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Experimental Demonstration of Optical Colorless Direct-Detection OFDM Signals with 16- and 64-QAM Formats beyond 15 Gb/s

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Abstract

Both highly spectral-efficient direct-detection 15-Gb/s 64-QAM and 20-Gb/s 16-QAM OFDM signals are demonstrated. Negligible penalty is observed following 25-km SMF transmission.

Introduction

Combination of orthogonal frequency-division multiplexing (OFDM) and radio-over-fiber (RoF) systems (OFDM-RoF) has attracted considerable attention for future broadband wireless access (BWA) for high speed data and video services beyond 10Gb/s. RoF technology using millimetre-wave band is a promising solution to provide multi-gigabits/sec service, wide converge, and mobility. However, the transmission length of optical RF signal beyond 10Gb/s at millimetre-wave band is still limited by fiber dispersion [1,2]. Recently, OFDM modulation has been demonstrated to exhibit very high tolerance to fiber dispersion for long-haul communication and has capability to support higher level modulation formats to reach date rate of more than 10Gb/s [3].

In this paper, with an aim to reduce the occupied bandwidth of the RF signal and to support multi-gigabit BWA for IPTV, HDTV, or WirelessHD application, we investigate the performance of highly spectral-efficient 16- and 64-QAM OFDM for RoF links. Both 15/18-Gb/s 64-QAM and 20-Gb/s 16-QAM OFDM signals are experimentally demonstrated and negligible penalty is observed following 25-km of single mode fiber (SMF). To authors' best knowledge, this is the highest data rate of the direct-detection OFDM-RoF signal using highly spectral-efficient 64-QAM format beyond 15Gb/s.

Experimental Results and Discussions

Fig. 1 depicts the experimental setup. The principle of the proposed colorless OFDM transmitter is similar to our early OFDM transmitter using a frequency doubling technique [4]. As shown in insets (i) and (ii) of Fig.1, the generated optical OFDM signal consists of an upper sideband (USB) and a lower sideband (LSB), where the OFDM data is encoded at the USB and a sinusoidal subcarrier at the LSB. Note that the optical carrier suppression ratio and the undesired sideband suppress ratio of both RF OFDM and OOK signals are greater than 26dB, which has a negligible influence on the performance of the generated RF signals.

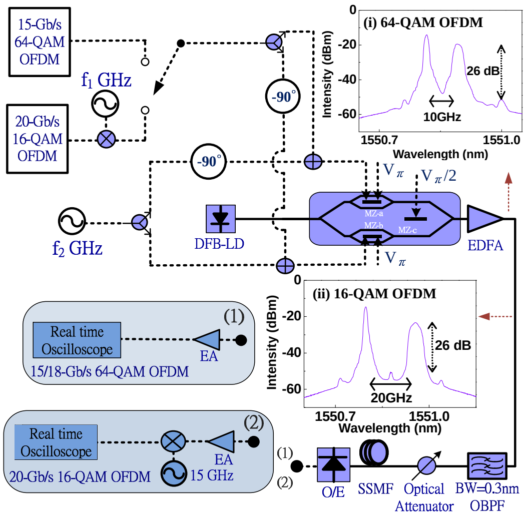

Figure 1: Experimental setup of optical RF OFDM generation

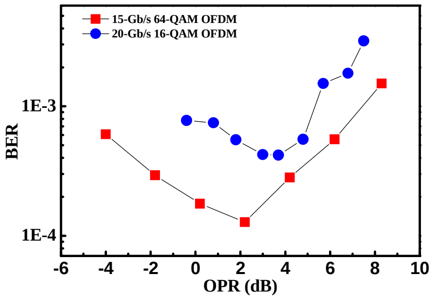

Figure 2: BER versus OPR at receiver powers of -13dBm.

The OFDM signals are generated by a Tektronix AWG7102 arbitrary waveform generator (AWG) using a Matlab program. The resolution of the digital-to-analogue converter of the AWG is 8 bits. The IFFT length is 128, resulting in a subcarrier symbol rate of 156.25 MSym/s. The cyclic prefix is set to 1/64 symbol time. For the 64-QAM OFDM system, the USB OFDM data occupies channel 13 to 28 (i.e. in the subcarrier center frequency range from 2.03125 to 4.375 GHz.) with the remaining 112 channels set to zero. A sinusoidal subcarrier with frequency of 6.71875 GHz is generated at the LSB. Therefore, an optical 15-Gb/s 64-QAM OFDM signal

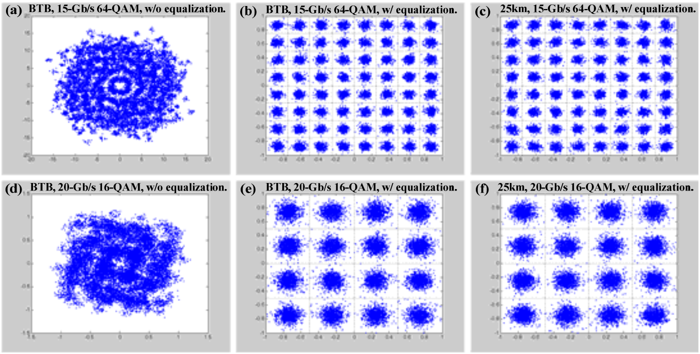

Figure 3: Constellation of OFDM signal with power of -11dBm.

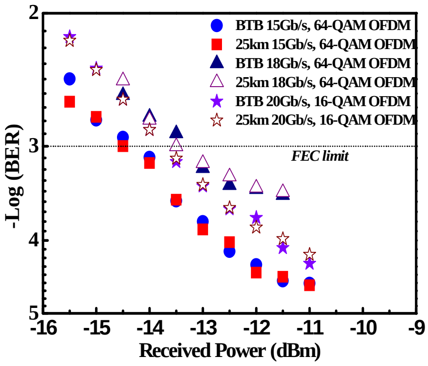

Figure 4: BER curves of RF OFDM signals

at 10 GHz that has 16 subcarriers and occupies a total bandwidth of 2.5 GHz can be generated.

For the 16-QAM OFDM system, the OFDM data utilizes channels 1 to 16 with the remaining 112 channels set to zero. After AWG, the 16-QAM OFDM signal is up-converted to 10 GHz by a mixer and a 10-GHz oscillator. A 10-GHz sinusoidal subcarrier is generated at the LSB. Therefore, an optical 20-Gb/s 16-QAM OFDM signal that has 32 subcarriers and occupies a total bandwidth of 5 GHz can be generated at a center frequency of 20 GHz. Note that a frequency doubling approach is achieved to reduce the cost of the electronic components, especially for the RF signal at the millimeter-wave range.

At receiver, the waveform of the generated 64-QAM OFDM signals at 10 GHz is directly captured by a Tektronix DPO 71254 with a 50-Gb/s sample rate and a 3-dB bandwidth of 12.5 GHz. For the generated 16-QAM OFDM signals at 20 GHz, the OFDM data are down-converted to 5 GHz by a 15-GHz oscillator and a mixer. The off-line DSP program is employed to demodulate the both OFDM signals. The demodulation process includes synchronization, Fast Fourier Transform (FFT), one-tap equalization, and QAM symbol decoding. The bit error rate (BER) performance is calculated from the measured error vector magnitude (EVM) [5].

Experimental Results and Discussions

The relative intensity between the optical subcarrier and the optical data-modulated subcarrier strongly influences the performance of the optical OFDM signals. One of the advantages of the proposed OFDM transmitter is that the relative optical intensity between USB and LSB can be easily tuned by adjusting the individual electrical amplitude of the LSB sinusoidal signal and the USB OFDM data signals to optimize the performance of the optical OFDM signals. Fig. 2 illustrates the receiver sensitivity of the 64-QAM and 16-QAM OFDM signals versus different optical power ratios (OPR) of the LSB subcarrier to the USB OFDM-encoded subcarrier. The optimal OPRs of 15-Gb/s 64-QAM and 20-Gb/s 16-QAM OFDM signals are 2.4 dB and 3.7 dB, respectively.

Fig. 3 shows 64-QAM and 16-QAM constellation diagrams before and after the one-tap equalizer in back-to-back (BTB) and following 25 km SMF transmission cases. The equalizer in OFDM receiver is used to combat both frequency response of various microwave components and fiber dispersion. Since the proposed OFDM transmitter can generate high-purity two-tone lightwave, the generated OFDM signals do not suffer periodic fading issue due to fiber dispersion. Only in-band distortion of the OFDM-encoded subcarrier induced by fiber dispersion is considered. Since the symbol rate of each subcarrier is only 156.25 MSym/s, the fiber chromatic penalty can be ignored. Fig. 4 shows the BER curves of the 15-Gb/s 64-QAM and 20-Gb/s 16-QAM OFDM signals using optimal OPRs after transmission over 25 km SMF. The 18-Gb/s 64-QAM OFDM signal is also demonstrated. The sensitivity penalties are negligible.

Conclusions

High spectral efficiency OFDM-RoF signals with 16- and 64-QAM beyond 15 Gb/s is successfully demonstrated using the proposed colorless OFDM transmitter without optical filtering. Besides, the proposed architecture utilizes the carrier suppression technique to achieve frequency doubling and successfully transmits a high capacity OFDM signal beyond 15 Gb/s over 25 km SMF with negligible penalty. This shows that the proposed OFDM transmitter is a promising solution for next-generation multi-gigabit/sec BWA for IPTV, HDTV , and Wireless HD applications at the millimeter-wave range.

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