Demonstration of 74.7 Gbit/s 4096QAM OFDM E-band Wireless Delivery over 700 m Employing Advanced DSP

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Abstract: We experimentally demonstrate a transmission of 74.7 Gbit/s 4096QAM OFDM signal at 73.5 and 83.5 GHz over 700m wireless distance using probabilistic shaping and Volterra nonlinearity compensation.

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1. Introduction

Millimeter wave (MMW) communication systems are considered a promising solution for broadband wireless access in the future[1]. Compared with the traditional microwave wireless system, MMW has the advantages of good direction and large bandwidth. So, MMW systems can easily support multi-Gbps services, which is considered a good candidate for future 5G and ultra-5G wireless networks. It is reported that many studies and experimental demonstrations of 5G technology have been reported. 5G is processing different bands from 600 MHz to a few tens GHz. The E-band licensed frequency range is from 71 to 76 GHz and from 81 to 86 GHz. For the E-band, atmospheric losses are relatively low, less than 0.5 dB/km.

However, to provide higher data rate, the limited bandwidth of 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 MMW has been investigated [2-4]. However, higher-order signal transmission requires a higher signal noise ratio (SNR) and is also affected by nonlinear effects from photoelectric devices such as optical modulators and electrical amplifiers (EAs). Currently, the most effective way to relax this requirement is probabilistic shaping (PS) technology, which has good rate flexibility and probability shaping gain, especially for higher order modulation formats[4-5]. Volterra nonlinearity compensation (VNC) technology can alleviate system nonlinearity caused by unsatisfactory transmitter and receiver devices, as well as the high PAPR of OFDM signal[6].

In this paper, we experimentally demonstrate a transmission of 5 Gbaud 4096QAM OFDM signal at 73.5 and 83.5 GHz over 700 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 74.7 Gbit/s 4096QAM OFDM signal transmission over 700 m wireless distance at E-band.

2. Experimental setup

Figure 1 gives the experimental setup and the process of offline DSP for the transmission of 4096QAM OFDM signal over 700 m wireless distance at E-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 offline DSP process for OFDM generation is shown in Fig.1. The bit per symbol of 64QAM, 256QAM, 1024QAM, 2048QAM, 4096QAM are 5.148, 7, 8, 9, 10 after PS. So the data rate of 5 Gbaud 4096QAM OFDM signal at 73.5 and 83.5 GHz is 74.7 Gb/s ($2\times5\times10\times12\times980/(512+1088\times14)$Gb/s), the net data rate is 53.8 Gb/s excluding 28% FEC overhead(SD-FEC threshold at 9.8×10-2)[7]. The produced data is first loaded into the arbitrary waveform generator (AWG). Before-used to drive the I/Q modulator, it is amplified through two parallel electrical amplifiers. The 3-dB bandwidth and insertion loss of I/Q modulator are 32 GHz and 6 dB, respectively. The signal is then loaded onto the external cavity laser 1 (ECL1) by I/Q modulator. The signal output from the modulator is amplified by a polarization-maintaining Erbium-doped fiber amplifier (PM-EDFA), and is combined with ECL2 and ECL3 by optical couplers (OC). Then, the coupled signal is transmitted in 100 m single mode fiber. Before the transmitted signal is detected by the photodiode (PD), a variable optical attenuator (VOA) is used to adjust the signal power into PD. The inserted spectrum after OC is shown in Fig. 1. In the PD, ECL1 and ECL2, ECL1 and ECL3 generate 83.5 GHz, 73.5GHz MMW signal by beating frequency, respectively, and then the produced MMW signal will be amplified by a power amplifier with 18 dB gain. Subsequently, the diplexer with 50 dB isolation is adopted to separate the two channels at E-band. Then the signal is delivered into the air by Cassegrain antenna (CA) with 48 dBi gain. After receiving by the CA at the receiver end, the MMW signal output from another diplexer is mixed with

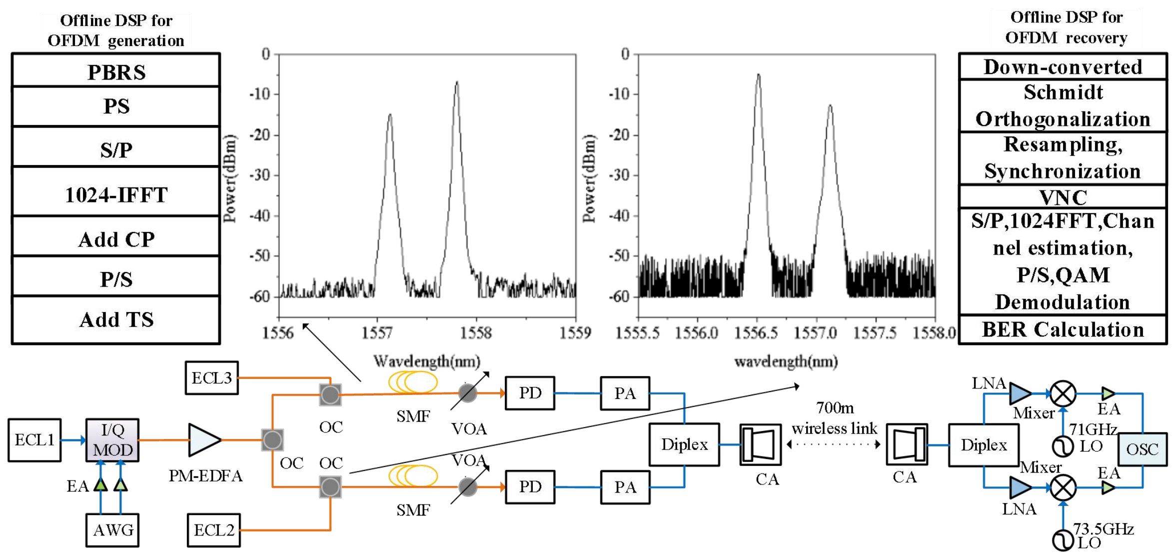

Fig. 1: Experimental setup, process of offline DSP and the spectra after OC.

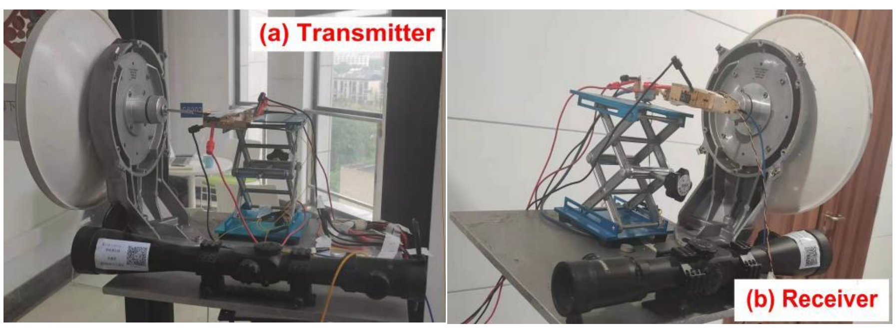

Fig. 2: Photos of the E-band (a) transmitter and (b) receiver.

electrical local oscillators with frequencies of 73.5 GHz and 71 GHz respectively in the mixer. Then the 10 GHz and 2.5 GHz IF signal is produced in two mixers, respectively. Next, 100 GSa/s digital storage oscilloscope (DSO) with

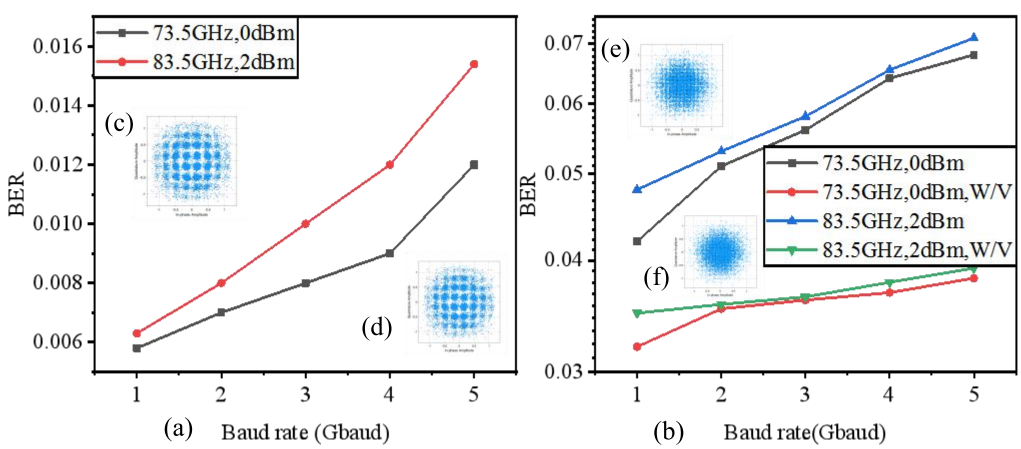

Fig. 3: (a) BER versus Baud rate at 64QAM; (b) BER versus Baud rate at 256QAM; (c) The constellation of 73.5GHz signal at 0dBm ROP; (d) The constellation of 83.5GHz signal at 2dBm ROP ; (e) The constellation of 73.5GHz signal at 0dBm ROP; (f) The constellation of 83.5GHz signal at 2dBm ROP.

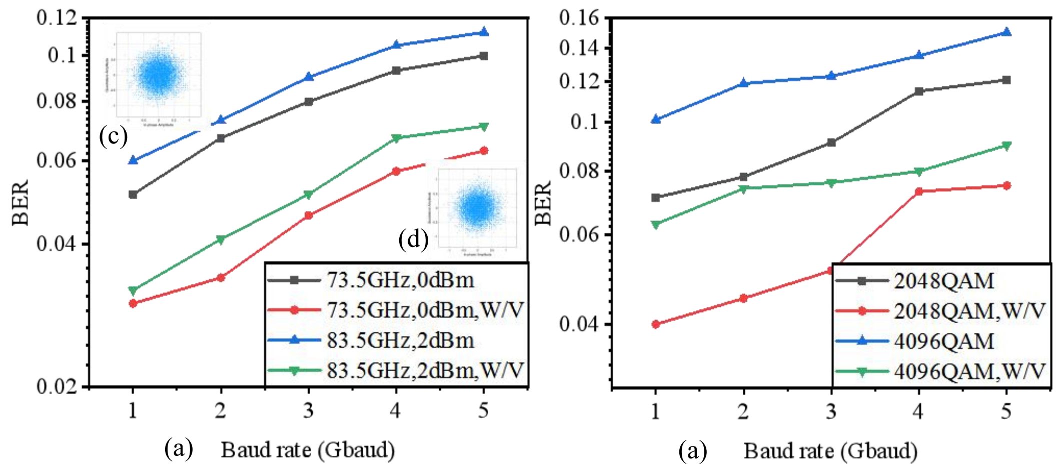

Fig. 4: (a) BER versus Baud rate at 1024QAM; (b) BER versus Baud rate at 2048QAM and 4096 ; (c) and (d) are the constellation of 73.5GHz and 83.5GHz 1024QAM signal at 1Gbaud with PS and VNC; V:VNC.

30 GHz bandwidth captures the IF signal for offline DSP. The specific offline DSP process for OFDM recovery is shown in Fig. 1. Fig. 2 shows the photos of the E-band transmitter and receiver.

3. Experimental results

Figure 3 depict the BER performance of 64QAM and 256QAM MMW OFDM signals versus baud rate at 73.5 GHz and 83.5 GHz after 700 m wireless transmission, and the inserted constellations at 1 Gbaud. With the help of PS, the BER of the 5 Gbaud 73.5 GHz and 83.5 GHz MMW signal can reach 1.2×10^{-2} and 1.54×10^{-2}, which are both below the SD-FEC threshold of 4×10^{-2}. The corresponding constellation diagrams of 73.5 GHz and 83.5 GHz MMW signal are inserted in Fig. 3 (c) and (d), respectively. Compared with using PS only, by using both PS and VNC, the BER of 5 Gbaud 73.5 GHz 256QAM MMW can be improved from 6.8×10^{-2} to 3.8×10^{-2}, which is below the SD-FEC threshold of 4×10^{-2}. The corresponding constellation diagrams of 73.5 GHz and 83.5 GHz MMW signal are inserted in Fig. 3 (e) and (f), respectively.

Fig. 4 describes the BER performance of 1024QAM, 2048QAM and 4096QAM MMW OFDM signals versus baud rate after 700 m wireless transmission, and also includes constellations of 1024QAM at 1 Gbaud. The BER of the 5 Gbaud 83.5 GHz 1024QAM MMW signal can be improved from 0.112 to 7.1×10^{-2} with the help of PS and VNC. And we can see that the BER performance of 73.5 GHz MMW signal is better than 83.5 GHz. So the next step, we just test the BER performance of 2048QAM and 4096QAM in 83.5 GHz MMW. Compared with only PS adopted, when PS and VNC are combined and used, the BER performance has an obvious improvement. With adopting the two techniques, the BER of 5 Gbaud 2048QAM and 4096QAM signals can reach 7.5×10^{-2} and 9×10^{-2}, respectively.

4. Conclusions

We experimentally demonstrate transmission of 74.7 Gbit/s 4096QAM OFDM signal in the E-band over 700m wireless distance using probabilistic shaping and Volterra nonlinearity compensation. With the help of PS and VNC, the performance of high-order QAM E-band signals can be improved obviously.

5. References

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