UWB system based on Gain-Switched Laser

A. Kaszubowska-Anandarajah and L.P. Barry

Radio and Optical Communications Lab., School of Electronic Engineering, Dublin City University, Dublin 9, Ireland

***Abstract* – Simulation results based on an Ultra WideBand (UWB) system employing a gain-switched laser are presented. 156 Mb/s data stream modulates the position of short electrical pulses, which are then used to gain-switch the laser. The output optical pulses are then transmitted over fiber to a Remote Antenna Unit (RAU), where the signal is detected and undergoes spectral shaping (according to UWB requirements). The resulting Pulse Position Modulated (PPM) electrical impulses are then converted to an amplitude-modulated signal and down-converted. Bit Error Rate measurements are carried out on a back-to-back system and a transmission link (over different lengths of fiber).**

***Index Terms* – Gain-switching, fiber dispersion, laser diode, optical fiber, pulse position modulation, UWB, wireless systems**

I. Introduction

Ultra Wide-Band (UWB) systems have attracted a lot of attention in recent years. Their ability to deliver high bit rate data (exceeding 100 Mb/s), good wall penetration, low power consumption, multipath and interference immunity makes them a very promising solution to many communications problems. The signals used for data transmission in such systems have spectral properties similar to noise, hence they could be transmitted using spectral bands already assigned to different systems without causing interference. They could also be transmitted using the unutilised spectral bands (based on the regulatory bodies allowing it [1, 2]). UWB can provide high-capacity connections over a short range, such as broadband links to a home computer or other Web appliance. The latest Federal Communications Commission's (FCC) Report and Order defines UWB as any signal that occupies more than 500 MHz in the 3.1 – 10.6 GHz band [3]. An UWB signal can therefore be a series of very short (10 to 1000 ps), low-power pulses. Due to the short duration of the pulses, the frequency spectrum of an UWB signal can be many gigahertz-wide, overlaying the bands used by existing narrowband systems.

One of the main drawbacks of UWB systems is their limited range, typically not exceeding 30 feet. This could be overcome by employment of optical fiber, which could extend the reach of UWB system to anything from metres to km depending on distance between optical transmitter and RAU. It could also be used for in-building distribution. In such a case it would be natural to generate the UWB signals optically at the central location before distributing them between the Remote Antenna Units (RAUs) [4 - 6]. Such a combination of radio and fiber transmission has been widely studied for employment in other wireless systems (such as 4G) and is often referred to as Radio over Fiber (RoF) technology. This paper presents simulation (using a commercial software package Virtual Photonic Incorporation Transmission Maker) results of an optical UWB generation using the technique of Gain-Switching (GS) a laser diode. The latter is a simple and reliable method used for the generation of short optical pulses [7]. It also allows the generation of pulses at any bit rate (limited only by the modulation bandwidth of the laser). The impact of fiber transmission on the detected electrical UWB signals is also studied.

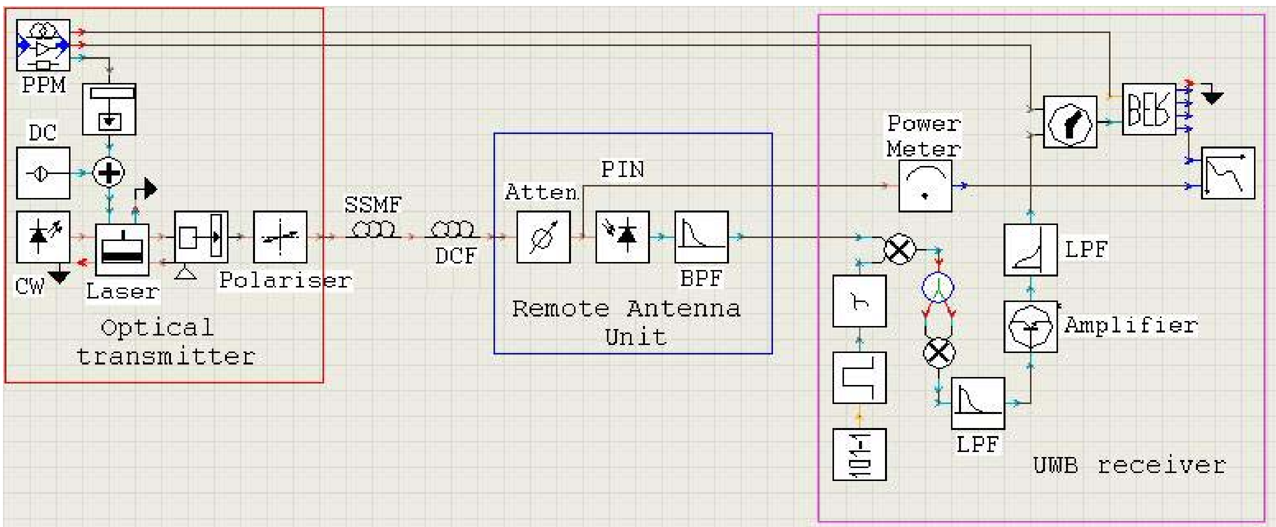

Fig. 1 Simulation model

II. Simulation Model

Fig. 1 presents the simulation model of a UWB system based on the gain-switched laser. Data to be transmitted is encoded using Pulse Position Modulation (PPM). PPM is realised by initially splitting the data signal in two. One branch is mixed with an electrical pulse stream, which results in a RZ modulated signal. The second branch of data is inverted and also mixed with electrical pulses. As a result at the output of each mixer there are electrical pulses representing ones (mixer 1) and zeros (mixer 2). The pulses representing zeros are delayed by half a bit period and then both streams are combined together. The resulting PPM signal is then combined with a DC bias current and used to gain-switch a Fabry-Perot (FP) laser. External injection is used to achieve single moded operation of the GS laser as well as to reduce the jitter [8]. Optical PPM pulses (duration of 17 ps) are transmitted to a Remote Antenna Unit (RAU). At the RAU the optical signal is detected and spectral shaping takes place using an electrical Band Pass Filter (BPF) (center frequency 5.5 GHz, BP 6.75 GHz). The bit rate used in the simulation was 156 Mb/s, but it should be noted that this could be easily adjusted to systems requirements since the method of gain-switching is very flexible in terms of pulse repetition rate.

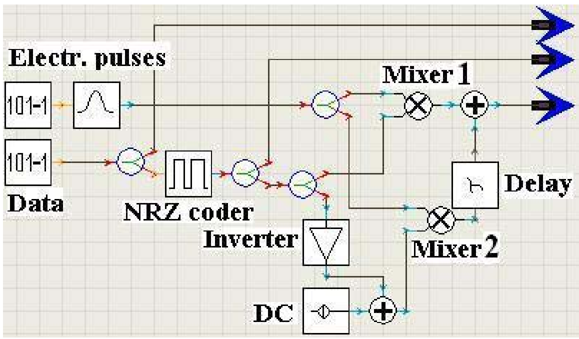

Fig. 2 Model of the Pulse Position Modulator

At the receiver the PPM data is converted to an On-Off signal by gating the UWB signal with a square wave exhibiting a 0.125 duty cycle. The amplitude-modulated signal is then downconverted by self-homodyning. Finally, the signal is converted into a Non Return-to-Zero (NRZ) format by filtering using a Low-Pass Filter (LPF).

The quality of the received signal is tested using the Bit Error Rate (BER) vs. received optical power measurements.

III. Simulation Results

A. Back-to-Back Simulations

The GS PPM optical pulses are shown in Fig. 3. It can be seen that the Full Width Half Maximum (FWHM) of the pulse is around 17 ps. The corresponding optical spectrum (with external injection) is shown in Fig. 4.

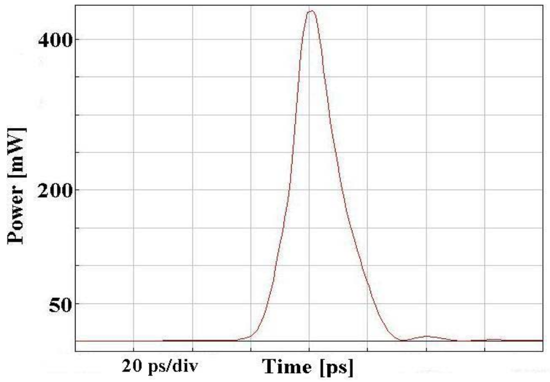

Fig. 3 Optical GS pulse

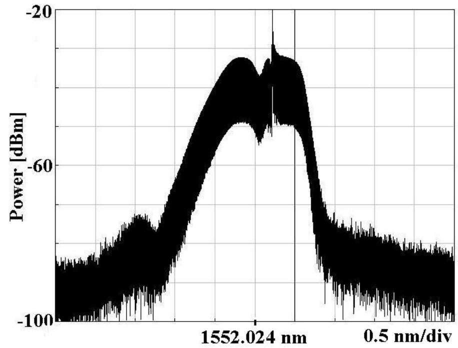

Fig. 4 Optical spectrum of GS pulses

The electrical spectrum of the detected optical data without any fiber transmission, before and after spectral shaping is shown in Fig. 5 and 6 respectively.

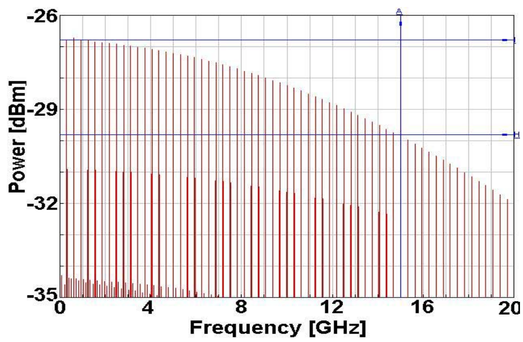

Fig. 5 RF spectrum of the detected GS pulses

The output of the photodiode consists of many spectral components ranging from 156 MHz up to 15 GHz due to the narrow widths of the optical pulses used. By using an electrical BPF the frequency components outside 2.8 – 9 GHz band were eliminated.

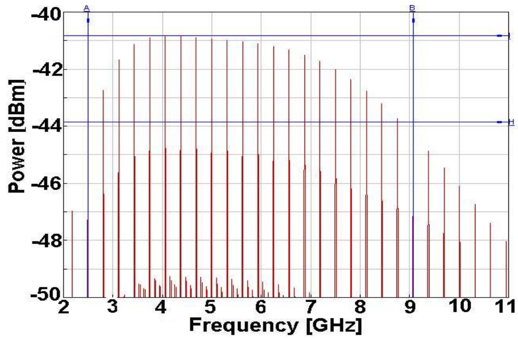

Fig. 6 RF spectrum of the UWB signal

The electrical filtering changed the shape of the data signal from a pulse to a monocycle as illustrated in Fig. 7.

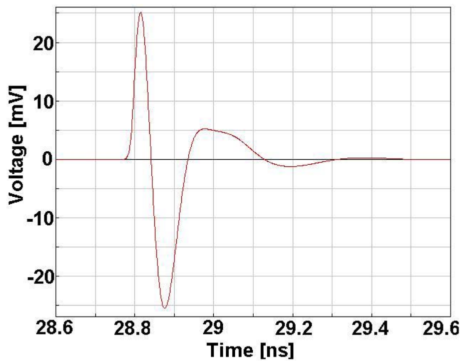

Fig. 7 UWB monocycle

The duration of the first cycle of the UWB impulse is 150 ps. The eye diagram and the RF spectrum of the received signal after downconversion and further filtration (using LPF) are shown in Fig. 8 and 9 respectively. The bandwidth of the LPF used was set to 60 MHz so as to enable the suppression (to achieve a NRZ data) of the fundamental frequency (156 MHz). Even subsequent to filtering a relatively strong frequency component is still noticeable in the spectrum (within the dotted circle in Fig. 9).

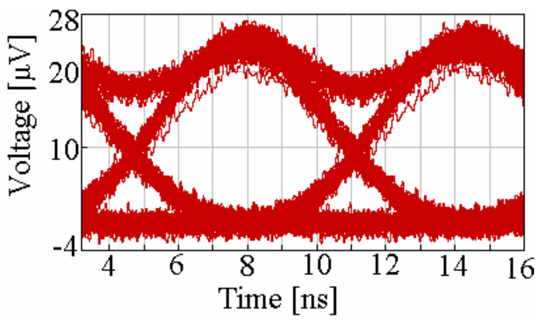

Fig. 8 Eye diagram of the received data (@ optical power –24 dBm)

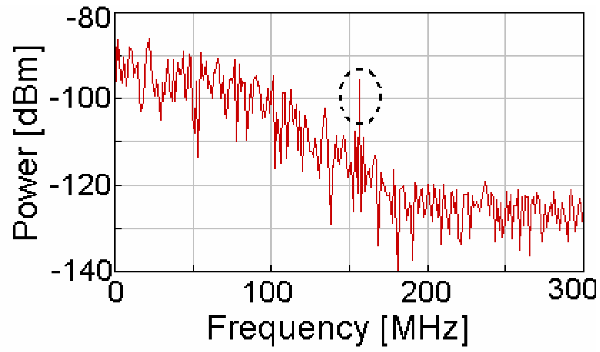

Fig. 9 RF spectrum of the received data signal

In order to verify the performance of the system the BER vs. received optical power was measured. The resulting plot is shown in Fig. 10. It can be seen from the plot that error free operation could be achieved at optical powers higher than –24 dBm.

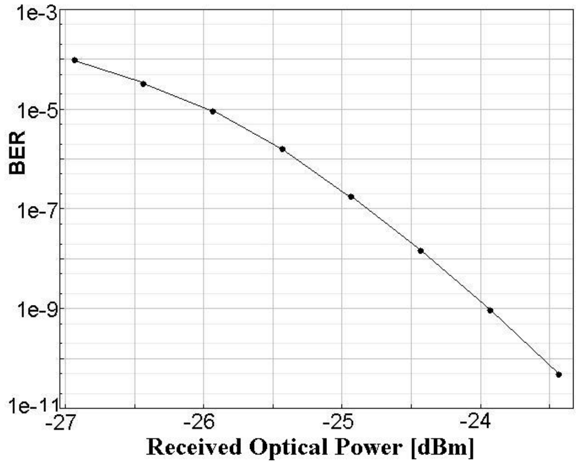

Fig. 10 BER vs. received optical power

B. Fiber Transmission Simulations

In order to verify the influence of fiber transmission on the optically generated UWB signal, different lengths of fibers were inserted between the transmitter and the RAU. The optical pulses have a large spectral width, which leads to broadening of these pulses as a result of chromatic dispersion faced in the fiber. This in turn reduces the electrical spectral width of the generated UWB signal. Fig. 11 presents the dependence of the 3-dB spectral width of the signal at the output of the BPF and the optical pulse width on the fiber length (fiber dispersion parameter 16 ps/nm.km).

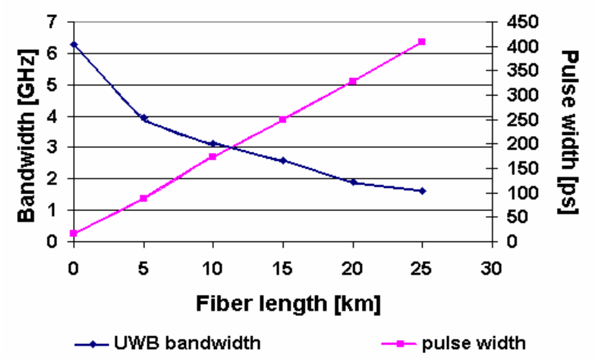

Fig. 11 Evolution of the 3-dB spectrum and pulse width due to fiber transmission

It can be seen that the spectral width of the signal drops below 4 GHz after propagating over only 5 km of fiber. Thus it is obvious that chromatic dispersion needs to be compensated, in order to fulfil the spectral requirements of the UWB standard. Four km of Dispersion Compensating Fiber (DCF) with a dispersion parameter of -100 ps/nm.km was inserted to counteract the pulse spreading caused by propagating over 25 km of Standard Single Mode Fiber (SSMF). The RF spectrum of the UWB signal without and with dispersion compensation is shown in Fig. 12 and 13 respectively. From the figures it can be seen that employing DCF has counteracted the degradation in the UWB spectrum due to fiber transmission.

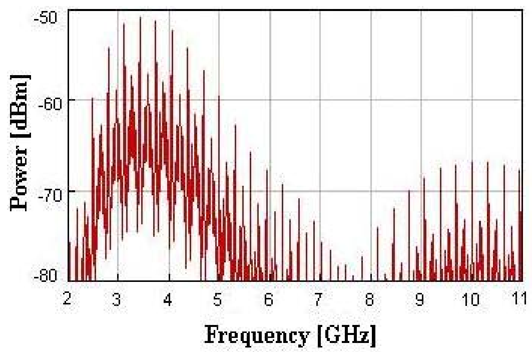

Fig. 12 RF spectrum of UWB after propagation over 25 km SSMF fiber

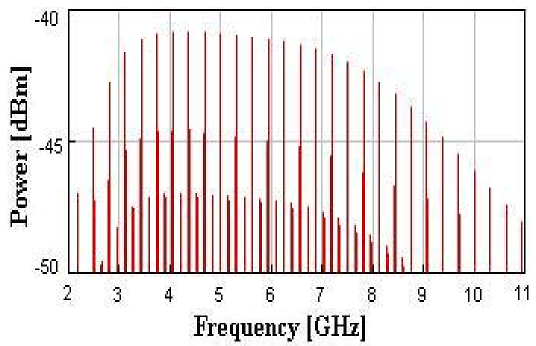

Fig. 13 RF spectrum of UWB signal after propagation over 25 km SSMF and 1 km DCF

IV. Conclusions

In conclusion, optical generation of an UWB signal using GS a laser has been demonstrated. This method portrays cost efficiency and reliability, which are assets gained from the technique of GS. Furthermore, the influence of fiber chromatic dispersion on the generated UWB signal has been also investigated. The results show that the spectral width of the detected signal reduces rapidly with an increase in fiber transmission length. These changes can be easily reverted by using simple dispersion compensation techniques, allowing UWB signals to be generated remotely from the RAU and distributed over long fiber lengths.

Acknowledgements:

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