A Radio over Fiber System for Simultaneous Generation and Transmission of Multiband Signals

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Abstract we propose and experimentaly demonstrate a novel RoF system for simultaneous generation and transmission of baseband, micro-wave and millimeter-wave signals with a single wavelength using a dual-parallel Mach-Zehnder modulator and a single-drive Mach-Zehnder modulator.

Introduction

Multiband optical transmission technology [1, 2] can simultaneously deliver baseband, micro-wave (MW) and millimeter-wave (MMW) signals in radio over fiber (RoF) systems. It exhibits flexible application potential for future wireline and optical wireless access networks. In [1], however, individual light source and modulator are needed for the generation of each frequency-band signal, which results in complex wavelength management and added cost. In [2], multiband signals are superimposed in RF domain to drive a modulator by using two electronic summing circuits, which introduces excess resistive loss and degrades transmission performance. Moreover, in these demonstrations, the need for high-frequency MMW signal generator and high-bandwidth modulator at the central station (CS) could result in complex transmitter architecture and high configuration cost.

In this paper, we propose an integrated multiband RoF system to provide broadband wireline and multiple wireless access services for users. Our scheme uses a dual-parallel Mach-Zehnder modulator (DPMZM) [3] followed by a single-drive Mach-Zehnder modulator (SDMZM) to realize the centralized modulation of multiband signals with a single wavelength. A baseband signal, a 20-GHz MW signal and a 40-GHz MMW signal are generated using 10-GHz components through frequency shifting with the optical carrier suppression (OCS) technique [4]. The system is scalable in frequency band if higher speed devices were available, thus optical MMW signal above 100 GHz can be obtained using this technique. This system shows compact and cost-effective configuration and enables simple and flexible network architecture for multiband signal transmission.

Principle

The schematic diagram of the proposed RoF system is depicted in Fig.1. The transmitter consists of a DPMZM [4] and a SDMZM. The DPMZM comprises a pair of x-cut LiNbO3 MZMs (MZMA, MZMB) embedded in the two arms of a main MZM structure. The two sub-MZMs have the same structure and performance, and the main MZM combines the outputs of the two sub-MZMs. At the CS, a continuous wave (CW) laser is launched into the DPMZM. The MZMA is biased at its null point and driven by a RF

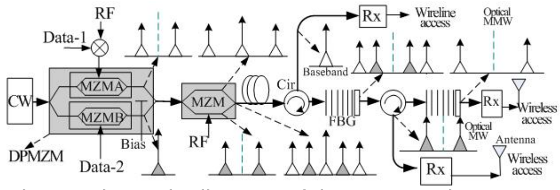

Fig.1. Schematic diagram of the proposed system

signal loaded with data-1 to generate a carrier suppressed RoF signal. The MZMB is biased at its quadrature point and driven by data-2. The two baseband data streams are independent and stem from different sources. The two optical signals are then added constructively by adjusting the bias of the main MZM, and they do not interfere with each other since the carrier of the RoF signal is suppressed. A following SDMZM biased at null point is driven by the same RF signal to shift the frequencies of the signals thus resulting in multiband signals. The output of the MZMA is modulated with OCS technique by the SDMZM to generate the optical baseband and MMW signals with data-1, therefore the wireline and wireless users can share the identical data service at the baseband and MMW frequency bands, while the output of the MZMB goes through the same frequency shifting to generate the optical MW signal with data-2. After the transmission, at the base station (BS), two fiber Bragg gratings (FBGs) with optical circulators are used to separate each band of the optical signals. Using this design, one can simultaneously deliver multiband signals with a single wavelength in an RoF system.

Experimental setup and results

Fig. 2 shows the experimental setup for the multiband signal generation and transmission. At the CS, a 10-GHz DPMZM (COVEGA Mach-10060) is used to modulate a CW light from a tunable laser at 1549.86 nm. An electrical data is obtained by mixing a 1.25-Gbps pseudorandom bit sequence (PRBS) signal of 2^7-1 with a 10-GHz RF signal, the waveform is shown in inset (i) of Fig.2. The sub-MZMA is biased at the null point and driven by the electrical data to generate RoF signal of 20-GHz rate, the eye diagram, the waveform and the spectrum are inserted in Fig.2 as insets (ii), (iii) and (iv) respectively. Sub-MZMB is biased at the quadrature point and driven by another 1.25-Gbps PRBS data with a word length of 2^7-1, the

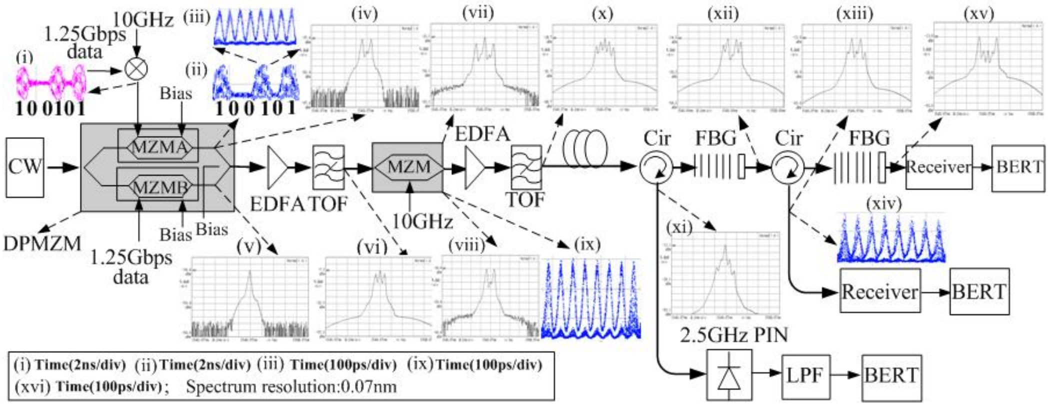

Fig.2. Experimental setup for the multiband signal generation and transmission

spectrum is shown in inset (v) of Fig.2. The two optical signals are constructively added and amplified by an erbium-doped fiber amplifier (EDFA) to 6 dBm. A tunable optical filter (TOF) with a bandwidth of 0.4 nm is employed to suppress amplified spontaneous emission (ASE) noise and the amplified-signal spectrum is provided in inset (vi) of Fig.2. A SDMZM is biased at null point and driven by a 10-GHz RF signal to obtain multiband signals. The baseband and 40-GHz MMW signals are generated by modulating the MZMA's output with the spectrum shown in inset (vii) of Fig.2. The MW signal of 20-GHz repetition frequency is obtained by modulating the MZMB's output, the spectrum and the eye diagram are shown in inset (viii) and (ix) of Fig.2. The multiband signals are amplified to reach a power level of 8 dBm for transmission, and the inset (x) of Fig.2 provides its spectrum.

After transmission over 25-km standard single-mode fiber (SMF), at the BS, an FBG with a 3-dB bandwidth of 0.1 nm and a reflection ratio of 90% is used to separate the baseband data from the multiband signals, the spectra of the reflected baseband signal and the passing signals are inserted in Fig.2 as insets (xi) and (xii), respectively. The passing signals from the first FBG is injected into a second FBG with a 3-dB bandwidth of 0.2 nm and a reflection ratio of 90% to separate the MW and MMW signals, the spectrum and the eye diagram of the reflected MW signal are shown in inset (xiii) and (xiv) of Fig.2, while the spectrum of the passing MMW signal is provided in inset (xv) of Fig.2. A low-cost 2.5-GHz PIN detector is used to detect the baseband signal and a low-pass filter (LPF) with a 3-dB bandwidth of 1.35 GHz is employed to reject the undesired RF components. Two high-speed receivers are needed to convert the optical MW and MMW signals to the electrical wireless signals, which are then sent to antenna after being amplified. In this experiment, the optical MW and the MMW signals are demodulated using a 2.5-GHz PIN by detecting their upper-sideband component for BER measurement purpose without a high speed photo-detector.

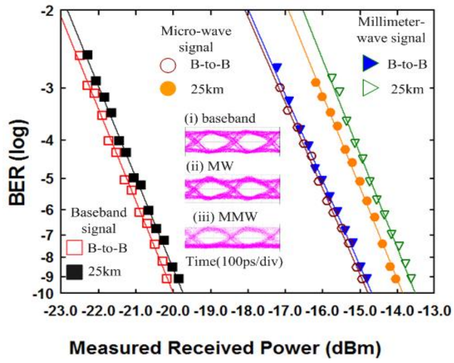

Fig.3. BER curves and eye diagrams

Fig.3 shows the measured BER performances and eye diagrams for the multiband signals. For the baseband data, after transmission of 25 km, the power penalty is about 0.2 dB as the chromic dispersion effect is negligible at this rate; while for the MW and MMW signals, the power penalties are lower than 1.2 dB, which can be attributed to the chromic dispersion of the transmission fiber. The eye diagrams of the multiband signals with an optical power of -10 dBm injected into the PIN are inserted in Fig.3 as insets (i), (ii) and (iii), respectively.

Conclusions

We have proposed a novel multiband RoF system and experimentally demonstrated the simultaneous generation and transmission of the 1.25-Gbps baseband, 20-GHz MW and 40-GHz MMW signals over 25-km SMF with less than 1.2-dB power penalties. The system is low cost using 10-GHz components and can be scaled to higher rates.

Acknowledgement

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