High-Speed Fiber–Wireless–Fiber Bridge System for Fixed Wireless Link in Millimeter-Wave Band Using Photonic Technology

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Abstract

We present photonics-enabled technologies to realize high-speed fiber–wireless–fiber bridge systems in the millimeter-wave band, including a photonics-enabled receiver and an all-photonic receiver. In the former method, the millimeter-wave signal is down-converted to the microwave band before being converted to the optical signal for further transmission using an optically generated local oscillator signal. In the latter method, the millimeter-wave signal is directly converted to the optical domain without any frequency conversion using a broadband optical modulator. Using the proposed technologies, we successfully transmitted high-speed signal over both systems.

1. Introduction

Fiber–wireless–fiber bridge systems in high-frequency bands are promising for interconnections, disaster recovery, and fixed access networks for indoor environments. In these systems, wireless receivers are normally installed outdoors, such as on rooftops or windows, and the received wireless signal should be further transmitted to end users, typically indoor residents, over a second fiber link. In addition, encoding radio signals collected at antenna sites to the optical backbone is essential for the uplink mobile fronthaul. In this application, the evolution of radio access networks, which are expected to continue beyond 71 GHz towards the terahertz band, poses significant challenges to transport networks, particularly the uplink fronthaul. In both scenarios, the simplification of antenna sites and fiber transport systems is vital to satisfying the rapid increase in the number of small cells. Currently, systems based on electronic receivers for radio-to-optical conversion at the antenna sites are widely used [1]. However, the inclusion of electrical local oscillator (LO) sources at antenna sites complicates the system configuration, operation, and management. In this paper, we present two different approaches based on photonic technology to simplify the antenna sites and the second fiber transmission link. The first method is based on a photonics-enabled receiver to convert a millimeter-wave (mmW) signal to the microwave band before converting it to the optical domain for further transmission to the receiver. In addition, for the further fiber link transmission, an optical phase modulation and direct detection technology using an optical filter is employed to simplify the system and the receiver. In the second method, an all-photonic receiver using a broadband optical modulator is used to directly convert an mmW signal to an optical signal without any frequency conversion. A photonic down-conversion technology is also utilized to down-convert the signal to the microwave band. Both the systems can simplify the antenna sites and the second fiber link transmission, rendering them a simple and efficient method for high-speed bridge and uplink mobile fronthaul in ultra-high frequency bands.

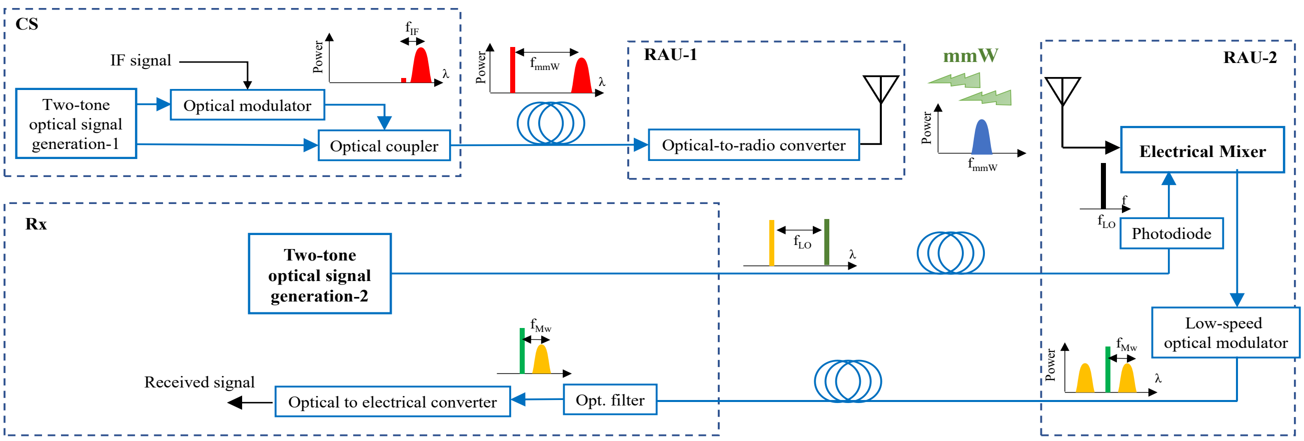

Figure. 1: Schematic diagram of fiber–wireless–fiber system using photonics-enabled receiver.
CS: central station; RAU: remote antenna unit; Rx: receiver; mmW: millimeter-wave; Mw: microwave; IF: intermediate frequency; LO: local oscillator.

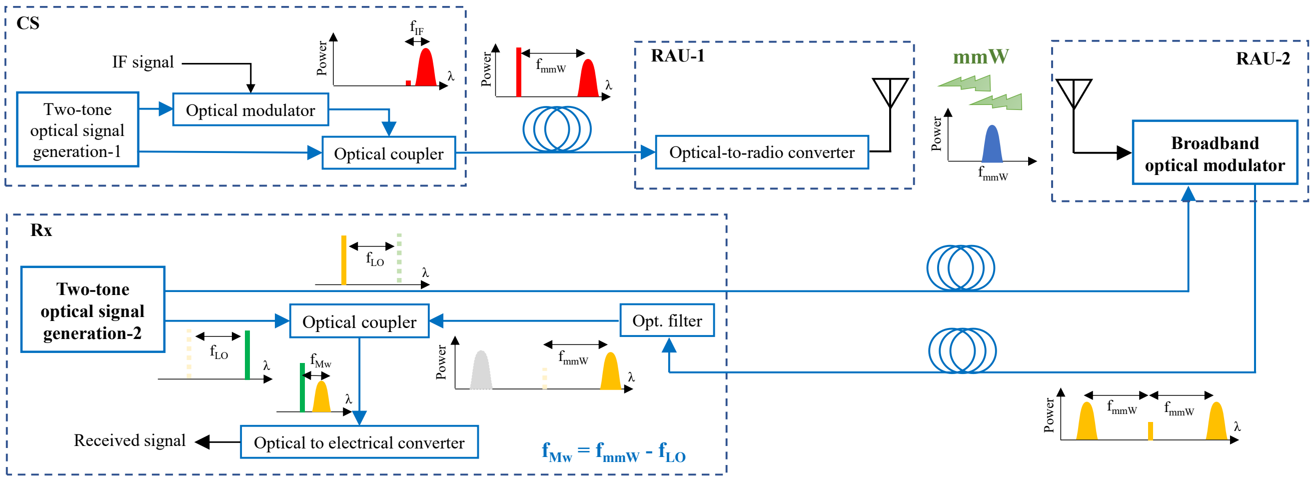

Figure. 2: Schematic diagram of fiber–wireless–fiber system using optical modulator and photonic down-conversion.

2. Photonics-enabled receiver

The system concept of a fiber–wireless–fiber system using a photonics-enabled receiver is shown in Fig. 1. The system consists of four main blocks: a central station (CS), remote antenna unit 1 (RAU-1), remote antenna unit 2 (RAU-1), and receiver (Rx). The CS generates and modulates the data on the optical signal. A two-tone optical signal consisting of two coherent optical sidebands is generated using optical modulation technology. The two optical sidebands are separated, and one of them is modulated by a data signal using an optical modulator. The modulated and unmodulated sidebands from the two-tone optical signal are combined to construct a radio-over-fiber (RoF) signal. At RAU-1, the RoF signal is up-converted to an mmW radio signal using a high-speed photodetector. The generated signal can be further amplified to increase the power level before transmitting to RAU-2. At RAU-2, the mmW signal is received and down-converted to the microwave band using an electrical mixer. To simplify RAU-2, a local oscillator signal is optically generated at the Rx and sent to RAU-2 for the signal down-conversion. The down-converted signal is converted to an optical signal using a low-speed optical modulator. The signal is transmitted to the Rx and detected using a low-speed photodiode. To prove the system concept, we successfully transmitted 80-Gb/s line rate signal over the system [2].

3. All-photonic receiver

The system concept of a fiber–wireless–fiber system using an all-photonic receiver is shown in Fig. 2. Similar to the first method, the system consists of four main blocks, including a CS, RAU-1, RAU-1, and Rx. The CS and RAU-1 are same as in the first case. At RAU-2, the mmW signal is received and converted to an optical signal using a broadband optical modulator. For the mmW-to-optical conversion, the optical carrier signal is directly modulated by the mmW signal. Compared with the electronics-based conversion method, which needs to down-convert the signal to a low-frequency band before converting to the optical signal, the direct mmW-optical conversion method can significantly simplify the antenna site. The Rx performs signal reception, detection, and down-conversion to the microwave band. A direct photonic down-conversion method can also be used to simplify the receiver and reduce the frequency offset and phase noise of the detected signal. Another two-tone optical signal is generated, and the two sidebands are separated. One of them is transmitted to RAU-2 for data modulation. The other sideband is used for signal detection and down-conversion. The received optical signal from RAU-2 is filtered to select only one of the sidebands using an optical filter. The filtered signal is then combined with the unmodulated sideband from the generated two-tone optical signal. The combined signal is input to a photodiode for conversion to a microwave signal. As a proof-of-concept demonstration, we successfully transmitted more than 70 Gb/s line rate over the system [3].

4. Conclusions

We present high-speed fiber–wireless–fiber systems in the millimeter-wave band using a photonics-enabled and an all-photonic receiver. The proposed systems significantly simplify the antenna sites and optical receivers. We successfully demonstrated high-speed signal transmission over the proposed systems with a line rate of over 70 Gb/s. The proposed systems are promising for fiber–radio bridges and uplink fronthaul systems in ultra-high frequency bands in beyond-5G networks.

References

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