GP CODS 2022/23

Linearization and practical implementation of digital optical communication links through the optical fiber (RoF) or free-space (OWC)

Introduction

The need for high-speed data transmission is continuously increasing with a growing interest of high-speed and mobility for the end-user. At the same time, it is required to improve the energy efficiency of the systems of transmission and their capacity to address larger volume of data.

In this trend of higher capacity and mobility, photonics is playing a major role nowadays. While the fiber was restricted to the long and mid haul in the past, optical communications are getting every day closer and closer to the end user with a greater electronics/photonics convergence. The fiber is deployed from the communication centrals down to the home, through FTTH architectures. Convergence of internet and mobile communication is exploiting the fiber to transmit both digital internet signals and radio-over-fiber signals for a denser 4G/5G base stations system. Within homes and buildings, the distribution of 4G/5G mobile wireless signals is performed also through optical fiber for such DAS systems when the building is large. More recently LiFi and Optical Wireless Communications (OWC) are showing another progress in connecting mobile data devices and users at high data rates at the room level without cables. Such wireless optical link is providing less exposure of the user to radio-frequency signals; it provides much higher data rates and it gives solution to preserve the security of the transmitted data.

Those optical infrastructures and systems evolve regularly with the main trend which is to make the devices more compact, lower-cost and more efficient. The improvement can be measured in terms of transmission response but also in terms of energy efficiency.

Among devices which can be considered, *Vertical-Cavity-Surface-Emitting-Lasers* (VCSEL) are excellent candidates that are further deployed because of their low cost but good performance. Furthermore, VCSELs are showing excellent density of integration. Their dimensions are small (down to ~250µm in width). They are low cost because of their wafer-level production and testability. Finally their current consumption is very low due to the small threshold current, which make VCSELs very energy efficient.

VCSEL however are to be compared with edge-emitting lasers (EEL) that may have superior performances in terms of maximum emitting optical power. By the way, EEL are often superior when the challenge is to feed an optical system where the signal is divided toward a large number of end-terminals.

Given the VCSEL power limitations, and the interest to use their low-cost and high-frequency properties, it is of prime interest to bring solutions that would let the VCSEL to operate at higher optical power without degrading the signal quality. This will be the purpose of this work to contribute by practical means to this development.

Purpose of the work

Non-linearities are increased when the intensity of the signal injected into the VCSEL is increasing. They also increase when the quiescent point for the VCSEL biasing is too close from its laser current threshold. In this situation, a clipping effect occurs when the modulated signal gets below the threshold current.

While such biasing point helps to reduce the power consumption, it is thus essential to compensate the non-linearity of the signal. One well-known technique is pre-distortion, where the input signal is pre-compensated for the distortion that will affect it through the transmission medium.

Inspired by the design of high efficiency electrical power amplifiers, it is proposed in the ESYCOM lab to apply such predistortion to compensate for the non-linearities induced within VCSEL-based Radio-over-Fiber systems.

The proposed work will tackle this challenge by practical implementation of such pre-distorter. The link will exploit 850nm high-speed VCSELS. The project will implement the algorithm on a FPGA and will apply it for two different cases of applications:

(1) Radio-over-Fiber transmission of signals respecting the WiFi standards; the quality of transmission should be measured in terms of EVM and ACPR and frequency of interests are 2.4 / 5.4 GHz.

(2) Optical Wireless Communications, where the non-linearities also come from the optical interferences and fading effects in the air, in addition to the intrinsic non-linearities of the VCSEL (high power compression and clipping effect at low level).

Planning and deliverables:

The deliverables expected at the end of the project are:

Phase 1 (September-December)

- Setting up an FPGA platform to transmit modulated signals compatible with the WiFi and LiFi standards
- Setting up a practical VCSEL RoF Link at 850nm

Phase 2 (February-July)

ROF Systems:

- Implementation of a simple Memory-Polynomial (MP) real time pre-distorter within a RoF links exploiting 850nm VCSELs
- Exploring the limitations in bandwidth and complexity for the pre-distorter in terms of EVM and ACPR figures of merits
- Implementing an original combination of pre-distortion and post-compensation proposed within the ongoing PhD thesis of Bernalyn Decena, invited researcher at ESYCOM and coming from the University of Philippines, Diliman.

OWC Systems:

- Setting up a practical OWC link using the VCSEL
- Providing an extensive study of the non-linearity induced in the link due to the air transmission
- Implementing and analyzing the efficiency of aforementioned pre-distortion and post-compensation systems on OWC links.

Team Environment

The work will be supervised by Dr. Anne-Laure Billabert, MCF HdR, ESYCOM-CNRS-Le Cnam, and co-supervised by Dr. Jean-Luc Polleux, CTO of ICON Photonics, within the chair of research between ESYCOM and ICON Photonics.