A 60GHz Wireless Access Scheme with Electrical LO Devices Free in Mobile Terminals and Base Stations

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Abstract: we propose a 60GHz wireless access network scheme with centralized LO service delivered to mobile terminals and base stations from the central office. Bidirectional transmission based on the scheme has been experimentally demonstrated.

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1. Introduction

Due to the increasing demand for in-door, high speed wireless access networks for next generation, millimeter-wave (MM-W) wireless-over-fiber (WoF) technology has been considered as a very promising solution. However, with the increasing of the carrier frequency up to 60GHz, the diameter of the coverage area of each base station (BS) is limited within tens of meters. As a consequence, numerous electrical local oscillator (LO) devices of high frequency are required in each BS and mobile terminal (MT), incurring high system complexity and cost. Hence, cost-effective microwave photonic techniques for frequency up-conversion have been developed for system integration [1-4]. However, in most recent MM-W WoF research, the MT (e.g., handsets) has not yet been fully taken into account in the central office (CO)-BS-MT system architecture. Therefore, there is an urgent need to push for the realization of electrical LO device free in both BSs and MTs. It would improve the end-to-end performance of CO-BS-MT if BSs and MTs are provided with quality-guaranteed LO service from the CO.

In this paper, we propose a new CO-BS-MT architecture to construct a bidirectional 60GHz WoF system, while providing both remote BS and MT with LO service of high-quality from the CO. For the downlink transmission, frequency up-conversion via optical beating and self-heterodyne detection techniques have been utilized to transmit and receive MM-W signals, while eliminating the use of electrical LO generators in both BS and MT. For the uplink transmission, the high-frequency LO, which is required for data up-conversion in MT and the MM-W signal down-conversion in BS, is provided by the centralized LO service distributed from CO, instead of relying on electrical LO generators in MT and BS. The stability and operational parameters of LO are pre-determined and controlled in CO. A proof-of-concept experiment is carried out to demonstrate the feasibility of the proposed scheme.

2. Principle of the system operation

The scheme of the proposed system is shown in Fig. 1. As for the downlink transmission, both the data for remote wireless subscribers and the broadcasting LO service for uplink reuse are simultaneously carried by the light from Laser_A via an I-Q modulator (IQM) in the CO. With the lower Mach-Zehnder (MZ) arm of the IQM biased at its null modulation point, a MM-W signal of 30 GHz is modulated by double sideband optical carrier suppression (DSB-OCS) technique; while in the upper MZ arm of the IQM, the downlink data is modulated upon the optical carrier through another RF input port. The RF spectra depicted in the bottom left of Fig. 1, show the hybrid data and LO that is to be transmitted over fiber to a remote BS. In the BS, an independent laser source with the wavelength centered 0.37nm (i.e., ~53GHz) away from the CO laser is employed to optically up-convert the baseband downlink data to a MM-W frequency of 53GHz. Meanwhile, in the PD, coherent beating between two optical sidebands with 0.48nm separation generates a pure electrical sinusoidal signal of 60GHz. This way, the 60GHz electrical LO carrier is partially delivered wirelessly to MT for frequency up-conversion in uplink transmission, and the remainder is reserved in the BS to down-convert the uplink 60GHz signal to its baseband/IF band.

Since the free running laser in the BS is incoherent with the laser in the CO, it introduces severe phase noise on the 53GHz MM-W downlink wireless signal. To resolve the problem, self-heterodyne detection technique has been implemented in the MT by using an envelope detector (ED). The strong DC component contained in the output of the ED, which is due to the self-mixing of the 60GHz sinusoidal carrier, could be blocked by a DC block before the data receiver.

In viewing of the uplink transmission from MT to BS to CO, the uplink data in MT is electrically up-converted to MM-W band in a mixer using the distributed LO at 60GHz. After transmitting wirelessly from MT to BS, the MM-

W uplink data will be reverted back to its baseband/IF form by mixing again with the 60GHz LO in the BS. Thereafter the baseband data is used to modulate the uplink laser, which also functions as downlink heterodyne signal as previously discussed.

It's noticeable that the downlink 53GHz carrier, on which the downlink data is loaded, can be treated as an uplink MM-W carrier. There is a concern that the frequency overlapping between the down- and up-link data may degrade the uplink signal quality at the receiver in CO. However, this concern could be resolved by adopting time division duplexing (TDD) for the up- and down-link transmission. In the timeslots for downlink transmission, the 60GHz carrier in the CO could be turned off; while during the timeslots for uplink transmission, the downlink data is turned off in the CO. Thus, pure LO service for up-conversion in MT and down-conversion in BS in the uplink transmission is quality guaranteed.

It's noteworthy that the LO carrier delivered from the CO is treated as a broadcasting service and is reusable for uplink. Hence, the deployment of wireless access network is more scalable and the system maintenance cost is reduced. In addition, the LO quality is highly flexible and under precise control in CO.

3. Experimental results and discussion

A proof of concept experiment has been designed and carried out. For the downlink transmission in the experiment, a downlink 2.5-Gbps pseudo-random bit sequence (PRBS) with a 2^{31}-1 sequence length has been modulated via a RF port of a 40GHz IQM on a laser, whose wavelength is centered at 1552.852-nm. The baseband downlink data is delivered over a single mode fiber of 25-km to the BS, where an independent laser centered at 1552.356-nm (i.e., 0.496-nm away from the laser in the CO) is employed to up-convert the downlink data on to 61.7-GHz by beating in the PD. A pair of 60GHz horn antennas associated with MM-W amplifiers is used to transmit and receive the data wirelessly from the BS to a MT over 3-feet air. By self-heterodyne detection in an ED, on one hand the PRBS data can be down-converted to its baseband form; on the other hand the severe noise introduced by the optical beating between two incoherent lasers can be eliminated. Error free transmission has been achieved in the experiment with the eye diagrams and BER curves shown as (a) in Fig. 2. To prevent signal degrading induced by spectrum over-lapping between the uplink and downlink data, TDD technique has been applied to transmit the uplink and downlink data at different timeslots. During the timeslots for uplink transmission, the other MZ arm of the IQM is modulated by a quadrupled 6.6-GHz (i.e., 26.4-GHz) sinusoidal signal via the other RF port, while the downlink data is turned off in the uplink transmission duration. With the corresponding MZ arm biased at its null point, the 26.4-GHz sinusoidal signal is modulated with DSB-OCS, the wavelength between the upper and lower sidebands corresponds to 52.8-GHz in the electrical domain. In the remote PD in the BS, a pure electrical LO carrier of 52.8-GHz is generated, part of which is transmitted over the antenna to MT. In the MT, a 2-Gbps PRBS data is electrically up-converted by the 52.8-GHz carrier for uplink wireless transmission over air. The remaining part of the LO carrier has been reserved in the BS to down-convert the uplink signal back to its baseband form. The advantage of baseband optical transmission for uplink from BS to CO is to relief the requirement on the bandwidth of the modulator in the BS; meanwhile, chromatic dispersion tolerance is enhanced. To avoid low efficiency caused by phase mismatching in frequency down-conversion, a MM-W phase shifter is used in the BS to align the 52.8-GHz uplink data from the MT with the LO carrier from the CO to achieve a desired frequency conversion efficiency in the MM-W mixer. Fig. 2 (b) shows the BER curves and eye diagrams for the uplink transmission over 3 feet air and 25-km single mode fiber. Compared to the downlink transmission case, the BER curves for uplink in Fig. 2 (b) indicates more severe power penalty between the 3-feet air and B2B fiber transmission and the 3-feet air and with 25-km fiber situation. This is reasonable due to the extra refold wireless path loss and power consumptions during frequency conversions in the MT and BS for the uplink transmission.

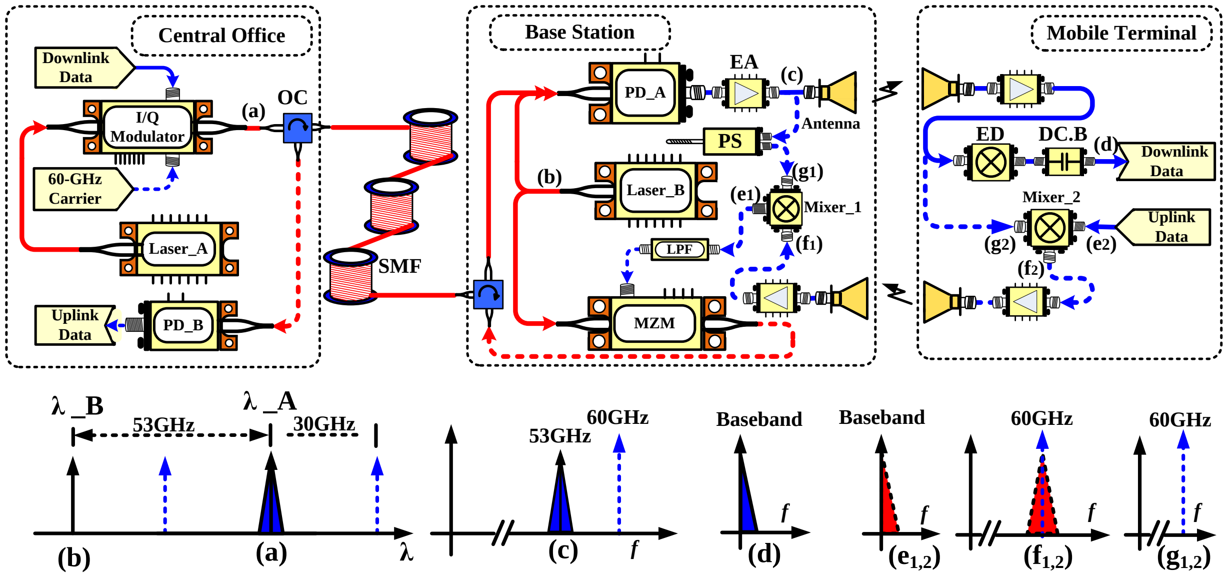

Fig. 1. Schematics of the proposed bidirectional 60GHz wireless-over-fiber CO-BT-MT transmission system. OC: optical circulator; SMF: single mode fiber; PD: photo detector; EA: electrical amplifier; PS: phase shifter; ED: envelop detector; DC.B: direct current block; LPF: low pass filter.

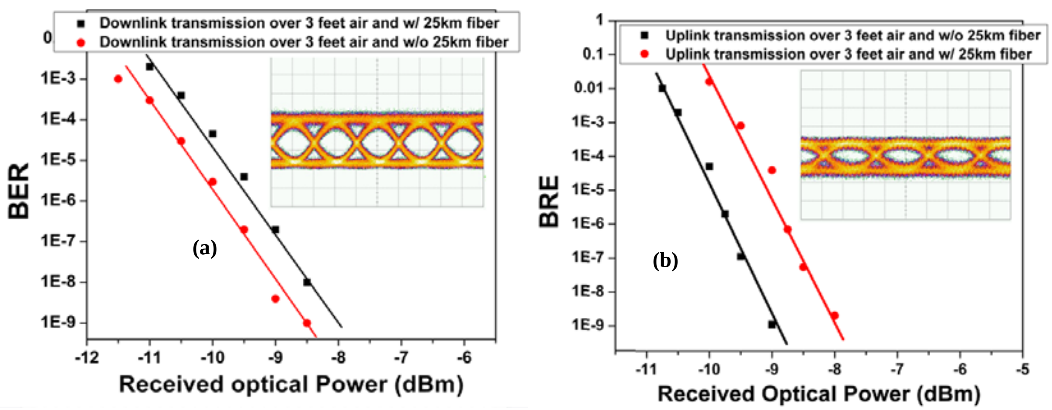

Fig. 2 Eye diagrams and BER curves of multi-gigabit data transmission. (a) for downlink data transmission at 2.5-Gb/s over 3 feet air and 25km fiber; (b) is for uplink data transmission at 2-Gb/s over 3 feet air and 25km fiber.

4. Conclusions

In summary, a bidirectional 60GHz wireless-over-fiber for multi-gigabit access network system has been proposed and implemented. In our scheme, numerous electrical LO devices at MM-W frequencies in BSs and MTs can be eliminated. Because LO is centralized in CO and distributed to BSs and MTs as a broadcasting service in the form of downlink data. Therefore, it can be reused for the uplink in BSs and MTs. The operation principle and feasibility of uplink and downlink transmission of multi-gigabit data have been demonstrated experimentally. This proposed CO-BS-MT system architecture is a promising solution for providing function-centralized, cost-effective MM-W wireless-over-fiber access networks.

5. References

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