Optical Generation, Fiber Distribution and air transmission for Ultra Wide Band over Fiber System

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Abstract: A system for all-optical generation and distribution of Impulse Radio UWB signals has been implemented and demonstrated experimentally. Bit error rate measurements at 1.625Gbps and "over the air" performance is presented.

OCIS codes: (060.2330) Fiber optics communications; (060.5625) Radio frequency photonics

1. Introduction

Ultra Wide Band (UWB) technology uses a wide band spectrum to provide high bandwidth wireless connectivity over a short range distance. UWB has received significant interest and attention after the Federal Communications Commission (FCC) of the United States approval on February 2002 [1]. The regulation of FCC has allocated the unlicensed band between 3.1 – 10.6GHz for the UWB signal at transmit power of less than -41.3dBm/MHz. Impulse Radio UWB (IR-UWB) is the one of the proposed techniques used for transmitting UWB signal which is based on sending very short duration pulses [2]. UWB, short radio technology, allows a transmission of high data rate with low power consumptions for less than 10m distance.

With the use of radio over fiber (RoF) technology, UWB can be transmitted to the end users in home residents or business offices with the range extended to a few km using optical fiber. Thus, this system allows the distribution of wireless high video stream contents from DVDs and personal video recorder to High Definition Television (HDTV) displays. In this paper, we used the proposed system for the photonic generation of UWB signal presented in [3] where we demonstrate how the UWB can be generated optically by using a gain-switched laser. In this work we have performed the full generation, fiber distribution and air transmission of IR-UWB signals at a bit rate of 1.625Gbit/s. In addition, the BER is evaluated for various fiber lengths versus the received RF signal.

2. UWB Generation and Distribution over the fiber

In our system, the generation and modulation of the data occurs at the Optical Distribution Centre (ODC) before being transmitted over the single mode fiber (SMF) to the Remote Antenna Unit (RAU). Fig.1 shows the block diagram for the full distribution system for generation and receiving of the UWB signal. In the ODC, the optical Gaussian pulses are generated by using a gain switched distributed feedback laser (DFB-LD) which is biased below threshold and driven by a signal generator at 1.625GHz. These pulses are divided into two paths by using 3dB coupler and fed into two Mach Zehnder Modulators (MZMs).

The data sequence at a rate 1.625Gbps (synchronized with the signal generator with 10MHz clock reference) drives the upper MZM to transmit bit "1" and the inverted data sequence drives the lower MZM with the bit "0". The output pulses are combined again using a 3dB coupler after delaying bit "0" for a specific delay by using an optical delay line (ODL). The generated waveform represents a pulse position modulation (PPM) signal, which is then transmitted over fiber to the RAU. The RAU converts the optical PPM pulses into electrical pulses by using a PIN photodiode (PIN-PD) with a 10GHz bandwidth.

These electrical pulses are amplified and filtered by using an electrical bandpass filter (BPF) from 3GHz to 10GHz, which acts as a differentiator and converts these Gaussian pulses into doublet Gaussian pulses which have a wide 3dB bandwidth, and have better performance in terms of BER and multipath immunity than other signals [4]. These pulses are transmitted over the air by using UWB shaped monopole antennas with 0dBi gain [5]. The RT receives the UWB signal which is amplified and is then mixed with the forth harmonic at 6.5GHz from the local oscillator (LO) to down-convert the UWB signal into a baseband signal.

The output from the mixer is subsequently amplified and passed through a low pass filter (LPF) to remove the unwanted frequency components. The eye diagram is measured at the output of the RT by using

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high speed sampling oscilloscope. Moreover, the BER versus the received RF power at the front of the RT is measured using a BER tester (BERT).

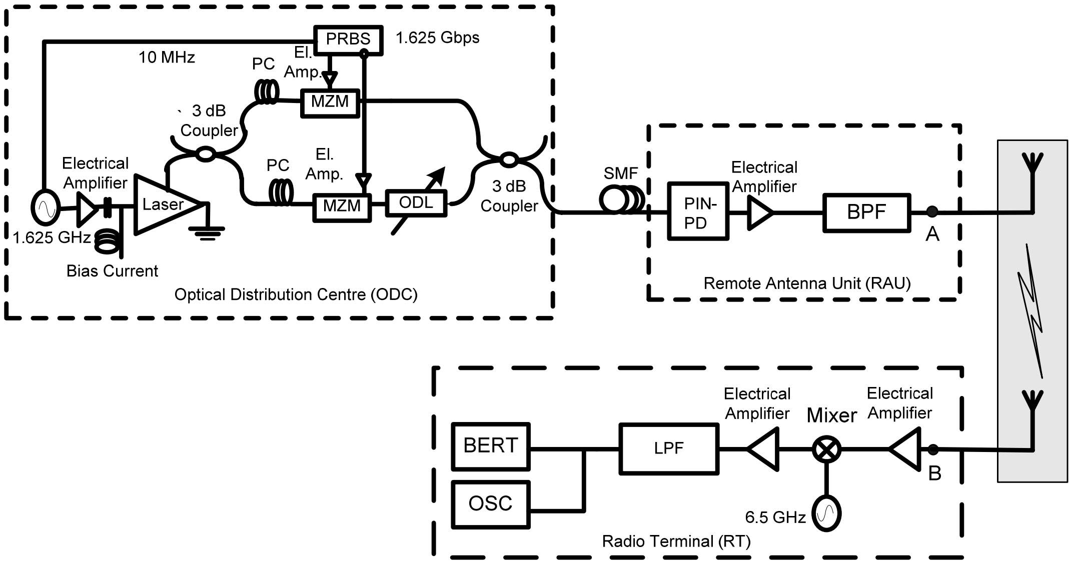

Fig. 1. Full generation and distribution system for UWB

3. Experimental Results and Discussion

The schematic system in Fig.1 has been implemented experimentally. The DFB-LD is a commercial 1550 nm device that generates output pulses with duration of approximately 50 ps. These pulses are modulated with a non-return to zero (NRZ) data stream from a pulse pattern generator at 1.625Gbps. The pulses in the lower path are delayed by a 41 % of the bit slot before being combined with the modulated pulse train from the upper path. The resulting optical PPM signal is then transmitted over different fiber lengths of SMF-28.

The RF spectrum output was measured at the RAU before transmission and is shown in Fig.2. We can clearly see that the illustrated spectrum matches the assigned FCC bandwidth and mask for indoor communications. The BER for various fiber lengths with the received RF power is demonstrated in Fig.3. In this case the RAU was directly connected to the RT using an RF cable and total RF power from the RAU was calculated by integrating from 3.1 GHz to 10.6 GHz. The received RF power was then attenuated by using variable attenuators and maintaining constant power into the mixer in the RT. Fig.3 represents the degradation of the BER when the received RF power decreases.

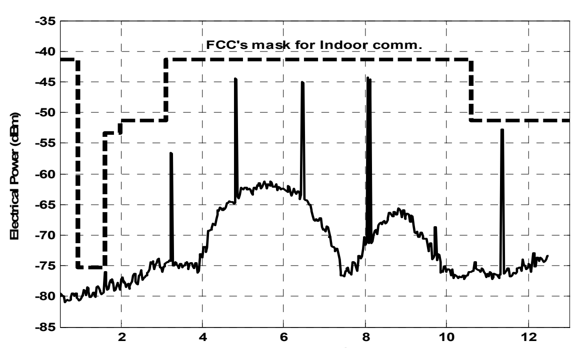

Fig. 2. The RF spectrum of the UWB signal

There is a small difference in performance between the various length of fiber and this is due to increased noise on the received optical pulses as a result of mode partition noise from the GS-DFB laser. This is due to a degradation of DFB side mode suppression ratio (SMSR) caused by the gain switching process [6]. Fig.4 shows the received eye diagram when the RF power to the RT is -36dBm and there is a direct cable connection between RAU and RT. Fig. 5 presents the received eye after transmission through the air which introduces 32 dB losses due to the radio propagation. In this case the UWB signal is amplified by 22 dB to overcome these losses and gives a total received signal power at the RT of -46dBm. This corresponds to the eye-diagram shown in Fig. 5 which has a BER of 10^{-5}. Due to the high data rate transmitted the radiated power is very low which makes it difficult to achieve error free (10^{-9}) transmission.

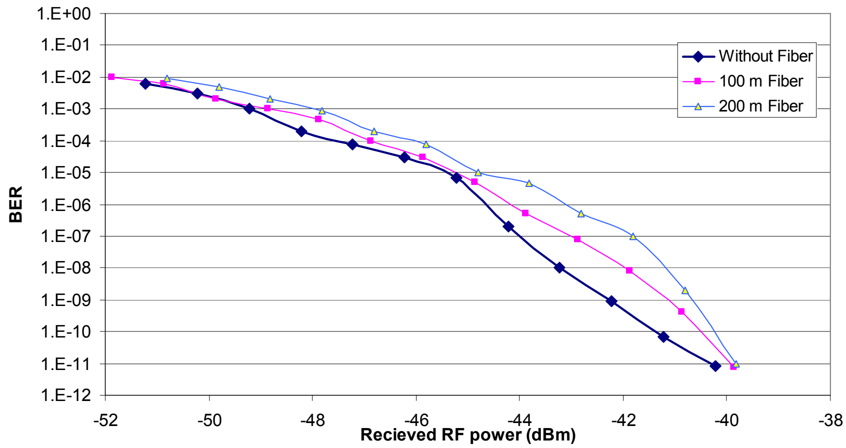

Fig. 3. The BER versus received RF power for different fiber lengths

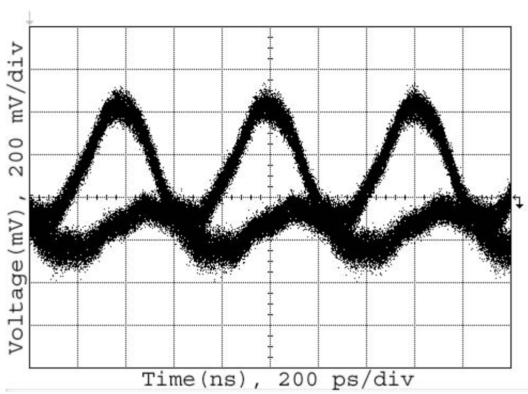

Fig. 4. Eye diagram for back to back when the received power to RT is -36dBm

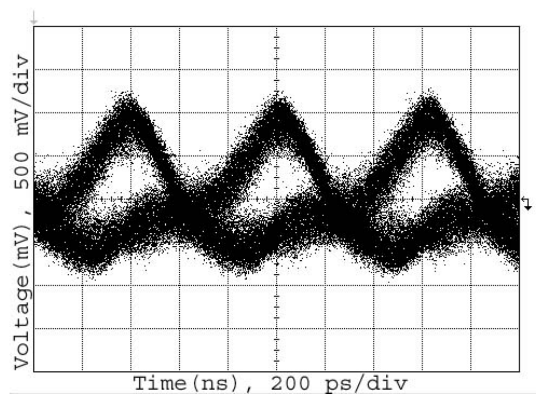

Fig. 5. Eye diagram using UWB antenna when the received power to RT is -46dBm

4. Conclusions

The all-optical generation and distribution of 1.625 Gbps UWB signals has been implemented experimentally. The system which can easily be integrated provides a feasible and cost effective solution to cover a small/medium sized building for high data video streams, or data. The presented results show good performance and the radio transmission experiment shows the highest bit rate transmission reported to date for such a system.

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5. References

[1] "Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems," First Note and Order, Federal Communications Commission, ETDocket 98- 153 (2002).

[2] M. Z. Win and R.A. Scholtz, "Ultra-wide bandwidth time-hopping spread spectrum impulse radio for wireless-access communications," IEEE Trans. Comm. **48,** 679-689 (2000).

[3] A. Kaszubowska-Anandarajah, P. Perry, L.P. Barry and H. Shams, "An IR-UWB Photonic Distribution System," Accepted for publication in IEEE Photon. Technol. Lettrs.

[4] X. Chen and S. Kiaei, "Monocycle shapes for ultra wideband system," in Proceedings of IEEE International Symposium on Circuits and Systems (IEEE, 2002), pp. 1597-1600.

[5] M. John and M.J. Ammann, "Spline-based geometry for printed monopole antennas," Electron. Lett. **43,** 317-319 (2007).

[6] P. Anandarajah, M. Rensing, and L. P. Barry, " Signal degradation due to output filtering of self-seeded gain-switched pulses exhibiting weak inherent side-mode-suppression ratios," Appl. Opt. **44,** 7867-7871 (2005).