Long Term Evolution- Advanced Multiband Wired and Wireless Transmission over Thick-Core Plastic Optical Fiber for Short Distance Communications

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High indoor throughput is fundamental for the current Long Term Evolution-Advanced (LTE-A) and future 5G networks. Carrier aggregation and femto-cells are foreseen as major solutions to boost the throughput. Therefore, an in-home widespread multiband wired backbone for LTE-A traffic is highly desirable. Plastic optical fibers (POFs) are an attractive medium to transport LTE-A 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 9 OFDM 64-QAM LTE-A band signals over a 35 m long 1mm core diameter PMMA graded-index POF link and 3.5m line-of-sight anechoic chamber wireless transmission.

Introduction

Improved carrier aggregation and heterogeneous networks (HetNets) are enabling technologies for the high throughput and ubiquity required by 4G/5G mobile networks. In order to support the multiband carrier aggregation and connect the indoor femtocell to the mobile core network through the in-home residential gateway a low cost broadband wired backbone is needed. Plastic optical fibers (POFs) with its do-it-yourself technology can take up the challenge providing a broadband wired link connecting the residential gateway to each femtocell antenna and at the same time carrying the other wired and wireless based in-home services, as shown in Fig. 1.

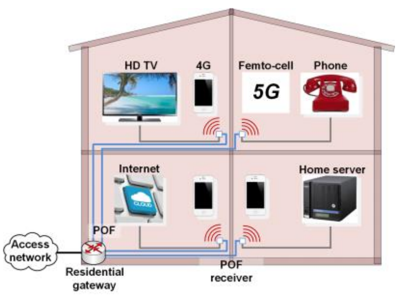

Fig. 1. Home Area Network using POF.

Our previous work has shown that the transmission of 9 Long-Term Evolution – Advanced (LTE-A) bands and 2Gb/s 4-PAM over 35m of 1mm core diameter PMMA POF followed by 3.5m wireless link was possible but the wireless link was strongly affected by multipath propagation and interference [1].

In this work, we demonstrate the successful transmission of 9 OFDM 64-QAM LTE-A band signals over a 35 m long 1mm core diameter PMMA graded-index POF link and 3.5m line-of-sight anechoic chamber wireless transmission.

Experimental setup

We transmitted multiple standard-compliant LTE-A bands by employing analogue radio-over-fiber technology, without frequency shifting. 9 LTE-A bands with the highest modulation order (64-QAM) are generated in accordance with the test model 3.1, as listed in Tab. 1. Due to the LTE-A signals combining and the LTE-A transmitter, the LTE-A signal power is related with the channel bandwidth, wider bands have relatively lower

Tab. 1: LTE-A transmitted bands and their most significant parameters.

Index i	1	2	3	4	5	6	7	8	9
E-UTRA operating band	12	13	14	20	18	19	8	32	24
Carrier frequency (MHz)	738	751	763	806	868	883	944	1470	1540
Bandwidth (MHz)	10			20	15		10	20	10
Modulation format	64-QAM								
Transmitter gain Gi (dB)	0			3		4	2	6	4.5

powers. Furthermore, the bands 8 and 9 are exceeding the 1.1GHz POF link bandwidth, hence have a higher attenuation. Therefore, as shown in Fig. 2, the LTE-A signals are created and the equalizer flattens the power spectrum and also balances the extra optical link losses by tailoring the amplifier gains (Gi). After the equalization, the LTE-A signals are combined and sent to an arbitrary waveform generator (AWG) working as a digital-to-analog converter.

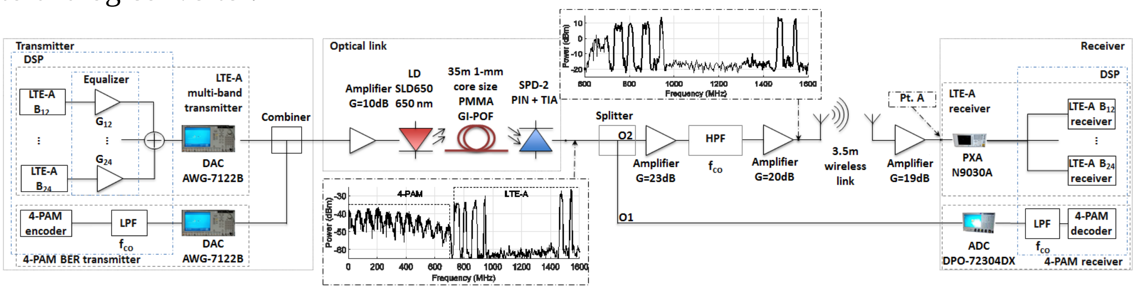

Fig. 2 Experimental setup.

According to the LTE-A bands allocation, the spectrum up to band 1 is unused. In this frequency range a PRBS 2^7-1 sequence is offline encoded in a 4-PAM baseband signal and transmitted. The symbol sequence is filtered by a finite impulse response (FIR) low pass filter (LPF) with the cut-off frequency (f_{co}) equal to 700MHz. Subsequently, the baseband signal is generated by a second AWG, which was necessary for the only purpose to co-transmit two signals with different sampling rates. The baseband signal and LTE-A signals are electrically combined, amplified by a 10dB MMIC amplifier in the laser driver, and sent to the optical source. The optical link is an intensity-modulated direct-detection system. The optical source is a low-cost Fabry-Perot edge-emitting laser diode (LD). The emitted optical output power of the LD is 5.7dBm at a wavelength of 650 nm and is coupled into the un-polished end of a GI-POF. The optical signal is then transmitted over 35m of 1mm core diameter PMMA GI-POF, with fibre loss of 0.24dB/m at 650nm. The optical receiver is a Graviton SPD-2, consisting of a p-i-n photodiode followed by a transimpedance amplifier. The SPD-2 allowed maximum input power is -4dBm, hence the received optical power is limited to -5.2dBm for the optical back-to-back (oB2B) and 35m links. After the optical link the signal is split. The first splitter output (O1) is connected to the baseband receiver, which consists of the analog-to-digital converter, a multirate FIR LPF with cut-off frequency f_{co}, and the 4-PAM receiver. For simplicity, no equalization or precoding is used. The second splitter output (O2) is connected to the antenna amplifiers. A cascade of two amplifiers is chosen to boost the LTE-A signal power up to 10dBm, as shown in Fig. 2. Before the wireless transmission the baseband signal must be removed, hence a high-pass filter (HPF) with cutoff frequency f_{co} has been implemented. The amplified and filtered signals are then transmitted through the antenna. Two identical off-the-shelf LTE-A multiband antennas with average gain of 3dBi are used. An estimation of the wireless link loss is made with the free-space Friis' equation. Aiming at a minimum received power at Pt.A in Fig. 2 of -20dBm, from the equation a 3.5m link length seemed to be feasible. The wireless transmission is performed in an Faraday caged anechoic chamber on a LOS link. The receiver antenna is connected to the front-end and then to the LTE-A receiver.

Experimental results and discussion

The 4-PAM signal is required to have a pre-FEC bit error rate (BER) lower than 1×10^{-3}. The LTE-A performance is evaluated in accordance with[2], which sets the error vector magnitude (EVM) threshold for 64-QAM at 8% end-to-end. As a reference, the individual transmission of the 4-PAM and LTE-A over the POF link are also evaluated.
Considering the 4-PAM transmission first, the oB2B and 35m POF link solitary transmission achieved 2Gb/s. Increasing in the 4-PAM amplitude does not show any bitrate improvement, therefore the 4-PAM throughout is bandwidth limited by the imposed 700MHz bandwidth.

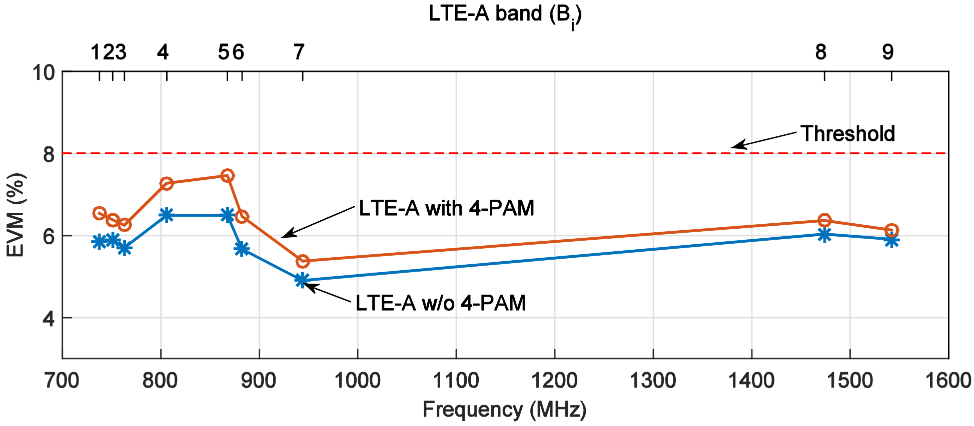

Fig. 3 LTE-A EVM results.

Next the LTE-A EVM performance is considered. Firstly, the LTE-A solitary transmission is analyzed. As depicted in Fig. 3, the LTE-A EVM is between 5% (band 7) and 6.5% (band 5), hence all the LTE-A bands are correctly received. The anechoic chamber has a residual multi-path propagation, which give a frequency. Hence, bands 4, 5, and 6 have higher EVM due to that.
When also the 4-PAM is co-transmitted the LTE-A EVM increase of less than 1% up to 7.5% (band 5). Bands 4, 5, and 6 have the highest penalty, which could be related with the transmitter amplifier saturation.
Having optimized all operational parameters, 9 LTE-A signals are transmitted over 35m GI-POF link and further re-transmitted over a 3.5m wireless link. Simultaneously on the same fiber using frequency division multiplexing a 2 Gb/s 4-PAM baseband signal is transmitted and decoded after the POF link.
With the prospect of the 5G indoor femtocell high-capacity wireless technology using LTE-like signals higher flexibility in the signal processing is needed. The spatial densification by means of femtocell deployment in hotspots can increase capacity and

coverage. 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-A signals for the next generation 5G wireless communication systems. Our results showed that 9 LTE-A 64-QAM signals can be transmitted. Longer wireless links could be achievable with a higher amplification at the RF front-end reaching the maximum allowed power of 20dBm as per specifications. This work demonstrates the suitability of POF in complying with next-generation home-appliance wireless and wired services.

Acknowledgements

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References

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