Beyond 2.5Gb/s Photonic Generation and Wireless Transmission of Different Pulse Modulation Formats for a High Speed Impulse Radio UWB over Fiber System

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Abstract: We experimentally demonstrate beyond 2.5Gbps photonic generation of different pulse modulation formats for impulse radio ultra-wideband (IR-UWB) over fiber application. IR-UWB transmission over 20km fiber and 0.25m wireless link without any compensation is also presented.
OCIS codes: (060.2330) Fiber optics communications; (060.5625) Radio frequency photonics

1. Introduction

Ultra-wideband (UWB) impulse radio technology, sharing the existing radio spectrum resource, has received considerable attention recently for future short-range, high-speed wireless communication systems and sensor networks [1]. Due to the low power density (<-41.3dBm/MHz from 3.1 to 10.6GHz) regulated by the Federal Communications Commission (FCC), the UWB radio signal can only propagate several meters or tens of meters. As a result, techniques for photonic UWB signal generation and transmission over optical fiber have been proposed to extend UWB reach [2,3]. For a practical UWB over fiber system, different pulse generation and modulation schemes are desirable to encode the information. Till now, many modulation schemes have been demonstrated in the optical domain [4-6], such as on-off keying (OOK), pulse bipolar modulation (PBM), pulse position modulation (PPM), pulse amplitude modulation (PAM), and pulse shape modulation (PSM). We also proposed several flexible photonic UWB pulse generation schemes, which can be reconfigured to generate UWB signals with different modulation formats [7,8], but the transmission performance over the combined fiber and wireless link of the schemes has been seldom reported.

In this paper, we experimentally demonstrate a reconfigurable impulse radio UWB (IR-UWB) over fiber system, which implements 3.3Gbps monocycle pulses and 2.5Gbps doublet pulses both with OOK and PBM modulation formats, and 2.5Gbps PSM in the optical domain based on the symmetric phase modulation to intensity modulation (PM-IM) conversion architecture. Successful transmission of IR-UWB signals over 20km single-mode fiber (SMF) and 0.25m wireless link is also presented. Transmission performance is evaluated and compared based on electrical spectra analysis and bit error rate (BER) measurement, which is performed using digital signal processing (DSP) in a bit-for-bit comparison between the transmitted and received signals. The proposed high-speed pulse modulation scheme provides a promising solution for UWB-over-fiber technologies.

2. Experimental Setup

Fig.1 shows the proposed experimental setup. Laser1 and Laser2, with the same output power, are tuned at 1543.85nm and 1544.05nm respectively, and the optical bandpass filter (OBPF) as a frequency discriminator has a central wavelength of 1543.95nm and a 3dB bandwidth of 0.25nm. Two sequences of Gaussian pulse patterns with predefined modulation process, which are generated by two channels of Tektronix Arbitrary Waveform Generator (AWG) running at 10GSamples/s, are applied to the phase modulator (PM) to modulate the light wave. By optimally predefining the encoding of the AWG's two channels, monocycle and doublet pulse trains both with OOK, PBM or

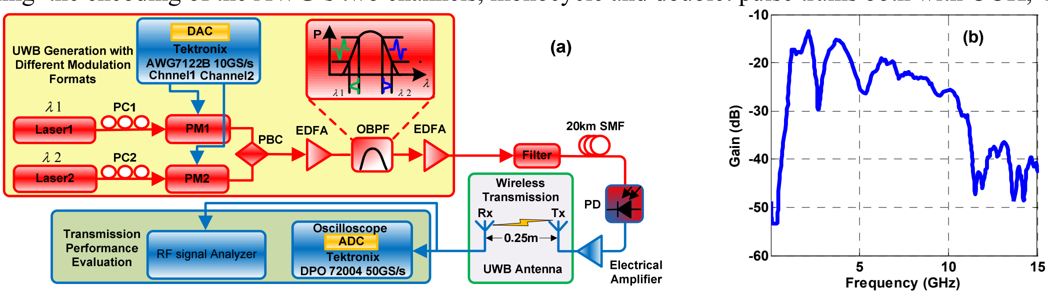

Fig. 1. (a) Experimental setup of the UWB over fiber system reconfigurable for different modulation formats (b) Frequency response of the lab-made UWB antennas pair with a distance of 0.25m

PSM modulation formats can be generated after the OBPF due to the PM-IM conversion [8], the principle of which is described Fig. 1(a). In our proposed system, the modulated UWB data pattern with a 2^{11}-1 pseudo-random bit sequence (PRBS) is constructed in such a way that two 3 bits-length sequences with a bit rate of 10Gb/s are used to generate a single monocycle pulse, and two 4 bits-length sequences to get a single doublet pulse, which are equivalent to the bit rates of 3.3Gb/s and 2.5Gb/s respectively.

To evaluate the transmission performance, the modulated UWB signal is transmitted over 20 km SMF link and detected by a photodiode (PD). The obtained electrical signal is amplified by a broadband electrical amplifier, and emitted to free space through a lab-made UWB antenna. After 0.25m wireless transmission, the radiated UWB signal is received by another UWB antenna. The frequency response of the antennas pair is shown in Fig. 1(b) and the 10-dB bandwidth of the antennas pair is about 9GHz (1-10GHz). Due to the radiation of the Global System for Mobile Communication (GSM), such as GSM 900 and GSM 1800 in China, our lab-made UWB antenna can receive feeble signals, with frequency lower than 2GHz, which would add some low frequency components to the UWB signals and deteriorate the performance of the UWB transmission system. A Tektronix Digital Phosphor Oscilloscope (DPO) running at a sampling rate of 50GSamples/s is used to observe the time-domain waveforms and collect data for demodulation and BER measurement, and the spectra are measured by the RF spectrum analyzer and compared to the FCC indoor requirements.

3. Experimental Results and Discussion

To verify the implementation of the different modulation formats, part of the wireless transmitted data is taken before and after 20km SMF transmission without dispersion compensation fiber (DCF). The temporal waveforms of the UWB signals with OOK, PBM and PSM corresponding to a binary sequence of 8 bits "10100001" is clearly shown in Fig. 2, Fig. 3, Fig. 4, Fig. 5 and Fig. 6. By carefully predefining the encoding of the AWG excellent OOK, PBM and PSM of the UWB signals are experimentally realized.

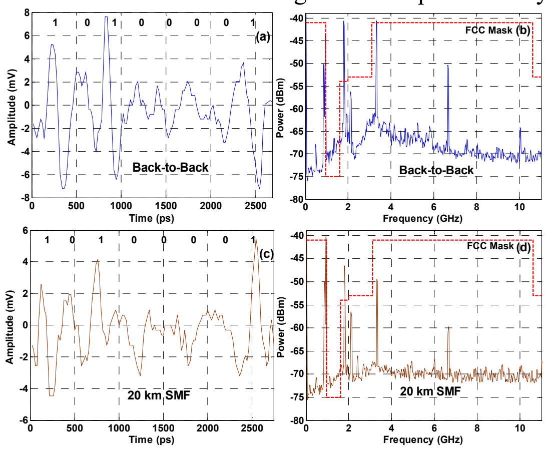

Fig. 2. Temporal waveforms and electrical spectra of monocycle OOK scheme, before and after transmission over 20km SMF

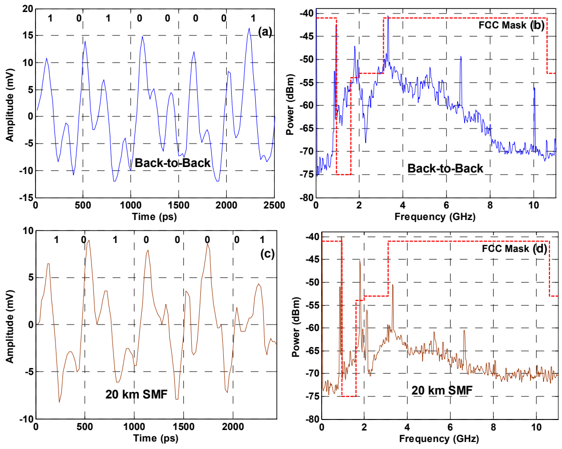

Fig. 3. Temporal waveforms and electrical spectra of monocycle PBM scheme, before and after transmission over 20km SMF

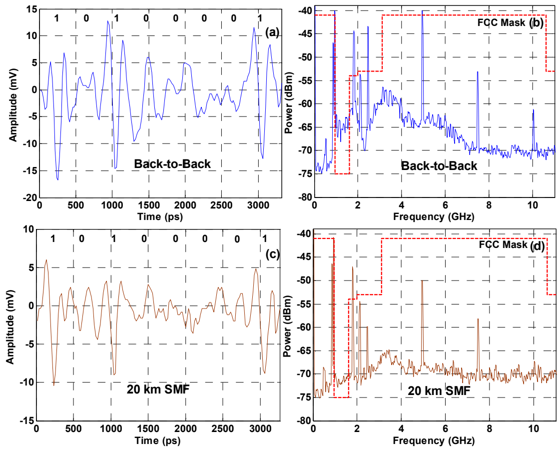

Fig. 4. Temporal waveforms and electrical spectra of doublet OOK scheme, before and after transmission over 20km SMF

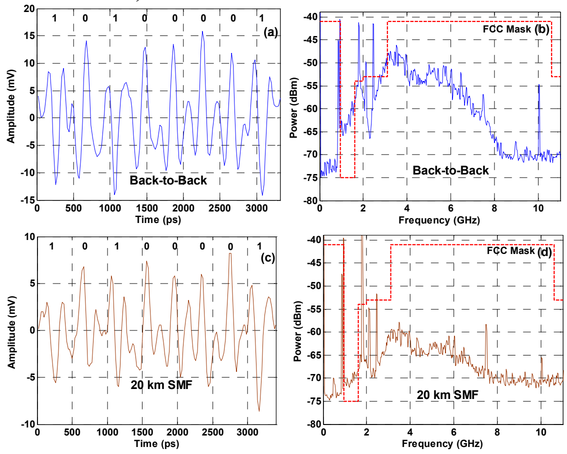

Fig. 5. Temporal waveforms and electrical spectra of doublet PBM scheme, before and after transmission over 20km SMF

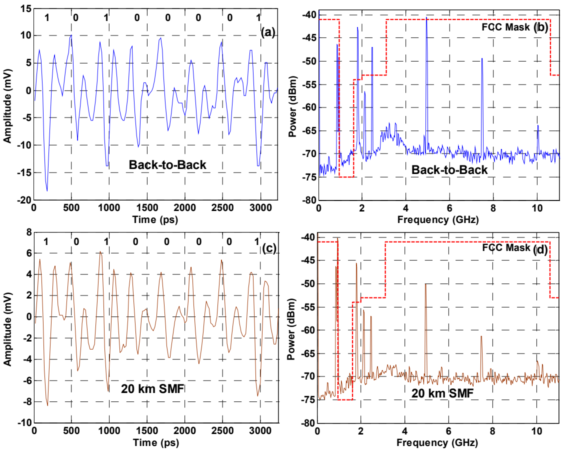

Fig. 6. Temporal waveforms and electrical spectra of PSM scheme, before and after transmission over 20km SMF

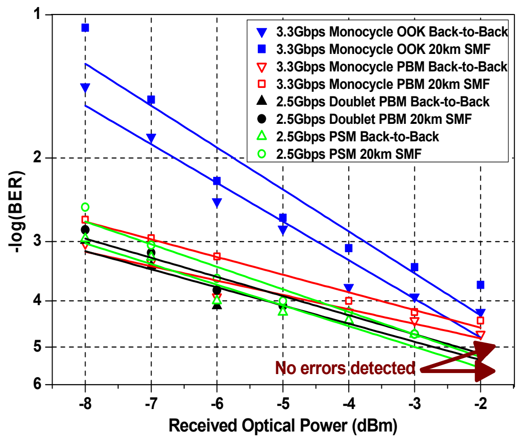

Fig. 7. BER measurements of UWB over fiber system with OOK, PBM, and PSM before and after 20km SMF transmission

The temporal waveforms and corresponding electrical spectra of the IR-UWB pulses with different modulation schemes after both wireless and fiber transmission are shown in Fig. 2(c) and (d), Fig. 3(c) and (d), Fig. 4(c) and (d), Fig. 5(c) and (d), Fig. 6(c) and (d). The electrical spectra of the signals are manually attenuated to comply with the FCC mask between 3.1-10.6GHz. The results clearly confirm that the fiber transmission only causes reduction in amplitude and negligible alteration to the pulse shape comparing with the modulated data after wireless transmission.

The BER performance vs. received optical power of the UWB over fiber system with different modulation formats is evaluated and the result is plotted in Fig. 7. For each BER measurement point, 50000 UWB bits following a 2^{11}-1 PRBS pattern are transmitted and recorded. The BER is computed offline using a DSP algorithm, which distinguishes between binary "1" and "0" by performing the correlation and a bit-for-bit comparison between the transmitted and received data [8]. The optimum decision threshold and clock recovery timing are appropriately chosen to minimize the BER. The bit is assigned for a logical "1" if the peak of correlation output is greater than the decision threshold, otherwise for a logical "0". The BER measurement demonstrates that the UWB signal with PBM format has much better performance in our proposed system and the monocycle UWB signal with OOK scheme has the poorest BER performance due to its higher transmission speed (3.3Gbps) and lower modulation efficiency. For all the three modulation schemes, the 20km fiber transmission introduces penalties less than 1.2dB due to the impact of fiber chromatic dispersion and noise induced by EDFA. Especially, for the 2.5Gbps doublet PBM-based and PSM-based UWB of fiber systems, no errors are detected when the received optical power levels above -3dBm.

4. Conclusions

We have experimentally demonstrated a high speed IR-UWB over fiber system for the photonic generation and successful transmission of 3.3Gbps monocycle pulses and 2.5Gbps doublet pulses both with OOK and BPM schemes and 2.5Gbps PSM schemes over 20km SMF and wireless transmission without any compensation. For all the modulation schemes, the power penalties are less than 1.2dB. Demodulation and BER measurement of the UWB signals with different modulation schemes are also performed offline using a DSP based algorithm.

5. Acknowledgement

This work was partially supported by the NSFC under Contract 60736002, 60807026, 60932004, the International S&T Cooperation Program of China under Contract 2008DFA11670 and National 973 Program of China under Contract 2006CB302806.

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