Radar-Assisted MMW-over-Fiber System for B5G Mobile Communications

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Abstract: We experimentally demonstrated a radar-assisted MMW-over-fiber system for B5G mobile communications based on polarization interleaving. Centimeter-level ranging accuracy at K-band and 23-Gbit/s wireless rate at 28GHz band were simultaneously achieved without using polarization tracking methods. © 2022 The Authors

1. Introduction

The intelligentization of the future society puts forward the urgent demand of high-precision sensing and high-speed communication for B5G mobile communications. Nowadays, radar and B5G mobile communications are developing towards MMW band due to the large bandwidth of MMW [1]. In MMW networks, radio-over-fiber (RoF) technique shows great potential, since it can largely simplify the structures of remote units (RUs). To achieve high-precision sensing, linear frequency modulation (LFM) waves are widely used [2], which is quite different from communication systems [3]. Because of the different signal formats, the most direct way to integrate communication and sensing in one RoF link is frequency division multiplexing [4]. To improve the spectral utilization and reduce the crosstalk between two optical signals in adjacent bands, polarization diversity can be adopted [5]. However, polarization tracking mechanisms [6] or demultiplexing algorithms [7] are required, which increases the complexity of the RU.

In this paper, we proposed and experimentally demonstrated a radar-assisted MMW-over-fiber (MoF) system for B5G mobile communications. The proposed system is implemented by polarization interleaving and filtering. Thanks to the polarization interleaving, no photocurrent rises by beating the LFM and communication sidebands. Consequently, a pure LFM wave and a pure 16QAM signal at MMW band can be simultaneously generated and demultiplexed by filtering out one LO sideband at the opposite side of the signal sidebands. Correspondingly, it is no longer necessary to use polarization tracking methods. Moreover, the use of a shared laser eliminates the need for frequency offset compensation algorithms. Experimental results show that ±15-mm ranging accuracy at K-band and 23-Gbit/s wireless rate at 28GHz band are simultaneously achieved.

2. Principle

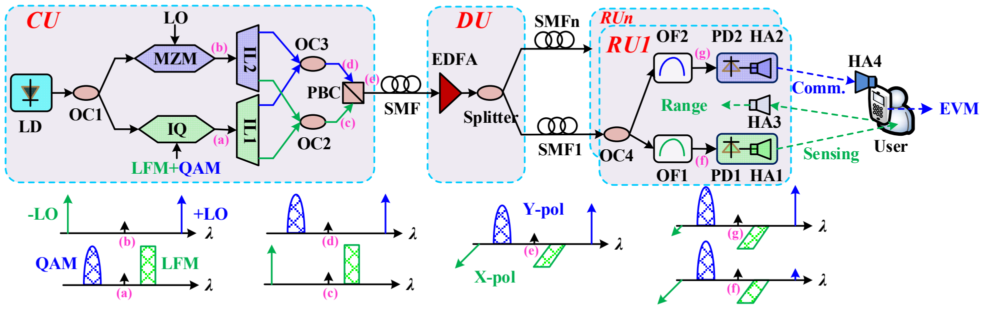

Fig.1. Schematic diagram of the proposed radar-assisted MMW-over-fiber system.

Figure 1 shows the schematic diagram of the proposed radar-assisted MoF system. In the central unit (CU), a LFM sideband (LFM-OSB) and a QAM sideband (QAM-OSB) are generated by independent single-sideband modulation via the IQ modulator, as shown in Fig.1(a). Two LO sidebands (-LO-OSB and +LO-OSB) are obtained by carrier-suppressed double-sideband modulation via the MZM, as shown in Fig.1(b). The four optical sidebands are separated by two interleavers (IL1 and IL2) and then recombined by two optical couplers (OC2 and OC3), as shown in Fig.1(c) and (d). The recombined sidebands are polarization interleaved by a polarization beam combiner (PBC), as shown in Fig.1(e), and then transmit over the single-mode fiber (SMF) to the distributed unit (DU) for power compensation and signal distribution. The split optical signal at the DU transmits over another SFM to the desired

RU. At the RU, the received optical signal is divided into two parts for filtering. Owing to the polarization interleaving, no photocurrent rises by beating the optical LFM-OSB and QAM-OSB. As a result, a pure LFM wave at MMW band for sensing can be generated by filtering out the +LO-OSB via the optical filter1 (OF1), as shown in Fig.1(f). Meanwhile, a pure QAM signal at MMW band for communication can also be generated by filtering out the -LO-OSB using the OF2, as shown in Fig.1(g). The generated LFM wave with lager scanning angle can be used to accurately sense the user's position for improving the quality of B5G communications. Thanks to the polarization interleaving and filtering, no polarization tracking methods is needed. Besides, the four sidebands are originating from a shared laser, so frequency offset estimation algorithms is not required, resulting in low DSP complexity.

3. Experimental setup and results

A proof-of-concept experiment is conducted according the setup shown in Fig.1. The QAM signal driving the IQ modulator is a 5.75-GBuad 16QAM signal centered at 10GHz. The LFM wave ranges from 6GHz to 7.15GHz. The LO signal is set at 1dBm and 18GHz. Therefore, the generated LFM wave and 16QAM signal at the RU1 locate at Ku-band and 28GHz band, respectively. The lengths of the SMF and the SMF1 are 5.3km and 100m, respectively.

For radar sensing, a metal plate is placed on the perpendicular bisector of the transmitting antenna (HA1) and the receiving antenna (HA3). The metal plate moves away from the HA1 in a 50-mm step within the range of 1500mm to 2050mm. Figure. 2(a) shows the instantaneous frequency of the MMW LFM signal reflected by the metal plate. The frequency of the reflected LFM wave varies linearly from 24GHz to 25.15GHz. Figure 2(b) the measured distances and the corresponding measurement errors. The measured results indicate that the measurement error is within ±15mm. The inset in Fig.2(b) gives the pulse-compressed result of the reflected LFM wave in the range of 1600mm. Excellent main-to-sidelobe ratio is obtained, which leads to centimeter-level ranging resolution.

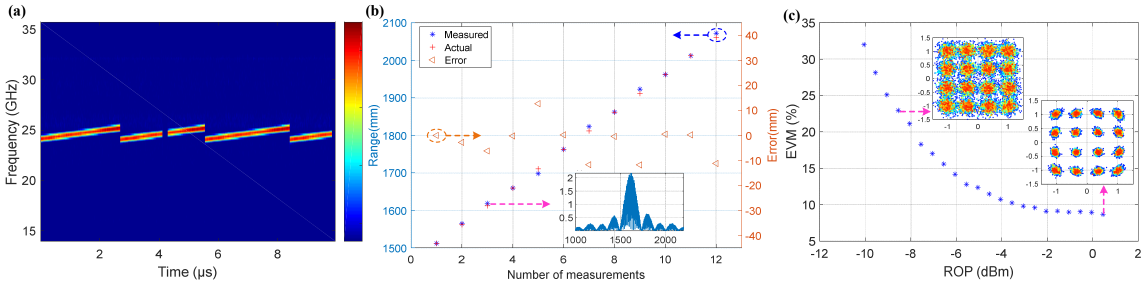

Fig. 2. (a) Instantaneous frequency of the reflected LFM wave; (b) measured distances and the corresponding errors; (c) measured EVM and constellation diagram of the 16QAM signal versus the ROP of the PD2.

For mobile communications, the wireless distance between the transmitting antenna (HA2) and the user antenna (HA4) is fixed at 2000mm. Figure 2(c) shows the measured error vector magnitude (EVM) of the generated 16QAM signal versus the received optical power (ROP) of the photodetector2 (PD2). At 0.45-dBm ROP, the constellation points of the generated 28GHz 16QAM signal present good aggregation, and the EVM is as low as 8.66%. As a result, 23Gbit/s wireless transmission rate is successfully realized. At -9.55-dBm ROP, the constellation points deteriorate, but 22.95%-EVM is still achieved. It should be pointed that such good EVM is achieved without using frequency offset compensation algorithms because of the good coherence of the beating optical sidebands.

4. Conclusion

we proposed and experimentally demonstrated a radar-assisted MoF system for B5G mobile communications by polarization interleaving and filtering. No polarization tracking methods and frequency offset estimation algorithms is utilized, which greatly reduces the complexity of the RU. Experiment results shows that centimeter-level ranging accuracy at K-band and 23-Gbit/s wireless rate at 28GHz band are simultaneously achieved. The proposed MoF system is of great potential in the coming B5G mobile communication networks.

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5. References

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