Optics Communications 284 (2011) 3403–3407

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Employing inverse return-to-zero and Manchester formats for uplink wavelength reuse in RoF systems

Zhenbo Xu

Oplink Communications Inc., 46335 Landing Parkway, Fremont, USA

ARTICLE INFO

Article history:
Received 19 November 2009
Received in revised form 2 November 2010
Accepted 2 November 2010
Available online 21 November 2010

Keywords:
Frequency conversion
Modulation
Optical signal processing
Optical fibers
Radio over fiber

ABSTRACT

The inverse return-zero (IRZ) modulation format and Manchester format were investigated as wavelength reusing schemes in the RoF downlink systems. Since both of the modulation formats featured power remaining in the bit slot regardless of the bit value, the downlink optical carrier can be reused as the uplink light source. The performances of two formats were analyzed in the symmetrical and asymmetrical duplex RoF system. It was found that IRZ is more suitable for symmetrical system, and the duty cycle of IRZ pulse is the critical factor on the asymmetrical RoF system performance. However the Manchester format demonstrated the large system tolerance on asymmetrical duplex RoF system with the receiver sensitivity degradation within 1 dB.

1. Introduction

The radio over fiber (RoF) technique is a promising way to deliver high frequency millimeter wave through optical fiber. Due to the low fiber loss and broad fiber bandwidth, the cell coverage becomes more flexible and geographically wider. However, considering the cost saving for the RoF system, some research work aim on realizing double or even quadruple data capacity with limit resource facilities [1–4]. Alternatively, large amount of research have also been conducted to reduce the necessary electrical and optical components while still achieving the same performance and capacity. Recently, instead of employing an independent light source in each BS, the centralized light source in the center office (CO) has become an imperative hardware demand for the easy control and management of the light and accompanied driving circuits. A lot of research activities have been demonstrated to realize wavelength reuse function by modulating base band uplink data onto the optical carrier that comes directly from the CO as in [4–8]. It can be realized by adding a continuous wave (CW) into downlink signal in the CO and filter the CW out at the BS for uplink reuse. An alternative method adopted the carrier suppression technique to obtain two subcarriers, one was modulated with downlink data and the other was left for further uplink modulation. Schemes of using differential-phase-shift-key (DPSK) modulation format were also investigated to guarantee the continuous lightwave reuse for uplink modulation, with the cost of the complicated transceiver [9,10].

IRZ format is well known with optical power in each bit slot and applied in wavelength division multiplexing (WDM) system and passive optical network (PON) [11–13]. Especially when dealing with original narrow signal, using IRZ format, which is a reverse of the original signal width in the bit duration, provides the advantage on chromatic dispersion. Alternatively, Manchester format also features optical power in each bit slot. This paper, to the most of our knowledge, first time investigated the IRZ and Manchester formats as the uplink wavelength reusing scheme in RoF system.

2. Proposed techniques

2.1. IRZ and Manchester pulse generation and demodulation

The generation of IRZ or Manchester format can be implemented by the proper manipulation of a dual-drive Mach Zehnder modulator (MZM). The optical IRZ pulse is normally obtained when the initial electrical RZ pulse drive the MZM, which is biased at the maximum transfer point. Thus the power allocation of the optical IRZ pulse is a reverse of the input electrical RZ pulse. Note in this paper, we define the duty cycle (DC) as the initial electrical RZ pulse duration divided by the bit duration. Since IRZ pulses always carry optical power in both bits of '1' and '0' as shown in Fig. 1 (a), this feature enables the IRZ modulated carrier to be further reused for uplink modulation.

In order to generate Manchester pulses, the dual-drive MZM is biased at the minimum or maximum transfer point and works as a XOR operator. One branch of the dual-drive MZM is driven with NRZ format at specific data rate, while the other branch is loaded with alternative voltage of '1' and '0' at a double data rate as of the NRZ [14,15], so that in each NRZ bit slot there is always optical power

E-mail address: xuzhenbo@gmail.com.

0030-4018/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.optcom.2010.11.008

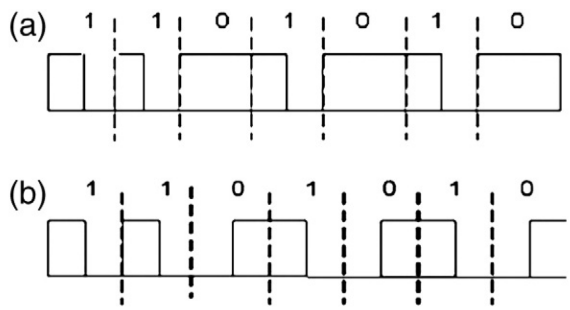

Fig. 1. Bit power allocation in (a) IRZ format pulse and (b) Manchester format pulse.

within half bit duration. In this way the generated optical Manchester pulses featuring the same optical power in each bit slot as shown in Fig. 1 (b), which can be used as uplink light source.

In the receiver, since the IRZ pulse is just an inversion of RZ pulse, an inversed electrical amplifier can be used to obtain the corresponding initial RZ signal for bit error rate (BER) evaluation. For Manchester format, the bit value is determined by the judgment on either the rising or falling edge in the middle point of the bit duration. The Manchester demodulator normally consists of an optical Mach-Zehnder interferometer (MZI) with a half bit duration delay in one arm and a pair of balanced photodetection subsequently [15].

2.2. System setup

Fig. 2 illustrates a duplex RoF system with IRZ or Manchester modulated downlink and NRZ modulated uplink. The duplex system with IRZ format in downlink is shown in Fig. 2 (a). The external cavity laser (ECL) generates continuous optical power of 1 mW and incident into a dual-electrode MZM with an extinction ratio of 30 dB. The electrical RZ pulse train with a pseudo random bit sequence (PRBS) of 2048 bits drives the dual-electrode MZM with push pull method. The 2.5 Gb/s electrical RZ pulse with specific duty cycle characterizes a rise time of ¼ the pulse duration. Since the MZM is biased at the maximum point, IRZ format optical pulse is achieved. Fig. 3 (a) shows the IRZ modulated optical baseband spectrum and eyediagram with 2.5 Gb/s data rate, right after the dual-electrode MZM. A phase modulator (PM) is driven by a sinusoidal of 20 GHz with the driven voltage of $V\pi/4$. Although there will be multiple order subcarriers generated in either sides of the optical carrier, in this investigation, we just considered the pair of first order optical subcarriers beside optical carrier with a frequency spacing of 40 GHz. Fig. 2 (a) inset shows the up-converted baseband signal on the two optical subcarriers by the phase modulator. This is because, after photo-detection in the receiver, we only demodulate the mixing frequency term at 40 GHz. The optical signal is amplified by an erbium-doped fiber amplifier (EDFA). The output signal is 3dBm and delivered through a single mode fiber (SMF) of 20 km with a dispersion of 17 ps/nm/km. A commercial optical interleaver with a channel spacing of 25 GHz (half bandwidth of the 50 GHz ITU frequency grid) is employed to filter out the optical carrier from the two subcarriers. The two subcarriers are incident on an ideal photodiode for downlink 40 GHz RF mm-wave generation. Subsequently this 40 GHz mm-wave signal is mixed with a 40 GHz clock by proper clock phase control and then is down-coverted to the baseband. A 3rd order low-pass electrical Bessel filter with a bandwidth of 5 GHz is adapted to reduce the out-band noise. Then the baseband IRZ signal passes an amplitude-inversed electrical amplifier to recover back into RZ pulse train. Bit error rate (BER) is

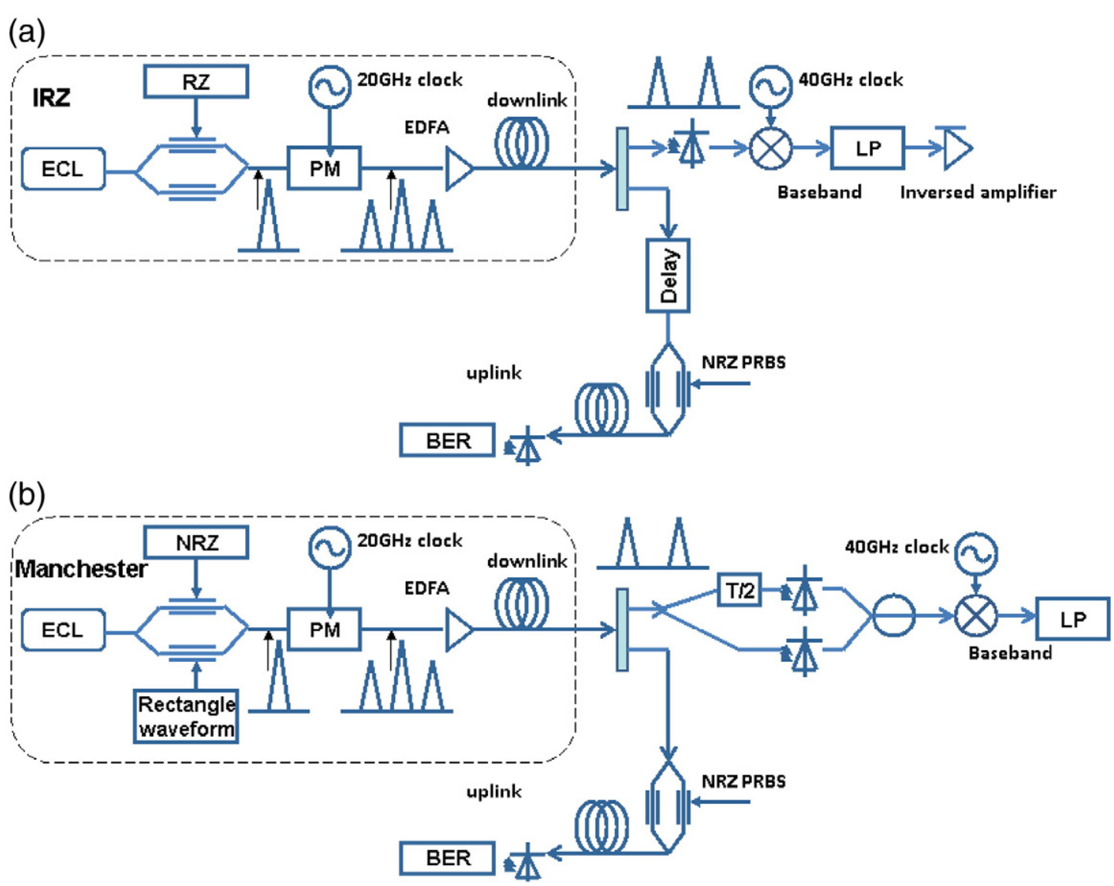

Fig. 2. Optical carrier reusing duplex RoF systems with delivering downlink (a) IRZ format and (b) Manchester format optical mm-wave signal and uplink NRZ modulation. ECL: external cavity laser, T/2: half of bit duration, LP: low pass Bessel filter.