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Dispersion tolerant radio-over-fibre transmission of 16 and 64 QAM radio signals at 40 GHz

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Generation of a 39.9 GHz microwave carrying 16 and 64 QAM radio signals was transmitted over different fibre lengths to investigate the dispersion tolerance of the approach.

Results and discussion: Fig. 2 shows the RF spectra obtained at the output of the photodiode in the back-to-back system. Fig. 2a shows the harmonics of \( f_{\text{RF}} = 6.4 \) GHz generated at the output of the photodiode due to FM-IM conversion through the MZI. When a low frequency subcarrier \( f_{\text{sub}} = 1.5 \) GHz modulates the intensity of the optical FM with a chirp-free Mach-Zehnder intensity modulator (IM), the resulting optical signal is passed through a Mach-Zehnder interferometer (MZI) with 10 GHz free spectral range (FSR), launched into an SSMF link, and then recovered by a 40 GHz photodiode. The output of the photodiode is amplified and sent to a vector signal analyser for evaluation.

Fig. 2 Spectrum measured at antenna site (back-to-back)

To assess the quality of the QAM radio signals obtained at 39.9 GHz, the error vector magnitude (EVM) was measured and compared with the maximum transmitter constellation error specification of standard IEEE 802.11a for wireless signals in the 5 GHz band (i.e. 5.6 and 7.9% for 64 QAM with code rate 3/4 and 2/3, respectively; and 11.2% for 16 QAM with code rate 3/4). Fig. 3a shows the IQ constellation diagrams of the 16 and 64 QAM signals (20 MS/s) obtained at 39.9 GHz after 25 km of SSMF. The measured EVM values of the recovered QAM signals at \( f_{\text{RF}} = 39.9 \) GHz are depicted in Fig. 3b against the symbol rate for the back-to-back system (0 km) and after transmission over 25 km of SSMF, and compared with the EVM values of the input signals at \( f_{\text{sub}} = 1.5 \) GHz from the vector signal generator (VSG). As can be seen in the Figure, EVM does not depend on the modulation format, but only on the signal bandwidth (symbol rate), which increases from 0.6 to 2.2% for 4 to 20 MS/s, respectively, for the input signals. In the back-to-back case, the recovered 20 MS/s 64 QAM signal at 39.9 GHz experiences an EVM value of 4.88%, which means a signal-to-noise ratio (SNR) degradation of \(-7\) dB due to the upconversion with respect to the input signal at 1.5 GHz. After the 25 km
SSMF link, the measured EVM value is 6.23%, which adds an extra SNR degradation of 2.1 dB due to transmission.

To investigate the dependency on fibre length variations, the optical signal after the MZI was launched into SSMF links of different length (0, 2.5, 5.3, 12.5, 25 km) with the same average optical power (+3.5 dBm). The measured EVM values are depicted in Fig. 3c. For comparison, the theoretical attenuation profile of a directly transmitted 39.9 GHz carrier is also plotted (typical attenuation and dispersion values at 1310 nm: $\alpha = 0.38 \text{ dB/km}$ and $D = 2.2 \text{ ps/\text{nm-km}}$), which shows an attenuation peak (carrier suppression) at 24.96 km. As can be observed, EVM increases initially with the fibre length due to fibre attenuation; however, it experiences an improving tendency with the 12.5 and 25 km fibre links, without carrier suppression effect. This happens due to the additional FM-IM conversion caused by chromatic dispersion, which enhances the FM-IM conversion of the MZI optimised for the selected harmonic. Thus, chromatic dispersion does not jeopardise system performance, and the link could be flexibly incorporated in 1310 or 1550 nm passive optical networks (PONs) provided that the power budget is properly dimensioned.

Conclusion: We have demonstrated the dispersion tolerant radio-over-fibre transmission of 16 and 64 QAM radio signals at 40 GHz exploiting FM-IM conversion through a periodic bandpass filter. The results obtained at 40 GHz meet the signal quality figures (EVM) specified in the IEEE 802.11a standard for the 5 GHz band. This approach enables a cost-effective RoF-based access infrastructure and a flexible convergence with wavelength division multiplexed PONs.

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References

Fig. 3 Error vector magnitude (EVM) performance (VSG: vector signal generator)
a IQ constellation diagrams of 20 MS/s 16 QAM (80 Mbit/s) and 64 QAM (120 Mbit/s/s) signals recovered at 39.9 GHz after 25 km of fibre
b EVM against symbol rate; input signals at 1.5 GHz (VSG); recovered signals at 39.9 GHz after 0 and 25 km of SSMF

c EVM against fibre length (left axis); theoretical attenuation profile of direct transmission of 39.9 GHz carrier against fibre length (right axis)