A Multiband Radio over Fiber System Using One Single-drive Mach-Zehnder Modulator

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Abstract: We propose and experimentally demonstrate a simple and cost-effective bi-directional radio-over-fiber (RoF) system for simultaneous transmission of downstream baseband, microwave (MW) and millimetre-wave (MMW) signals based on a single-drive Mach-Zehnder modulator (MZM). Upstream data transmission is realized by re-modulation of the downstream signals.

1. Introduction

Multiband optical transmission technology enables flexible applications in future access networks, where wireline data transport and wireless signal deliveries at different radio-frequency (RF) carriers are seamlessly converged in an integrated platform. In previous work [1], individual light sources and modulators are needed to generate multiband signals, which significantly increase the system complexity and the configuration cost. Reference [2] demonstrated a radio-over-fiber (RoF) system for transmission of multiband signals using a dual-parallel Mach-Zehnder modulator (DPMZM) followed by a single-drive Mach-Zehnder modulator (MZM), with complex transmitter architecture and high insertion loss. In addition, the high-speed electrical combiners or mixers used at the central station (CS) further increase the system cost [2, 3].

In this paper, we propose a simple and low-cost full-duplex RoF system to simultaneously transmit downstream wireline data and multiband wireless signals. The transmitter consists of only a single-drive MZM without additional RF electronic processing devices (combiners or mixers). For the first time to the best of our knowledge, we experimentally demonstrate baseband, 20-GHz microwave (MW) and 40-GHz millimeter-wave (MMW) signal generations using only a 10-GHz single-drive MZM. Our scheme is also scalable: if 30-GHz RF source and devices were available, optical MMW signal above 100 GHz would be obtained using frequency quadrupling technology.

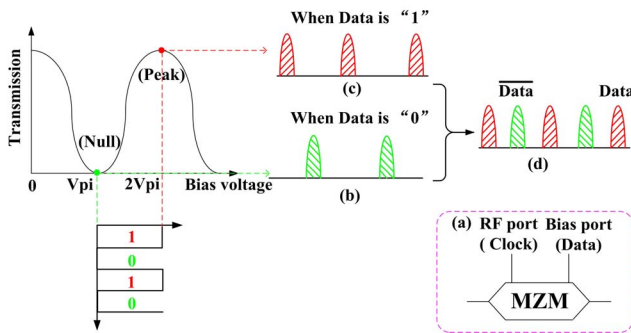## 2. Principles and architecture

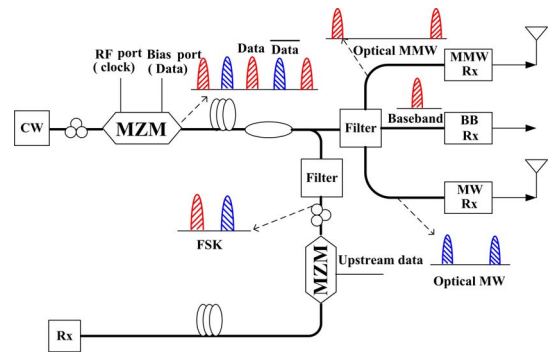**Fig. 1** The principle of the generation of multiband signals.

Fig. 2 Schematic diagram of the proposed RoF system.

Fig. 1 shows the principle of the generation of multiband signals based on a single-drive MZM, which is driven by a 10-GHz RF clock at the RF port and a unipolar Data at the bias port (Fig. 1 (a)). When the Data is "0" (low electrical level), the MZM is biased at its transmission null and an optical carrier suppression (OCS) signal (Fig. 1 (b)) is generated [4]. When the Data is set to "1" (high electrical level), the MZM is biased at the peak of the transmission curve and the output signal consists of the optical carrier and second-order harmonic components [4] (Fig. 1 (c)). As a result, if the electrical level of the Data switches between the low and high levels, a five-tone signal (Fig. 1 (d)), consisting of a baseband and a MMW signal carrying the Data, and a MW signal carrying inversed Data, can be achieved.

The schematic diagram of the proposed bi-directional RoF system is illustrated in Fig. 2. A continuous wave (CW) light is launched into a commercial single-drive MZM, which is modulated to simultaneously generate baseband, MW and MMW signals. After the transmission, at the base station (BS), an optical filter is used to separate each band. The proposed scheme provides wireline and two wireless services for the end users. In order to

save light sources at the BS, we use a pass-band filter to filter out the baseband and the right band of the MW signal, to generate a frequency shifting keying (FSK) signal, which is on-off keying (OOK) re-modulated by upstream data.
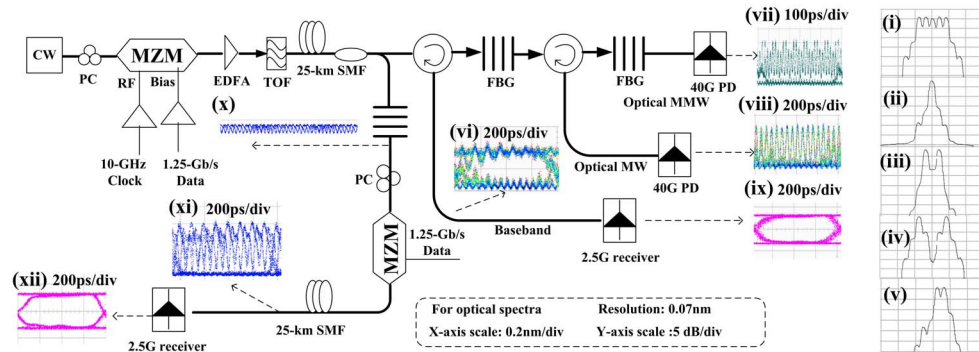
3. Experiment and results

Fig. 3 Experimental setup and results.

To verify the proposed scheme, we perform an experiment with its setup depicted in Fig. 3. At the CS, a CW light from a tunable laser at 1550.99 nm is fed into a single-drive MZM. The MZM is driven by a 10-GHz clock at the RF port and a 1.25-Gbps pseudorandom bit sequence (PRBS) data with a word length of 2^{31}-1 at the bias port. The output of the MZM (inset (i) of Fig. 3), consisting of baseband, 20-GHz MW and 40-GHz MMW, is amplified to reach a power level of 6 dBm using an erbium-doped fiber amplifier (EDFA). After the transmission of 25-km standard single-mode fiber (SMF), at the BS, the signal is separated by a fiber Bragg grating (FBG) with a 3-dB bandwidth of 0.106 nm and a reflection ration of 90%. The baseband signal is reflected and its spectrum and optical eye diagram are shown in insets (ii) and (vi) of Fig. 3. The passing signals are injected into a second FBG with a 3-dB bandwidth of 0.203 nm and a reflection ratio of 96% to separate the MW and MMW signals, whose spectra are provided in insets (iii) and (iv) of Fig. 3, respectively. The baseband signal is detected by a 2.5-GHz photo-detector (PD) and inset (ix) of Fig. 3 depicts the recovered electrical eye diagram. A 40-GHz PD is used to receive the MW and MMW signals respectively and their electrical eye diagrams are shown in insets (vii) and (viii) of Fig. 3, respectively. A part of the multiband signal is tapped by a 50:50 optical coupler and filtered by an FBG to generate a FSK signal, whose spectrum and optical eye diagram are provided in insets (v) and (x) of Fig. 3. After passing through a polarization controller (PC), the generated FSK signal is OOK re-modulated using a MZM driven by a 1.25-Gbps upstream data with a PRBS length of 2^{31}-1. After transmission through 25-km SMF, at the CS, the upstream data is detected by a 2.5-GHz receiver, insets (xi) and (xii) of Fig. 3 show its optical and electrical eye diagrams, respectively.
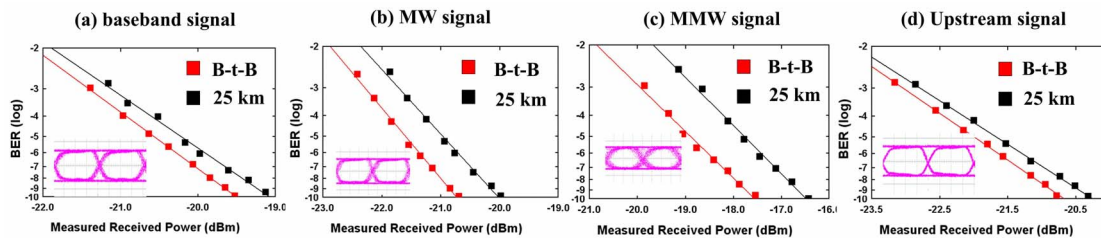

Fig. 4 BER performances and electrical eye diagrams.

The BER performances and electrical eye diagrams of the downstream multiband signals and upstream data are shown in Fig. 4. Error-free performances are achieved for all the data.

4. Conclusion

We have proposed a simple, cost-effective and scalable RoF architecture and experiments verify that our scheme could be a desirable candidate for future wireline and wireless converged networks. This work was supported by the 863 High-Tech program (2009AA01Z257).

References:

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