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# Comparison of two types of 60 GHz photonic millimeter-wave generation and distribution of a 3 Gb/s OFDM signal

F. Lecoche<sup>1,\*</sup>, B. Charbonnier<sup>1</sup>, E. Tanguy<sup>2</sup>, Hongwu. Li<sup>2</sup>, F. van Dijk<sup>3</sup>, A. Enard<sup>3</sup>, F. Blache<sup>3</sup>, M. Goix<sup>3</sup>, F. Mallecot<sup>3</sup>

<sup>1</sup> Orange Labs, 2 Avenue Pierre Marzin, 22307, Lannion, France

<sup>2</sup> Université de Nantes, IREENA, UFR Sciences et Techniques, 2 rue de la Houssinière, 44322, Nantes, France

<sup>3</sup> Alcatel-Thalès III-V Lab, 1, avenue Augustin Fresnel, 91767 Palaiseau, France

\* F. Lecoche : Phone: +33 296 051 042, E-Mail: frederic.lecoche@orange-ftgroup.com

**Abstract** – We demonstrate and compare experimentally two set-ups achieving very high data rate (3 Gbps) wireless transmission in the 60 GHz window, both using Radio-over-Fiber (RoF) for reach extension with OFDM signal compliant to the IEEE 802.15.3.c pre-standard.

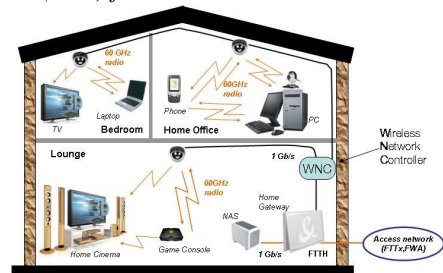
**Introduction** – Multiplication of connected devices and services (computers, media center, videophony, TVoIP etc...) [1] lead to a novel home network architecture and technology to enable wireless coverage offering a data rate above 1 Gbps (Figure 1) [2]. This Home Network architecture is based on a wired backbone network distributing local very high speed wireless connectivity in the different rooms of the house/building because the only radio technology whose capacity approaches some Gb/s uses the 60 GHz frequency window as for instance ECMA-387 [3] or upcoming standards like IEEE 802.15.3c [4] or IEEE 802.11ad [5]. Such radio interfaces are inherently short reach (<15 m) and the radio signal is confined to within one single room. The radio home network then becomes a multicellular network where the cell interference and management issues are similar to that of larger scale mobile/radio networks. In this context, again, the use of the optical infrastructure with RoF, to link the different remote antennas to provide a cost effective and flexible solution, must be considered. In this paper, we present and compare the performance of two types of photonic system for 60 GHz millimeter-wave generation and distribution of a 3 Gb/s OFDM signal. The first one uses low cost well known components and the second one a new generation of optoelectronic components designed for 60 GHz applications.

## I. RADIO OVER FIBRE SET-UPS

In this part, we show two RoF set-ups generating a 60 GHz millimeter-wave radio signal. For both set-ups, we use an OFDM QPSK signal compliant to IEEE802.15.3.c pre standard [4] (3 Gb/s).

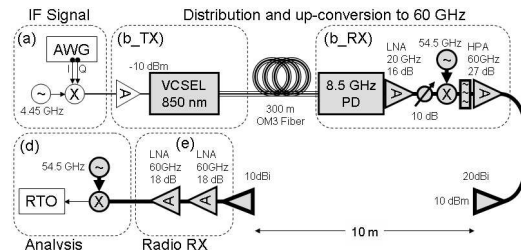
### A. Multi-Mode Fibre Set-up (Fig 2)

The OFDM signal is generated first on an intermediate frequency (IF=4.5 GHz) and is used to modulate directly a VCSEL (850 nm) which converts



**Fig 1:** RoF home architecture and solution for very high data rate wireless next generation

the electrical signal into an optical one. After transport over 300 meters of multimode fiber (OM3 with 4000 MHz.km), an 8.5 GHz photodiode converts the optical signal into an electrical one. After, the signal is sent into a low noise amplifier (LNA) and a mixer fed with a 54.5 GHz local oscillator (LO) to reach the 60 GHz radio frequency window. A high power amplifier (HPA) and a 20 dBi horn antenna are used for the subsequent wireless transmission (10 m). In the radio receiver, two LNA amplify the signal before frequency down-conversion and analysis by a Real Time Oscilloscope (RTO).

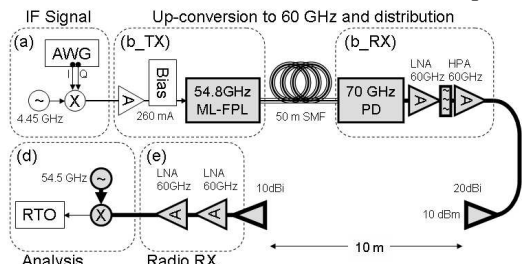


**Fig 2:** VCSEL set-up with distribution of OFDM QPSK signal before up-conversion to 60 GHz

### B. Single Mode Fibre Set-up (Fig3)

This set-up up-converts signal to 60 GHz before transmission over fiber using a 54.8 GHz Mode Locked Fabry Perrot Laser (ML-FPL). The IF OFDM signal modulates directly the ML-FPL. The laser pulses with a repetition rate of 54.8 GHz. Its

modulation produces a mixing between the pulsating frequency and the IF carrier leading to an optical frequency up-conversion of the original signal to 59.3 GHz. The optical radio signal is then transmitted through 50 m of standard Single Mode Fibre (SMF) up to a commercial 70 GHz photodetector followed by a LNA, a band-pass filter and a HPA. The transmit antenna and the receiver radio front end are identical to the ones used in the Multi-Mode Fibre Set-up.



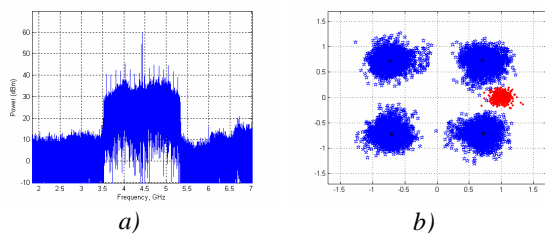
**Fig 3:** ML-FPL set-up with OFDM QPSK signal up-conversion to 60 GHz before distribution

## II. RESULTS

In this part, we show the results obtained for an OFDM modulation at 3 Gb/s and for each set-up.

### A. Multi-Mode Fibre Set-up

The electrical power at the input of VCSEL is set to -10 dBm and the power at the output of the 20 dBi horn antenna is also +10 dBm. In figure 4 a) and b), we present respectively the spectrum of the received OFDM signal and the associated QPSK constellation diagram obtained after demodulation. In spite of a strong disturbance of the spectrum, the mean computed EVM is 18.7% for a signal to noise ratio (SNR) of 23 dB. From the calculated EVM, a BER can be estimated to be around  $10^{-10}$  [6]. Theoretically, the measured SNR should provide an EVM of 7% [6]. The difference between the measured and theoretical values of EVM is attributed to the residual non-linearities of the system.

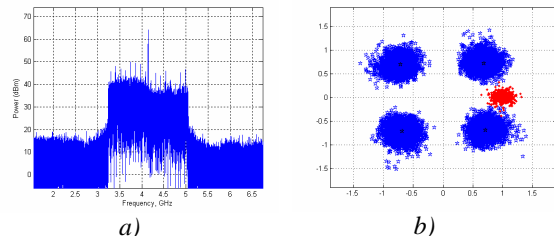


**Fig 4:** Multi-mode fibre set-up received OFDM Spectrum (a) and respective constellation (b) (dots around coordinates [1,0] are pilot tones used for equalization).

### B. Single-Mode Fibre Set-up

The level of radiated power is similar to the previous set-up at the output of the transmit horn antenna. In figure 5 a) and b), we exhibit, respectively, the

spectrum of the received signal and the QPSK constellation diagram. The computed EVM is 19% for a SNR of 21.5 dB. The value of BER can be estimated at  $10^{-10}$  [6]. Again, the measured SNR should provide a theoretical EVM of 8.4% [6]. Distortions and non linearity do affect the calculated EVM but results are still acceptable.



**Fig 5:** Mono-mode fibre set-up received OFDM Spectrum (a) and respective constellation (b).

## III. CONCLUSION

In this paper, we presented two different set-ups for very high data rate wireless transmission using radio-over-fibre at 60 GHz. The first one uses low cost commercial components (VCSEL emitting at 850 nm and 8.5 GHz photodiode) as well as Multi Mode Fibre and the up-conversion to 60 GHz is performed at the remote antenna site after the signal optical distribution. The second one uses a ML-FPL at 54.8 GHz which is able to up-convert directly the signal to 60 GHz before distribution over Single Mode Fibre. For both set-ups, we present the performance evaluations with an OFDM QPSK signal carrying 3 Gb/s. At 10 meters of wireless radio transmission, we report a computed EVM of 18.7% for the VCSEL set-up and 19% for ML-FPL. These values should lead to a BER around  $10^{-10}$  and show that both set-ups have quite similar performances. On one hand, the Multi-Mode Fibre Set-up has proven commercial availability but requires a more complex remote antenna station. On the other hand, the Single Mode Fibre Set-up allows the remote antenna station to be simplified but the components maturity is not yet achieved.

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