DPSK-Labeled Direct-Detected Optical OFDM Transmission

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Abstract: We propose the generation, detection, and label swapping methods for DPSK-labelled OFDM transmission. Without increasing the signal bandwidth, we show the attached label has almost no influence on the superior performance of OFDM payload.

OCIS codes: (060.2330) Fiber optics communications; (060.4080) Modulation

1. Introduction

Optical OFDM has been treated as a serious candidate for next-generation metropolitan networks or long-haul transmission systems due to its strong tolerance against various linear impairments [1-2]. Within the topics of OFDM, the direct-detected approach (DD-OFDM) [1,3], using simpler hardware implementations and less complex signal processing algorithms, has became an alternate low-cost choice other than the coherent approach (CO-OFDM) [2].

On the other hand, optical packet switching (OPS) technique provides a new capability to address the input packets directly in the optical layer [4] and has been proposed as a promising scheme for future IP-over-WDM network due to the benefit of statistical multiplexing [5]. To combine the advantages of superior transmission performance and all-optical packet forwarding, using DD-OFDM payload in OPS technique would be a laudable goal for future high-quality transmission network. However, the OPS technique needs an extra optical label for routing purpose which should be easily attached to and detached from the payload. Unfortunately, as far as the author's knowledge, there has been no relevant labelled OFDM proposal to date.

In this paper, we demonstrate the DPSK-labelled OFDM generation, detection, and the label swapping techniques, which enables the use of OFDM in OPS network. Without increasing the signal bandwidth, we show that the attachment of the PSK label has almost no influence on the OFDM payload in terms of its receiving sensitivity and CD tolerance. We verify our proposal by transmitting 4-QAM, 20-Gbps OFDM payload with 156-Mbps DPSK label through ~600-km standard single mode fibre (SSMF).

2. Transmitter, Receiver, and Label Swapping Methods

Shown in Fig. 1(a) is the transmitter of the proposed DPSK-labelled OFDM signal. The typical gapped OFDM signal is generated with an optical I/Q modulator [1, 3]. The electrical OFDM waveform and the output spectrum are shown as the inset (i) and (iii), respectively. The frequency gap between the carrier and sideband is reserved for the beat interference [1, 3]. The output signal is then sent to the phase modulator (PM) for further DPSK label encoding. The waveform of input DPSK label and the output spectrum of PM are shown in insets of (ii) and (iv), respectively. The DPSK label symbol duration should be equal to the OFDM symbol duration, and synchronized with the OFDM payload. From the optical spectrum in inset (iv), we found only the carrier has been broaden due to DPSK

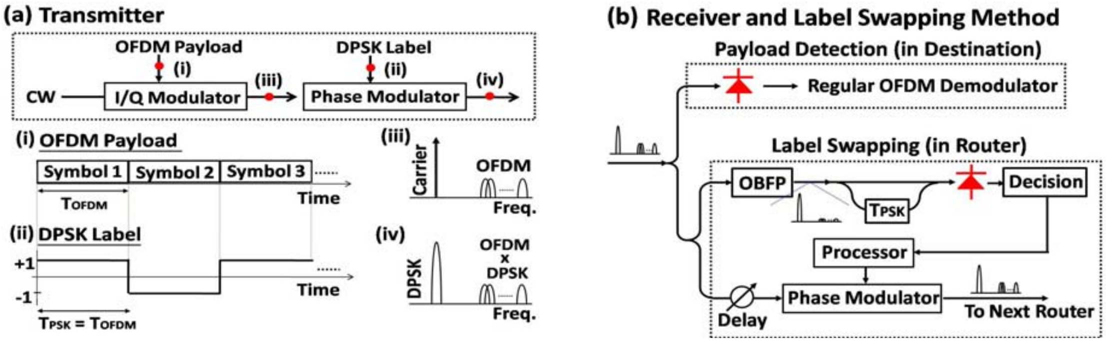

Fig. 1. (a) Transmitter of the DPSK labelled OFDM, and (b) payload detection in destination and the label swapping technique in the router.

modulation and the sideband spectrum has been left still, thus retaining the original signal bandwidth.

At the receiver, as shown in Fig. 1(b), only one photodiode is needed for payload detection since the phase-encoded label information would be completely removed out with the power detection nature of photodiode. For label swapping, the label will be firstly extracted by an optical filter centred at the optical carrier and sent to the delay interferometer (DI) for DPSK detection. The decisions are then processed to generate an updated label information to replace the payload's original label via a PM. With such a technique, the label on the payload could be repeatedly attached and detached throughout the routing transmission.

3. Results and Discussions

To test its performance we setup a numerical model of 4-QAM, 20-Gb/s OFDM payload with 156-Mbps DPSK label. Fig. 2 shows the received Q factors of both the payload and label versus the carrier to sideband power ratio (CSPR). The Q factor is defined as the ratio between the averaged symbol distance and the standard deviation of noise, which could be found with its rigorous definition in [1]. A Q factor of 9.8 dB matches to a bit error rate (BER) of ~10^{-3}. The receiving OSNR is fixed at ~18 dB and the noise bandwidth is ~0.1 nm throughout this paper. The laser linewidth (LLW) is set at 5 MHz without losing the generality. Due to the lower data rate, the label performance is much better than the payload and shows insensitive to CSPR; whilst the OFDM payload has an optimum value at CSPR = 0 dB. Therefore, we take CSPR = 0 dB for the following simulations since it optimizes the payload without sacrificing the label performance.

In Fig. 3 we investigate the influence of the label's symbol rate on its back to back performance and the payload's maximum transmission distance[6]. The higher symbol rate of the DPSK label is found to have a better performance since it reduces the variance of phase noise for the given 5-MHz LLW [7]. However, the higher symbol rate corresponds to a shorter symbol duration which will reduce the maximum transmission distance for OFDM payload [6]. This trade-off between a better label performance with a higher symbol rate and a longer maximum payload's transmission distance could be obviously observed via Fig. 3.

Fig. 4 shows the CD tolerance of the DPSK labelled OFDM signal. The fibre used in modelling is linearly dispersive with a dispersion parameter of D = 16 ps/nm.km and the cyclic prefix (CP) supported distance of the OFDM payload is ~400 km. With LLW = 0 Hz we found the payload performance has been almost unchanged for distance of up to 400 km, which is sustained by the applied CP; while with LLW = 5 MHz, the payload performance has gradually degraded with distance since the accumulated CD will induce relative phase noise between the carrier and data subcarrier when LLW becomes significant. One great benefit of this labelled payload is the attached label doesn't hurt the payload's receiving sensitivity or the CD tolerance, as depicted in Fig. 4. As for the DPSK label, due to its relatively lower data rate, the considered maximum 600 km fibre still has no influence on the label's performance.

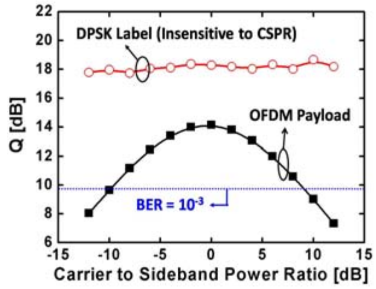

Fig. 2. Q factors of 156-Mbps label and 4-QAM, 20-Gbps payload versus the carrier to sideband power ratio (CSPR). Laser linewidth (LLW) = 5 MHz.

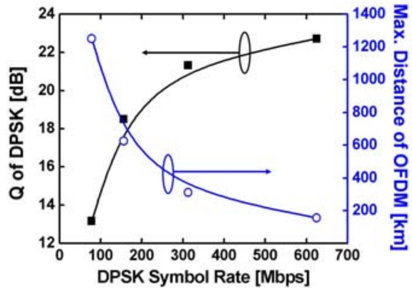

Fig. 3. Q factor of DPSK label and the maximum achievable distance (D=16 ps/nm.km) of OFDM payload with a function of the label symbol rate. The OFDM payload is with 4 QAM and 20 Gbps, and LLW = 5 MHz.

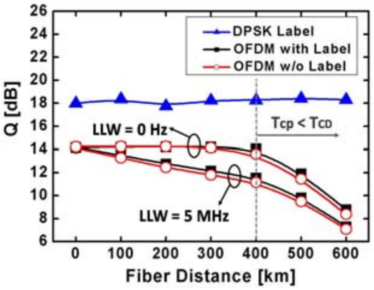

Fig. 4. Q factors of 156-Mbps DPSK label and 4-QAM, 20-Gbps OFDM payload versus fiber distance (D = 16 ps/nm.km). LLW: laser linewidth.

References

[1] B. J. C. Schmidt et al., J. Lightwave. Technol., **26**, pp. 196, 2008.
[2] W. Shieh, Proc. OFC'09, Paper OWW1.
[3] W. R. Peng et al., Proc. ECOC'08, Paper Mo3.E.6.
[4] D. J. Blumenthal et al. J. Lightwave Technol., **18**, pp. 2058, 2000.
[5] C. Qiao et al., Comm. Magazine, **38**, pp. 104, 2000.
[6] W. R. Peng et al. Proc. LEOS'08, Paper MH2.
[7] A. H. Gnauck et al., J. Lightwave Technol., **23**, pp. 115, 2005.