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1Gbps Impulse Radio Ultrawideband Multi-hop System Employing a Single Mode Fiber Repeater

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Abstract: we experimentally demonstrate a 1 Gbps impulse radio ultrawideband multi-hop system for wireless-over-fiber applications. The system consists of two 2 m air links and a 23 km single mode fiber based optical repeater.

1. Introduction

Ultrawideband (UWB)-over-fiber has recently become an attractive broadband wireless technology, since it provides the well-known advantage of UWB wireless range extension. Typically, impulse radio (IR) UWB is regulated by the Federal Communications Commission (FCC) specifications and exhibits extremely low radiation power, high bit rate capacity and very low signal-to-noise ratio (SNR). Several experiments on UWB-over-fiber transmission systems have been demonstrated [1-3]. Furthermore, with the aim to build hybrid optical-wireless systems, many efforts have been contributed to increase both wireless distance and access bit rate. For example, 500 Mbps×65 cm [4] and 1.025 Gbps×20 cm [5] have been demonstrated. Very recent, a system based on 100 Mbps@60 GHz IR-UWB over 4 m wireless×100 m polymer fiber×4 m wireless multi-hop link has been proposed and experimentally demonstrated as well [6]. It is noted that an optical repeater is very elegant and facilitates possible point-to-point, or point-to-multipoint UWB communications between remote UWB end-users in the building networks. In this paper, we demonstrate a wireless-optical-wireless multi-hop UWB transmission system with enhanced UWB bit-rate of 1 Gbps, two 2 m air links, a 23 km single mode fiber (SSMF) based repeater and a digital signal processing (DSP) based receiver.

2. Experimental Setup

The experimental system is shown in Fig.1. An arbitrary waveform generator (Tektronix AWG7122B) is used to generate on-off keying modulated pulses with fifth-derivative Gaussian profile. The pattern length of the used pseudo random bit sequence (PRBS) is $2^{11}-1$. A high pass filter (HPF) is employed to remove low frequency component below 3.1 GHz and suppress noise level. Subsequently, the output signal from HPF is used to drive the first transmitter antenna. After wireless propagation, the signal is received by the first receiver antenna and amplified by a low noise broadband amplifier. Thereafter, the signal is imposed into a lightwave carrier by using a directly modulated laser (DML), transmitted over 23 km standard single mode fiber (SSMF), and detected by a high-speed photodiode (PD). In order to fit the FCC mask at the second transmitter antenna, we use another HPF and a broadband amplifier to reshape and amplify the signal, respectively. After the second wireless link receiver antenna, the signal is sampled at the 40 GS/s (Agilent Infinium DSO80000B with 13 GHz analogue bandwidth) and then digitally processed offline by using DSP. Furthermore, an electrical spectrum analyzer (ESA) is employed to measure the signals in the frequency domain. From Fig.1, we can notice that the optical fiber link in the system acts as a UWB repeater, which delivers the wireless signals coming from one wireless user in one coverage area to another wireless coverage area.

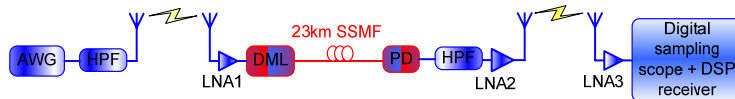


Fig.1 The schematic configuration for IR-UWB multi-hop system. AWG: arbitrary waveform generator, HPF: high pass filter, LNA: low noise amplifier, DML: directly modulated laser, SSMF: standard single mode fiber, DSP: digital signal processing.

3. Experimental Results and Discussions

In the experiment, 1 Gbps UWB pulses are generated and both wireless links are 2 m. The HPF has pass band from 3.4 GHz to 9.9 GHz with less than 2 dB loss. The DML has +3.5 dBm output optical power. The generated fifth derivative Gaussian pulse from the AWG is shown in Fig.2 (a) measured at a 40 GS/s sample rate. The measured pulses after the first 2 m wireless propagation, 2 m wireless plus 23 km SSMF link, and the complete multi-hop link (including a second 2 m wireless link) are shown in Fig.2 (a), (b) and (c), respectively. By comparing Fig.2(b) and (c), we can observe that the pulse shape does not change a lot. Fig.2 (e) displays the measured equivalent isotropically radiated power (EIRP) before the second transmitter antenna. At the meantime, we show FCC mask and modified effective mask by taking into account the frequency response of the antenna. We can notice that the UWB signals after the first 2 m air link plus 23 km SSMF transmission still meet the FCC specifications.

For the reception of UWB signals, a DSP receiver based on correlation, synchronization and adaptive threshold is used. Moreover, a bit-for-bit comparison between DSP recovered pattern and the original pattern is employed to calculate the bit-error-rate (BER). Fig.3 displays the eye diagrams for back-to-back (B2B, without 23 km optical fiber), and complete multi-hop transmission link (with 23 km optical fiber link). In this system, the dispersion

induced pulse broadening is only a few picoseconds, which can be ignored for digital signal processing in the pulse period at 1Gbps bit rate. However, due to laser phase noise to intensity noise conversion caused by optical fiber chromatic dispersion [7], the eye diagram in the B2B case shown in Fig.3(a) is more open than in the fiber transmission case in Fig.3(b). After the DSP based BER determination, no error bit is detected for the B2B link, and the BER is 2.5×10^{-4} for the complete transmission link. In both cases, a total of 1×10^5 UWB bits are taken into account.

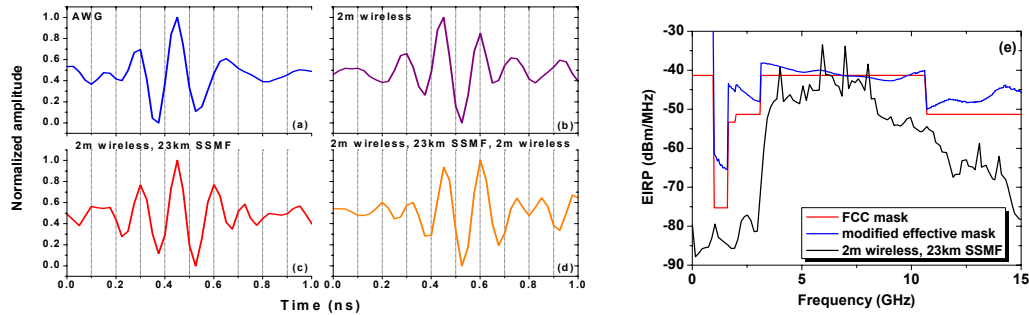


Fig.2 (a) the generated fifth derivative Gaussian UWB pulse from AWG, (b) pulse after the first 2m air link propagation, (c) pulse after the first 2m wireless and 23km SSMF transmission, (d) pulse after the first 2m wireless, 23km SSMF and the second 2m wireless link transmission, (e) the measured frequency spectra before the second transmitter antenna, as well as FCC mask and modified effective mask taking in account transfer function of the transmitter antenna.

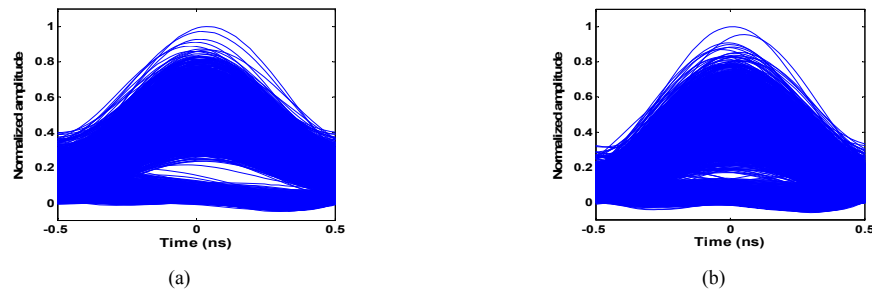


Fig.3 (a) eye diagram in B2B case, (b) eye diagram after complete wireless-optical-wireless multi-hop transmission system.

4. Conclusions

We propose and demonstrate a wireless-optical-wireless multi-hop UWB transmission system and a 1 Gbps UWB experiment system which consists of two 2 m air links and 23 km SSMF. At the receiver side, a DSP based receiver is employed to calculate the BER. The experiment results show no error bit detected for B2B case and 2.5×10^{-4} BER for the complete multi-hop transmission link. In this system, the optical link acts as a wireless repeater, and thus this system is a promising solution to extend UWB access range and has potential application in future wireless access networks.

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