OFDM Radio-over-Fibre Systems Employing Routing in Multi-Mode Fibre In-building Networks

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Abstract

We report a radio-over-fibre system for all-optical routing OFDM signal at 18.3 GHz over 950 m multi-mode fibre, with error vector magnitude penalty < 3%.

Introduction

With the evolution of high data rate broadband access networks, high carrier frequencies of 10 GHz and above are required for in-building broadband wireless services, resulting in the reduction of wireless cell size and the increase of the cost for antenna site (AS). The emerging radio-over-fibre (RoF) technology potentially provides a low-cost solution to wireless access network, by centralizing microwave signal processing in the central office (CO) and delivering radio frequency (RF) signal to AS via optical fibre, hence simplifying the antenna [1]. In RoF systems, orthogonal frequency division multiplexing (OFDM) attracts lots of interests due to its dispersion robustness [2]. This is especially beneficial when deployed in multi-mode fibres (MMFs), which are easily installed in in-building access networks.

In this paper, we demonstrate a RoF link for in-building access networks using MMF to transport OFDM signal above 10 GHz with the functionality of optically routing the RF signals for different end-users, as shown in Fig. 1. The building may be a residential area, an office building or an airport lounge, etc. The CO connects the in-building network to the outside access network, delivering one or more RF signals at different RF carriers with certain optical wavelength (λ_1) over MMF and routed to another wavelength (λ_2 *or* λ_3) by the routing device (denoted as "R" in Fig. 1), followed by another length of fibre transmission to different AS, where the RF signals are radiated. Creating the possibility of inter-room wireless communications by means of the routing in "R", this structure brings more flexibility in operating, maintaining and reconfiguring the network as well as adapting the coverage area.

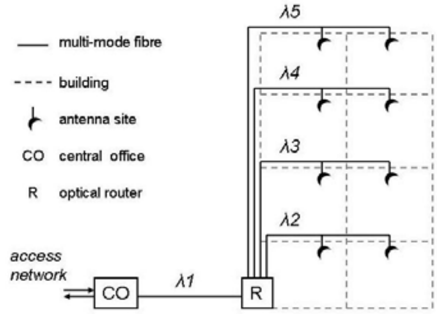

Fig. 1: Distributed MMF RoF links with optical routing

Experimental setup

Among various RoF transmission techniques reported, optical frequency multiplication (OFM) proposed in [3] has shown to be a low-cost and effective method to generate highly pure microwave frequency carrier and to transport RF data beyond the fundamental bandwidth of MMF [4]. This experiment employs OFM technique to transport the RF signal, and wavelength conversion and filtering to realize all-optical routing, see Fig. 2.

A continuous wave (CW) pump signal at 1552 nm wavelength is phase modulated (PM) by an electrical sweep signal at 9 GHz. The OFDM RF data signal with a central carrier frequency of 300 MHz is then put onto the optical carrier by a Mach-Zehnder modulator (MZM). The electrical input of MZM is labelled "*A*". The OFDM signal is 16-quadrature amplitude modulation (16-QAM) with the data rate of 36 Mbit/s and 52 frequency sub-carriers. After amplification, a Mach-Zehnder interferometer (MZI) with a free spectral range of 40 GHz converts the phase modulated signal into intensity modulation (IM). The PM-IM conversion through the MZI generates several harmonics in the frequency domain, each of which is separated from the adjacent harmonic by the sweep frequency 9 GHz [3]. By using this effect, the harmonic frequency is up-converted to the multiple of 9 GHz. The output of the OFM transmitter is labelled "*B*", and after 750 m MMF transmission "*C*". After that, the wavelength conversion employing a semiconductor optical amplifier (SOA) is performed. Another CW light (acting as probe) at 1535 nm is injected into the SOA. From the cross gain modulation (XGM) effect in the SOA, the OFDM data at 1552 nm is copied to the target wavelength of 1535 nm, which is aligned to one of the pass-bands of the filter. The converted signal, labelled "*D*", is sent to the second MMF span of 200 m before reaching the AS. At the AS, we employ a photo-detector with 25 GHz bandwidth, followed by an electrical band-pass filter at 18.3 GHz for

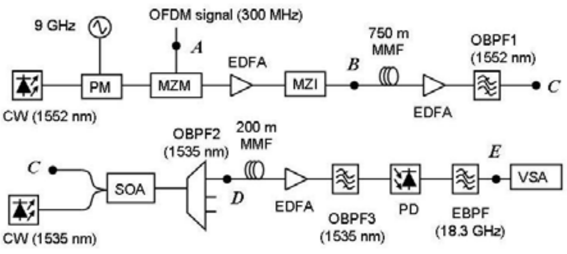

Fig. 2: Experimental setup. OBPF: optical band-pass filter; PD: photo-detector; EBPF: electrical band-pass filter

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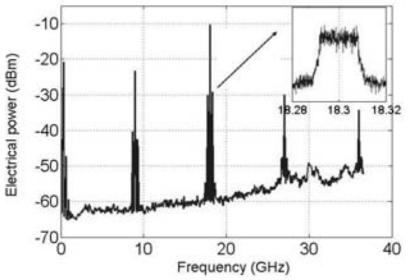


Fig. 3: Spectrum of 16-QAM OFDM signal at point "B"

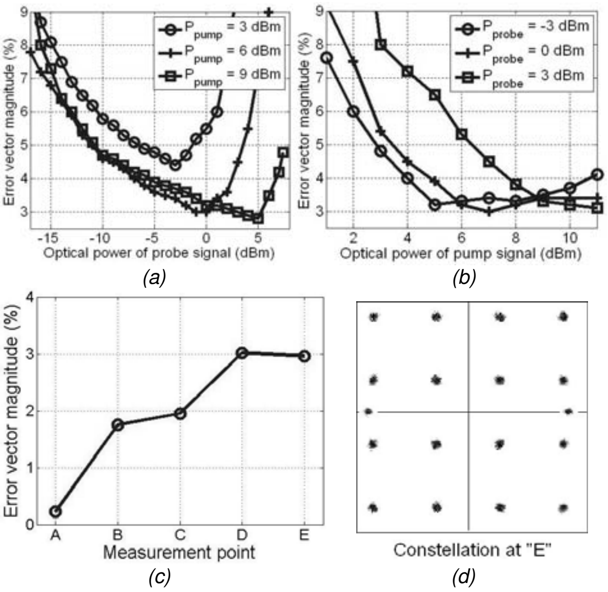
detecting the 2^{nd} harmonic frequency of 18 GHz plus the RF sub-carrier 300 MHz, labelled "E".

Measurement results

First, we present the spectrum of the signal generated by the OFM transmitter in Fig. 3. Five harmonics are displayed in the plot, where the power of the second harmonic at 18 GHz is optimized. The inset plot shows the spectrum of OFDM signal around 18.3 GHz.

Second, we investigate the effect of parameters in the wavelength conversion in order to find an optimum system performance. The results in the averaged error vector magnitude (EVM) are taken at point "E". In Fig. 4(a), EVM values are plotted versus the probe power, for three different pump powers. For each pump power, we find an optimum probe power. Results left from the optimum value are caused by low optical signal-to-noise ratio; while those rights from the optimum are due to the deep gain saturation of the SOA. The optimum probe power shifts to the larger value for larger pump powers. We observe that the system can handle 8 dB probe power fluctuations within an EVM increase of less than 1%.

In Fig. 4(b), EVM values are shown versus pump powers for different probe powers. We observe that to keep EVM low for larger probe powers, larger pump powers are needed. As an example, for 3 dBm probe power, 9 dBm pump power is necessary while for −3 dBm probe power, only 5 dBm pump power is needed for the same EVM.



(a) (b)

(c) (d)

Fig. 4: (a): EVM vs. probe power for different pump powers; (b): EVM vs. pump power for different probe powers; (c): EVM at different measurement points; (d): Constellation diagram at point "E"

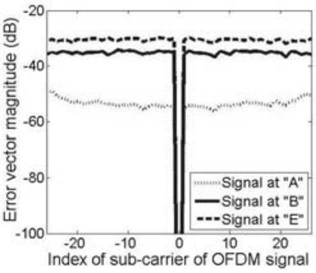


Fig. 5: EVM vs. index of sub-carrier of OFDM signals

Finally, we report the EVM value at different measurement points ("A", "B", "C", "D" and "E"), as shown in Fig. 4(c). The pump power and probe power are set to 6 and 0 dBm, respectively, according to Fig. 4(a, b). It is seen that even though 52 sub-carrier OFDM signal is transmitted over 950 m MMF and is converted to another wavelength in the link, the measured EVM value is only around 3%, with the total system penalty less than 3%. For comparison, in IEEE 802.11a standard, the required EVM is 11.2% for 16-QAM. It is also seen from "$B-C$" and "$D-E$" in Fig. 4(c) that the MMF gives negligible EVM penalty in the system, due to the robustness of the OFM technique to the modal dispersion [4]. Fig. 4(d) shows the constellation diagram of the demodulated 16-QAM signal at point "E". In Fig. 5, we also show the EVM vs. the index of sub-carrier of the OFDM signals, at three measurement points "A", "B" and "E", by using the same parameters as Fig. 4(c, d).

Conclusions

By employing OFM we have successfully demonstrated the feasibility of transporting 18.3 GHz 52 sub-carriers OFDM signal of 36 Mbit/s data rate over 950 m MMF link. We have also shown a mid-span all-optical routing with EVM less than 3%. We observed that the penalties induced by the MMF modal dispersion are negligibly small, thanks to the OFM technique, enabling large operational flexibility for in-building broadband access networks.

Acknowledgment

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References

1. Koonen et al OFC'07, OThP3, 2008
2. Mitchell et al EL, Vol. 40 (2004), p. 1353
3. Koonen et al ECOC'04, Th1.1.1, 2004
4. Larrode et al PTL, Vol. 18 (2006), p. 2428