Evaluation of Radio over Plastic Optical Fiber Communications

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Abstract

In this work, we have experimentally evaluated the performance of a Radio over Plastic Optical Fiber (RoPOF) communications link by simultaneously transmitting Long-Term Evolution (LTE) and Narrow-Band Internet of Things (NB-IoT) signals over 75-meters of PMMA large-core Graded-Index POF (GI-POF).

Introduction

In the recent years, the connectivity demand has experienced a dramatic rise derived not only by the end user requirements, but also by the ever-increasing number of connected devices and equipment. Thus, short-range communication networks, such as in-building or in-vehicle, are gaining a huge significance and drive the continuous development of the associated technologies. In this context, the paradigm of distributed antenna system (DAS) can efficiently provide the short-range coverage with improved service quality. Although the wired backbone of DASs can be implemented by using coaxial cable yet it introduces significant attenuation and poses stringent limits to the system capacity. In contrast, the use of fiber optics as wired transmission medium provides high capacity and low attenuation and is considered as the best choice in this scenario. In fact, convergence of radio and fiber optic technologies enables the delivery of broadband wireless services in short-range applications that support extremely rising data traffic [1]. In this context, Plastic Optical Fibers (POFs) having crucial advantages over Glass Optical Fibers (GOFs) regarding installation and maintenance costs, power-consumption, ruggedness and safety appears as a promising technology in short-range scenarios [2].

In this work, we aim at evaluating the feasibility of PMMA large-core Graded-Index POF as a transmission medium for RoPOF communications links by focusing on the downlink transmission of NB-IoT along with 10-MHz bandwidth LTE over a carrier frequency of 800 MHz in the guard-band operation mode. The transmission performance was assessed by the estimation of the Error Vector Magnitude (EVM), while some other metrics such as Peak to Average Power Ratio (PAPR) and Adjacent Channel Power Ratio (ACPR) were also obtained in order to understand the mechanisms underlying the obtained transmission performance and to evaluate the impact of the non-linear effects.

Experimental Setup

The experimental setup consisted in the establishment of an optical data link with the most suitable optoelectronic components (optical source, GI-POF segment and receiver) and an RF electronic board (Xilinx Zed-BoardZynq-7000) which acted as digital/analog interface by performing the required conversions. The Plastic Optical Fiber considered was a 75-meter segment of a commercial Graded-Index fiber, OM-Giga from Optimedia [3]. Signal generation/demodulation and transmission performance evaluation were carried out offline with a computer directly connected to the RF electronic board. Several transmission parameters were considered such as RF power, and power ratio between NB-IoT and LTE signals.

Results

Transmission performance was evaluated by obtaining the EVM of both LTE and NB-IoT signals. Results are plotted in Figure 1 and Figure 2, respectively. The EVM values obtained met the standard requierements for an ample range of input RF powers. Moreover, Figure 1 demonstrates that the impact of the NB-IoT transmission over the LTE transmission is very small. In both cases, the transmission quality degrades at the lower and higher input RF power ranges. We argue that lower Signal-to-Noise Ratio (SNR) at the receiver side is responsible for the degradation of the transmission quality at lower input power values. On the other hand, the average EVM rise at higher input power values can be related to non-linear distortion. In Figure 3, we represent the measured power spectral density of the combined signal (LTE and NB-IoT at

PRB 50) for a particular range of input RF powers at the input and the output of the system. A comparison of the input and output spectra illustrates the presence of spectral regrowth at both sides of the LTE channel or main channel. Power leakage to adjacent channels can be attributable to the presence of non-linear distortion. In order to quantify it, in Figure 4 the ACPR against input RF power (blue line) has been represented. ACPR is below -33 dB for input RF power higher than -10 dBm. At the very low values of input RF power, ACPR is higher because the low main channel power, while above 2 dBm, its increase, is attributable to an increase of the adjacent channel power due to the non-linear behaviour of the devices. Futhermore, in Figure 4, we also represent the input and output PAPR, showing a decrease of the latter above 1.82 dBm input RF power consequently with the presence of non-linear effects.

Conclusion

We found that the NB-IoT signal has little effect over the transmission performance of the LTE signal and thus, it is reasonable to introduce a higher power boost to the NB-IoT signal to get a better transmission performance for the NB-IoT over a wider range of input power values. On the other hand, it is advisable to keep the input RF power below the non-linear range. However, for the analysed range of input RF powers, PAPR and ACPR indicate that non-linearities do not severely affect RoPOF tranmission. The reported results are very encouraging and reveal that the combined transmission of NB-IoT and LTE over the POF meets the standard quality for both services, demostrating the feasibility of RoPOF transmission over PMMA large-core GI-POF for future short-range networks.

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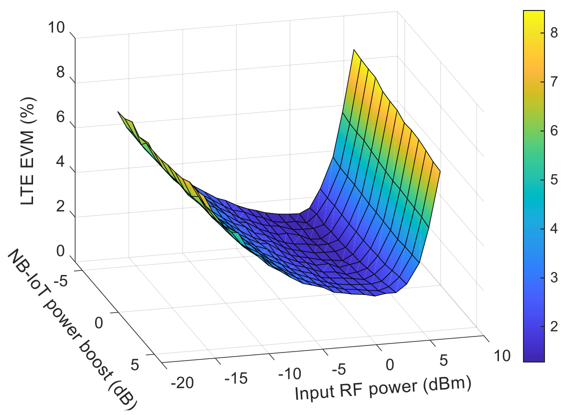

Figure 1. Error Vector Magnitude (EVM) for LTE signal.

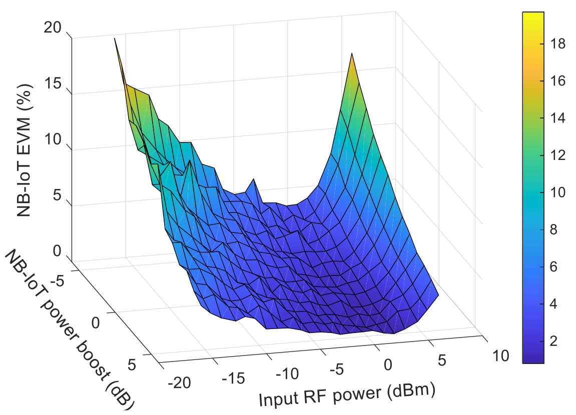

Figure 2. Error Vector Magnitude (EVM) forNB-IoT signal.

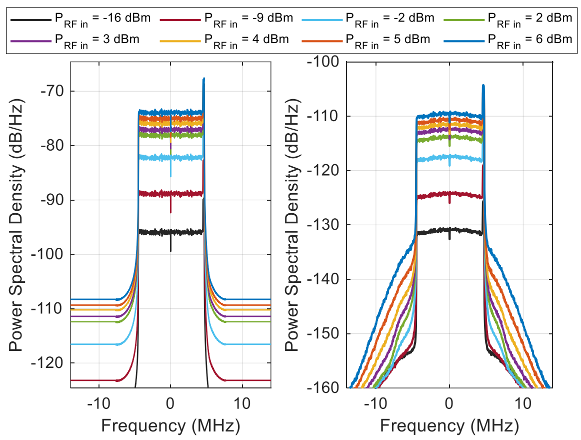

Figure 3. Power Spectral Density of the RF input (left) and output (right) signals for different values of input power.

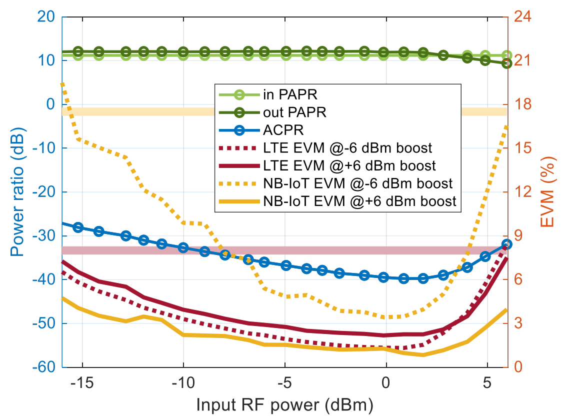

Figure 4. LTE & NB-IoT EVM as a function of input power (right axis). Input/output PAPR and ACPR (left axis).