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High capacity wireless data links in the W-band using hybrid photonics-electronic techniques for signal generation and detection

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[Abstract] Seamless convergence of fiber-optic and the wireless networks is of great interest for enabling transparent delivery of broadband services to users in different locations, including both metropolitan and rural areas. Current demand of bandwidth by end-users, especially using mobile devices, is seeding the need to use bands located at the millimeter-wave region (30-300 GHz), mainly because of its inherent broadband nature. In our lab, we have conducted extensive research on high-speed photonic-wireless links in the V-band (50-75GHz) and the W-band (75-110GHz). In this paper, we will present our latest findings and experimental results on the W-band, specifically on its 81-86GHz sub-band. These include photonic generation of millimeter-wave carriers and transmission performance of broadband signals on different types of fibers and span lengths.

[Introduction]

Hybrid fiber-wireless transmission systems can serve as the key building block to support many services and applications that can bring conveniences to our daily life. Services like e-health monitoring, distance e-education and holographic video conferencing all rely on machine to machine communication, employing wired or wireless physical media. With the recent maturity and popularity of portable devices like tables and smartphones, services in wireless are normally preferred by end-users. Due to the high bandwidth demand for these applications, conventional wireless bands won't be able to support enough capacity in the near future. Therefore, using wireless carriers at higher frequency bands with broader transmission bandwidth, e.g. millimeter-wave (mm-wave) region is becoming necessary [1-2].
Recently, experimental demonstrations on high-speed fiber-wireless transmission in the V-band (50-75 GHz) [3-5], W-band (75-110 GHz) [6-9] and higher frequency bands have been reported [10]. From a practical architectural point of view, considerations on bidirectional mm-wave over fiber transmissions have also been stressed in the Ka-band (26.5-40 GHz), V-band and E-band (60-90 GHz). In this paper we will show two experimental demonstrations of fiber-wireless and fiber-wireless-fiber links operating on the W-band. These links can be employed in multiple network scenarios, such as indoor wireless signal distribution and high-capacity wireless bridges.

[Hybrid Fiber-Wireless links]

Figure 1 presents the experimental setup of a fiber-wireless system. A continuous-wave (CW) lightwave at 1550.2 nm from an external cavity laser (ECL) is fed into a Mach-Zehnder modulator (MZM) driven by a 20.35 GHz modulation signal. One of the side bands of the signal is launched into an integrated LiNbO3 dual parallel MZM driven by a two-channel 8 Gbaud pseudo-random binary sequences (PRBS) with a word length of 2^{15}-1, resulting in an overall 16 Gbit/s QPSK signal at the output. The side modes are then regrouped with a 3 dB coupler. After a mixed SMF/MMF transmission, the signal is up-converted at a 100 GHz photodetector (PD) and radiated to the air by a 25 dBi horn antenna. At the receiver side, the received signal is firstly amplified by a 40 dB gain low noise amplifier (LNA), before being electrically down-converted and sampled by a 40 GSa/s digital storage oscilloscope (DSO) for offline signal processing and demodulation.

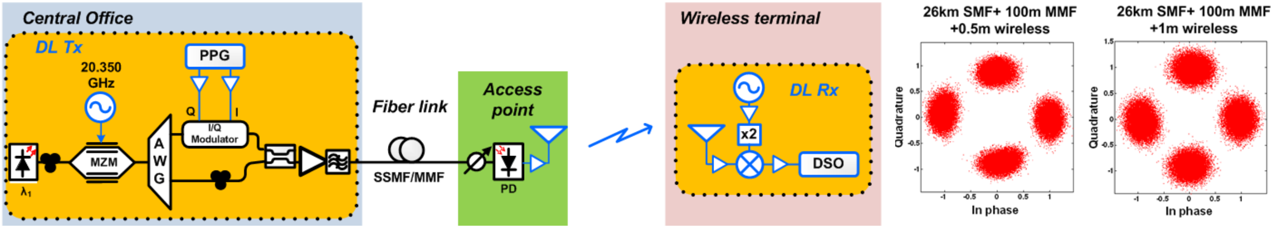

Figure 1. Experimental setup for a W-band fiber-wireless link.

The mixed SMF/MMF link was composed by 26 km of SMF and 100 m of MMF, simulating an indoor distribution scenario. Figure 1 also shows the constellation of the signal at the wireless terminal. Certain distortion can be observed for the 0.5 m wireless constellation, which is attributed to certain degree of saturation of the W-band LNA at the wireless receiver. Eye diagrams before and after fiber transmission at -14 dBm received optical power for both wireless distances are shown in Fig. 2. Despite the distortion in the eye shapes after fiber transmission, the eye openings are still clear to recover the transmitted data at the receiver. Figure 2 also shows the measured BER as a function of received optical power at the PD, for transmission cases of different combination of fiber types and lengths. The receiver sensitivity at the FEC limit is -5 dBm and - 2.5 dBm for 0.5 m and 1 m wireless transmission without fiber links, respectively. Optical transmission over the 26 km SMF and 100m MMF induce ~0.5 dB receiver sensitivity penalty for both wireless cases. Further extension of wireless transmission distance is limited by the radiated signal power at the transmitter. Therefore, it can be expected to further increase the wireless distance by using active access point with mm-wave signal power amplifiers.

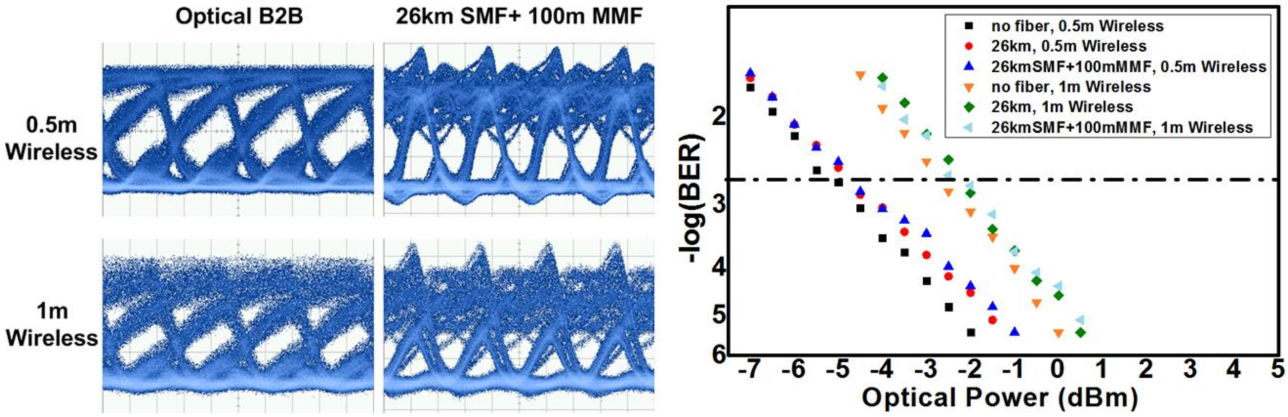

Figure 2. Eye diagrams of the transmitted signal and bit error rate performance curves of the fiber-wireless link.

[Hybrid Fiber-Wireless-Fiber]

Figure 3 presents the experimental setup of the proposed wireless hybrid fiber-wireless-fiber link. As it can be noticed, the setup up to the access point is exactly the same as in the previous fiber-wireless link setup. The main difference is a second span of fiber link. At the receiver side of the wireless terminal, the received signal is first amplified by a 40 dB gain low noise amplifier (LNA) and then electrically down-converted to an intermediate frequency (IF) centered at 6.4 GHz using a W-band balanced mixer. The IF signal is then re-modulated onto lightwave at a second MZM and transmitted through a fiber span of 10 km SSMF. At the receiver, the IF-over-fiber signal is converted back to electrical domain at a second PD and sampled for offline signal processing and demodulation.

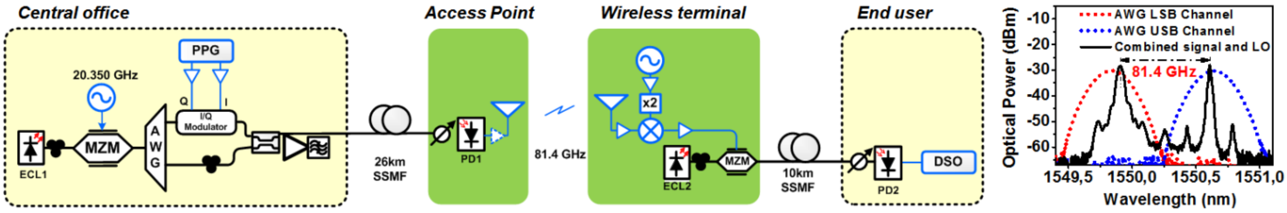

Figure 3. Experimental setup for a W-band fiber-wireless-fiber link.

Figure 4 shows the BER performance of this system with wireless distance of 2 m, 5 m, 10 m and 15 m. The wireless transmission reaches 15 meters in this setup with received bit error rate performance within the 7% FEC limit. The BER performance for higher transmission distances is mainly hindered by the frequency selective fading induced by multipath effect in the indoor experimental environment rather than wireless power. MIMO algorithms could be employed to mitigate this impairment at the receiver side in case of indoor systems; in open spaces we expect this effect to be negligible.

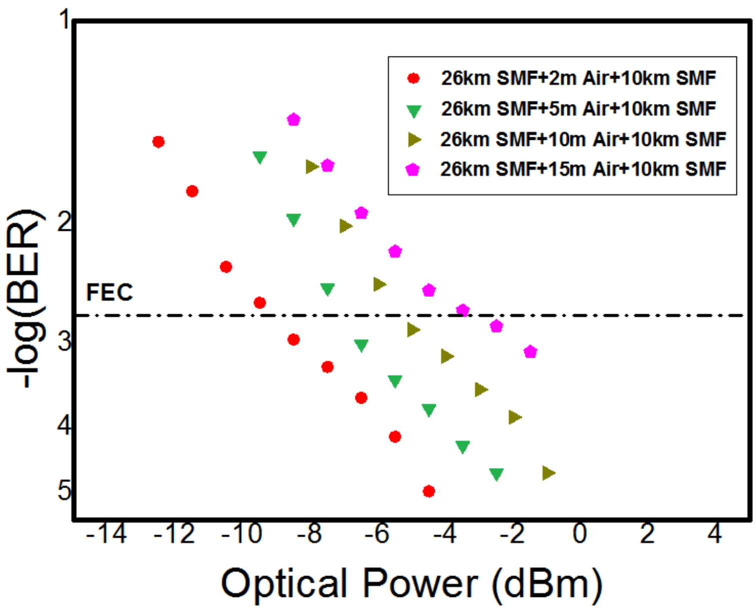

Figure 4. Bit error rate performance curves of the fiber-wireless-fiber link.

[Conclusions]

We have shown two experimental demonstrations of hybrid fiber-wireless-fiber links operating in the W-band with a multigigabit channel capacity. The signals can be effectively transported over 36km of fiber, and wireless transmission is currently limited by radiated power. The proposed systems have simple structured access points, high transparency and scalability to system data rates.

[Acknowledgements]

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