Performance Investigation of Radio Over Fiber Link with High-Speed Interface of IEEE 802.15.3c

Moussa El Yahyaoui, Mohammed Amine Azza and Ali Elmoussati

Abstract 60 GHz frequency band is candidate for future broadband wireless networks for the last mile because of high available of unlicensed bandwidth worldwide. However, 60 GHz frequency band has limited coverage due to the high free-space losses and the waves do not penetrate the walls. Radio over Fiber (RoF) technology combining both, the high capacity of optical communication and the flexibility of wireless access, can help in extending 60 GHz radio coverage in indoor environment. This paper presents a study of RoF link employing IEEE 802.15.3c Physical Layer (PHY) for 60 GHz frequency band. A simulation of 802.15.3c High-speed interface (HSI) mode in radio over fiber system using the co-simulation technique between OptiSystem and Simulink have been realized. Finally, a BER performance of IEEE 802.15.3c HSI mode in Radio over Fiber system versus the Multi-mode Fiber (MMF) length have been calculated.

Keywords Radio over fiber · IEEE 802.15.3c · 60 GHz · BER · MMF

1 Introduction

The evolution of wired technologies such as xDSL and Fiber to Home connections provides high broadband access network which now allows the delivery of services in the order of Gb/s. Current wireless systems have limited capacity e.g. 802.11a provide up to 54 Mb/s and 802.11n up to 400 Mb/s [1]. However, new indoor

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wireless applications need for higher data throughput, such the wireless multimedia applications (IPTV, HDTV, in-room gaming) and kiosk applications. Data rates required is in range of several GB/s to transmit signals like uncompressed video streaming signals [2]. To support high data, new radio standards, as ECMA-387, IEEE 802.15.3c and IEEE 802.11ad, providing up to 7Gbit/s throughput using unlicensed 5 GHz of spectrum at 60 GHz are emerging. Transmission at 60 GHz can cover limited area, around 10–15 m in indoor environment due to free space path loss (loss over 1 m at 60 GHz is 68 dB). We investigate the use of radio over fiber solution to cover huge spaces or even building and large rooms.

Radio-over-Fiber (RoF) technology is becoming the promising solution for the broadband access networks because it can increase the capacity, coverage, and mobility and it decreases the cost of the base station [3]. In RoF systems, radio signals optically transported between the central management networks Home Communication Controller (HCC) and Radio Access Point (RAP), signal generation and processing are centralized in the HCC. RoF technology for micro cell and multiservice is becoming one of important technologies for the future communication systems [4, 5].

Wireless Personal Area Network WPAN IEEE 802.15.3c have been proposed for the future high data rate operates in the 60 GHz millimeter-wave band. The IEEE 802.15.3c support uncompressed video streaming at 1.78 or 3.56 GB/s and fast downloading in Kiosks [6]. Recently, numerous studies of RoF in millimeter-wave have being published [7–9]. BER performances of ieee 802.15.3c PHY for AWGN channel have been calculated in [8]. The generation of millimeter-wave techniques have been demonstrated in [10, 11]. This paper investigates the performances of applying the PHY layer of IEEE 802.15.3c in Radio over Fiber system at 60 GHz based on MMF fiber and Optical Carrier Suppression (OCS).

This paper has been organized as follows. We present the architecture of Radio over Fiber system, and then we introduce the IEEE 802.15.3c standard. Finally, we provide numerical results of the performance of the IEEE 802.15.3c in RoF system.

2 Radio Over Fiber Architecture

RoF network architecture employing IEEE 802.15.3c PHY is shown in Fig. 1 [5]. Home Communication Controller (HCC) is the central management unit for in-home networks. HCC is responsible for radio access control, signal processing, and RoF signal generation. Every room has one or more RAPs, which forwards the packets to its destinations. RAP contains only opto-electronic interfaces and RF modules and is connected to the HCC via optical fiber. There is three main Schemes of Signal Transport over fiber as shown in Fig. 2. The first Scheme consists of transposing the electrical radio signal onto an optical carrier for distribution over optical fiber. the second scheme consists in transposing the radio signal at an

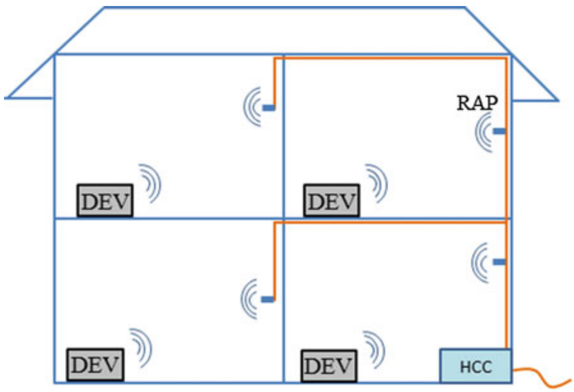

Fig. 1 RoF home network architecture

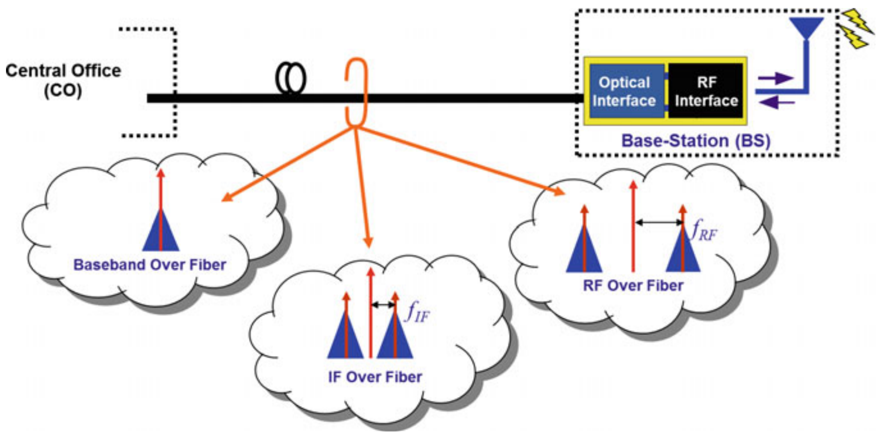

Fig. 2 Radio over fiber transport techniques

Intermediate Frequency (IF) before the optical transmission over fiber. The third scheme consist in transposing the base band signal onto an optical carrier for transmission over fiber.

2.1 RoF at Radio Frequency Architecture

RoF architecture realized in OptiSystem is shown in Fig. 3. The in-phase (I) and quadrature (Q) components are transposed to IF by mixing with an RF oscillator split in two paths with a 90 phase shift. The continuous-wavelength (CW) optical source of 850 nm wavelength is used to generate the optical carrier. the optical

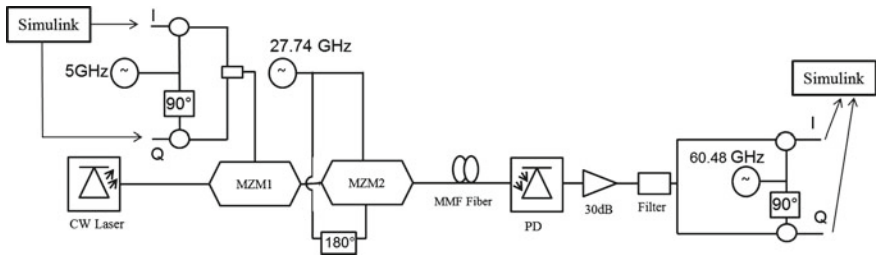

Fig. 3 Schematic diagrams RF architecture at 60.48 GHz

carrier is modulated by IF signal using Mach-Zehnder modulator MZM1, and then modulated by 27.75 GHz signal using dual arme Mach-Zehnder modulator MZM2 in order to delete the optical carrier [12]. The optical signal is transported by MMF fiber to the receiver. At the reception the PD convert the optical signal to electrical signal. The received signal amplified, filtered and demodulated to recover I and Q HSI OFDM signal.

2.2 802.15.3c HSI Model

The mmWave PHY is defined for the frequency band of 57.0–66.0 GHz, which consists of four channels. Three different PHYs modes are defined known as Single Carrier (SC PHY), High Speed Interface (HSI PHY), and Audio-Visual (AV PHY) modes. In our work, we have focused on HSI PHY. The HSI PHY is designed for NLOS operation and uses OFDM with an FEC based on Low-density Parity-check (LDPC) codes. In this usage model, all of the devices in the WPAN will have bidirectional, NLOS high speed, low-latency communication, which is provided for by the HSI PHY. OFDM technology is adopted in a large number of wireless standards as a mature technology. Figure 4 presents the block diagram of HSI PHY mode modeled in Simulink according to the standard 802.15.3c. The data bits

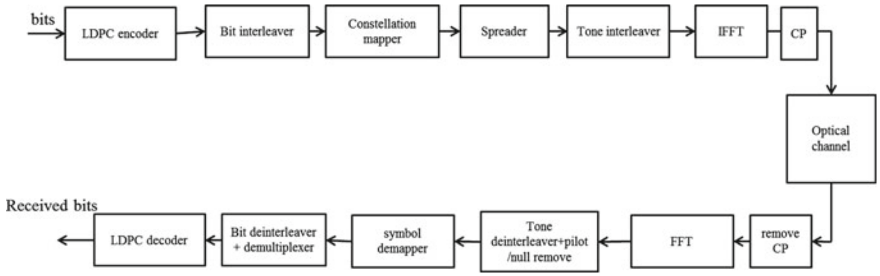

Fig. 4 HSI transmitter and receiver block diagram

Table 1 HSI OFDM PHY parameters

Description	Value
Reference sampling rate	2640 MHz
FFT size	512
Number of data subcarriers	336
Number of pilot subcarriers	16
Number of DC subcarriers	3
Nominal used bandwidth	1815 MHz
OFDM Symbol duration	218.18 ns

encoded by two LDPC encoders use 1/2 or 5/8 rate, and the output of LDPC encoder multiplexed to form a single data stream. After the data multiplexer, the bits are interleaved by a bloc interleaver of length of 2688 bits. The interleaved bits are mapped into a serial complex data using the QPSK, 16QAM or 64QAM modulation format. Each group of 336 complex numbers assigned to an OFDM symbol. The output data of the constellation mapper are then parallelized, and Pilots, dc and null tones are added up before the tone interleaver. Tone interleaver makes sure that neighboring symbols are not mapped into adjacent subcarriers. The interleaved tones are modulated by OFDM modulator that consists of 512-point IFFT. Finally, adding a cyclic prefix of 64 tones and transmitting the symbols in optical link.

The received signal from OptiSystem is removed from the cyclic prefix and then demodulated by OFDM that consist of 512-point FFT. After de-interleaving process, data carriers are identified and QPSK, 16QAM or 64QAM symbols are demodulated by the de-mapper block. The obtained bit stream is de-interleaved and demultiplixed into 2 bit streams to be decoded with 2 LDPC decoders. Table 1 presents the parameters of HSI OFDM system.

3 Results and Discussion

After the simulation of the complete system, IEEE 802.15.3c HSI mode with RoF link, we obtained results as presented below. HSI OFDM IF signal at 5 GHz is shown in Fig. 5. The 5 GHz IF signals were later transposed to optical carrier using MZM1 and MZM2 as shown in Fig. 6a. Figure 6b shows 60 GHz OFDM spectrum at receiver and Fig. 7 shows the recovered signal constellation diagram at the RF OFDM receiver, after propagating through 200 m MMF fiber length.

Figure 8 shows the BER performances of three MCS as shown in Table 2 versus MMF fiber length. As we can see in the graph, we have reached, 350, 295 and 210 m length of MMF fiber respectively for MCS1, MCS4 and MCS7 with BER below than 10^{-5}. Thinks to dual arm MZM enabling OCS that make able to reach long distances of MMF fiber.

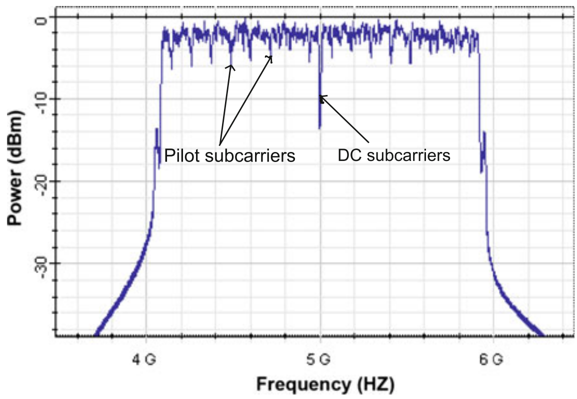

Fig. 5 HSI OFDM spectrum at 5 GHz intermediate frequency

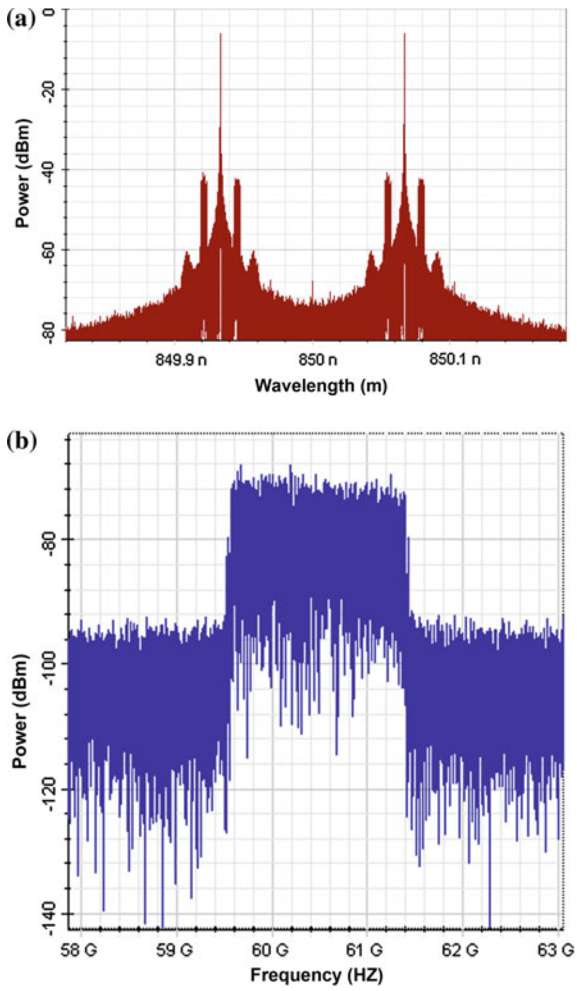

Fig. 6 Optical spectrum for double-sideband carrier suppression scheme after MZM2 (**a**). Electrical spectrum of HSI-OFDM signal at 60.48 GHz carrier frequency after 400 m MMF fiber Length at receiver unit (**b**)

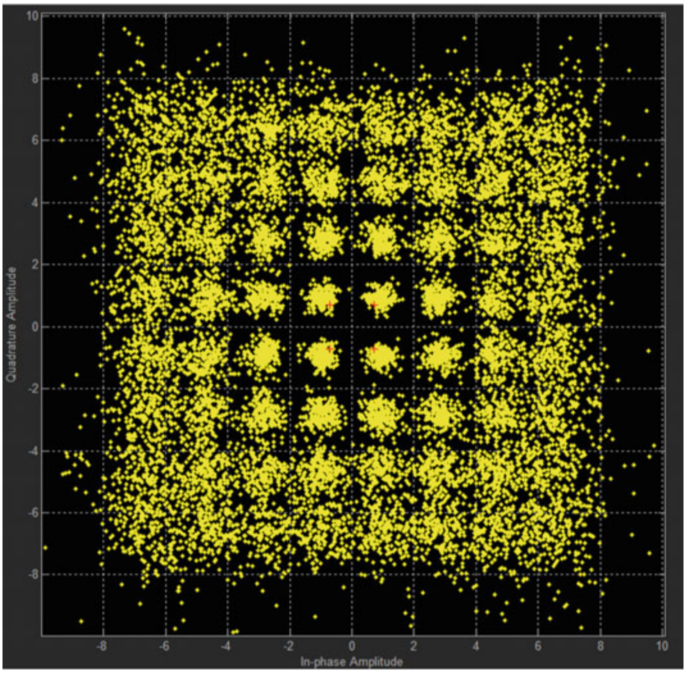

Fig. 7 Constellation diagram of 64QAM at the receiver with EVM = 14

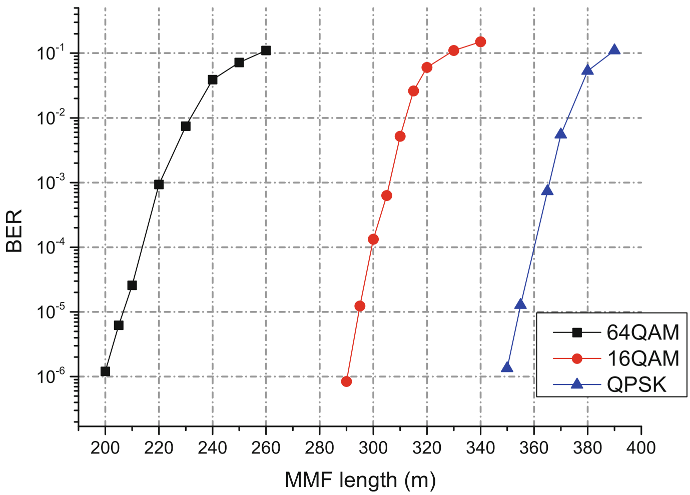

Fig. 8 BER performance in RF architecture

Table 2 HSI modulation and coding schemes parameters

MCS index	Data rate(Mb/s)	Modulation scheme	LDPC codes rate
1	1540	QPSK	1/2
4	3080	16QAM	1/2
7	5775	64QAM	5/8

4 Conclusion

In this paper, we established an ROF link with HSI PHY communication system in SIMULINK and OptiSystem. This have been done by ROF architecture based on MMF fiber and optical carrier suppression. We have calculated the BER performance of the system for various modulation schemes QPSK, 16QAM and 64QAM.

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