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A multi-band access radio-over-fiber link with SSB optical millimeter-wave signals based on optical carrier suppression modulation

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ABSTRACT

In this paper, we have reported a radio-over-fiber (RoF) link with a single sideband (SSB) optical millimeter (mm)-wave signal to support the 20 GHz, 40 GHz and 60 GHz mm-wave multiband wireless accesses, based on the optical carrier suppression (OCS) modulation via a nested Mach–Zehnder modulator (MZM). The downstream data is only modulated on one of the multiple tones of the optical signal. At the base station (BS), according to the requirement of the wireless users, the multitone optical signal can be decomposed as different SSB optical signals using tunable fiber Bragg gratings (FBGs). Each SSB optical signal consists of two tones: the data-bearing optical tone and a referenced optical local oscillator to convert the baseband optical signal to the electrical mm-wave one based on heterodyne beating. The simulation results reveal that our proposed scheme can provide multiband wireless accesses and without dispersion compensation after 30 km single-mode fiber (SMF), the 10 Gb/s 4-QAM downstream data on the three-band mm-waves have minor degradation.

1. Introduction

Global internet traffic is predicted to grow threefold in 2017 driven by high-definition (HD) real-time video streaming, ultrafast data download and teleconferencing [1]. With the penetration of smart mobile-connected devices coupled with the sharp rise in the data traffic of mobile video services, the requirements of the wireless bandwidth have increased explosively. The millimeter (mm)-wave band, especially for 60 GHz band with the globally available 7–9 GHz unlicensed bandwidth [2,3] and negligible interference compared with current low radio-frequency (RF) wireless services, has been viewed as a promising candidate for high-speed wireless data transfer. But the large transmission loss in the air limits its distribution coverage and the cell size of wireless communication system [4]. The radio-over-fiber (RoF) technology, making full use of the advantages of the ultra-low transmission loss, ultra-wide bandwidth of the optical fiber and the high flexibility of the wireless system, has been nominated as one of the promising solutions for wireless network to not only extend the coverage of the mm-wave band wireless signals but also release the system complexities for both base station and central office [5,6]. It has been also considered as an enabling technology to increase the communication capacity and reduce the system costs [7]. Recently, the generation and transmission of the multiband signals have been demonstrated in Ref. [8–18]. In Ref. [8–10], the multiband electrical signals are firstly electrically combined together and then converted into an optical signal via a single electro-absorption modulator (EAM). In these schemes, the optical modulator needs to be properly operated to find its optimal operation point, and special attention needs to be paid

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to the distortion produced by the nonlinearity of EAM. Moreover, the signal performance in these schemes is limited by the EAM nonlinearity, residual chirp, and the crosstalk among multiband signals. A scheme, integrating a wavelength division multiplexed-passive optical network with a 60 GHz radio-over-fiber system to simultaneously provide wired and wireless signals and only using $N+1$ single-drive Mach–Zehnder modulators (MZMs) for a N-channel wavelength-division multiplexed passive optical network converged with RoF (WDM-PON-RoF) system, is proposed in Ref. [11]. In this scheme, the electrical wired and 10 GHz wireless data are firstly merged together in electrical domain, so the wired and wireless data are independent of each other. They are modulated on the first-order sideband and optical carrier. Moreover, at the optical network units/base stations, the wired and wireless users can only receive their own data and the scheme can only provide two-band signals. In Ref. [12], based on a hybrid mode locked laser, a scheme capable to simultaneously generate up-to 5 WDM-PON and RoF channels is presented. This scheme has the same issues in Ref. [11]. In Ref. [13], an arrayed waveguide grating (AWG) multiplexer with proper selection is used to enable the integration of dense WDM multiband signals with channel spacing of 12.5 GHz. But in this scheme, for a channel, in order to generate the baseband, intermediate frequency (IF), and mm-wave RF signals, there needs to be three laser sources along with three modulators in the central office, which makes the system more expensive. Reference [14] has proposed a scheme based on a dual-parallel Mach–Zehnder modulator, following a single-drive Mach–Zehnder modulator to generate the multiband signals including baseband, frequency-doubled, and frequency-quadrupled through optical carrier suppression and frequency-shifting techniques. However, the multiband signals generation is implemented with an expensive and complicated modulator and the spectrum structure of the optical mm-wave signal is more complex since each sideband carries the downstream data, which can induce amplitude fading effect as the beating tones with the different frequencies added coherently in the photodiode (PD) at the base station. To improve the dispersion tolerance, a scheme with multiband generation is proposed in [15,16] using two cascade MZMs. The first one is used to generate a DSB optical signal, and the second one is worked at the minimum transmission point to generate an optical carrier suppression signal. Even though the scheme has high-dispersion tolerant transmission, there needs an optical filter to convert the DSB optical mm-wave signal to the SSB one after the first MZM. Subsequently, they have proposed a full-duplex RoF system transmitting downlink wireless 20 GHz, 60 GHz mm-wave, and wired baseband data via a single MZM [17]. But it has the same issues as [14] with complex spectrum. In [18], a bidirectional three-band lightwave transport system is proposed. By cascading a phase modulator (PM) and a MZM, multiple coherent lightwaves are generated to convey downstream baseband (BB)/microwave (MW)/millimeter wave (MMW) signals. But all the multiple coherent lightwaves carry the downstream data, which induces the fading effect due to the fiber dispersion and degrades the generated RF signal performance as they are heterodyne beating at the base station.

In this paper, we propose a RoF link with SSB mm-wave signals to support multiband wireless accesses, including 20 GHz, 40 GHz and 60 GHz mm-wave signals, based on optical carrier suppression (OCS) modulation. In the central station (CS), the optical signal is generated via a nested Mach–Zehnder modulator and a laser source, and it consists of four tones with the equal frequency spacing. Only one carries the downstream data, while the other ones are unmodulated. At the base station (BS), mm-waves at 20 GHz, 40 GHz and 60 GHz are obtained via two tunable fiber Bragg gratings (FBGs) [19–21] and a PD for wireless access. One of these three unmodulated sidebands can be used as the uplink optical carrier for uplink. The feasibility and scalability of our proposed multiband wireless accesses for simultaneous distributions of mm-wave data are confirmed by the simulation. Compared with the previous reports [8–18], our scheme has several advantages: firstly, only a single mm-wave oscillator and a nested MZM are required in the CS, which makes the CS cost-efficient; besides, only one tone of the optical signal carries the downstream data, so the influence of the fiber chromatic

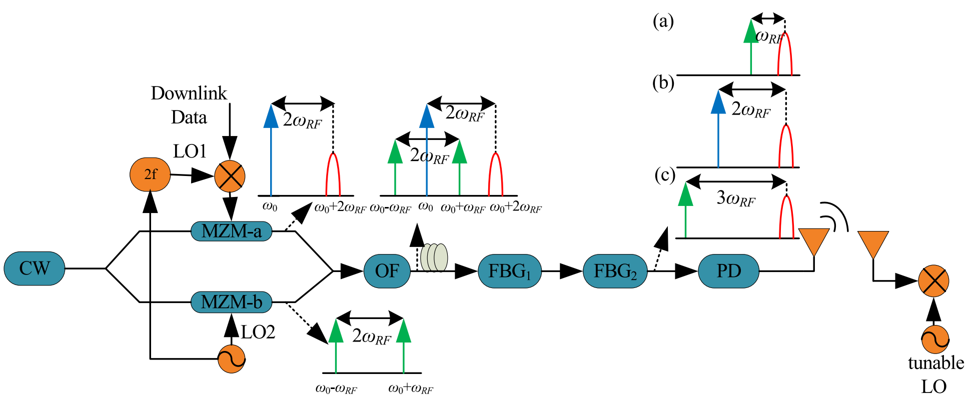

Fig. 1. Schematic diagram of the proposed multiband wireless access link. CW: continuous wave laser, MZM-a: the upper sub-Mach–Zehnder modulator, MZM-b, the lower sub-Mach–Zehnder modulator, OF: optical filter, FBG: fiber bragging gating, PD: photoelectric detector, LO: local oscillator.