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Study on 4PAM Radio over Fiber System Using Self-Mixing Technique

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Abstract

In this paper, a simplified optical millimeter-wave generated by two optical sidebands beating together in a 60 GHz radio over fiber (RoF) system with 10 Gbit/s 4-pulse amplitude modulation (4 PAM) transmission signal is proposed and simulated. 10 Gbit/s electrical 4 PAM signals modulated are conveyed over the length of 40 km standard single mode fiber (SMF) and recovered via the self-mixing technique after detecting directly at the receiver. Graphs of time-domain wave, frequency-domain and optical spectrum are measured out in different period, and the comparison of error vector magnitude curves of NRZ and 4 PAM signals under the different length of fiber is accomplished. The capacity of 4 PAM modulation is higher, though NRZ performs better than 4 PAM selected in RoF system within 80 km of fiber length as shown in the simulation results.

Keywords

Optical Communication, 4PAM, RoF, Self-Mixing

1. Introduction

Recently, high-speed and large-capacity transmission has been the focus of attention in the field of communication as global data growing fast. Wireless, digital and broadband communication is the trend of communication industry development in the future. Various transmitting schemes including radio over fiber (RoF) attract strong interest of researchers as well as the large scale deployment of fiber to the building (FFTB), fiber to the office (FTTO), fiber to the home (FFTH) and fiber to the desk (FFTD) which are considered to be the potential solution of "the last mile" [1]. By the technology of RoF, radio frequency (RF) signal processing function centralized in the optical line terminal (OLT) is converted to mm (millimeter)-wave with lower attenuation through the photoelectric device, then distributed from a base station (BS) to a mobile station (MS) with antennas, the optical network unit (ONU) offers access points to various users [2]-[4]. As shown in **Figure 1**, the compact RoF optical access network is where high speed of text, voice, RF video data are provided to different service terminations between the OLT and ONU. RoF as an important method realizing the seamless integration of wired and wireless access system can offer high-throughput information with utilizing massive bandwidth of the fiber [5]. However, to reduce implementation costs is an essential issue for commercial applications. Orthogonal frequency

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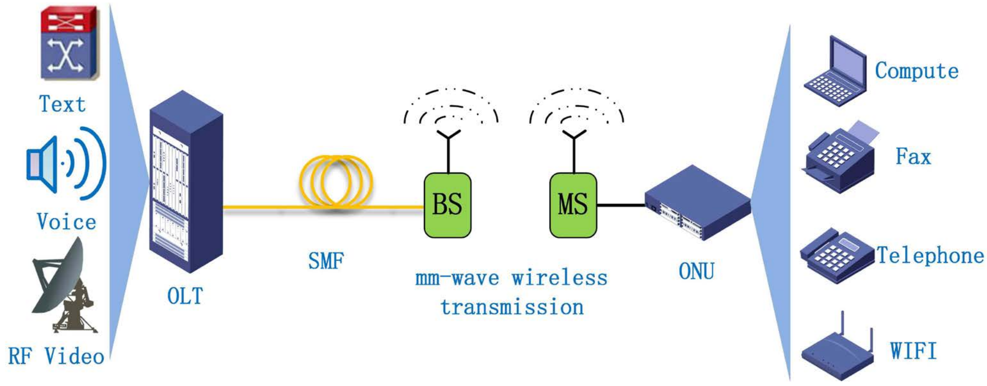


Figure 1. RoF system configuration (OLT: optical line terminal; SMF: single mode fiber; BS: base station; MB: mobile station; ONU: optical network unit).

division multiplexing (OFDM) is always used to modulate RF signals in RoF system [6] [7], meanwhile, the high peak-to-average power ratio (PAPR) is one of the main drawbacks of the OFDM modulation format, which not only degrees the performance of a linear amplified component but also pulls down overall property. In [8], a novel 60 GHz RoF system was proposed and experimentally demonstrated with 16 QAM-OFDM downstream signals, which employed partial transmit sequence to diminish the high PAPR from the OFDM signals that will increase the computation complexity of the system. 4 PAM was implemented to release this condition we proposed in the work because of its straightforward process and low-cost structures [9].

In this paper, we propose a simulation scheme of 4 PAM-RoF optical access system with the Optiwave. The 4 PAM signal is intensive signal modulated by a Mach-Zehnder modulator (MZM) at baseband and directly detected by a positive-intrinsic-negative photodiode (PIN-PD), and two paths of the mm-wave divided from a splitter are mixed together without wireless broadcast before one passing a phase shift. Among the 10 Gbit/s 4 PAM signal conveyed over 40 km SMF, graphs of time-domain, frequency-domain and optical spectrum are measured out in different period. Moreover, the comparison of error vector magnitude curves between Non-Return-to-Zero (NRZ) [10] and 4 PAM under the different length of the fiber is accomplished.

2. System Setup and Results

Figure 2 Illustrates the configuration of the proposed scheme. At the transmitter, light-wave source emitted from two external cavity lasers (ECL1 and ECL2) as the continuous wave (CW) laser, the frequency tone spacing of the two ECLs is 60 GHz. The maximum line width of the two CWs is 10 MHz and coupled together by a 3 dB optical coupler, where one (work frequency at 193.1 THz) is modulated intensity via a MZM driven with the 10 Gbit/s baseband 4 PAM signal and the other one (work frequency at 193.16 THz) without data modulation. The graph of time-domain and frequency-domain of the RF-4 PAM signal is presented in **Figure 3(i)** and **Figure 3(ii)**, respectively. We can see that the main bandwidth of RF baseband is 5 GHz because all the power is concentrated in the innerbroad band of 5 GHz.

Before transmitted over 40 km SMF with an erbium-doped fiber amplitude (EDFA), the time-domain diagram of the optical coupled signal shows in **Figure 3(iii)** and its optical spectrum shows in **Figure 3(iv)**, the commonly used fiber parameters we setup are as shown in **Table 1**. 60 GHz mm-wave is generated by two direct received optical sidebands beating together in a positive intrinsic-negative photodiode (PIN PD) with a bandwidth of 70 GHz and a DC responsivity of 1 A/W and dark current is 10 nA, the graphs of time-domain/frequency-domain are shown in **Figure 3(v)** and **Figure 3(vi)**. After that, the process of wireless transmission removed that mm-wave is transformed into the baseband by the self-mixing immediately, using phase shifter can ensure that the initial phase of two channels signal consistent, relevant figures are as shown in **Figure 3(vii)** and **Figure 3(viii)**. We assume the mm-wave $E_m(t)$ expressed simply as

$$E_m(t) = A\cos(f_m t)\cdot\left[1+\cos(f_r t)\right] \quad (1)$$

where f_m and f_r are the amplitude, high-frequency (60 GHz) and base-frequency (RF frequency) of the millimeter signal, then the electrical signal self-mixed $E_r(t)$ is

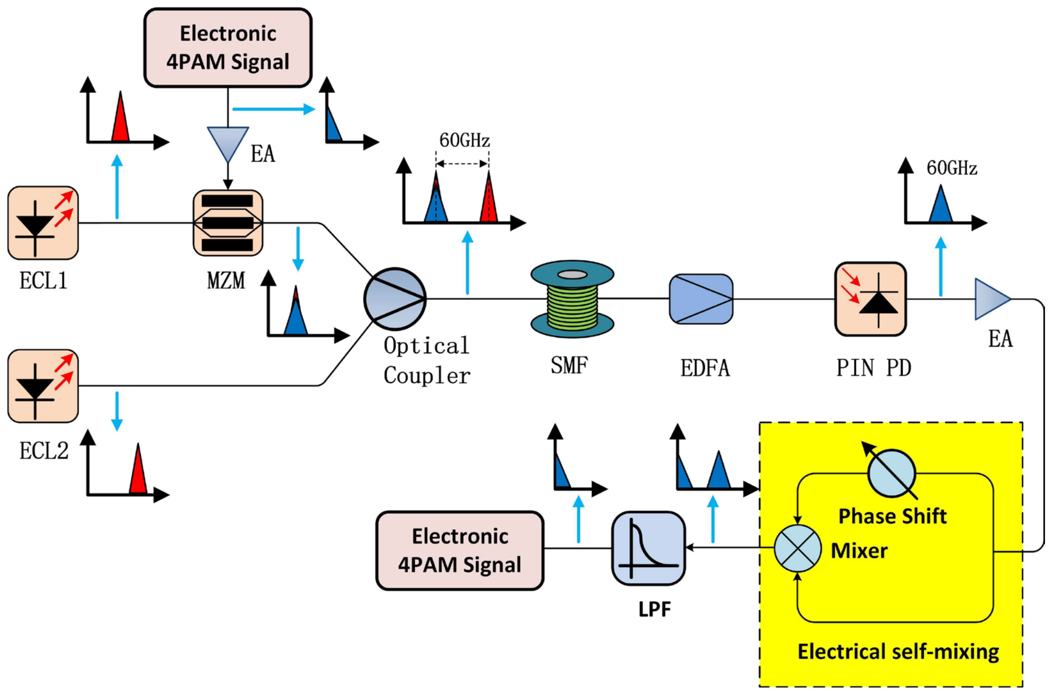
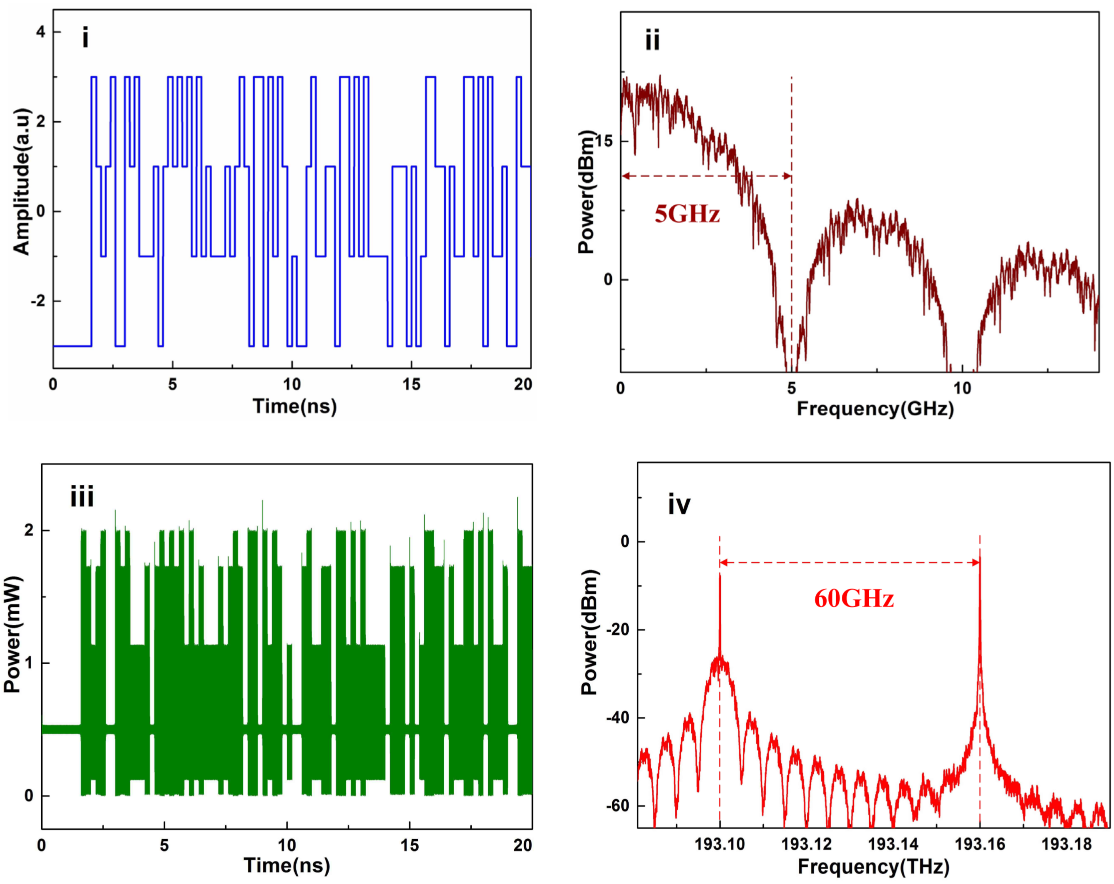


Figure 2. Schematic diagram of 60 GHz 4 PAM-RoF optical transmission system set up (ECL: external cavity laser; EA: electrical amplifier; MZM: Mach-Zehnder modulator; EDFA: erbium doped fiber amplifier; PIN PD: positive intrinsic-negative photodiode; LPF: lower pass filter).



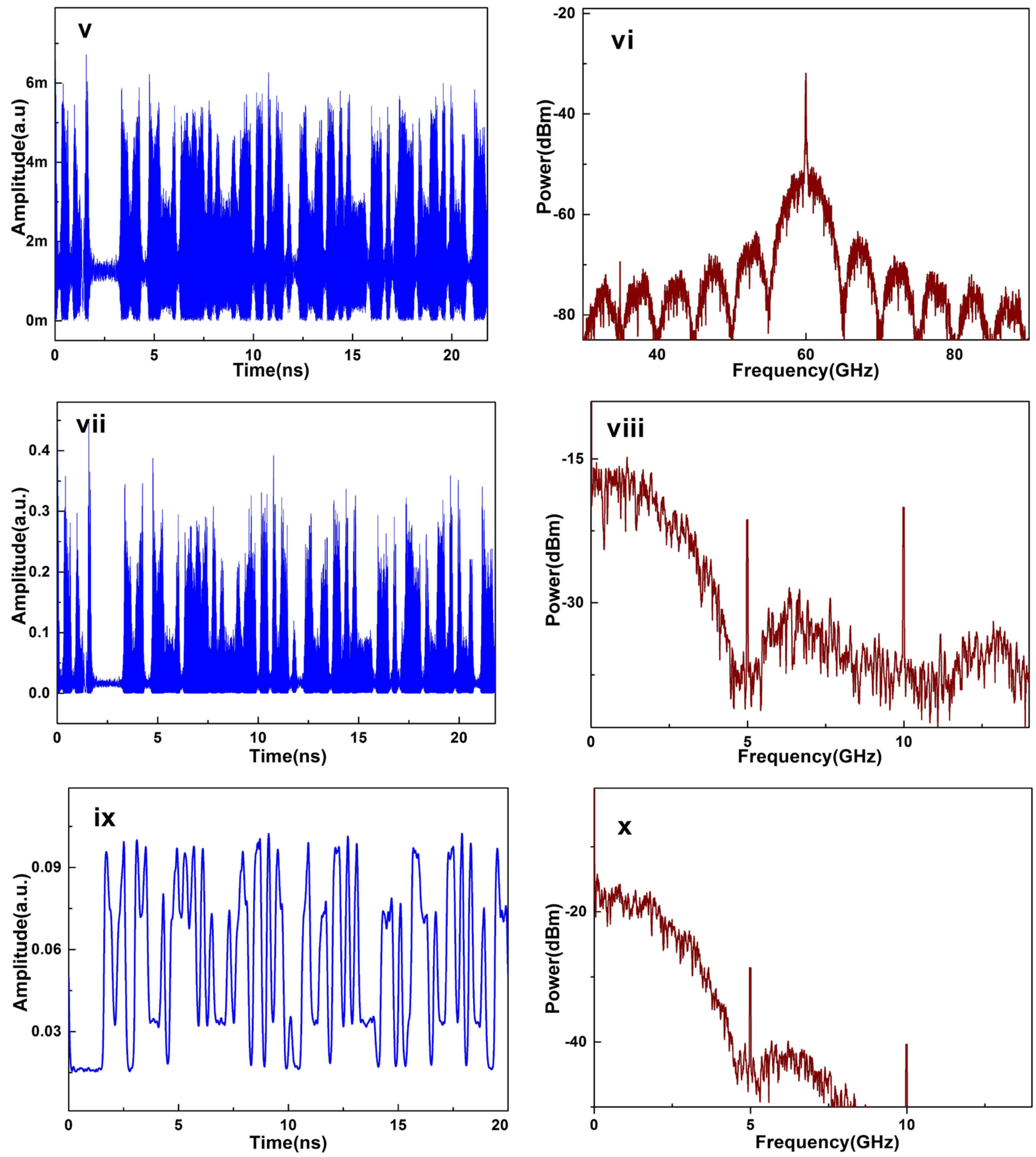


Figure 3. Time-domain wave, frequency-domain and optical spectrum in different stage of transmission.

$$\begin{aligned} E_r(t) &= E_m(t)\cdot E_m(t) \\ &= A^2\Big[\cos(f_r t)+\frac{3}{4}\cos\left(2f_m t\right)+\frac{1}{4}\cos(2f_r t) \\ &\quad +\cos(2f_m t)\cos(f_r t)+\frac{1}{4}\cos\left(2f_m t\right)\cos(2f_r t)+\frac{3}{4}\Big] \end{aligned} \tag{2}$$

Thus, the baseband f_r can be filtered out with a low pass filter, we select the third-order Bessel filter as the LPF.

With the clock recovered, the time-domain and frequency-domain of the electrical 4 PAM signal demodulated are as shown in **Figure 3(ix)** and **Figure 3(x)**.

From the EVM curves shown in **Figure 4**, NRZ performs better than 4 PAM selected in RoF system within length of 80 km fiber. However, the 4 PAM modulation has higher capacity than NRZ.

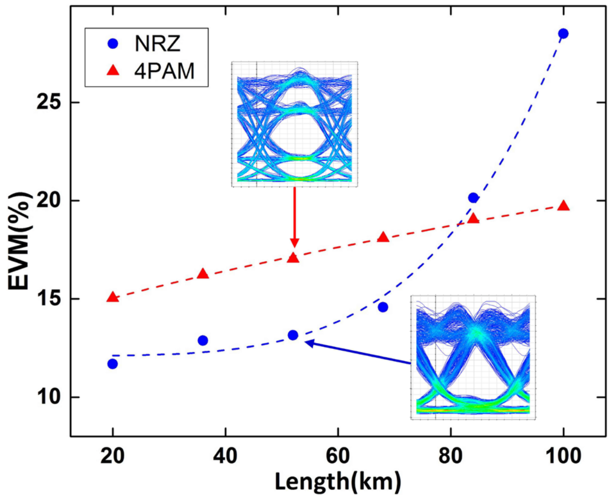


Figure 4. The EVM curves of NRZ and 4 PAM signal after transmission over different length fiber.

Table 1. The SMF parameters

	Parameters	Value
SMF parameters	Length(km)	40
	Attenuation(dB/km)	0.2
	Dispersion(ps/nm/km)	16.75
	Dispersion slop(ps/nm^2/km)	0.075
	Nonlinear coefficient(W^{-1}km^{-1})	2.6
	Core area(um^2)	80

3. Conclusion

We propose a 10 Gbit/s 4 PAM transmitted in the RoF optical access system with a method of self-mixing to recover the RF signal. Different graphs of time-domain wave and frequency-domain are measured by the optical software of Optiwave, and the comparison of EVM between NRZ-RoF and 4 PAM-RoF under the various length of the fiber is accomplished, the result shows that NRZ performs better than 4 PAM selected in RoF system within 80 km fiber, but the capacity of 4 PAM modulation is higher than NRZ.

Acknowledgements

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