Long Haul Transmission of Optical Minimum Shift Keying Format

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Abstract

We performed the first long-haul transmission experiments with optical minimum shift keying format (MSK). Single channel 10Gbit/s MSK transmission was achieved over 6400 km of standard single mode fiber.

Introduction

Advanced optical modulation formats for high-capacity WDM systems like QPSK, 8-PSK and 16-QAM have drawn a lot of attention in the last few years. In spite of their higher complexity, they promise to carry more information at lower costs over longer distances because of their enhanced bandwidth efficiency.

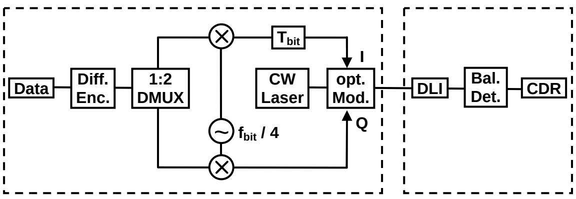
Although MSK is approved for a long time in wireless communications being a good compromise between spectral efficiency, robustness and complexity [1], the transmission properties of optical MSK have not yet been studied extensively, not least because optimal transmitter and receiver implementation is still an open issue [2-4].

Relying to a great extent on simulation, previous publications point out the good spectral efficiency of optical MSK and its high tolerance against fiber dispersion and nonlinearity [5].

In this paper, we focus on the long-haul transmission properties of optical MSK. For the first time, single channel transmission of a 10 Gbit/s optical MSK signal is demonstrated over 6400 km of standard single mode fiber in a recirculating loop setup.

Principle of operation

Fig. 1 shows the principle of the proposed optical MSK transmitter and receiver. In the transmitter, data is differentially encoded and demultiplexed.



a **b**

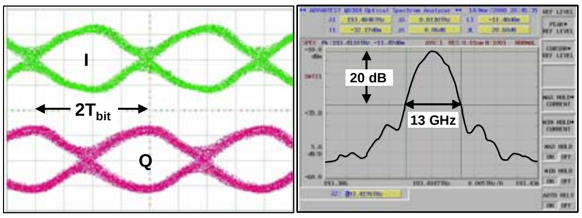
Figure 1: Principle of optical transmitter (a) and receiver (b) for optical MSK

The resulting halfrate bitstreams are multiplied with sinusoidal signals of quarter bit frequency to form the driving signals of an optical IQ-modulator. The I-branch is delayed by a bit duration to drive the optical IQ-modulator by sine halfwaves with a 90° phase deviation. In contrast to the transmitter configuration proposed in [5], the sinusoidal weighting is less complex because it is performed electrically.

The receiver is the same as for optical DPSK [6]. It consists of an optical delay line interferometer (DLI) with a delay of one bit duration, a balanced detector and a clock and data recovery (CDR) for bit decision.

Experimental Setup

For simplicity of the experimental setup, a PRBS-7 is chosen as data source, and the electrical signals in the transmitter were generated directly by a Tektronix AWG 7102 Arbitrary Waveform Generator with 20 GS/s plus external splitter and delay line. Measured eye diagrams of the modulator driving signals and the optical spectrum of the implemented MSK transmitter are shown in Fig. 2.



a **b**

Figure 2: Measured driving signals (a) and optical spectrum (b) of implemented MSK transmitter

The clear eye diagrams for the I and Q branch show the good signal quality of the switched 2.5 GHz sine halfwaves and the characteristic delay of one bit duration between the modulator branches. The optical spectrum exhibits a 20 dB bandwidth of only 13 GHz.

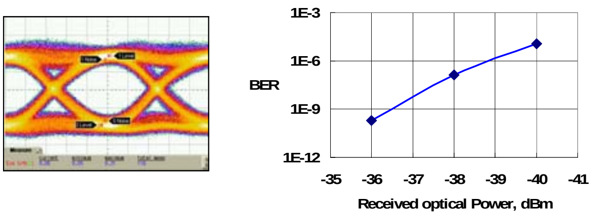


Figure 3: Back-to-back experiments: Eye diagram after balanced detection and BER vs. Rx-power

In back-to-back experiments (see Fig. 3), the receiver with optical preamplifier, Optoplex DLI, u2t balanced

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detector and Maxim CDR with limiting amplifier required a received optical power of -36.5 dBm for a BER of 10^{-9} corresponding to an OSNR of 18 dB.

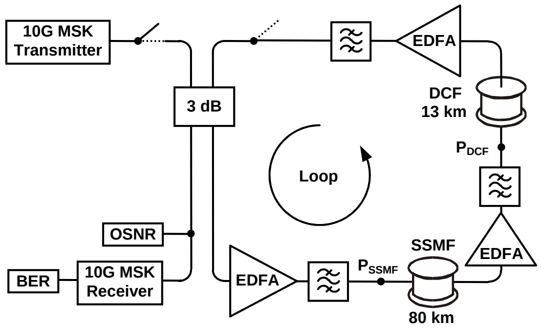

Figure 4: Recirculating loop setup to investigate the long-haul transmission properties of optical MSK

Fig. 4 shows the recirculating loop setup to investigate the long-haul transmission properties of optical MSK. The loop was composed of 80 km standard single mode fibre (SSMF) and a dispersion compensating fibre (DCF) which fully compensates for the chromatic dispersion of the SSMF.

To control the fiber launch power, an erbium-doped fiber amplifier (EDFA) is placed in front of each fibre section. An additional EDFA compensates for the loss of the loop switch and optical bandpass filters and keeps the loop gain at unity.

While no change in the measured BER was found varying the launch power into the DCF from -7 to -3 dBm, an optimum launch power into the SSMF was identified for a certain transmission distance. This reflects the best compromise between limitations by noise and fibre non-linearity. Fig. 4 shows BER vs. launch power into the SSMF for a transmission distance of 4000 km (50 loops).

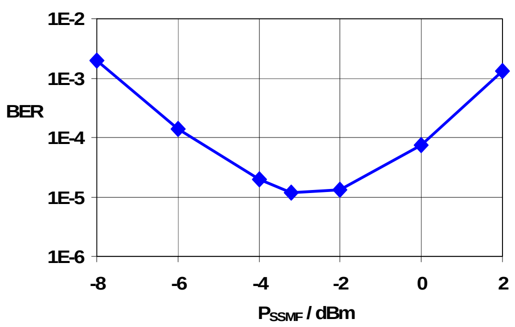

Figure 5: BER vs. launch power into SSMF for a transmission distance of 4000 km (50 loops)

The graph shows an optimum SSMF launch power of about -3 dBm. For shorter transmission distances the optimum launch power is higher because the overall non-linearity of the link is reduced.

To evaluate the maximum transmission distance which can be bridged in the loop setup with the chosen implementation of transmitter and receiver for optical MSK, the launch power into the SSMF was tuned to an optimum value of -3.2 dBm; the launch power into the DCF was kept at -6.5 dBm.

BER vs. transmission distance, depicted in Fig. 6, was measured by evaluating the BER performance for different numbers of loop round trips (25 – 80).

The graph shows that even for a distance of 6400 km a transmission below FEC threshold (BER of about 10^{-3}) is feasible.

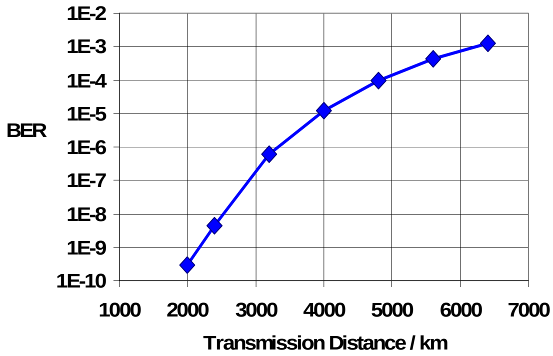

Figure 6: Long-haul transmission of a single 10 Gbit/s MSK channel, BER vs. transmission distance

Conclusion

Long-haul transmission of optical MSK has been successfully demonstrated in a recirculating loop setup. A single channel at a data-rate of 10 Gbit/s has been transmitted over 6400 km of standard single mode fibre without optimisation of the dispersion map. The very narrow spectrum of the generated optical MSK signal makes it a promising format for WDM systems with high spectral efficiency and moderate complexity.

References

1. S. Pasupathy, “Minimum Shift Keying: A spectral efficient modulation”, *IEEE Comm. Mag.*, Vol. 17, No. 4, July 1979, pp. 14-22
2. J. Mo et al, ”Optical minimum-shift keying modulator for high spectral efficiency WDM systems”, *ECOC 2005*, Th 1.2.3
3. T. Sakamoto et al, “Initial phase control method for high-speed external modulator in optical minimum-shift format”, *ECOC 2005*, Th 2.2.5
4. Y. Dong et al, “Generation of 16-Gb/s MSK signal using a single 10-GHz SSB modulator and simplified encoder/decoder”, *OFC 2006*, JTHB40
5. J. Mo et al, “Externally Modulated Optical Minimum Shift Keying Format”, *JLT*, Vol. 25, No. 10, October 2007, pp. 3151-3160
6. M. Rohde et al, “Robustness of DPSK direct detection transmission format in standard fibre WDM systems”, *Electron. Lett.*, Vol. 36, No. 17, August 2000