Simultaneous Transmission of Baseband and UWB Signals in a WDM-PON Using Phase-Amplitude Hybrid Modulation

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Abstract: We propose and experimentally demonstrate a scheme to integrate UWB wireless signal transmission in a 10-Gb/s WDM-PON architecture. The UWB and 10-Gb/s baseband signals are simultaneously transmitted using phase-amplitude hybrid modulation.
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1. Introduction

Wavelength-division-multiplexed passive optical network (WDM-PON) is recognized as an attractive solution of next-generation access networks for providing higher bandwidth, larger coverage range, and better security [1-6]. In addition, it is desirable to support multiple wireline and wireless services for end-users simultaneously. Meanwhile, ultra wideband (UWB) is a promising short range wireless communication technology for its merits of very low energy level, high bandwidth, low cost, and coexistence with other wireless systems. Different schemes of UWB-over-fiber (UWBoF) technology have been proposed to increase transmission distance [7-10]. However, in previous reports, the UWB signals and the baseband signals have to be located at different frequency bands. High-speed baseband wireline data cannot coexist with UWB signals due to the overlapping of radio frequency (RF) spectra.

In this paper, we propose and experimentally demonstrate a WDM-PON system that simultaneously supports an UWB monocycle signals and 10-Gb/s baseband data. A 1.5-GHz UWB signal is modulated onto a downstream differential phase-shift keying (DPSK) signal using a Mach-Zehnder modulator (MZM) with low amplitude modulation (AM). Upstream signal transmission is realized by re-modulation of the low amplitude modulated DPSK signal using amplitude shift-keying (ASK) modulation with high extinction ratio (ER). The proposed scheme superimposes the UWB signal onto the 10-Gb/s baseband signal in the same spectrum range, and provides a more preferable UWB application in high-speed WDM-PON system. Error-free performances for the 10-Gb/s downstream and upstream signals are achieved after 12.5-km standard single-mode fiber (SSMF) transmission.

2. Operation principle

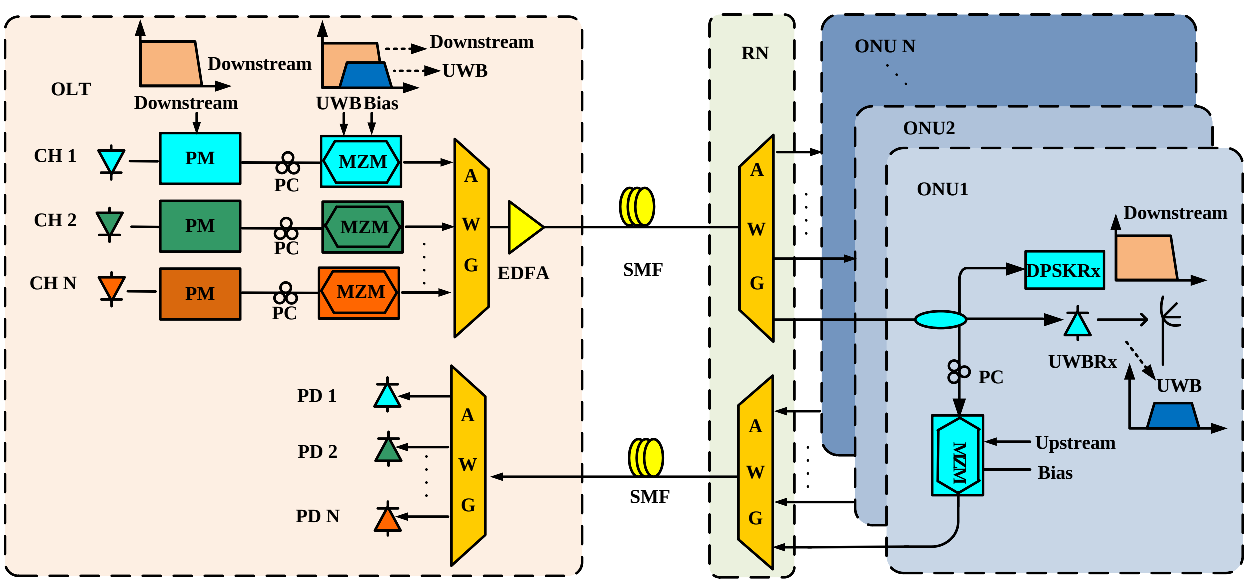

Figure 1. Schematic diagram of the proposed UWB and WDM-PON converged system

Fig. 1 shows the schematic diagram of the proposed WDM-PON system. In the optical line terminal (OLT), the downstream carrier of each wavelength channel is generated from a continuous-wave (CW) laser. A phase modulator (PM) is driven by a 10-Gb/s non-return-to-zero (NRZ) signal to generate a downstream DPSK signal. The downstream signal is then fed into a following single drive MZM, which is driven by an UWB signal. Low AM is obtained by carefully adjusting the bias of the MZM. The UWB signal has a spectral band of 3.1 - 10.6 GHz, which overlaps with the spectrum of the baseband signal by using DPSK/AM hybrid modulation. Then, signals from different wavelength channels are combined by an arrayed waveguide grating (AWG).

After transmission over fiber, another AWG is used in the remote node (RN) to demultiplex the optical signals, and distribution fibers route them to individual optical network units (ONUs). At each ONU, the received downstream signal is divided into three parts. One part is directly detected by a photo detector (PD) to obtain the UWB signal; another part goes through a Mach-Zehnder delay interferometer (MZDI) to recover the downstream DPSK signal; the third part is re-modulated by an upstream 10-Gb/s NRZ signal with high ER, and then sent back to the OLT for upstream detection.

3. Experimental setup and result

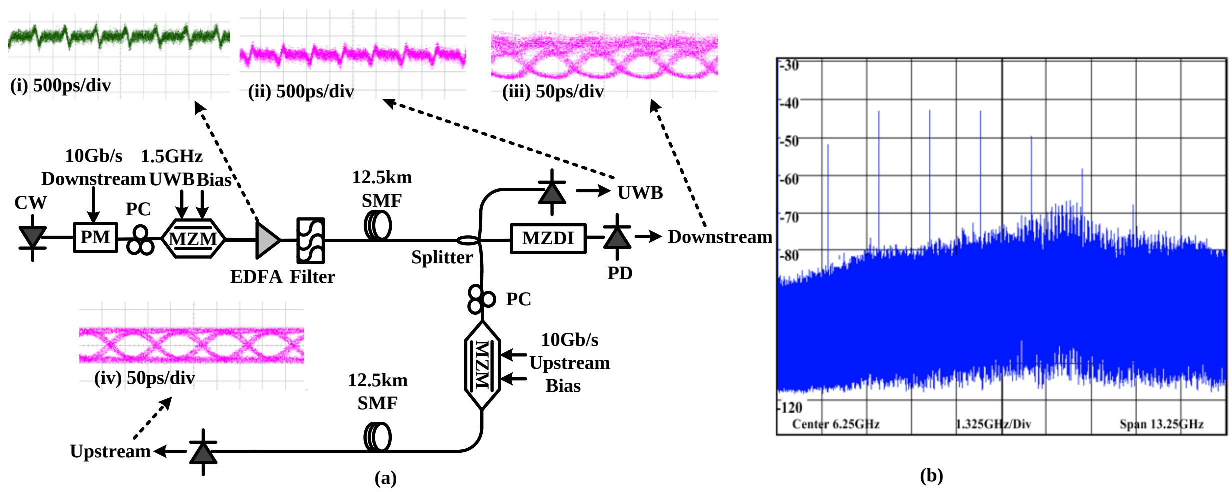

Figure 2. Experimental setup (a), and electrical spectrum of the UWB signal after transmission (b).

We perform an experiment to verify the feasibility of the proposed scheme as shown in Fig. 2 (a). In the OLT, a CW light from a tunable laser at 1550 nm is fed into a PM to generate a DPSK downstream signal. The PM is driven by a 10-Gb/s NRZ signal with a 2^{31}-1 word length from a pulse pattern generator (ANRITSU, MP1763c). A following MZM is driven by an UWB signal. The 1.5-GHz UWB signal with 1.2 Vp-p voltage amplitude and a pattern of "0, 0, 0, 1, -1, 0, 0, 0" is generated by an arbitrary waveform generator (Tektronix, 7122c) at 12-Gs/s sampling rate. The MZM has a half-wave voltage of 4 V and is biased at ~90% of its transmission peak. The optical UWB signal is shown in inset (i) of Fig. 2. The output signal from the MZM is amplified by an erbium-doped fiber amplifier (EDFA) before transmission, and a tunable optical filter (TOF) is used to suppress amplified spontaneous emission (ASE) noise.

After transmission over 12.5-km SSMF, in the ONU, the DPSK/AM signal is divided into three parts by two 50:50 couplers with a 1:1:2 splitting ratio. One part is directly detected by a PD to obtain the UWB signal, as shown in inset (ii) of Fig.2. The electrical spectrum is measured by an electrical spectrum analyzer (ESA) as shown in Fig.2 (b), where the central frequency is ~4.5 GHz and the 10-dB bandwidth is ~6 GHz (from 1.5 to 7.5 GHz), corresponding to a fractional bandwidth of ~133%. This is in accordance with FCC regulations that the fractional bandwidth is larger than 20% or a 10 dB bandwidth is at least 500 MHz in the frequency range from 3.1 to 10.6 GHz [11]. Another part is demodulated using a MZDI to convert the DPSK signal into an intensity signal, and the constructive port is detected by a 10-GHz PD. The eye diagram is shown in inset (iii) of Fig.2. The third part is re-modulated by a 10-Gb/ NRZ signal using an MZM with a high ER. The electrical eye diagram of re-modulated ASK after 12.5-km transmission is shown in inset (iv) of Fig.2.

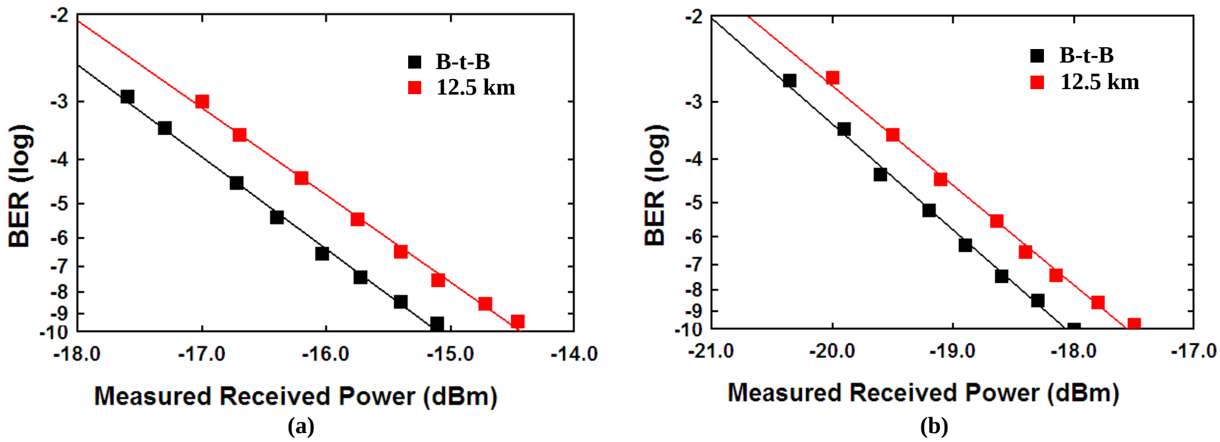

Figure 3. BER curves for (a) downstream, (b) upstream signals.

The BER performances of the downstream and upstream signals are shown in Fig. 3. For the downstream signal, the power penalty is ~0.6 dB after 12.5-km SSMF transmission as shown in Fig. 3(a). The power penalty of the upstream re-modulation signal is ~0.3 dB after 12.5-km transmission as shown in Fig. 3(b). Compared with the upstream signal, the downstream baseband signal suffers from higher power penalty due to the lack of balance receiver for the DPSK signal detection.

4. Conclusion

We experimentally demonstrated a scheme for simultaneous transmission of 1.5-GHz UWB and 10-Gb/s baseband signals on a single wavelength in a 12.5-km WDM-PON system. Our experimental results indicate that phase-amplitude hybrid modulation allows UWB signal and baseband data in the overlapped spectrum. The spectrum efficiency is increased by superimposing the UWB signals onto the high-speed baseband data, and the proposed scheme could be a desirable candidate for high speed WDM-PON system converged with UWBoF.

5. References

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