RF Bandwidth Capacity and SCM in a Radio-over-Fibre Link Employing Optical Frequency Multiplication

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Abstract *We demonstrate the feasibility of generating two 24Mbps 64-QAM radio signals simultaneously at 17.3GHz and 17.8GHz after 4.4km of multimode fibre in an OFM radio-over-fibre link for wireless multistandard support at the antenna site.*

Introduction

Emerging wireless standards, like IEEE 802.16, are moving towards the use of carrier frequencies beyond 10 GHz to provide increased data rates to the end user. Since these standards specify the radio interface access and physical layer in single cells, a dedicated access architecture to fixed networks, like the ones defined in mobile cellular networks, is missing, and the integration of the spots into the fixed networks is usually performed by protocol convergence layers. As a result, the infrastructure costs rise enormously in in-building and business environments, where many micro- and picocells with even line-of-sight coverage and high signal processing load have to be deployed. An attractive option to reduce the infrastructure costs and to provide a kind of wireless access network architecture for the emerging wireless systems is the consolidation of the radio access control and signal processing at a central location, and the delivery of the radio signals transparently to the antenna site. In this way, in addition to the cost reduction achieved by the antenna site simplification, efficient and flexible strategies for dynamic capacity allocation, common radio resource management and seamless mobility management, can be enabled from the centralized controller.

For this purpose, the benefits of a transparent radio-over-fibre (RoF) distribution antenna system have been long recognised, and different RoF techniques have been developed. The optical frequency multiplication technique (OFM) proposed in [1] (Fig. 1) is a cost-effective method to optically generate microwave frequencies significantly beyond the fundamental bandwidth of multimode fibres (MMF). Experiments have demonstrated the high accuracy of the microwave carriers generated by OFM [2] and the feasibility of transporting typical radio signal modulations (e.g. 64-QAM) after several kilometres of MMF [3]. In this paper, we analyse the RF bandwidth capacity offered by a transparent OFM RoF link, and we demonstrate the potential of OFM to serve as a cost-effective technique for wireless multistandard support in RoF distribution antenna systems, by means of transporting different radio signals along 4.4km of MMF in subcarrier multiplexing (SCM) scheme.

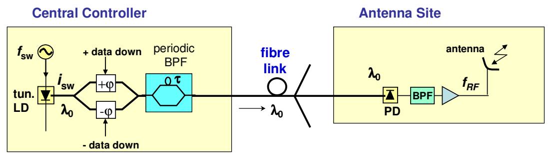

Fig. 1: Basic Optical Frequency Multiplication scheme [2]

RF bandwidth capacity and SCM with OFM

Employing the OFM technique for microwave frequency generation, several harmonics of the sweep frequency f_{sw} are generated at the photodiode output, as shown in [1]. The intensity modulated data signal is also detected by the photodiode and upconverted double-sided at each generated harmonic. Thus, the maximum RF bandwidth supported by one wavelength is limited by half the sweep frequency f_{sw}. As depicted in Fig. 2, data channels on subcarriers below $f_{sw}/2$ can be used to modulate the swept light source. After the photodetector, they can be separately recovered by filtering out the desired subcarrier. If the data signals on the subcarriers that modulate the swept light source exceed $f_{sw}/2$, overlapping of the double-sided bands obtained at every harmonic occurs. This causes dramatic interference and mixing between the different RF channels, impairing their recovery at the antenna site.

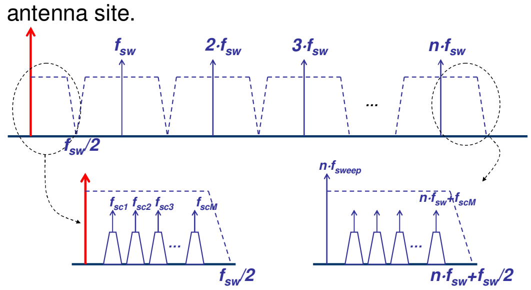

Fig. 2: RF bandwidth capacity employing OFM

Experimental setup

An experiment has been set up to demonstrate the feasibility of transporting two different radio signals in a SCM scheme employing OFM for wireless multi-standard support at the antenna site. Two data channels composed of 64-QAM radio data signals on two subcarriers at 500MHz and 1GHz were introduced simultaneously in an OFM radio-over-fibre link. The OFM system experimental setup is depicted in Fig. 3. A laser source frequency (λ_0=1310 nm) was swept by an optical phase modulator with a sweeping frequency f_{sw}=2.8GHz. A Mach-Zehnder intensity modulator (IM) was used to introduce the data channels into the system. A 24Mbps 64-QAM data signal (4 Msymb/s) was put onto a subcarrier at f_{sc1}=1GHz by a signal generator; the second data channel at f_{sc2}=500MHz was obtained as depicted in Fig. 3. The intensity modulated swept light source was amplified by a semiconductor optical amplifier (SOA) and launched into a Mach-Zehnder interferometer (MZI) with 10 GHz free spectral range (FSR). The output of the MZI was launched into a 4.4km 50μm-core MMF link, and recovered by a 25 GHz IR photodetector to generate the RF harmonics of the f_{sw}. The output of the photodetector was amplified by a low noise amplifier (LNA) and analyzed by a vector signal analyzer (Rhode & Schwarz FSQ-40). At the output of the photodetector, the two data channels were obtained along with all the generated harmonics of f_{sw} at the high frequencies $f_{RF1}=n\cdot f_{sw}\pm f_{sc1}$ and $f_{RF2}=n\cdot f_{sw}\pm f_{sc2}$. On the upper sideband of the 6th harmonic, the data signals carried by f_{sc1} and f_{sc2} were recovered simultaneously at 17.8GHz and 17.3 GHz, respectively.

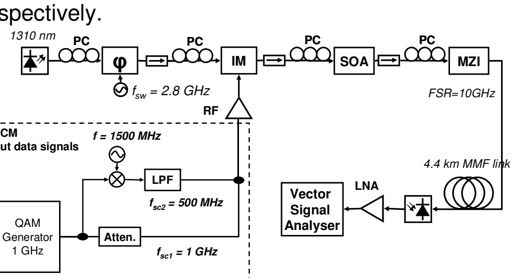

Fig. 3: Experimental setup. (PC: polarization controller; LPF: low pass filter)

Measurement results

Table 1 shows the measurement results obtained for the 24Mbps 64-QAM signals carried by f_{sc1} and recovered at 17.8GHz, in terms of error vector magnitude (EVM) and signal-to-noise ratio (SNR), at the input (subindex *i*) and at the output (subindex *o*) of the optical link, in case of *single* channel and *SCM* transmission. When only one single channel carried by f_{sc1} was inserted into the optical link, the 24Mbps 64-QAM signal recovered at 17.8GHz experienced an EVM value of 3.926%, which lies within the boundaries allowed by the wireless LAN IEEE802.11a physical layer specifications for the transmitter constellation error of 64-QAM signals in the 5GHz band (7.9% for code rate 2/3 and 5.6% for code rate 3/4). When the channels carried by f_{sc1} and f_{sc2} were inserted simultaneously into the optical link, the EVM of the 24Mbps 64-QAM signal recovered at 17.8GHz augmented to 5.657%, which still lies within the acceptable values defined by the mentioned standard. Simultaneously, an EVM estimation of 10.271% was observed for the 24Mbps 64-QAM signal recovered at 17.3 GHz. This larger EVM value was caused by the high EVM value (5.855%) of the input signal at f_{sc2}, due to imperfections in the generation of the second channel. Thus, the impact of the SCM transmission can be only evaluated on the RF signals obtained at $f_{RF1}=n\cdot f_{sw}\pm f_{sc1}$. Fig. 4 shows the IQ diagrams of the 64-QAM signals obtained at 17.8GHz and 17.3GHz in SCM transmission.

$EVM_o\|_{SCM}$	$EVM_i\|_{SCM}$	$EVM_o\|_{single}$	$EVM_i\|_{single}$
5.657 %	2.513 %	3.926 %	1.319 %
$SNR_o\|_{SCM}$	$SNR_i\|_{SCM}$	$SNR_o\|_{single}$	$SNR_i\|_{single}$
24.9 dB	32.0 dB	28.1 dB	37.6 dB

Table 1: 24Mbps 64-QAM signal measurements at the input (1GHz) and output (17.8GHz) of the optical link, in SCM and single carrier transmission, after 4.4km of MMF

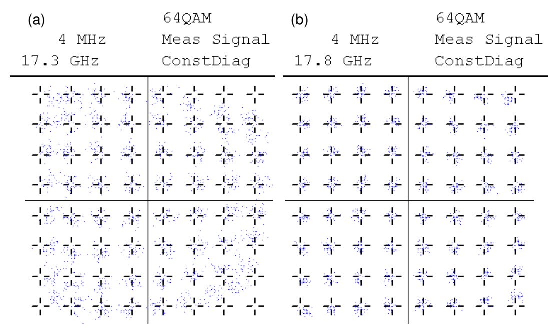

Fig. 4: 64-QAM data signals recovered simultaneously at (a) 17.3 GHz, and (b) 17.8 GHz, after 4.4km of MMF in SCM transmission

Conclusions

The feasibility of generating two 24Mbps 64-QAM radio signals simultaneously at 17.3GHz and 17.8GHz after 4.4km of multimode fibre in an OFM radio-over-fibre link has been demonstrated. EVM values of 3.926% and 5.657% were obtained for the 64-QAM signal recovered at 17.8GHz in the cases of single channel and SCM transmission, respectively. This result reveals the potential of OFM radio-over-fibre links for transporting different wireless signals simultaneously in distributed antenna systems, while satisfying the requirements of current wireless LAN standards.

Acknowledgement

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References

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