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A bidirectional radio-over-fiber system using differential phase-shift keying signals for downstream and remodulated OOK for upstream

Fady I. El-Nahal

Electrical Engineering Department, Islamic University of Gaza, Palestine

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ABSTRACT

Radio-over-fiber (ROF) is a promising technology to achieve future broadband access requirements with reliability, transparency and flexibility. We propose a novel full-duplex bi-directional radio-over-fiber (ROF) system transmitting 10 Gb/s differential phase-shift keying (DPSK) signals at the central office (CO) for downstream and ON–OFF keying (OOK) re-modulation of the downlink carrier at the base station (BS) for upstream. As the same optical carrier is used for both uplink and downlink, no additional light source is required at the BS, which significantly reduces the cost, improves the wavelength utilization efficiency and simplifies the overall system. The simulation results show that the downstream 10 Gb/s DPSK data and the upstream 1 Gb/s OOK data can transmit over 50 km single-mode fiber successfully without dispersion compensation. The results show that this scheme provides a practical solution to meet the data rate and cost requirement of tomorrow's ROF access networks.

1. Introduction

Future broadband access networks need to offer cost-effective, high transmission capacity support for the increasing number of new broadband end-customer services. Radio-over-fiber (ROF), the integration of optical and wireless systems, is a practical solution to increase the capacity and serve both fixed and mobile users. In a RoF system, Most of the signal processing processes (including coding, Multiplexing, and RF generation and modulation) are carried out by central office (CO), which makes the base station (BS) cost-effective. Therefore, RoF will become a key technology in the next generation mobile communication system [1–3].

While ROF technique can be used for the distribution of wireless signals, differential phase-shift keying (DPSK) signal has high spectrum efficiency and great chromatic dispersion tolerance, which can increase the bandwidth and extend transmission distance over fiber [4]. Thus the integration of ROF technology and DPSK modulation is expected to play key role in future broadband wireless networks. At present, most optical signals can support on-off keying (OOK) format, however other modulation formats, such as phase-shift keying and quadrature amplitude modulation format are occasionally supported. Phase-modulated ROF links present several advantages over the intensity modulated links, such as no need for dc bias, better link gain, and linearity [5]. Thus these modulation schemes are expected to play key role in future broadband wireless networks.

The reflective semiconductor optical amplifier (RSOA) plays an important role in bidirectional ROF systems [6–12]. The RSOA can be used as a modulator and amplifier. This gives additional gain enabling the possibility of avoiding the use of an Erbium Doped Fiber Amplifier (EDFA) in the system [13]. In these systems, both the upstream and downstream channels use the same wavelength for improving the wavelength utilization efficiency.

In this paper, a full-duplex ROF system employing a 10 Gb/s DPSK modulated ROF for the downstream signal and 1 Gb/s OOK remodulated ROF for the upstream signal, has been demonstrated.

2. System architecture

The proposed ROF architecture is shown in Fig. 1. For downlink, the 193.2 THz signal generated by a CW laser is differential phase-shift keying (DPSK) modulated using a 10 Gb/s non-return to zero (NRZ) downstream data to generate the desired downstream signal. The generated signal is sent over the 50 km bidirectional single-mode fiber (SMF). A circulator is used in the central office (CO) to separate the downstream and upstream traffic. At the base station (BS), using optical splitter/coupler, portion of the DPSK modulated signal is fed to a DPSK receiver. For up-link, the other portion of the downstream DPSK modulated signal from the splitter/coupler is ON–OFF Keying (OOK) re-modulated using 1 Gb/s NRZ upstream data by RSOA in the BS. The re-modulated OOK signal re-pass through the bidirectional SMF and get back to the CO where a PIN receiver is used to receive the upstream signal.

E-mail address: fnahal@iugaza.edu.ps

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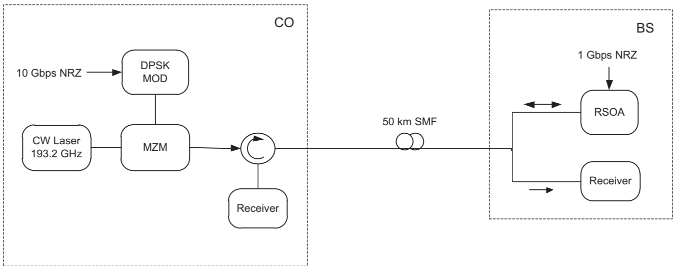

Fig. 1. Full-duplex ROF system.

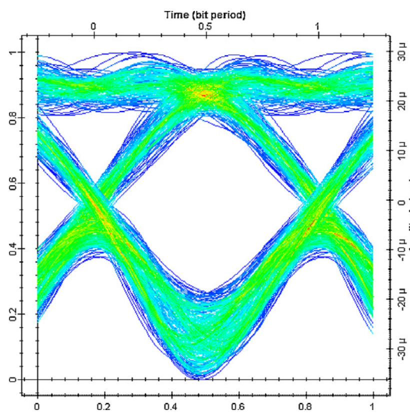

Fig. 2. Eye diagram of de-mod DPSK signal-downlink.

3. Results and discussions

The WDM-ROF system was simulated using a commercial package [14]. The proposed scheme uses differential phase shift keying (DPSK) signal for downstream and OOK signal re-modulated by the RSOA for upstream. Eye diagrams for both demodulated downlink and uplink signals are shown in Figs. 2 and 3 respectively. It can be seen that the eye still keeps open despite transmission over 50 km SMF, which is long enough for access network coverage. An open eye corresponds to minimal signal distortion that results from inter symbol interference and noise. It means that the 10 Gbps DPSK signal has good tolerance to chromatic dispersion. Moreover, the results show that the Eye closure penalty is greater for the uplink than that of the downlink which is expected, as the data rate for the downlink is 10 times that of the uplink.

BER simulations were carried out for both uplink and downlink with a Bit Rate of 10-Gb/s for downlink and a 1-Gb/s for uplink respectively. Fig. 4 shows the bit-error rate (BER) results for both uplink and downlink as a function of the input optical

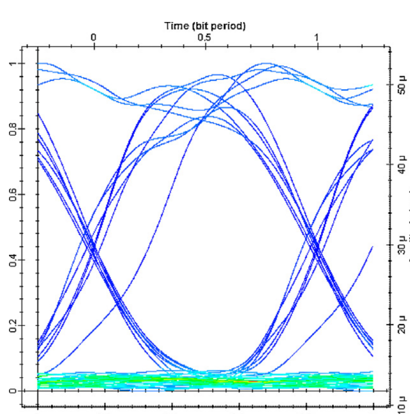

Fig. 3. Eye diagram of de-mod OOK signal-uplink.

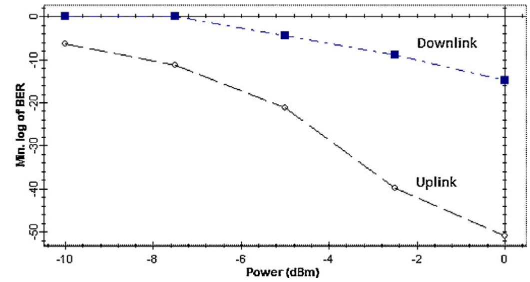

Fig. 4. BER versus input optical power.

power (P_{in}). It is clear that both uplink and downlink do provide good BER performances, however the uplink exhibits a better performance than the downlink. For example, when $P_{in} = -2.5$ dBm, the BER = 1.2×10^{-9} and the Q factor = 5.97 for the downlink while it is 1.42×10^{-40} and the Q factor = 13.2 for the uplink. When $P_{in} = 0$ dBm, the BER = 1.7×10^{-14} and the Q factor = 7.6 for the downlink while it is 1.42×10^{-51} and the Q factor = 15.01 for the uplink. This can be explained by the fact that the data rate for the downlink is much higher than that of the uplink. The higher data rate makes downlink more prone to chromatic dispersion which results higher BER.

4. Conclusion

The DPSK–RoF model has been proposed as solution for increased bandwidth demand. The integration of ROF technology and DPSK modulation has been performed to provide high data rates and bandwidth in wireless communication. We have proposed a full-duplex novel ROF scheme to provide a 10-Gb/s differential phase-shift keying (DPSK) signal for down-link and a 1 Gb/s ON–OFF Keying (OOK) signal for up-link. For the uplink, the need for additional light source at the base station (BS) is avoided by reusing the same optical carrier via Reflective Semiconductor Amplifier (RSOA). Proposed ROF architecture was simulated at a longer distance (50 Km) with acceptable bit-error-rate. The results show that this scheme is a practical solution for the future ROF-based optical-wireless access networks.

References

[1] G.-K. Chang, J. Yu, Z. Jia, J. Yu, Novel optical-wireless access network architecture for simultaneously providing broadband wireless and wired services, in: Proc. OFC, Anaheim, CA, 2006 (Paper OFM1).
[2] J. Zhensheng, et al., Bidirectional ROF links using optically up-converted DPSK for downstream and remodulated OOK for upstream, IEEE Photon. Technol. Lett. 19 (May (9)) (2007) 653–655.
[3] M. Haider Raza, S.M. Hassan Zaidi, M. Ramzan, K. Zaidi, Bidirectional radio-over-fiber architecture based on frequency up- and down-conversion with light-source and LO-source free BS, in: IEEE-ICET, 2008.
[4] J. He, D. Yang, L. Chen, A full-duplex radio-over-fiber system with differential phase-shift keying signals, J. Phys. Conf. 276 (2011) 012062.
[5] V.J. Urick, F. Bucholtz, P.S. Devgan, J.D. Micknney, K.J. Willams, Phase modulation with interferometric detection as an alternative to intensity modulation with direct detection for analog-photonic links, IEEE Trans. Microw. Theory Tech. 55 (September (9)) (2007) 1978–1985.
[6] J. Prat, C. Arellano, V. Polo, C. Bock, Optical network unit based on a bidirectional reflective semiconductor optical amplifier for fiber-to-the-home networks, IEEE Photon. Technol. Lett. 17 (January (1)) (2005) 250–252.
[7] M.D. Feuer, J.M. Wiesenfeld, J.S. Perino, C.A. Burrus, G. Raybon, S.C. Shunk, N.K. Dutta, Single-port laser-amplifier modulators for local access, IEEE Photon. Technol. Lett. 8 (September (9)) (1996) 1175–1177.
[8] N. Buldawoo, S. Mottet, F. Le Gall, D. Sigonge, D. Meichenin, S. Chelles, A semiconductor laser amplifier-reflector for the future FTTH applications, in: Proc. Eur. Conf. Opt. Commun. (ECOC 1997), Edinburgh, UK, 1997, pp. 196–199.
[9] J.M. Kang, S.K. Han, A novel hybrid WDM/SCM-PON sharing wavelength for up- and down-link using reflective semiconductor optical amplifier, IEEE Photon. Technol. Lett. 18 (February (3)) (2006) 502–504.
[10] G.C. Kassar, N. Calabretta, I.T. Monroy, Simultaneous optical carrier and radio frequency re-modulation in radio-over-fiber systems employing reflective SOA

modulators, in: Lasers and Electro-Optics Society (LEOS 2007), October 2007, pp. 798–799.
[11] A. Kaszubowska, L. Hu, L.P. Barry, Remote downconversion with wavelength reuse for the radio/fiber uplink connection, IEEE Photon. Technol. Lett. 18 (February (4)) (2006) 562–564.
[12] T. Kuri, K. Kitayama, Y. Takahashi, A single light-source configuration for full-duplex 60-GHz-band radio-on-fiber system, IEEE Trans. Microw. Theory Tech. 51 (February (2)) (2003) 431–439.
[13] M.C.R. Medeiros, R. Avó, P. Laurêncio, N.S. Correia, A. Barradas, H.J.A. da Silva, I. Darwazeh, J.E. Mitchell, P.M.N. Monteiro, Radio over fiber access network architecture employing reflective semiconductor optical amplifiers, in: Proc. ICTON-MW'07, Sousse, Tunisia, 2007, pp. 1–5.
[14] Optisystem from optiwave.