Suitability of thick-core plastic optical fibers for Long-Term Evolution multiband transmission

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Long-Term Evolution (LTE) is considered to be the basis for 5G wireless standards. LTE and 5G will need to coexist efficiently with conventional WiFi traffic. Therefore, a common backhaul link for 3GPP-LTE and WiFi traffic is highly desirable. Plastic optical fibers (POFs) are an attractive medium to transport LTE for short distances. Especially for applications in in-home communications, POF shows remarkable advantages such as easy do-it-yourself fiber installation. This paper demonstrates the successful transmission of 3 64-QAM LTE band signals over a 35 m long 1-mm core diameter PMMA graded-index POF link.

Introduction

In the coming years, it is expected that the use of pico-/femto-cells in high-capacity radio access networks will become more important. Most of the radio access traffic will be generated indoor [1] (e.g. homes, offices, shopping malls). LTE of the 3rd generation partnership project (3GPP [2]) and its evolution toward 5G will need to coexist in a more efficient way with conventional wired and wireless traffic (i.e. wired Ethernet and wireless WiFi). Therefore, a common backhaul link for 3GPP and conventional traffic is highly desirable. Plastic optical fibers (POFs) with their easy do-it-yourself installation capability are an attractive medium to transport 3GPP, WiFi and Ethernet traffic simultaneously, see Fig. 1.

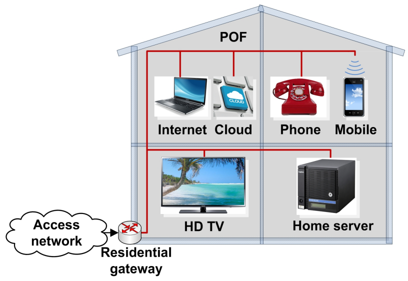


Fig. 1. Home Area Network using POF.

Our previous work has shown that transmitting 3 LTE signals in parallel with a pulse amplitude modulation (PAM) baseband Ethernet signal for in-home scenario up to 20 m PMMA graded-index POF (GI-POF) is feasible [3].

In this work, we focus on the improvement of the transmission of multiple LTE signals up to 35 m of PMMA GI-POF. This paper is organized as follows: in Section 2, the measurement setup and the LTE signals are presented. Then, in Section 3, the LTE performance is analyzed and discussed. Finally, in Section 4 concluding remarks are given.

Experimental setup

The transmission testbed is shown in Fig. 2. The LTE air interface defines more than 40 bands in the range from 455 MHz to 3.7 GHz. We aimed to avoid frequency up/down shifting and overlapping of frequency bands. Following these criteria, 3 widely deployed downlink bands are available between 800 MHz and 1 GHz, as listed in Table 1, and all of them were used. In order to maximize the bitrate, only the maximum standardized LTE bandwidth and modulation order were considered. For sake of simplicity single-input single-output spatial multiplexing was used. The carrier power was optimized in order to minimize the error vector magnitude (EVM) and at the same time avoid the VCSEL saturation.

Table 1. LTE bands used during the test and their most significant parameters.

LTE band number	Downlink channel (MHz)	Bandwidth (MHz)	Modulation format	Carrier Power (dBm)
20	791-821	20	64-QAM	-1.5
5	869-894	10		
8	925-960			-1

The LTE signal used in the experiment was a 3GPP release 9 signal. The LTE signals were generated offline, each band was created in accordance with the test model (E-TM) 3.1 [4]. The analogue-to-digital conversion and the generation of the RF signals were provided by a Vector Signal Generator (VSG) and the RF signal is therefore driving the VCSEL.

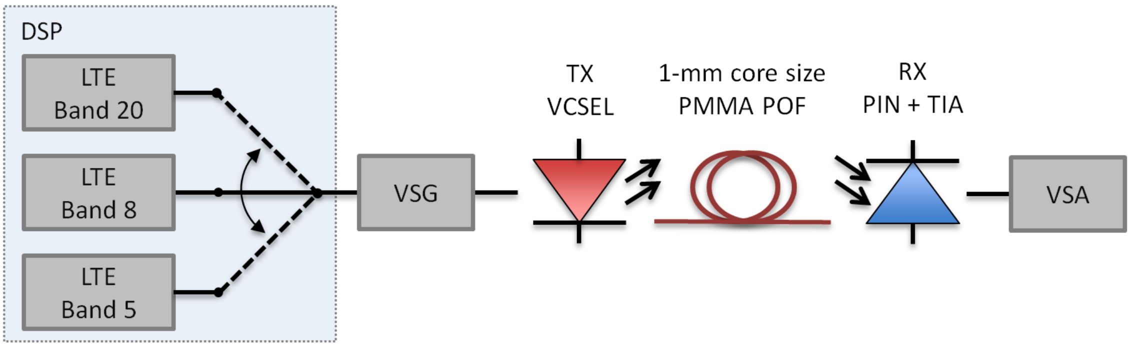


Fig. 2. Block diagram of the transmission setup, VSG is Vector Signal Generator, VSA is Vector Signal Analyzer.

The optical link consists of a directly modulated eye-safe VCSEL, a PMMA GI-POF and an optical receiver. The wavelength of the VCSEL is 682 nm and the fiber-coupled power in the GI-POF is 0.5 dBm. The GI-POF used in all the tests is the Optimedia OM-Giga S E 100 with a core diameter of 1 mm and 35 m length. The POF loss per meter at 680 nm wavelength is 0.3 dB/m. The optical receiver consists of a Hamamatsu S5052 PIN photodiode in combination with a transimpedance amplifier (TIA) provided by POF-AC (the POF Applications Centre in Nuremberg, Germany). The fiber coupling is performed by an OptoLock connector at the transmitter side and through butt coupling at the receiver side. At the receiver side, the LTE signal is acquired by a Vector Signal Analyzer (VSA) running the LTE receiver software.

Experimental results and discussion

The LTE signal is transmitted firstly over the optical back-to-back (B2B, so directly connecting the transmitter to the receiver) link to evaluate the influence of the optical devices and subsequently the link distance is increased to 35 m. The electrical B2B EVM value measured beforehand is equal to 0.894%. As depicted in Fig. 3, in optical B2B case, the EVM is slightly higher than the electrical B2B, approximately 1.1%, which suggests a negligible penalty introduced by the optical devices. However, this value is still considerably below the EVM threshold of 8% [5]. As depicted in Fig. 3, after transmission over 35 m GI-POF, the EVM increases up to 7.3%. Band 20 has a higher EVM than band 5. Band 8, even with the same bandwidth as band 5, has the same EVM as band 20. Most probably this is related with its central frequency, which is very close to the system bandwidth. Therefore, the maximum achievable distance for these 3 LTE bands is 35 m.

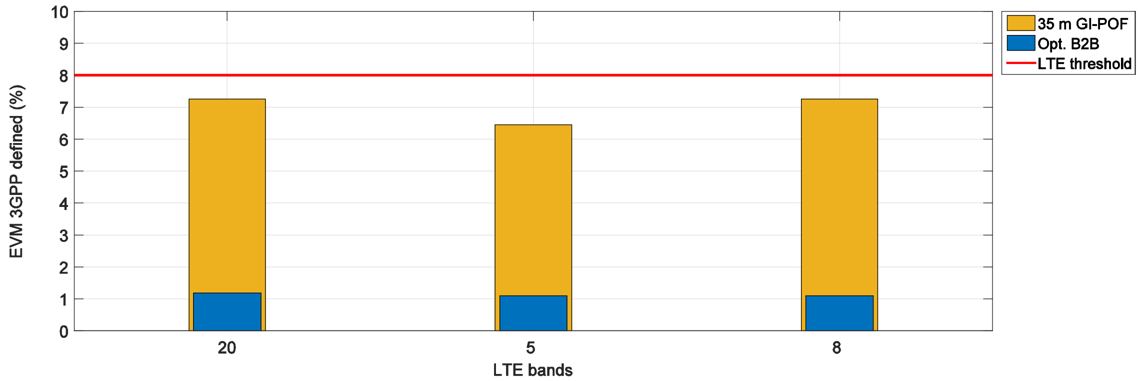
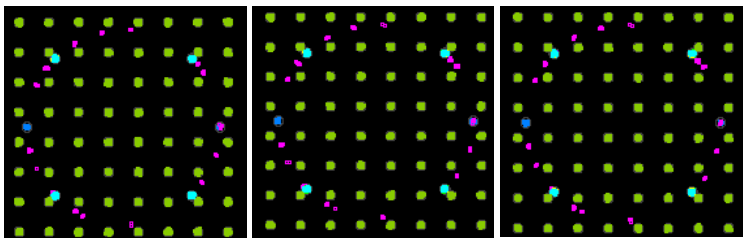


Fig. 3 LTE EVMs for different link lengths.

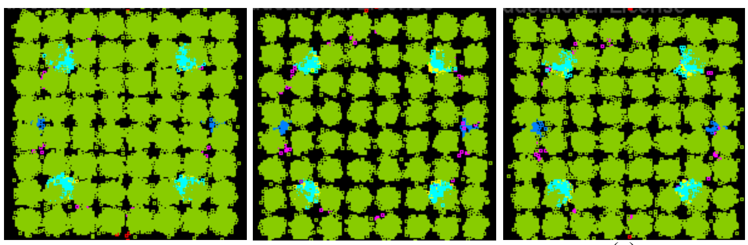
As shown in Fig. 4, among the different bands the quality of the received signal is the same for the optical B2B, which suggests no penalty introduced by the optical transceivers.



(a) (b) (c)

Fig. 4 Constellation diagrams for the optical B2B link of band 20 (a), 5 (b) and 8 (c). The user downlink channel with 64-QAM (green marks) and control channels (yellow, light blue, purple and red) are shown.

The situation is slightly different with 35 m GI-POF, as shown in Fig. 5, since among the different bands, the quality of the received signal varies. Band 5 has a better performance, than band 20 and 8 (see Fig. 5(b) with respect to Fig. 5(a) and (c), respectively).



(a) (b) (c)

Fig. 5 Constellation diagrams for 35 m POF of band 20 (a), 5 (b) and 8 (c). The user downlink channel with 64-QAM (green marks) and control channels (yellow, light blue, purple and red) are shown.

Having optimized all operational parameters for the LTE signals, we obtained for 35 m a standard compliant transmission performance of 3 LTE 64-QAM signals. Our earlier work on transmitting wireless signals through POF involves down/up shifting the signal [6]. This shifting brings a lot of complexity to the antenna access points. As a consequence, the transmission link becomes non-format transparent, which in its turn makes the link optimized only for a specific wireless signal format. With the prospect of the 5G indoor femtocell high-capacity wireless technology using LTE-like signals higher flexibility in the signal processing is needed, as well as, a cost-effective solution for the deployment of more and more antennas to increase the coverage and the capacity. This could be achieved reducing the complexity at the antenna site, moving the signal processing from hardware to software and choosing reliable and cost-effective backbone infrastructure. POF, especially GI-POF, could comply with such requirements without the use of any additional complex signal processing at antenna sites. This makes a POF-based in-home communication infrastructure a promising low-cost alternative to be deployed for the next generation indoor wireless and wired communication system.

Conclusion

This work explores the feasibility of GI-POF links to comply with the stringent requirements of LTE signals for the next generation 5G wireless communication systems. Our results showed that 3 LTE 64-QAM signals can be transmitted using an eye-safe POF transceiver. Longer POF lengths and more LTE channels could be achievable with a higher power budget and increased bandwidth of the transceivers. This work demonstrates the suitability of POF in complying with next-generation home-appliance wireless and wired services.

Acknowledgements

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