Demonstration of 73.15Gbit/s 4096-QAM OFDM D-band Wireless Transmission Employing Probabilistic Shaping and Volterra Nonlinearity Compensation

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Abstract *We experimentally demonstrate a transmission of 73.15Gbit/s 4096-QAM OFDM signal at 117GHz over 13.42-m wireless using probabilistic shaping and Volterra nonlinearity compensation.*

Introduction

Recently, due to the emerging services such as 4K/8K large video application, 5G internet of things, and cloud computing, the capacity demand for access network is exploding. However, due to insufficient frequency resources, current 4G data rates for wireless communications are limited and can only support a few hundred Mbps. Therefore, to meet enhanced mobile broadband (eMBB) and provide multi-Gbps resources, the millimeter wave in D-band (110GHz-170GHz) is a promising solution [1]. However, to provide higher data rate, the limited bandwidth for the electronic devices becomes a bottleneck to further enhance the system capacity. To overcome this issue and produce multi-Gbps signals, high order QAM modulation together with the generation technology of photonics-assisted mm-wave has been investigated [1-3]. Moreover, OFDM as multi-carrier signals are favored by multi-user access network due to independent subcarrier optimization and higher spectral efficiency.

Probabilistic shaping (PS) technology, as a new technology, has been intensively studied and well verified to be able to bring significant performance gains with extended distance or increased capacity [4]. Volterra nonlinearity compensation (VNC) technology can alleviate system nonlinearity due to unsatisfactory transmitter and receiver devices, as well as the high PAPR of OFDM signal [5].

In this paper, we experimentally demonstrate a transmission of 10-Gbaud high order QAM OFDM signal over 13.42-m wireless distance. In order to bring significant performance gains and alleviate nonlinearity of system, PS and VNC have been adopted. To our knowledge, this is the first time to demonstrate 73.15-Gbit/s 4096-QAM OFDM signal transmission over 13.42-m wireless distance at D-band.

Experimental setup

Figure 1 gives the experimental setup and the process of offline DSP for the transmission of high order QAM OFDM signal over 13.42-m wireless distance at D-band. The FFT size of OFDM is 1024, and the size of the cyclic prefix is 64. A frame of data includes 14 OFDM symbols, including 2 training sequences (one for synchronization and one for channel estimation) and 12 effect data sequences. 512 zeros are inserted in front of a frame of data. The specific signal generation process is shown in Fig. 1 for offline DSP for OFDM generation. The bit per symbol of 256-QAM, 1024-QAM, 2048-QAM and 4096-QAM are 7.2856, 8.0586, 9.0592 and 10.0585 after PS. So the net data rate of 10-Gbaud 4096-QAM OFDM signal is 75.13 Gb/s (10×10.0585×12×980/(512+1088×14)Gb/s). The produced data will be loaded into arbitrary waveform generator (AWG). Before it

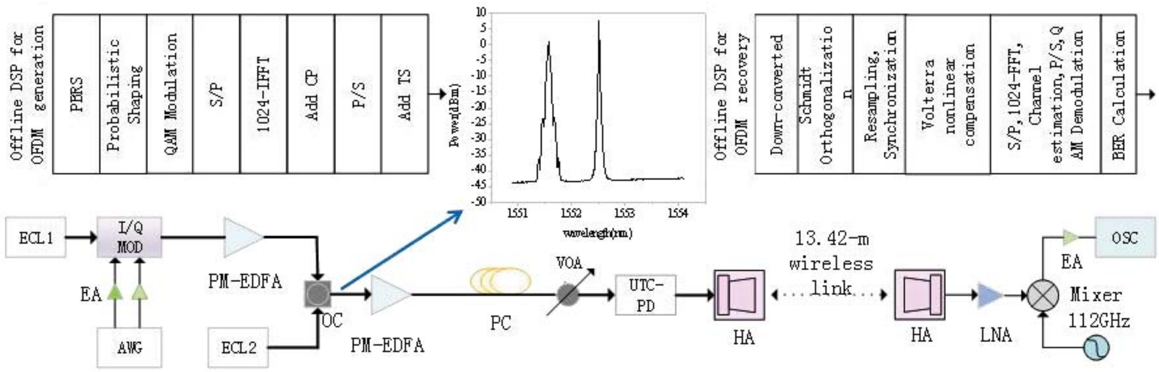

Fig. 1: Experimental setup, process of offline DSP and the spectrum after OC.

used to drive I/Q modulator, it will be amplified through two parallel electrical amplifier. The 3-dB bandwidth and insertion loss of I/Q modulator are 32 GHz and 6 dB, respectively. The signal will be loaded onto the external cavity laser (ECL1) by I/Q modulator. The signal output from modulator is amplified by polarization-maintaining Erbium-doped fiber amplifier (PM-EDFA), which will be combined with ECL2 by an optical coupler (OC). Before signal is controlled by polarization control (PC), which will be amplified by another PM-EDFA. Before signal will be detected by Uni-Traveling-Carrier Photodiode (UTC-PD), a variable optical attenuator(VOA) will be used to adjust the signal power into UTC-PD. The inserted spectrum after OC is shown in Fig. 1. In the PD, two lasers generate 117 GHz millimeter-wave signal by beating frequency, then the produced MM-wave signal will be delivered into the air by horn antenna. At the receiver of horn antenna, the MM-wave signal and the signal output from 112-GHz electrical local oscillator will be mixed in mixer. Then the IF signal will be produced in mixer. Next, 80 GSa/s digital storage oscilloscope (DSO) with 30-GHz bandwidth will capture the IF signal for offline DSP. The specific signal recovery process is shown in Fig. 1 for offline DSP for OFDM recovery.

Experimental results

Figure 2 (a) shows the measured BER versus the input optical signal power into the UTC-PD (ROP) at different QAM modulation in the case of 10-Gbaud. As shown in Fig. 2 (a), with the increase of the order of QAM, the BER of 10-Gbaud OFDM signal become worse, and we can see that when the ROP reaches 9-dBm, the optimal BER just can arrive at 0.14 due to long wireless transmission distance, though PS has been adopted in this case. In

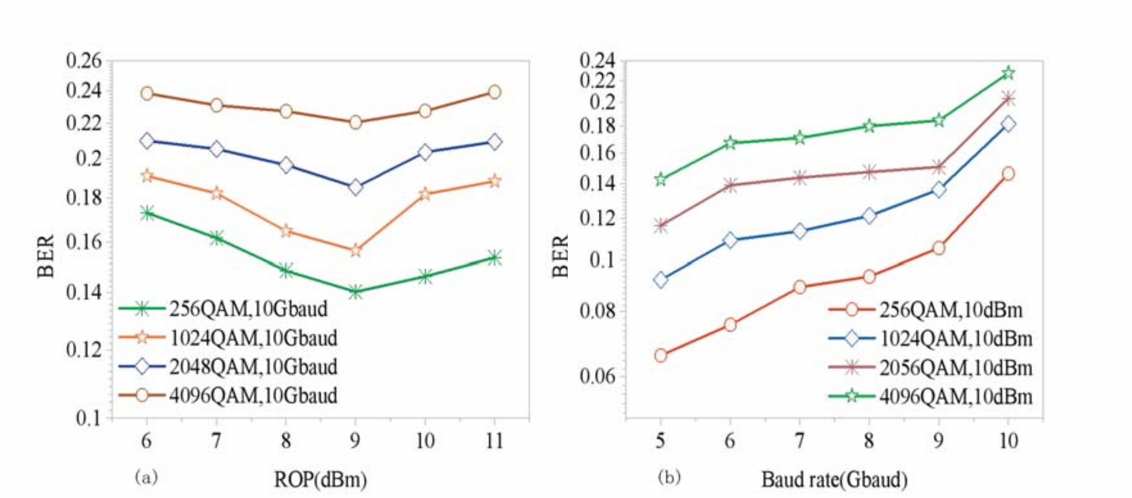

Fig. 2: (a) BER versus ROP at different QAM in the case of 10Gbaud with PS; (b) BER versus Baud rate at different QAM in the case of 10dBm ROP with PS.

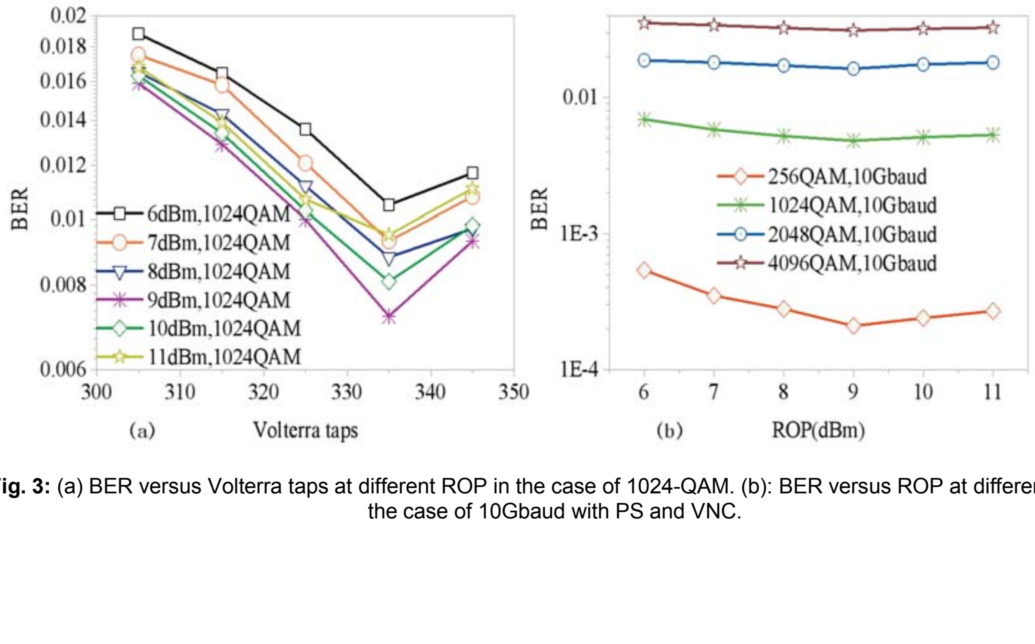

Fig. 3: (a) BER versus Volterra taps at different ROP in the case of 1024-QAM. (b): BER versus ROP at different QAM in the case of 10Gbaud with PS and VNC.

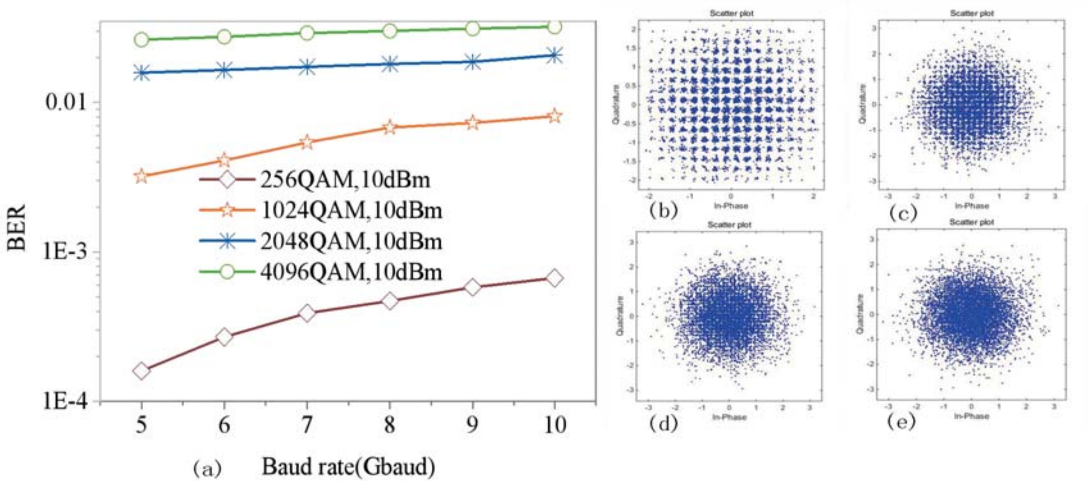

Fig. 4: (a) BER versus Baud rate at different QAM in the case of 10dBm ROP with PS and VNC; (b) the constellation of 256QAM; (c) the constellation of 1024QAM; (d) the constellation of 2048QAM; (e) the constellation of 4096QAM.

order to improve BER performance, we sacrifice the baud rate for BER performance. As shown in Fig. 2 (b), when the baud rate decrease from 10-Gbaud to 5-Gbaud, the BER performance has an obvious improvement, for the case of 256-QAM, the BER decrease from 0.14 to 0.066, which still above SD-FEC threshold of 4×10^{-2}. To further improve the BER performance, VNC will be applied in the next step of the experiment.

We test the BER performance versus different Volterra taps at different ROP in the case of 1024-QAM. As shown in Figure 3 (a), with the increase of Volterra taps, when the length of Volterra taps is 335, the optimal BER performance can be get. When the length of the taps continue increase, the VNC will tend to converge, so the BER performance will become worse. And we can see that the optimal ROP is 9-dBm. Too small ROP leads to low SNR, too large ROP leads to signal saturation. At the case of 9-dBm, the BER of 10-Gbaud 1024-QAM is 7.2×10^{-3}, which below the SD-FEC threshold of 4×10^{-2}.

At the case of optimal Volterra taps, the BER performance versus ROP has been tested at different QAM modulation in the case of 10-Gbaud. As shown in Fig. 3 (a), with the increase of ROP, the BER performance gradually improved, the optimal BER performance can be get at the point of 9-dBm ROP. And we can see from Fig. 3 (a), only 10-Gbaud 256-QAM OFDM signal can reach at BER of 6.7×10^{-4}, which lower than HD-FEC threshold of 3.8×10^{-3}, the BER of all other 10-Gbaud signal just can reach below SD-FEC threshold of 4×10^{-2}. We further explored the case of lower baud rate. As shown in Fig. 4 (a), with the decrease of baud rate, the BER performance has an improvement, especially for the 256-QAM. At the case of 10dBm ROP, at the point of 5Gbud, the corresponding constellation of 256QAM, 1024QAM, 2048QAM and 4096QAM are shown in Fig.4 (a), (b), (c) and (d), respectively.

Conclusion

We experimentally demonstrate transmission of 75.13-Gbit/s 4096-QAM OFDM signal in the D-band over 13.42-m wireless distance using probabilistic shaping and Volterra nonlinearity compensation. At the point of 9-dBm ROP, BER can reach 3.12×10^{-2} lower than soft decision FEC threshold of 4×10^{-2}.

Acknowledge

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