Full-Duplex Radio-over-Fiber Transport Systems Based on Direct-Detection Scheme

Hsiang-Chun Peng, Chung-Yi Li, Chia-Hsien Lee, Yu-Chiao Hsiao and Hai-Han Lu

Abstract—A full-duplex radio-over-fiber (ROF) transport system based on direct-detection scheme is proposed and experimentally demonstrated. In this approach, the RF power degradation introduced by fiber dispersion can be cancelled since the optical carrier and one of the sidebands are eliminated before detecting. A data stream of 70 Mbps transmitted over an 80-km single-mode fiber (SMF) transmission both for down/up-link with good bit error rate (BER) performance was achieved. Such proposed full-duplex ROF transport systems are suitable for long-haul microwave optical links.

Index Terms—Direct-detection, full-duplex, only one optical sideband, radio-over-fiber.

I. INTRODUCTION

The microwave/millimeter-wave radio-over-fiber (ROF) transport systems, which integrate the advantages of wireless radio and fiber optical communications, have been developed with high expectations for future communications that require ultra-high-speed, higher capacity, and lower cost [1], [2]. In such way, systems’ bandwidth suffers from the limitation of RF devices’ characteristic. And further, expensive RF devices will increase capital expenditures. So that a successful deployment of ROF transport systems strongly depends on the availability of simple architecture. In this paper, a full-duplex ROF transport system based on direct-detection scheme is proposed and demonstrated. With the assistance of light injection technique at the transmitting site and optical band-pass filter (OBPF) at the receiving site, the optical carrier and one of the sidebands are eliminated before detecting. Only one optical sideband is processed by optical devices, and the digital baseband signal is obtained from only the sideband. Electrical generated RF signal comes from the beating between two optical wavelengths after PD detection, and the carrier frequency of the electrical generated RF signal is the same as the frequency difference between these two optical wavelengths [3], [4]. Thereby, the electrical RF signal can not be obtained from only one optical sideband without optical carrier and the other optical sideband. The generated signal should be digital baseband signal. In our proposed approach, the RF power degradation can be avoided even when the optical carrier is transmitted. A data stream of 70 Mbps transmitted over an 80-km SMF transmission both for down/up-link with low BER values were obtained.

Fig. 1 shows the schematic architecture of our proposed direct-detection full-duplex ROF transport systems. For down-link transmission, the central station (CS) is composed of a microwave signal generator, two distributed feedback laser diodes (DFB LDs), two light injection sources, two 3-port optical circulators (OCs) and one erbium-doped fiber amplifier (EDFA). The CS, a 70 Mbps data stream is mixed with 10 GHz microwave carrier to generate data signal which is compatible with WiMAX format. The mixed data signal is split into two copies by a 1×2 RF splitter before been directly modulated into DFB LD1 and DFB LD3. Both optical signals are combined by a 2×1 optical coupler, amplified by EDFA-I, and fed into the fiber backbone.

At the CS, the optical signal is generated and then distributed through standard SMF to the remote base stations (BSs) (BS1 and BS2) by using cascaded EDFAs and optical add-drop multiplexers (OADMs). The optical signal is transmitted through three SMF spans (40km × 3) with the help of three EDFAs. Each BS is connected to the fiber backbone through an OADM which deals with an individual wavelength. The appropriate wavelength is dropped and added by the OADM in BS. The down-link data signal is passed through an OBPF to filter out the upper sideband. The filtered optical signal is adjusted by a variable optical attenuator (VOA), and then directly detected by a broadband PD to convert it into digital baseband signal. Finally, 70-Mbps down-link data stream is fed into a BER tester for BER analysis. For up-link transmission, the 70Mbps/10GHz data signal is transmitted through SMF from the BS to the CS, passed through a tunable OBPF to select the desired wavelength with only upper sideband, attenuated by a VOA, directly detected by a broadband PD, and also fed into a BER tester for BER analysis.

Fig. 1. The schematic architecture of our proposed direct-detection full-duplex ROF transport systems.
III. EXPERIMENTAL RESULTS AND DISCUSSION

Fig. 3(a) shows the optical spectrum of injection locking DFB LD1 locked at $\lambda_2$. The injection locking has been taken place as the frequency of slave laser (the upper sideband of DFB LD1) is locked nearly that of the master laser (DFB LD2).

To convert double sideband (DSB) format into only one optical sideband format, the tunable OBPF at the CS and the OBPF at the BS are aligned so that the optical carrier and the lower sideband have been eliminated. At the CS, the optical signal exhibits only one optical sideband (upper sideband, $\lambda_2$) for direct-detection is shown in Fig. 3(b).

![Fig. 3(a). The optical spectrum of injection locking DFB LD1 locked at $\lambda_2$.](image1)

![Fig. 3(b). The optical signal exhibits only one optical sideband (upper sideband, $\lambda_2$) for direct-detection.](image2)

The measured down-link BER curves of 70Mbps/10GHz data channel from CS to BS2 (80 km SMF links) are present in Fig. 4(a). At a BER of $10^{-9}$, a large power penalty of 16.7 dB is presented between the back-to-back case and optical DSB system due to RF power degradation induced by fiber dispersion. Similarly, a little power penalty of 1.4 dB is also demonstrated between the back-to-back case and only one optical sideband scheme due to the cancellation of RF power degradation. A -15.3 dB receiver sensitivity improvement is achieved when only one optical sideband scheme is employed. A higher signal-to-noise ratio (SNR) value we obtain. Only one optical sideband scheme increases systems’ SNR value, causing systems with better BER performance.

![Fig. 4(a). The measured down-link BER curves of 10GHz/70 Mbps data channel.](image3)

IV. CONCLUSION

A full-duplex ROF transport system based on direct-detection scheme is proposed. The feasibility of the system with compatible WiMAX format and a good BER performance over a long-haul fiber link have been experimentally demonstrated and obtained. Since optical carrier and lower sideband are eliminated before detecting, the RF power degradation induced by fiber dispersion can be cancelled. Therefore, the expensive RF devices can be eliminated to reduce the capital expenditures of such systems.

REFERENCES