Integrated performance analysis of UWB wireless optical transmission in FTTH networks

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***Abstract*— The optical transmission of full standard ECMA−368 OFDM−UWB signals 400 Mbit/s per single user over 50 km SSMF, and the impact of optical transmission in the radio performance experimentally analyzed in this paper.**

***Index Terms*—Optical communication, Ultra-wide band (UWB), access networks, fiber-to-the-home (FTTH)**

I. Introduction

ULTRA-WIDEBAND (UWB) wireless technology is experiencing a fast market introduction targeting low-cost short-range high bitrate communications (480 Mbit/s in market-available devices, capable of 1 Gbit/s per user [1]). UWB-on-fibre distribution in fiber-to-the-home (FTTH) networks, was first proposed for impulse-radio and OFDM-based UWB in [2]. UWB distribution on FTTH is an adequate approach forward because: (i) UWB employs, in large extent, Wimedia−defined orthogonal frequency-division multiplexing (OFDM) modulation [3], which is especially well suited for fibre transmission impairments as chromatic dispersion, intrachannel nonlinear distortion, and nonlinear phase noise can be compensated [4]. (ii) UWB employs the band from 3.1 to 10.6 GHz in current regulation, so a large number of UWB channels can be allocated on a single fiber. (iii) Is inherently a low cost solution as UWB signals transmitted through fiber can be received by commercial low-cost receivers.

This paper reports, by first time to our knowledge, the impact of optical transmission of UWB signals through four FTTH links in the performance expected by the final user after radio transmission. The error-vector magnitude (EVM) degradation due to optical fiber transmission, ranging between 5 and 50 km, is reported at the expected distances (0−3 m) in UWB wireless applications.

II. Experimental Set-up

UWB is defined as a radio modulation technique with bandwidth (BW) larger than 500 MHz or at least with 20 % fractional BW [5]. The experimental work herein reported employs ECMA−368 standard UWB signals [6] through standard single mode fiber (SSMF) at typical FTTH distances. After FTTH distribution, the UWB signal is photodetected, amplified, and radiated to the user. Amplification is required after photodetection to adjust the equivalent isotropic radiated power (EIRP) to −41.3 dBm/MHz, the maximum level allowed in current UWB regulation [5].

Fig. 1 shows the experimental set-up. The impact of integrated UWB fiber transmission and wireless radio is evaluated measuring the EVM at wireless distance *d*, after optical transmission through different FTTH spans. The UWB signal comprises two channels (generated by a Wisair DV9110 module) 528 MHz BW following current regulation [6]. Each channel bears one OFDM signal comprised by 128 carriers QPSK-modulated, 6 null carriers, and 12 pilot tones. Each channel bitrate is 200 Mbit/s, providing an aggregated bitrate of 400 Mbit/s per user. Each channel is centered at 3.432 GHz (Ch1) and 3.96 GHz (Ch2), respectively −Fig. 2(a). The two UWB channels are modulated on a Mach-Zehnder electro-optical modulator ($V\pi$=4.5) and transmitted through 5, 10, 25 and 50 km FTTH links as described in Fig. 1.

After fiber transmission the OFDM-UWB signals are photodetected, amplified adjusting the EIRP to the regulated level of −41.3 dBm/MHz, to generate the wireless signal. Fig. 2(c) shows the power spectrum density (PSD) of the two UWB channels where the degradation introduced by 25 km of optical transmission SSMF can be observed.

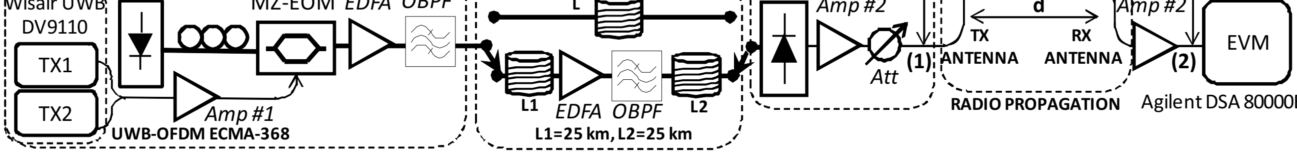

Fig. 1. Laboratory setup for combined performance analysis of UWB-on-fibre and further UWB wireless radio. MZ-EOM: Mach-Zehnder electro-optical modulator; Amp: RF amplifier; OBPF: optical band-pass filter; EDFA: erbium doped fibre amplifier; Att: attenuator; PIN: positive-intrinsic-negative; TX: transmitter, RX: receiver; DSA: digital signal analyzer.

At reception the signal is amplified and the EVM is evaluated by a digital signal analyzer (Agilent digital signal analyzer DSA 80000B). The received signal spectrum after 25 km of fiber and 1.5 meters radio propagation is shown in Fig. 2(d).

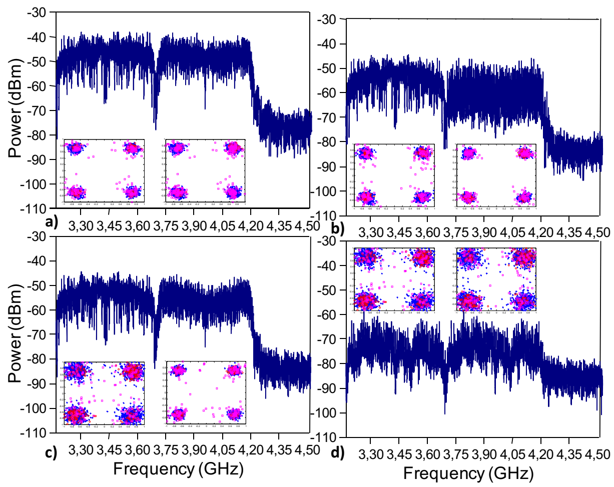

Fig. 2. UWB spectrum with inset constellations: (a) Before optical modulation. (b) Back to back configuration; (c) After 25 km SSMF transmission, photodetection and amplification –point (1) in Fig.1-; (d) UWB spectrum at d=1.5 m wireless -point (2) in Fig.1-.

III. Measurements

Fig. 3 shows the measured EVM at point (1) in Fig.1 for both UWB channels at different received optical powers before photodetection. The measurements have been done for back-to-back (B2B) and four FTTH links comprising 5, 10, 25 km SSMF links and a 50 km link (25 km SSMF + EDFA + 25 km SSMF) respectively. These are depicted in Fig. 1.

Fig. 4 shows the EVM measured at point (2) in Fig. 1 after 0 to 3 meters radio for the different FTTH transmission configurations. The EVM threshold for successful UWB communication is 18.84% [6]. The EVM limit is shown in dashed line in next figures

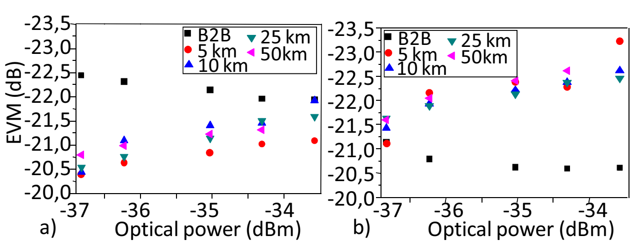

Fig. 3. EVM vs. fibre length transmission vs. optical power before photodetection for (a) channel 1 and (b) channel 2.

In Fig. 4 the EVM dependence with wireless radio distance after optical transmission, considering 5 to 50 km SMMF, can be observed. The EVM threshold limits the radio range after SSMF transmission to 2 m for Ch 1 after 5 km SSMF fiber propagation, 1.5 m for Ch 1 after 10 km SSMF or 1 m for all fiber lengths. For Ch 2 the EVM threshold limits radio distance to 1 m in all FTTH paths analyzed.

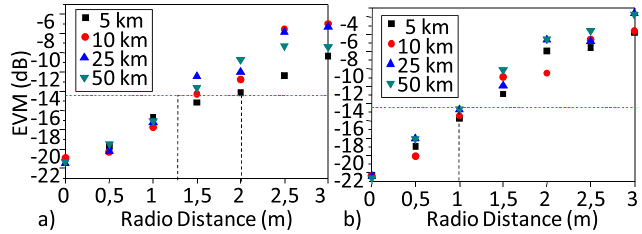

Fig. 4. Measured EVM vs. radio distance from 0 to 3 meters with optical power before photodetection of -34.305 dBm for the different FTTH transmission configurations 5, 10, 25 and 50 km of SSMF for (a) channel 1 and (b) channel 2.

In Fig. 4(a) it can be observed that fibre transmission limits the radio range in from 2 m, in 5 km SSMF link, to 1.3 m in the 50 km FTTH path. This is due to the higher amplification level required to meet the regulated UWB spectral mask in the 50 km optical transmission and the carrier suppression effect due to the fibre chromatic dispersion [7].

IV. Conclusions

The performance of a dual-channel UWB signal typically transmitted through 5, 10, 25 and 50 km SSMF FTTH links without dispersion compensation has been investigated. The experimental results indicate that UWB connectivity can be provided at 1.5 m wireless after 10 km SSMF transmission, or 1 m wireless after 50 km, SSMF providing 400 Mbit/s bitrate per user with 0.33 Bit/s/Hz spectral efficiency. The measured EVM on the radio signal is affected by the optical transmission of the UWB signal. Fibre propagation degrades the UWB SNR imposing a maximum radio penalty of 70 cm from 5 to 50 km SSMF transmission. This is an important factor as UWB technology targets short-range high bitrate communications. This effect should be mitigated by a careful configuration of the FTTH optical path.

Acknowledgment

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