Convergence of RoF and access systems employing dual-parallel modulator in the central station

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Abstract *We propose and demonstrate simultaneous delivery of wireless and baseband signals in a passive optical network architecture. The downstream baseband data and RF signals are generated based on a single-integrated dual-parallel modulator.*

Introduction

With the increasing bandwidth demand and possible frequency congestion in low frequency band, the emerging radio over fiber (RoF) transmission technique becomes a promising method in providing broadband wireless access services over wide areas. Meanwhile, future wideband services in access networks also require the fiber infrastructures to deliver wireline signals. Therefore, it is desirable to simultaneously transmit wireline and RoF signals based on the same network architecture in an integrated platform.

Among RoF systems in access areas, multi-band optical modulation technique is an attractive method, which simultaneously delivers baseband, micro-wave (MW) and millimeter-wave (MMW) signals. It exhibits flexible application potential in future multi-service access networks since wireline and multiple wireless services are seamlessly converged in a common network.

In addition, the convergence of video, voice and data into triple play service (TPS) in a single network is an effective solution for network service providers. Passive optical network (PON) technology is believed to be a promising scheme to provide TPS in an integrated platform with a cost-effective configuration.

In this paper, we perform two demonstrations based on converged RoF and access systems using a single-integrated dual-parallel Mach-Zehnder modulator (DPMZM) [1] in the central station (CS). The first one is a multi-band transmission system to deliver baseband data, 20-GHz, and 40-GHz RoF signals. The second system is a PON which generates and sends video, voice and data from the central state. Both systems employ a single-integrated DPMZM, and upstream transmission is realized by carrier reuse.

Experimental setups and results

In previous demonstrations [2, 3], the need for high-frequency MMW signal generator and high-bandwidth modulator at the CS could result in complex transmitter architecture. Also, prior to our work [4], upstream data transmission was not demonstrated, while in practical access networks bidirectional data transmission is needed.

Here we show a full duplex RoF system to generate and transmit downstream wireline baseband data, wireless MW and MMW signals on a single wavelength. Upstream symmetric data transmission is obtained through re-modulating downstream differential phase-shift keying signal (DPSK) signal [5, 6], therefore, the base station (BS) configuration cost is greatly reduced since no additional light source and wavelength management are required at the BS. The scheme is scalable in frequency band if higher speed devices are available, thus optical MMW signal above 100 GHz can be envisioned using currently available electronic components.

The schematic diagram of the proposed RoF system is shown in Fig.1. The transmitter consists of a DPMZM [1] followed by a single-drive Mach-Zehnder modulator (SDMZM). The DPMZM consists of 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 10-GHz RF signal loaded with data-1 of 1.25 Gb/s to generate a carrier suppressed optical sub-carrier multiplexed (SCM) signal , whose repetition rate is twice as the RF signal frequency. The MZMB is also biased at its null point and driven by another data-2 to produce a 1.25-Gb/s DPSK signal. 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 optical SCM signal is suppressed. A following SDMZM biased at null point is driven by the same RF signal to shift the frequencies of the DPMZM outputs thus resulting in multi-band signals. The output of the MZMA is modulated with carrier suppression technique by the SDMZM to generate the optical baseband and frequency quadrupled MMW signals with data-1, therefore the wireline and wireless users can share the identical data service at the baseband and MMW frequency band, respectively, while the output of the MZMB goes through the same frequency shifting process to achieve frequency-doubled optical MW DPSK data.

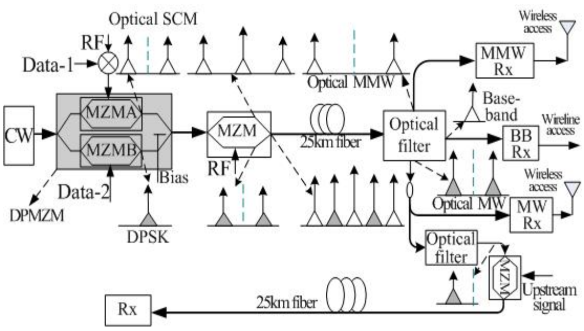

Fig.1. Schematic diagram of the proposed bidirectional RoF system

After the transmission, at the BS, an optical filter consisting of two fiber Bragg gratings (FBGs) with optical circulators are used to separate each band of the optical multi-band signals, which are detected respectively. The optical MW signal is split into two parts, one is detected by a MW receiver, and the other is filtered to obtain its lower sideband, which is re-modulated by the upstream on-off-keying (OOK) signal. The upstream re-modulation signal is sent back to the CS and then detected by a low-speed receiver. Using this scheme, one can simultaneously deliver downlink multi-band signals and uplink data with a single wavelength in a bidirectional RoF system.

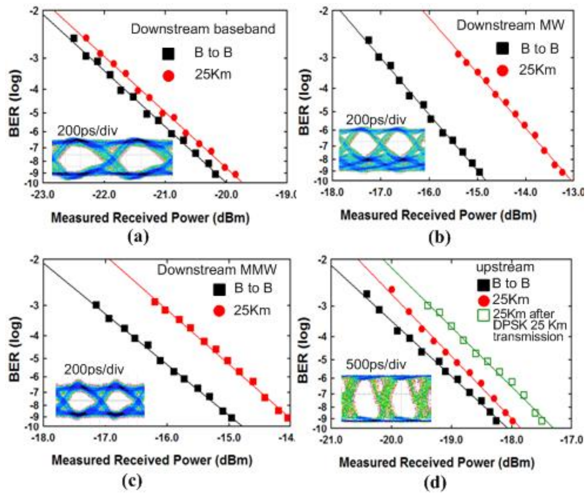

Fig.2. BER curves and electrical eye diagram. (a) Downstream baseband signal. (b) Downstream MW signal. (c) Downstream MMW signal. (d) Upstream re-modulation signal.

Fig.2 shows the measured bit error rate (BER) results. After transmission through a 25-km single mode fiber (SMF), for the downstream baseband data, the power penalty is about 0.2 dB as the chromatic dispersion effect is negligible at this rate; while for the MW and MMW signals, the power penalties are about 1.7 dB and 1.2 dB, respectively, which can be attributed to the chromatic dispersion of the transmission fiber in RF frequency band. The power penalty is less than 1 dB for the re-modulated upstream OOK signal. The electrical eye diagrams of the downstream multi-band signals and the upstream signal are provided as the insets in Fig.2, respectively.

Our second demonstration is a novel PON system to deliver video, voice and data using a single DPMZM [7]. In previous reports [8,9], only video, downstream data and upstream data were transmitted, simultaneous delivery of TPS including video, voice and data in the downstream were not demonstrated. To the best of our knowledge, our scheme realizes the first centralized modulation of TPS signals with a single wavelength. Upstream data re-modulation based on downstream DPSK format is also achieved.

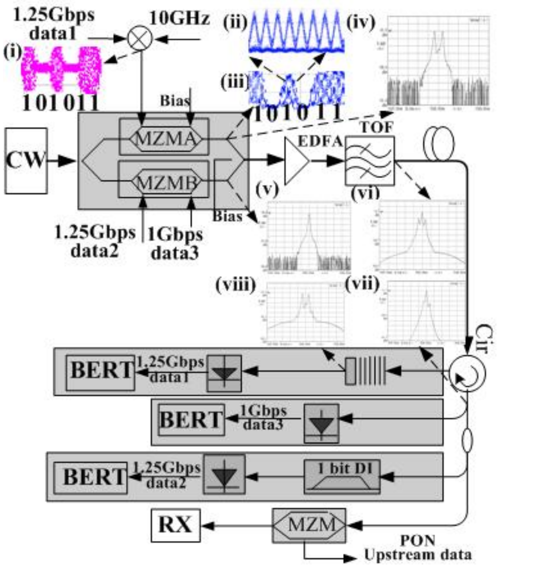

Fig.3. Schematic diagram of the proposed PON system.

The experimental setup of the proposed PON system is depicted in Fig.3. At the optical line terminal (OLT), the output of a CW laser is launched into the DPMZM. The MZMA is biased at its null point and driven by a 10-GHz RF signal loaded with a 1.25-Gb/s video signal to generate a carrier suppressed optical SCM signal. The MZMB is also biased at its null point and driven by 1.25-Gb/s data to obtain a DPSK signal. The 1-Gb/s voice signal is superimposed onto the DPSK signal to form ASK/DPSK format by modulating the bias point of the MZMB between the null and a small fraction of switching voltage [10]. The output of the MZMA and the MZMB are then added constructively by adjusting the bias of the main MZM. In this manner, the triple play signals are carried in the SCM, the ASK/DPSK formats, respectively.

After the transmission, an FBG with an optical circulator in an optical network unit (ONU) is used to reflect the ASK/DPSK signals while pass through the optical SCM signal. The passing optical SCM signal is directly detected by a 2.5-GHz receiver to retrieve the video signal. The reflected ASK signal is detected by an optical receiver to recover the voice signal, and the reflected DPSK signal is split into two parts, one is detected by a DPSK receiver to retrieve the data, and the other part is re-modulated by the upstream signal to the OLT.

Fig.4 shows the BER curves. For the downstream SCM signal and the ASK/DPSK signals, after transmission of 25 km, the power penalty is smaller than 0.8 dB. The electrical eye diagrams are shown in insets of Fig.4 (a), Fig.4(b) and inset (i) of Fig.4 (c), respectively, and the optical eye diagram for downstream DPSK after the interferometer is provided in Fig.4(c) as inset (ii). For the re-modulated upstream ASK signal, the power penalty for the DPSK signal is about 1.3 dB after 25-Km transmission at OLT, and the electrical eye diagram is shown in inset of Fig.4(d).

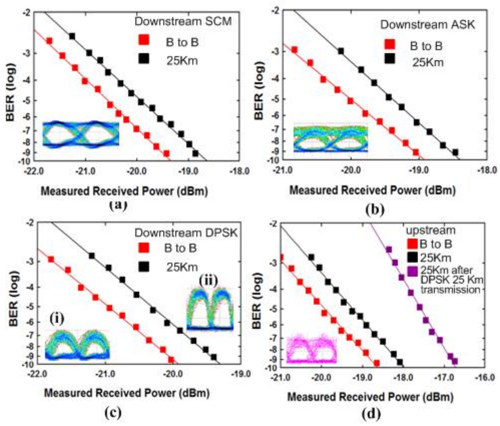

Fig.4. BER curves and eye diagrams for the downstream and upstream signals

Conclusions

We have proposed and demonstrated two RoF systems in a PON architecture. The first one generates baseband, MW, and MMW signals, and the second system delivers video, voice and data, all based on a DPMZM. The work is funded by the NSFC (60407008), and the 863 High-Tech program (2006AA01Z255).

References

1 K. Higuma et al *EL.*, vol. 37 (2001), 515
2 M. Bakaul et al *PTL*, vol. 18 (2006), 2311
3 K. Ikeda*, et al JLT*., vol. 21(2003), 3194.
4 Q. Chang et al *ECOC* 2007 paper p100
5 Z. Jia*, et al PTL*., vol. 19 (2007) 653.
6 W. Huang et al *PTL* ., vol. 15(2005) 1476
7 Q. Chang et al *ECOC* 2007 paper 4.4.7
8 J. Yu et al., *OFC* 2007, paper OWS4.
9 M. Khanal et al, PTL, Vol. 17(2005), 1992.
10 Yue Tian et al., ECOC 2006,Tu4.5.6.