source coherence time impairments in a direct detection DS-OCDMA system

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Abstract: We investigate the impact of laser source coherence time on bit error rate (BER) and autocorrelation function performances of a direct sequence OCDMA system. Congruence codes are suggested to reduce the observed coherence effects.

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1. Introduction
The autocorrelation function of a DS-OCDMA system operating with a broadband light source has been previously analyzed. In that work, the function is considered as the sum of optical powers of all combined chip pulses of the code [1]. In the direct detection DS-OCDMA system considered here, we show that we have to take into account the coherence time of the used pulsed laser source. First, we present some BER measurements at bit rate 1.25 Gbps per user and we notice that these measurements depend on the light’s polarization state. Second, we show that the laser source coherence time effects influence the code generation especially for periodic codes and consequently the autocorrelation function reconstruction which has to be considered as the sum of complex amplitudes of the combined chip pulses. Finally, we present some solutions to reduce the sensitivity of the DS-OCDMA system to the perturbations induced by the source coherence time.

2. BER measurements
Periodic Prime Sequence (PS) codes C_{1}(100010001) and C_{2}(100100100) are implemented by Sampled Fiber Bragg Grating: S-FBG_{1} and S-FBG_{2}. The encoding is performed in time domain. Each data pulse is splitted into a code pulse sequence upon multiple reflections from the three BGs of a S-FBG device [2].

Fig 1. (a) Experimental setup with 2 multiplexed users. (b) BER measurements vs. received optical power: (i) back to back, (ii) single user case, (iii) two user asynchronous case.

A BER experimental setup has been performed (Fig. 1a). It consists of a 1551 nm CW DFB laser associated to an Integrated eLectro-absorption Modulator (ILM) driven by a 10 GHz pulse signal, which allows the laser to operate in a pulse regime. The resulting 50 ps pulse train is RZ modulated by an electro-optic modulator (EOM 1) at 1.25 Gbit/s data rate per user. The RZ 1.25 Gbps signal is then modulated with a PRBS signal by a second electro-optic modulator (EOM 2). The resulting pulse train is amplified and encoded separately by S-FBG_{1} and S-FBG_{2}. The resulting signals are superimposed and transmitted to the matched S-FBG_{1} decoder. The bandwidth of the receiver is set to the chip rate. BER measurements are displayed in Fig. 1b. In the single user case, pulses are properly encoded and decoded. There is approximately less than 3 dB penalty at BER = 10^{-3} as compared to the back to back case. In the two user asynchronous case, the desired (S-FBG_{1}) and the interferer (S-FBG_{2}) users send their pulses to the decoder. A BER < 10^{-3} is obtained with low penalty (2 dB) compared to the single user case. For these
BER measurements, the autocorrelation function corresponds to a matched decoding and presents a main peak with lower optical power sidelobe. It should recover primary and secondary sidelobes with optical power equal respectively to 2/3 and 1/3 of the main peak power (Fig. 2a).

![Fig. 2](image)

(a) Measured and predicted autocorrelation function for the BER measurements, (b) and (c) Measured autocorrelation functions with coherence time effects.

3. Laser source coherence time effects

Let us note that BER measurements have been performed by carefully controlling the light polarisation state at the input of the decoder. Namely, the encoder/decoder is sensitive to the light polarisation state as it acts as a multipath interferometer. This is due to the fact that the incident pulse width \( T_p \) equal to the chip duration \( T_c = 50 \) ps is much less than the CW laser source coherence time \( T_c = 1 \) µs and of the same order of magnitude of the receiver bandwidth \( T_B = 100 \) ps. In such conditions, the encoded pulses remain phase correlated and optical interferences are observed.

When \( P \) is injected at the encoder input, optical powers \( P_1, P_2, P_3 \) are reflected from each grating, where \( P_3 = P_1 P_2 P_3 \), with \( P_1 \) and \( P_2 \) being reflected optical powers of the third pulse and the secondary reflected pulse due to the Fabry-Perot cavity between \( B_G_1 \) and \( B_G_2 \). The interaction between the fields associated to \( P_1 \) and \( P_2 \) within the chip duration leads to a third pulse which can take two extreme optical power \( P_{max} \) and \( P_{min} \). The code pulses pass through the decoder and generate three different sequences superimposed with different delay times (Fig. 3). The resulting destructive and constructive optical interferences within the chip duration lead to the autocorrelation function displayed on Fig. 2b. The main autocorrelation peak can even be less than sidelobes (Fig. 2c). The coherence time of the laser source leads to a complex envelope autocorrelation function.

To improve performances of the system, the source coherence time may be reduced (\( T_c \approx T_p \approx T_D \)) to combine incoherently the encoded pulses. As another solution, we suggest to use longer and sparser aperiodic Quadratic and Extended Quadratic Congruence codes. For these codes, the distance between chips to one is never the same. They present better auto/cross-correlation properties than those of the PS codes [3]. Using QC or EQC codes, the chips are no more be combined with multiple reflected pulses which leads to codes less sensitive to coherence time effects. Consequently, the coherence time effects are reduced as the pulse number to be combined within the chip duration is less. Experiments with QC and EQC codes are currently under investigation and will be presented in future works.

4. References

