Optical Fiber Technology 19 (2013) 529–532

Contents lists available at ScienceDirect

Optical Fiber Technology

www.elsevier.com/locate/yofte

Real-time dual-band wireless videos in millimeter-wave radio-over-fiber system

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ARTICLE INFO

Article history:
Received 30 April 2013
Revised 13 July 2013
Available online 13 August 2013

Keywords:
Millimeter-wave (mm-wave)
Optical-wireless
Radio-over-fiber (RoF)

ABSTRACT

A dual-band converged radio-over-fiber (RoF) access system at 60-GHz and 100-GHz millimeter-wave (mm-wave) is proposed. Real-time end-to-end delivery of two channels of independent high-definition (HD) video services simultaneously carried on 60-GHz and 100-GHz radios is demonstrated for the first time. PRBS data transmission with equivalent data rate and format is also tested to characterize the system performance. The analysis of the spectrum from the beating signal indicates the entire 60-GHz band and the W-band can be retrieved without interference. The real-time HD video display and error-free (BER < 10–9) data transmission demonstrate the feasibility of the proposed wireless access system using converged fiber-optic and mm-wave RoF techniques.

1. Introduction

Due to the exponential growth of data traffic in wireless access systems, the conventional low-frequency spectra (700 MHz to 5 GHz) have become over-congested and HD video and high-bit-rate data services are severely hampered by inter-channel interference. It is important to explore new RF spectra to drastically increase the system capacity and peak data rate for high-speed wireless access. Millimeter-wave (mm-wave) frequencies (30–300 GHz) have attracted many research interests for their abundant spectra and minimal interference with existing wireless services. Mm-wave technologies are considered to be an enabler of next-generation broadband wireless access networks with very high throughput (VHT) supporting diverse infrastructures consisting of wireless wide-area network (WWAN), local area network (WLAN) and local multipoint distributed systems. By combining the advantages of wireless and fiber-optic techniques, RoF technology has been considered as a promising solution to extend the limited reach of mm-wave radio and to simplify the generation and distribution of mm-wave signals in a cost-effective way [1,2]. In addition, by shifting the processing power of each individual mm-wave remote access point (RAU: Remote Antenna Unit) to a centralized location (CO: central office) through fiber-optic backhaul links, this centralized RoF access architecture provides a seamless integration with small-cell cloud radio access network (C-RAN) for multi-service in-building wireless access systems for the next generation [3,4].

Nowadays, the research on mm-wave RoF access system is mainly focused on the 7-GHz unlicensed band available at 60 GHz, as shown in Fig. 1. Band-mapping scheme of combining legacy low-frequency wireless services such as WiFi, WiMax, and LTE, together with emerging very-high-throughput (VHT) data services such as ECMA, IEEE 802.11ad, 802.15.3c and Wireless-HD within the 60-GHz band has been suggested and proposed with experimental demonstrations [5–8]. Meanwhile, the study on higher mm-wave frequencies at W-band (75–110 GHz) with 35-GHz light-licensed bandwidth is also in progress. Due to the broader bandwidth available at W-band, very-high-speed wireless access rates beyond 100 Gb/s can be achieved over these frequencies [9,10]. Therefore, RoF systems supporting both the 60-GHz band and the higher W-band will be a promising solution to provide ultimate wireless capacity.

In this paper, for the first time, we demonstrate a dual-band mm-wave RoF access system that delivers independent HD video services on both 60-GHz band and W-band simultaneously, as shown in Fig. 1. The similar physical characteristics of 60-GHz band and W-band such as inherent high propagation loss and high directional antenna lead to a consolidated deployment structure of the dual-band mm-wave RoF system. Based on RoF technologies, 60-GHz and 100-GHz services share the same optical infrastructure in a converged multi-service access system. To characterize the system performance, PRBS data streams are also tested through the system. Error-free (BER < 10–9) transmissions over 25-km standard single-mode fiber (SSMF) and 1-ft wireless distance are achieved for both 60-GHz and 100-GHz RF bands, which demonstrate the feasibility of the proposed dual-band RoF access system.

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1068-5200/$ - see front matter
http://dx.doi.org/10.1016/j.yofte.2013.07.005

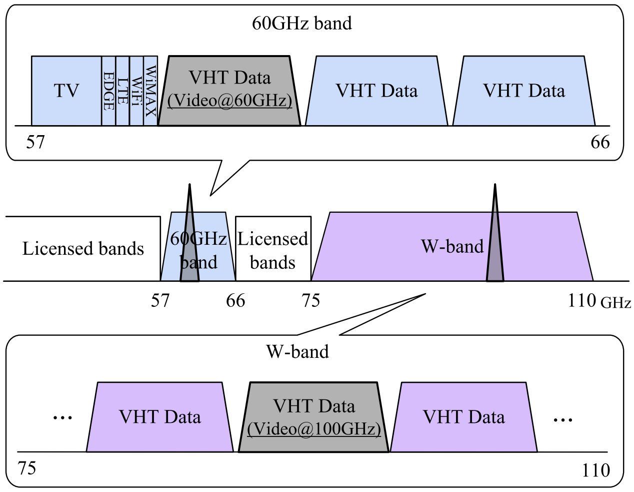

Fig. 1. Mm-wave band maps and allocation of two HD video services on 60-GHz and 100-GHz bands.

2. Experimental setup and results

Fig. 2 illustrates the experimental setup of the proposed dual-band mm-wave RoF access system and the photographs for different sections of the real-time wireless HD video transmission testbed.

At the video headend (VHE), two independent HD video sources together with audio signals as downlink data are converted into two serial OOK streams separately (1.485-Gb/s each) by using HDMI/SDI converters.

At the CO, the two data streams are amplified by electrical amplifier (EA) to modulate two separate tunable DFB lasers operating at 1553.826 nm and 1554.12 nm, respectively. External MZMs and intensity modulation are implemented here. Another DFB laser at 1554.608 nm without any modulation is then coupled into the link to generate the dual-band optical mm-waves with wavelength spacing of 97.1 GHz and 60.6 GHz [11]. The optical spectra of generated optical mm-waves are shown in inset (a).

After 25-km SSMF transmission and EDFA amplification, at the RAU, the dual-band optical mm-waves are optically separated into two branches corresponding to two different channels. In each channel, an interleaver (IL) is used before the independent photo detection to filter out the unwanted band so as to enhance the succeeding detection and EA efficiency. The optical spectra after the two ILs are shown in inset (b) and (c). After the beating of optical mm-waves at photo detectors (PDs), the generated 100-GHz and 60-GHz RF signals are amplified by high-frequency EAs and fed into horn antennas (HAs) over W-band and 60-GHz band for mm-wave wireless transmission, respectively. The wireless transmission distance is 35 cm (~1 ft) with an interval of 15 cm between the two pairs, as shown in the inset of Fig. 2. The near transmission distance is due to the limited RF transmitting power and also the strong propagation loss at very-high-frequency

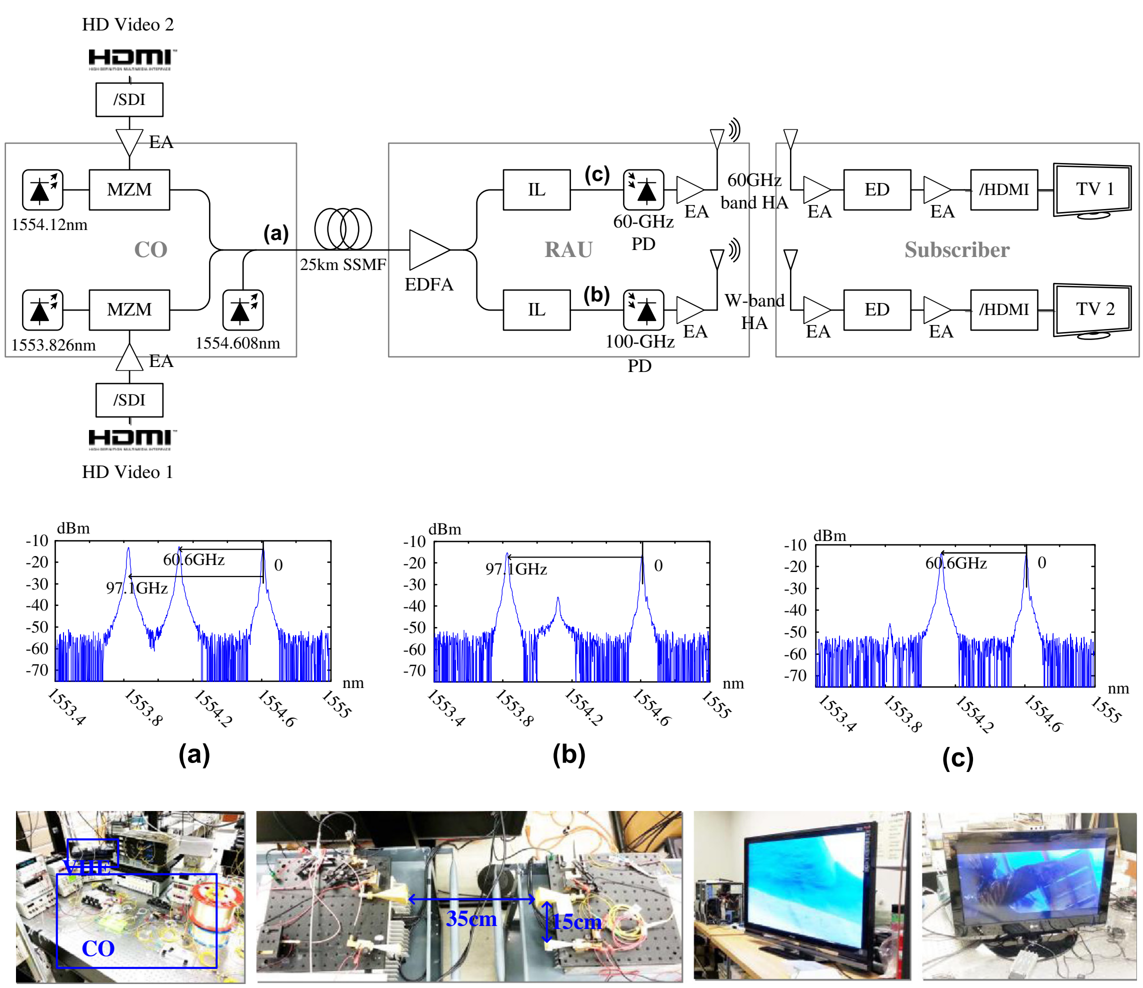

Fig. 2. Experimental setup of real-time wireless HD video transmission in dual-band (60-GHz and 100-GHz) mm-wave RoF access systems. Inset (a–c): optical spectra of dual-band optical mm-waves (a) before and (b and c) after optical interleavers for service separation.