Demonstration of Real-time 4×125.516 Gbit/s MMW-over-Fiber Passive Optical Network Transmission at W-Band Based on Optical Wavelength Routing Scheme

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Abstract: We proposed and experimentally demonstrate the first real-time transparent point-to-multipoint photonics-assisted MMW-over-fiber passive optical network transmission scheme with a record line rate of 4×125.516 Gbit/s at W-band based on optical wavelength routing scheme.

1. Introduction

The W-band millimeter waves (MMW, 75GHz-110GHz) is widely regarded as the key component of 5G/B5G mobile communication systems, which can achieve high-speed transmission due to small atmospheric attenuation and large bandwidth [1], [2]. In addition, the photonics technique utilizes the scheme of optical heterodyne beating to overcome the bandwidth limitation of electronic devices [3]. Furthermore, the photonics technique facilitates the seamless integration with existing optical networks [4]- [7]. In recent years, fixed wireless access (FWA) system that support 5G New Radio (NR) is proposed [8], but most research works of FWA systems are based on a single-carrier system, and the transmission rate is relatively low. To improve the transmission capacity, some typical technologies, such as wavelength division multiplexing (WDM), orthogonal frequency division multiplexing (OFDM), multiple-input multiple-output (MIMO), etc., are introduced into the photonics-assisted wireless communication system. And some researchers take into account multi-user application scenarios in the optical access segment. In [9], the concept of an optical and MMW/THz integration access network is proposed, but the specific network integration structure is not given out. And most research works are based on off-line DSP. A real-time 2.5 Gbit/s error free radio transmission at W-band was achieved in the optical and W-band wireless communication links, which utilizing optical heterodyne signal up-conversion [10]. However, the > 100 Gbit/s real-time point-to-multipoint photonics-assisted system transmission at W-band has not yet been reported.

In this paper, we proposed and experimentally demonstrate a novel real-time transparent point-to-multipoint photonics-assisted MMW-over-fiber passive optical network (MoF-PON) transmission system based on optical wavelength routing (OWR) scheme. In the system, precise routing of multi-user optical carrier and local oscillation (LO) can be realized by used an N×N AWG, and flexible MMW carrier frequency can be adjusted by changing the wavelength interval. It should be noted that, due to the lack of N×N AWG, two DWDM modules are used instead of N×N AWG in the experimental. A four channel 31.379 GBaud DP-QPSK signals with rates of 4×125.516-Gbit/s at W-band over 42 km SSMF fiber and 3 m wireless link are demonstrated under 15% soft-decision forward-error-correction (SD-FEC) for pre-FEC BER threshold of 1.56×10^{-2}. To the best of our knowledge, this is the first demonstration of real-time transparent point-to-multipoint photonics-assisted MMW wireless transmission with a rate of more than 500 Gb/s.

2. Experimental setup

Fig. 1 shows the test-bed setup of 4×125.516-Gbit/s real-time transparent point-to-multipoint photonics-assisted MoF-PON transmission scheme. The scheme includes the following modules: optical line terminal (OLT), remote node (RN), optical up-conversion (o-UC), electrical up-conversion (o-UC), optical down-conversion (o-DC), and optical network unit (ONU). In the OLT, an optical transport unit (OTU) includes a network management system (NMS) and four centum form-factor pluggable-coherent optical modules (CFP2-DCOs). As shown in Fig. 1(a) (b), four optical carriers from four CFP2-DCO modules operating at 100 GbE mode and four 12-dBm continuous-waves (CWs) from four external cavity lasers (ECLs) with < 100 kHz linewidth are coupled by an optical coupler (OC), respectively. Notably, fours CWs will be used as the LOs. Optical carriers and CWs reach RN through 20 km standard single mode fiber (SSMF) transmission. In the RN, two dense wavelength division multiplexer (DWDM) modules are used for the demultiplexing of the optical carriers and the LOs, respectively. A pair of optical carrier and LO with a frequency spacing of 93-GHz coupled by an OC, such as CH1 and LO1, as shown in Fig. 1(c), and reaches the o-UC module after 2km SSMF transmission. At o-UC, an Erbium-doped fiber amplifier (EDFA) is used to compensate for the fiber transmission and DWDM insertion loss. A polarization beam splitter (PBS) is used to separate the X- and Y-polarization components of the combined lightwaves. Subsequently, X- and Y-polarization signals are photomixed by PDs to generate two MMW wireless signals, respectively. Two MMW wireless signals from PDs are amplified by a 38dB gain low-noise amplifier (LNA), and then combined by an ortho-mode transducers (OMT). Finally, the coupled MMW wireless signal is transmitted to free space via an antenna.

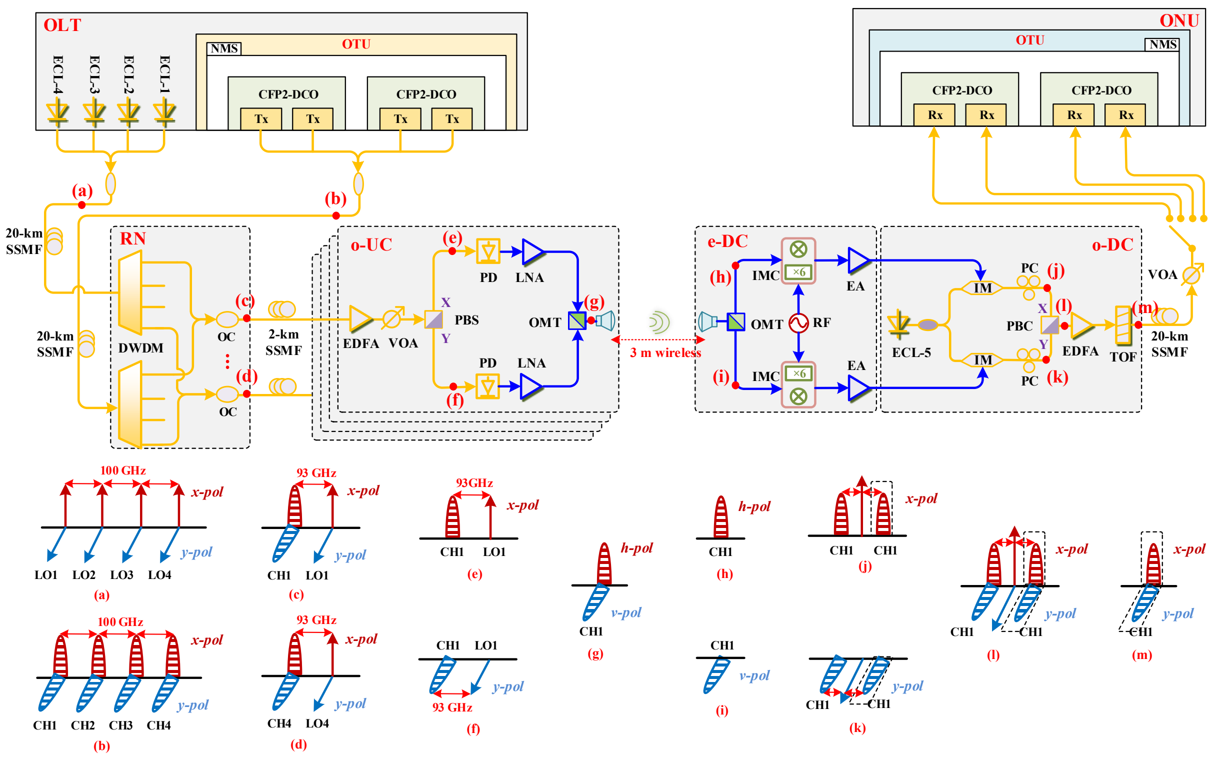

Fig.1. Experimental setup of real-time transparent MoF-PON transmission system.

At the e-DC, MMW wireless signal is received by an antenna, then divided into H- and V-polarization components via OMT. For H- and V-polarization MMW wireless signals, two identical MMW receivers are driven by two electronic LO sources to implement analog down conversion, and each MMW receivers consists of a mixer and a × 6 frequency multiplier chain. At the o-DC, the down-converted H- and V-polarization IF signals at 24 GHz are boosted by electrical amplifiers (EAs) to drive two intensity-modulators (IMs), respectively. As the optical carrier input of the two IMs, ECL-5 is used with 24 GHz frequency spacing to the initial optical baseband signal and 14.5 dBm optical output power. Each IM is DC-biased at optical-carrier suppression point. Then, the X- and Y-polarization optical signals are combined by a polarization beam combiner (PBC) and boosted by a EDFA. Subsequently, the TOF is set to filter out the lower sideband and the central optical carrier as well as the ASE noise, only leaving the upper sideband as optical baseband signal. Finally, the obtained optical baseband signal is delivered over the second span of 20 km SSMF, and received by the corresponding CFP2-DCO module. A variable optical attenuator (VOA) is used to adjust the receive optical power of CFP2-DCO module.

3. Results and discussion

Fig. 2 show the measured spectra of coupler signal, X- and Y-polarization and filtering at 0.03 nm resolution, which corresponding to test points (c), (j)(k), (m), in Fig. 1, respectively. We can observe that frequency spacing between optical carrier and LO is 93-GHz, and slight differences between the two polarization signals due to IM differences. Moreover, to find the optimal carrier frequency of millimeter wave signal of MoF-PON transmission system, we first measure the BER versus the carrier frequency of millimeter wave signal at CH1 with -5 dBm input power into each PD, as shown in Fig. 3(a). We can find that there is 3.3-GHz frequency drift at the BER of 3×10-3. When the MMW signal carrier frequency is 93 GHz, the transmission system has the best BER performance. Therefore, in the next test, the carrier frequency of millimeter wave signal is fixed at 93 GHz.

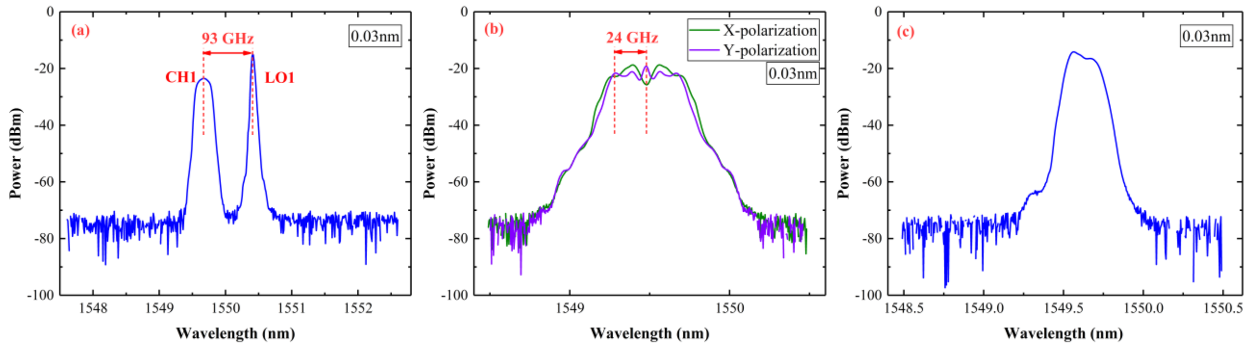

Fig. 2. Measured optical spectrum at 0.03-nm resolution after: (a) Optical coupler; (b) Intensity-modulator; (c) Tunable optical filter.

Fig. 3(b) gives the BER versus input power into each PD of four channels over 42 km SSMF and 3 m wireless link. When the input power into each PD < -8 dBm, the BER performance improves significantly as the input power into each PD increases, whereas the ROP > -8 dBm, the BER performance degrades rapidly as the input power into each PD increases. This is because the PD is already saturated when the input power into each PD is greater than -8 dBm. Furthermore, we can observe that the BER performance of four channels is similar, and can support 15% SD-FEC for pre-FEC BER threshold of 1.56×10^{-2}. It can be considered that different channels have the same performance in the system. Fig. 3(c) illustrates the highest OSNR of four channels is 14.1 dB when the incident power into each PD at -8 dBm. Finally, an aggregate line data rate of 4 channel × 64 Gb/s = 256 Gb/s in this system over 42 km SSMF and 3 m wireless link is successfully realized.

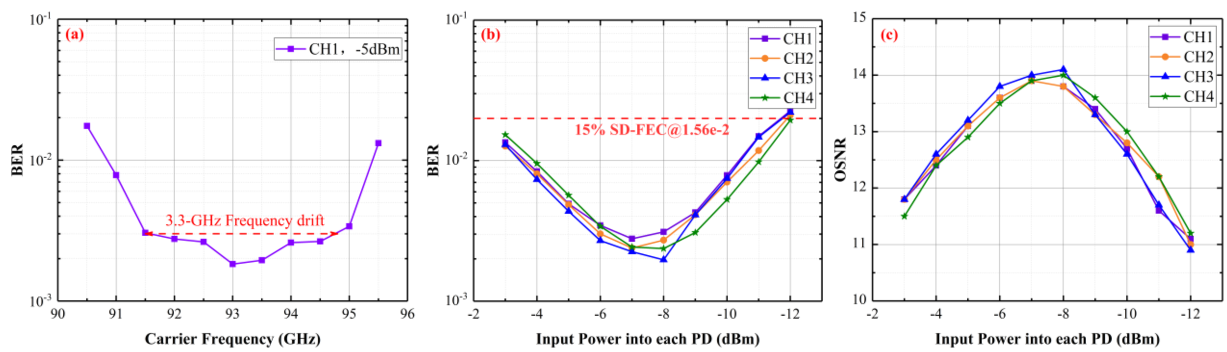

Fig. 3. (a) BER versus carrier frequency of millimeter wave signal; (b) BER versus input power into each PD of four channels; (c) OSNR versus input power into each PD of four channels.

4. Conclusions

We have proposed and experimentally demonstrated a novel real-time transparent point-to-multipoint photonics-assisted MoF-PON transmission scheme based on optical wavelength routing scheme. In this system, precise routing of multi-user and flexible millimeter-wave carrier frequencies are realized. And a four channel 4×125.516-Gbit/s DP-QPSK signals at W-band over 42 km SSMF fiber and 3 m wireless link are demonstrated under 15% SD-FEC. For all we know, it is the first time to realize >500 Gbit/s real-time transparent point-to-multipoint photonics-assisted MMW wireless transmission. *This work was partially supported by National Natural Science Foundation of China (62201397, 62271135, 62101121, 62201393, 62101126).*

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