

Digital Predistortion Algorithm of Advance Coherent Modulation Schemes Enabling Radio over Fiber for Access Networks

Ahmad Atieh[1], Mahmood Noweir[2], Mohamed Helaoui[2] and Fadhel M. Ghannouchi[2]
[1]*Optiwave System Inc, Ottawa, Ontario, K2E 8A7, Canada*
[2] *Department of Electrical and Computer Engineering, University of Calgary, Calgary, Alberta, T2N 1N4, Canada*
ahmad.atieh@optiwave.com

Abstract: Digital predistortion algorithms are demonstrated for 5G back-bone optical systems employing 64-QAM and 256-QAM advance modulation formats. The performance of the digitally linearized systems is compared experimentally and using simulation with standard coherent transmission systems.

1. Introduction

The existing fourth generation (4G) wireless access architectures broadcast radio frequency (RF) signals below 6 GHz are experiencing congestion in the available spectrum, which limits the possible data speed to few hundred Mbps. Researchers investigated the option of using millimeter wave (mm-wave) between 30-300 GHz as wireless carriers to broadcast and transmit signals with data speeds of 10 Gbps and higher. The development of the fifth-generation (5G) and beyond wireless systems motivates researchers to design innovative architectures that guarantee the delivery of data rate as high as 10 Gbps. A need for an efficient wired or wireless broadband link between base stations is vital to allow the delivery of variety of applications and services like interactive HD TV, internet video, augmented reality, vehicle telematics, high-speed train, the wireless cloud office, etc.

Radio-over-fiber (RoF) technology allows extending the distance between central stations and wireless end-users, thus maximizing the coverage of micro-cell and macro-cell-based networks. In addition, RoF technologies are able to generate radio signals at mm-wave frequencies in a cost-effective manner leading to reduced Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) compared to traditional all-electronic networks. However, the electrical-optical-electrical conversion process in RoF links inevitably comes with impairments that degrade the signal quality. The amplification of RoF signals cause nonlinearly in the transmission system leading to distortions during the electrical-optical-electrical conversion process, which degrades the overall signal quality. A solution to this problem is to linearize the RoF link. In this work, we describe a half-duplex RoF transceiver (TR) architecture augmented with an effective digital predistortion (DPD) technique to mitigate the nonlinearities of the RoF TR using memory polynomial (MP) model. An experimental validation of a linearized RoF fronthaul downlink transmitter is demonstrated.

2. Principle of Operation of RoF Fronthaul Link with mm-wave Generation

Fig. 1 illustrates the demonstrated RoF fronthaul link block diagram. The central baseband unit (BBU) has a single-mode continuous-wave (CW) laser that emits light in the conventional C-band (1530-1564 nm). The CW laser light is modulated using a Mach-Zehnder intensity modulator (comb-MZM) with a sinusoidal pre-selected RF local oscillator frequency (f_{LO}) resulting in a comb-like optical spectrum featuring many narrow lines spaced by f_{LO}. Adopting proper DC biasing of the comb-MZM, two optical tones (carriers) with a frequency difference of $\Delta f = 2f_{LO}$ are emitted [1]. Subsequently, the data-MZM modulates the incoming two optical tones with an RF modulated data signal at frequency f_c. The modulation creates two data bands around each optical carrier resulting in a total of four data bands. Erbium doped fiber amplifier (EDFA) is used to amplify the optical signal to enable signal transmission between the BBU and the RRH units. An optical band pass filter (OBPF) is used to remove the EDFA amplified spontaneous emission noise (ASE) out of the signal band. A photodetector (PD) at the RRH converts the received optical signal into three electrical data image bands at the frequencies fc, $2f_{LO}+f_c$ and $2f_{LO}- f_c$, and two unmodulated RF carriers at f_{LO} and $2f_{LO}$ through beating process. The current configuration can be easily expanded to accommodate multiple users having different carrier frequencies. This feature is the main drive for centralized radio access network (C-RAN) applications. The achieved result of the conducted experiments of a half-duplex fronthaul link for 256QAM modulation is shown in Fig. 2. It is clear that using DPD improves the link performance and enables 5G systems as it meets the LTE requirements of error vector magnitude (EVM) less than 3.5%.

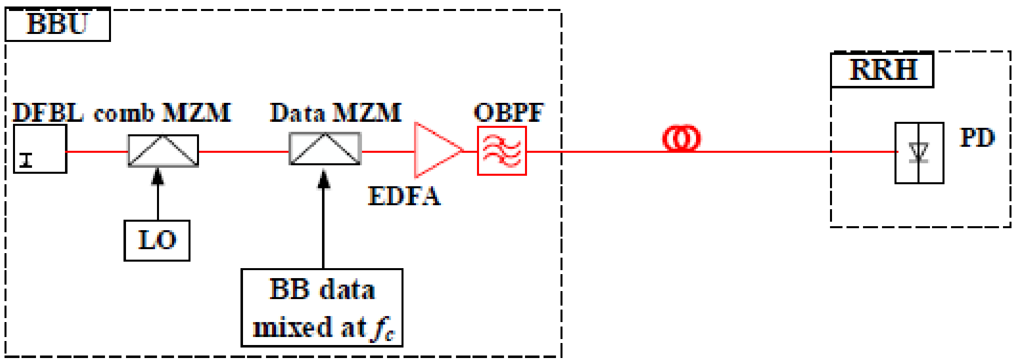

Fig. 1. RoF fronthaul link block diagram. BBU: Baseband unit; DFBL: Distributed feedback laser; EDFA: Erbium-doped fiber amplifier; BB: Base-band; LO: Local oscillator; OBPF: Optical bandpass filter; MZM: Mach-Zehnder modulator; PD: Photodetector; RRH: Remote radio head.

A distributed digital predistortion (DDPD) model for radio-over-fiber (RoF) downlink suitable for broadband 5G signals is also demonstrated. The model reduces the analog to digital converter (ADC) sampling frequency to about one third of that required for memory polynomial based DPD (MP-DPD) model. Thus, reducing the demodulator costs and hardware complexity. This model provides better inter-carrier interference (ICI) by reducing the adjacent channel leakage ratio (ACLR) leading to reduced crosstalk levels. Long-term evolution advanced (LTE-A) signals of a 256-quadratic-amplitude modulation (QAM) of different bandwidths are used to validate the model. A minimum reduction of 42dB in the ACLR is achieved for signals with bandwidths varying in the range 100-300 MHz while maintaining minimum error vector magnitude (EVM). The RoF downlink can deliver peak bit rate of 2.016 Gbps with spectral efficiency of 6.72 b/Hz and EVM less than 4 %. [2].

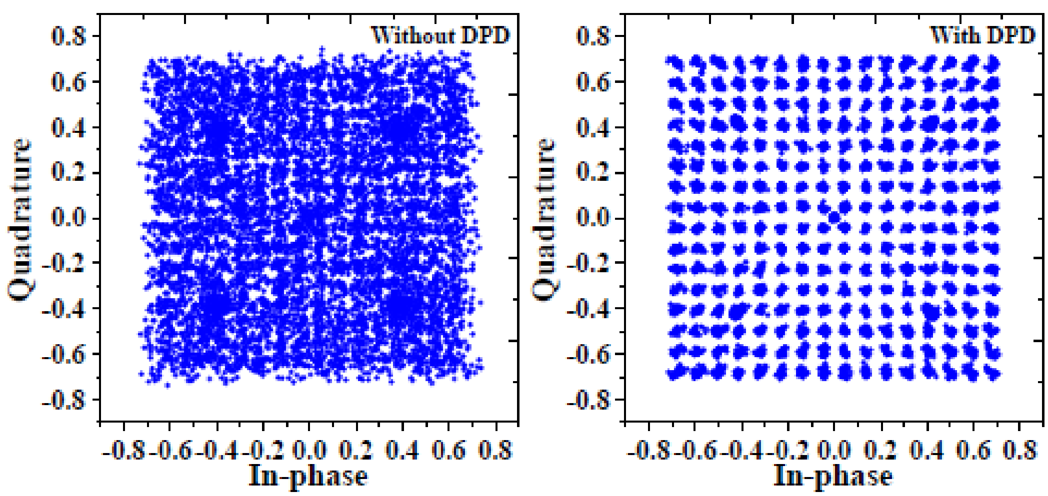

Fig. 2. Sample figure with preferred style for labeling parts.

3. References

[1] Noweir, Mahmood, et al. "Digitally linearized radio-over fiber transmitter architecture for cloud radio access network's downlink." *IEEE Transactions on Microwave Theory and Techniques* **66**,**7**, 3564-3574 (2018).

[2] Noweir, Mahmood, et al. "Carrier aggregated radio-over-fiber downlink for achieving 2Gbps for 5G applications." *IEEE Access* **7**, 3136-3142 (2018).