Design of a RoF-WDM-PON Structure Based on Coherent Detection and Polarization Multiplexing

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Abstract: Due to the increasing demand for bandwidth of current 5G applications, in order to make better use of optical millimeter wave resources this paper proposes a radio over fiber (RoF) - wavelength division multiplexing (WDM) - passive optical network (RoF-WDM-PON) architecture based on coherent detection and polarization multiplexing technology. The dual-polarized Mach-Zehnder Modulator (DP-MZM) was used to combine the wired and wireless signals modulated by different signal sources from Optical Line Terminal (OLT) in the same optical fiber through polarization multiplexing technology for the downlink transmission. And the Optical Network Unit (ONU) can implement the two signal distribution processing through coherent detection technology that improves receiver sensitivity and system performance. The 56-Gbit/s wired signal, 5-Gbit/s wireless signal for downlink, and 56-Gbit/s wired upstream signal and 2.5-Gbit/s wireless upstream signal have been transmitted over 30-km single mode fiber (SMF) successfully. Eventually we assess the performance of the RoF-WDM-PON system with the help of error vector magnitude constellations and eye diagram.

1. Introduction

High-capacity Wavelength Division Multiplexing-Passive Optical Network (WDM-PON) is particularly becoming more significant recently so as to handle increasing mobile traffic and attain a sustainable optical network. Current trends for future provision of broadband, interactive and multimedia services over wireless media in both mobile and fixed cellular networks are the development of a cost-effective optical network. The RoF system which refers to a technology whereby light is modulated by a radio signal and transmitted over an optical link to facilitate wireless access is characterized by low attenuation loss, and huge BW about THZ range, very less interference due to the information signal inform of light, low energy consumption[1]. Therefore, the WDM-PON and RoF can be merged to form RoF-WDM-PON structure[2].

Additionally, coherent detection with higher-order vector signals and MZM have been widely utilized in RoF-PON to yield a RF signal[3]. And in a conventional QPSK (Quadrature Phase Shift Keying) RoF system, the deployment of 10Gbps data rate signal with an input data rate of 10Gbps using DP-QPSK digital modulation technique have been demonstrated in[4]. It also negates the need for a radio source at the ONU through the re-modulation of the QDPSK signal using OOK (On–Off Keying) [5]. Based on the above technologies, hybrid fiber-optic wireless networks which benefit from high bandwidth and widespread assessment of fiber and wireless networks have been considered promising technology candidates for next-generation broadband access[6]. Therefore, the RoF-WDM-PON scheme can be deployed to meet bandwidth requirements. Multiple RoF signals that are wavelength-division multiplexed and coherent detected is transmitted through optical networks and distributed to different the user group for users' requirements for multiple services [7, 8]. Consequently in this paper, we have implemented a full duplex RoF-WDM-PON structure based on coherent detection and polarization multiplexing that effectively reduce noise and improve transmission quality.

The outline of the paper is organized as follows. In Section II, System Architecture is described. Section III, describes Experimental Setup and Discussion. Section IV concludes the paper.

2. System Architecture

The principle of the proposed novel RoF-WDM-PON architecture is shown in Figure 1. The system performs wavelength division multiplexing and demultiplexing through arrayed waveguide grating (AWG), so that multiple optical signals of different wavelengths are transmitted in the same fiber link. The following describes the system's principle by taking a transmission link as an example.

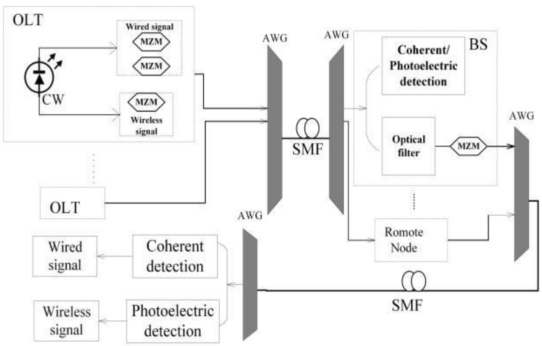

Figure 1: Principle of a RoF-WDM-PON system.
CW: continuous wave laser; MZM, Mach-Zehn-der modulator; SMF, single mode fiber.

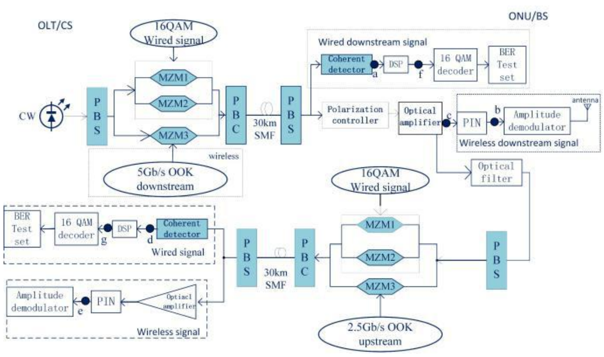

Figure 2: Detailed Block Diagram of RoF-WDM-PON Structure.

In OLT, the light emitted by a continuous-wave laser enter the DP-MZM to generate wired signal and wireless signal. Then the wireless channels and wired channels are modulated by wireless data and wired data for delivery to ONUs after multiplexing wireless and wired channels. After transmission through optical fiber, the wireless and wired channels are separated to each BS or remote node (RN) through an AWG, and then each ONU separates them through polarization multiplexing. On one hand, the wired signal and the wireless signal are detected respectively; on the other hand, the wireless signal is used for uplink. Moreover, the wired and wireless channels can be separated at the OLT so that the OLT performs coherent detection by a 2×4 90°mixer on them.

3. Experimental Setup and Discussion

The entire RoF-WDM-PON system shown in Figure 2 is implemented and simulated. The OLT constitutes the transmitter end of the system, which consists of a 45°linearly polarized CW laser of frequency 191.THz and 10MHz line width succeeded by a polarization beam splitter that splits the In-phase and Quadrature components. As is shown in Figure 2, the 56Gb/s cable signal is generated in two DP-MZM by 16QAM encoding. A sine generator of 20GHz is connected to the third MZM to generate 5Gb/s wireless signal by OOK modulation. Then a polarized beam combiner (PBC) is used to combine the in-phase and quadrature components of signals through a 30-km fiber-optic link.

After reception at the ONU, the signal is split using the polarization splitter. After the wired signal is received by the coherent receiver, it is used for wired access after signal processing and decoding. The wireless signal passing the polarization controller and optical filter with a center frequency of 193.1THz and a bandwidth of 10MHz is received by photoelectric detector to remote antennas and is extracted from a central optical carrier for uplink transmission, which avoids the introduction of additional light sources. As seen, figures 3(a)-(e) represent the spectral and electrical spectra of each point respectively. It can be seen that the demodulated signal is restored to a wired baseband signal at point a and point b is a wireless RF signal with the power is maximum at the frequency of 20GHz, which is recovered by photoelectric detection. And a pure central optical carrier with a central frequency of 1550 nm is filtered by optical filter in Figure 3(c).

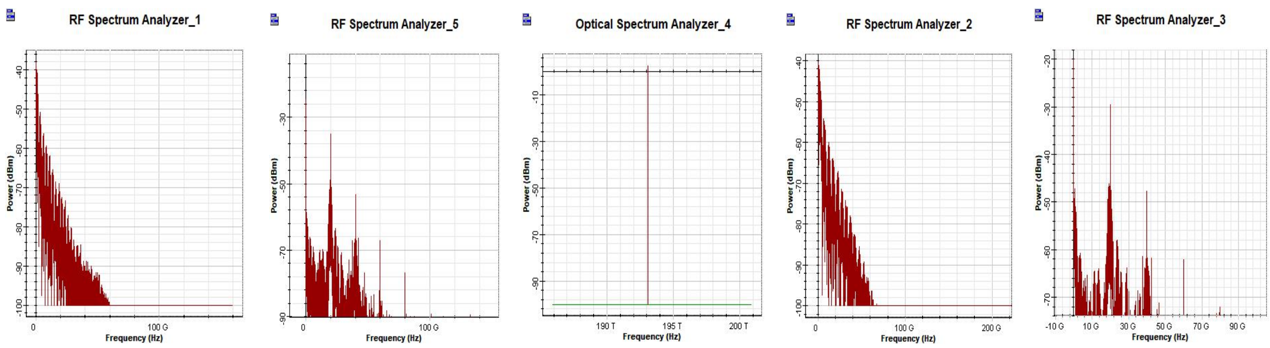

Figure 3: (a)wired downstream signal, (b) wireless downstream signal, (c)central optical carrier, (d)wired upstream signal, (e)wireless upstream signal.

The modulation of the wired and wireless upstream signal is the same as the downlink. However, the upstream wireless signal is re-modulated at 2.5Gb/s and transmitted to the OLT and is converted to electrical signals directly using a PIN photodiode and demodulated. Therefore, it can be seen that the original wired baseband signal is detected at point d after uplink transmission, and the original radio frequency signal is recovered by PIN detection at point e. Moreover, the final constellation diagram obtained for the received wired signal is given in Figure 4. The downstream and upstream wireless signal using OOK technique is also described by eye diagram in Figure 5. As seen, adding a DSP module for dispersion compensation and phase noise elimination can improve the quality of the received signal. Eventually the system realized full-duplex transmission, and both wired and wireless signals could be correctly demodulated.

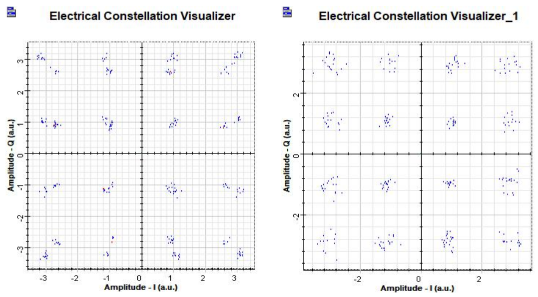

Figure 4: The constellation diagram of (e) downstream signal, (f) upstream signal.

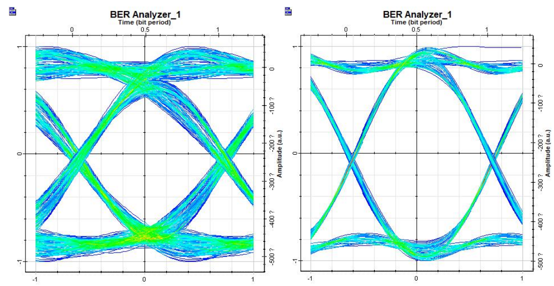

Figure 5: eye diagram of (g) downstream signal, (h) upstream signal.

4. Conclusions

A novel full duplex WDM-PON architecture compatible with 40 GHz RoF systems to provide wireless or wire-line channels is experimentally demonstrated and verified. In the case of a transmission distance of 30km and a bit rate of 20G Bit/s, the uplink BER is of 9×10^{-4}. The system cost and complexity can be decreased greatly, which will have a broad perspective of application.

Acknowledgments

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