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High Capacity Radio-over-Fiber Systems for Multi-carrier Signals with Dynamic Routing

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***Abstract*—We address the successful transmission and optical dynamic routing of high capacity RF data using an SCM or OFDM format over multi-mode fiber links, by the means of optical frequency multiplication.**

I. INTRODUCTION

With the evolution of high data rate broadband access networks, high carrier frequencies larger than 10 GHz and broad data bandwidth are required for wireless services. The combination of high capacity of fiber optics and the wireless access flexibility, a radio-over-fiber (RoF) system offers a low-cost solution to the wireless access network. It is especially beneficial for high frequency access networks, such as wireless access IEEE 802.16 family, due to the reduced cell sizes in these network configurations. RoF techniques enable the consolidation of the signal processing and access control at a centralized control station (CS) and the radio-frequency (RF) signal is transparently delivered to the simplified antenna station (AS) via optical fibers.

Over the last few years, various wireless communication standards have been vastly utilized in the market, including global system for mobile communications (GSM) and IEEE 802.1x standards, enabling larger data capacity and bandwidth. Among them, the emerging IEEE 802.16 (WiMax) standard offers up to 100 Mbit/s in the 10 to 66 GHz range; IEEE 802.11g (WiFi) standard supports up to 54 Mbit/s in 2.5 GHz range whilst IEEE 802.15 UWB standard also operates up to 60 GHz in the short-range area at 480 Mbit/s. Among these standards, multi-carrier techniques including orthogonal frequency division multiplexing (OFDM) are employed due to their primary advantage of higher robustness to multi-path dispersion compared to a single-carrier scheme. In passive optical networks (PONs), another multi-carrier technique, sub-carrier multiplexing (SCM), can be used due to its increased data capacity and simplicity. In SCM, the operation of multiplexing and de-multiplexing is carried out in the frequency domain electronically, which gives the advantage of SCM over a more costly pure wavelength division multiplexing (WDM) access. Also for OFDM the multiplexing is done electronically. Therefore, investigations of the RoF system employing multi-carrier schemes such as OFDM and SCM attract plenty of attention, in order to provide a robust and high capacity solution to the in-building and access networks.

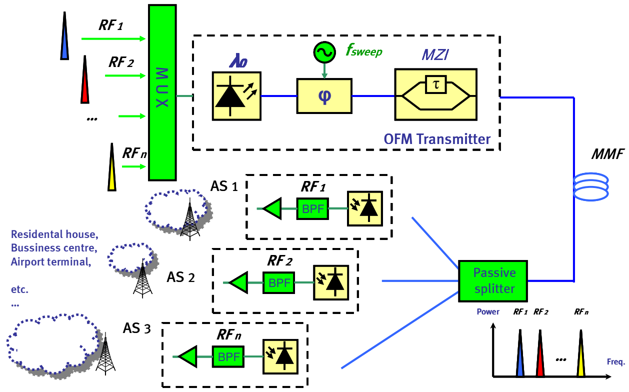

Fig. 1: High capacity RoF link using OFM

Among a few RoF techniques, optical frequency multiplication (OFM) has been shown to be very robust against chromatic and modal dispersion, and enables bidirectional communication for broadband access networks [1]. In this paper, we firstly present a RoF broadcast and select architecture employing SCM 64-level quadrature amplitude modulated (64-QAM) signal with up to 10 sub-carriers over 4.4 km multi-mode fiber (MMF), transporting 210 Mbit/s data. We also experimentally demonstrate a RoF routed architecture link using MMF to transport OFDM signals above 10 GHz with the added functionality of optical routing the RF signals to the different end-users.

II. EXPERIMENTAL RESULTS

The principle of the RoF link using SCM is shown in Fig. 1. The multiplexed electrical RF data is modulated, externally by a Mach-Zehnder modulator, onto the OFM transmitter. The OFM transmitter consists of a CW laser source, a phase modulator driven by a sweep signal and a Mach-Zehnder interferometer (MZI). At the AS, after transmitting over 4.4 km MMF, the RF signal is appropriately selected by the different users. In our experiment, we set the RF signal to be 64-QAM, with up to 10 sub-carriers and centered at 300 MHz. The sweep frequency for the OFM-based transmitter is 6 GHz, which enables us to obtain 18.3 GHz RF data on the right sideband of the third OFM harmonic. The achieved bit rate is 210 Mbit/s with an error vector magnitude (EVM) of less than 6%. In Fig. 2, the EVM

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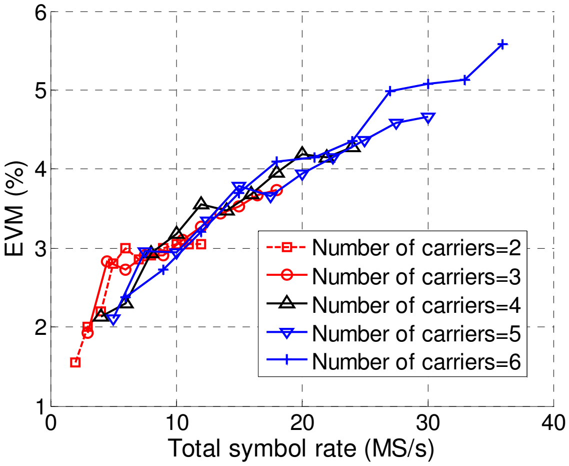


Fig. 2: EVM values dependence on total symbol rate

values as a function of the total symbol rate in the RoF system for different number of carriers is shown. Notice that the EVM value for a certain total symbol rate does not depend on the number of carriers in the system, which means the choice of the number of carriers is quite flexible for multi-carrier RoF systems, using the SCM scheme, which leads to the fact that the system performance is transparent to the number of carriers and signal format. It is also worthy to note that in this demonstration the total symbol rate exceeds 35 MS/s (210 Mbit/s) while the EVM is below 6%. (In the IEEE 802.11a standards the EVM value is required at below to 7.94% for 64-QAM of 2/3 code rates.) [2]

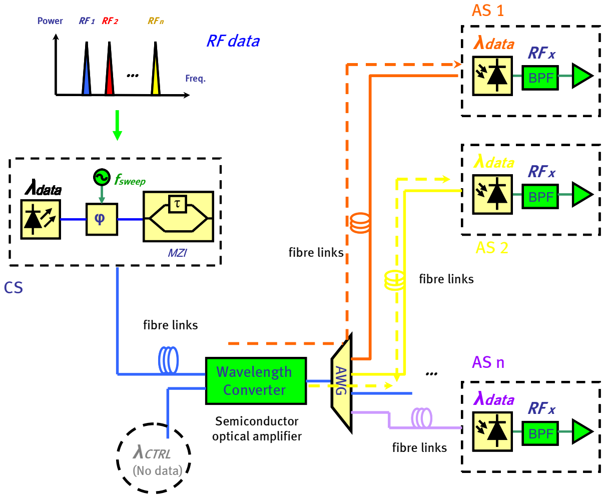
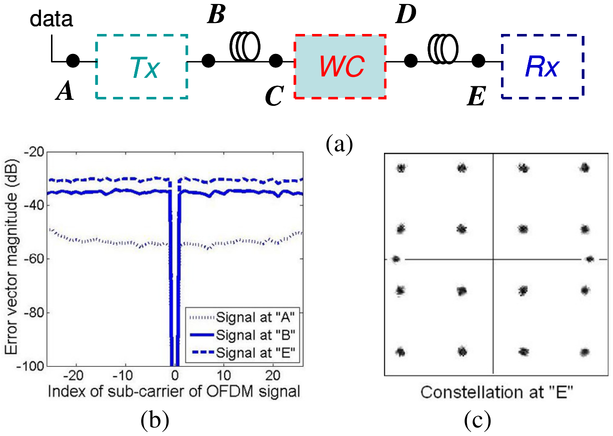


Fig. 3: Optical dynamic routing using SOA-based wavelength conversion



(a)

(b)

(c)

Fig. 4: (a) Simplified experimental setup; (b) EVM for different sub-carrier of OFDM, at different stage of the system; (c) the measured constellation at "E".

In the configuration of Fig. 1, we have very limited dynamic scale with respect to flexible user allocation. Therefore, we propose the optical dynamic routing of RoF signals, which is very much desirable for meeting the varying user service demand. Another advantage of routed architecture over broadcast-and-select mode is the potential to add security control and monitoring functionalities into the network. The proposed routed architecture is shown in Fig. 3. The RF data is again externally modulated to OFM transmitter, transmitted over 750m MMF and combined with a control wavelength in the semiconductor optical amplifier (SOA). By means of cross-gain-modulation the data signal copies the data from data wavelength to the control wavelength. The wavelength converted signal is then transmitted over a further 200m MMF to eventually reach the AS. In this experiment, we use the standard WiFi OFDM signal of 52 sub-carriers with 36 Mbit/s data rate. A simplified experimental setup is shown in Fig. 4a, where different stages of the system are labeled from "A" to "E". In Fig. 4b, we present the system performance in EVM at different stages of the system, for different OFDM sub-carrier index. Fig. 4c shows the measured constellation diagram at point "E". It is seen that all the constellation points are very well separated and we have only 3% EVM values after total 950 m MMF and mid-span routing. [3]

CONCLUSION

In this paper, we have demonstrated the transmission of multi-carrier 64-QAM signal at 18.3 GHz over 4.4 km MMF employing the SCM method. The performance of the SCM multi-carrier RoF system is transparent to the number of carriers and signal format. Furthermore, in order to improve the scalability of the system, we exploit wavelength conversion using a single SOA to achieve only 3% EVM value after a total of 950m MMF and mid-span routing for flexible routed RoF systems. Therefore, the proposed architecture provides a potential solution for future dynamic and high capacity RoF access network.

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