A new modulation technique for high data rate low power UWB wireless optical communication in implantable biotelemetry systems

A. De Marcellis[1], E. Palange[1], V. Liberatore[1], L. Nubile[1], M. Faccio[1], T.G. Constandinou[2]

1. University of L'Aquila, Dept. of Industrial and Information Engineering and Economics, L'Aquila, Italy
2. Imperial College London, Centre for Bio-Inspired Technology, London, United Kingdom

Summary

We report on the development of a novel modulation technique for UWB wireless optical communication systems for application in a transcutaneous biotelemetry. The solution, based on the generation of short laser pulses, allows for a high data rate link whilst achieving a significant power reduction (energy per bit) compared to the state-of-the-art. These features make this particularly suitable for emerging biomedical applications such as implantable neural/biosensor systems. The relatively simple architecture consists of a transmitter and receiver that can be integrated in a standard CMOS technology in a compact Silicon footprint. These parts include circuits for bias and drive current generation, conditioning and processing, optimised for low-voltage/low-power operation. Preliminary experimental findings validate the new paradigm and show good agreement with expected results. The complete system achieves a BER less than 10^{-7}, with maximum data rate of 125Mbps and estimated total power consumption of less than 3mW.

Motivation and Results

Emerging and future implantable biomedical devices will need to transmit large amounts of data through tissue/skin to achieve high dimensionality, real-time control of complex prosthetic devices. For example, the capability to observe neuronal signals in real-time, combined with new advances in neural signal processing for decoding information, can feed/control external devices ultimately to improve the life quality of patients with neurological disease and injury. Such systems will require wireless biotelemetry links that can achieve high data rate, reduced power consumption, small BER, high electromagnetic (e.m.) compatibility [1]. In current systems, carrier-based narrow-band RF links are predominantly used. These pose significant challenges when requiring high data rates, mainly due to excessive power dissipation and limitations due to e.m. compatibility constraints. A different approach is to adopt techniques used in UWB architectures. The main drawback here is related to the high absorption of the e.m. radiation as the carrier frequency increases [2]. If this is however applied to an optical biotelemetry, this could offer a new solution with several benefits, including high data rate, low BER, high e.m. compatibility and reduced power consumption. Generally, to improve the performance of a conventional optical link, the transmitted power needs to be increased. In the techniques reported in literature the overall link efficiency is improved by using a modulation scheme, derived from the on-off keying, and a large-area photodetector [3]. This results in an increase in BER and laser response time and thus a decrease in system bandwidth and data rate. The aim of this work is to overcome these intrinsic weaknesses of optical biotelemetry systems by proposing the use of a new UWB modulation for optical communications. The schematic architecture (Fig.1), implements the modulation technique (Fig. 2), using nanosecond pulses. The developed system (Fig. 3) operates up to 125Mbps (Fig. 4) consuming a maximum total power less than 3mW with a BER smaller than 10^{-7}. The maximum achieved data rate can allow for the transmission of raw data recorded from about 1000 intracortical neural recording channels, sampled at 16kHz with 8-bit resolution.

Word count: 484

References

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Corresponding author

Andrea De Marcellis, Dept. of Industrial and Information Eng. and Economics, Univ. of L'Aquila, Via G. Gronchi 18, 67100 L'Aquila, Italy. Phone: +39 0862 434424; e-mail: andrea.demarcellis@univaq.it

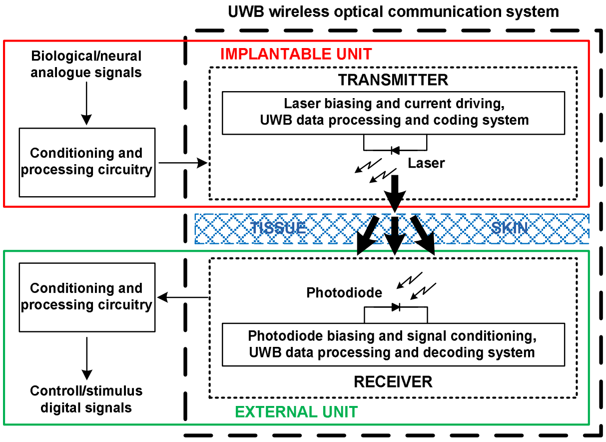

Figure 1: Architecture of a complete wireless optical biotelemetry system.

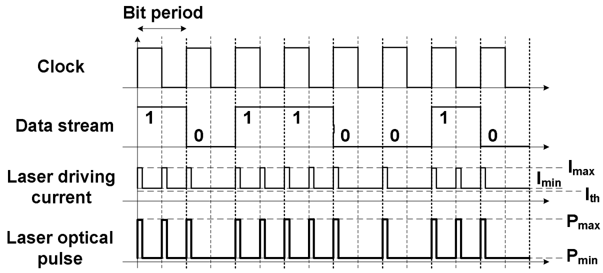

Figure 2: The proposed UWB modulation technique based on the generation of nanosecond optical pulses: example of the timing diagram related to the data coding process performed by the transmitter (I_{max}=maximum laser driving current; I_{min}=minimum laser driving current; I_{th}=laser threshold current; P_{max}=maximum emitted optical power; P_{min}=minimum emitted optical power).

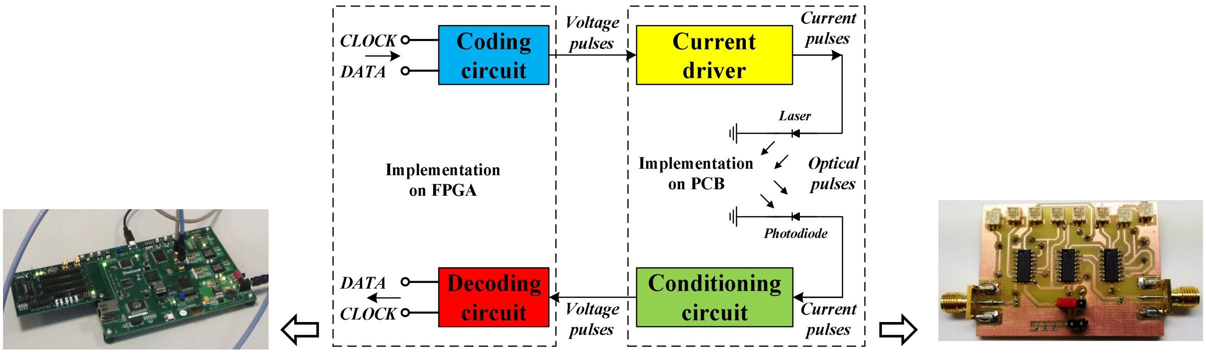

Figure 3: Block scheme of the implemented UWB wireless optical communication system: the laser is a 980nm Vertical Cavity Surface Emitting Laser (VCSEL) and the photodiode is a Silicon-based detector with a small photosensitive area. The FPGA has been employed for: (i) the clock generation and recovery; (ii) the data coding and decoding; (iii) the evaluation of the BER (on the left, the board FPGA XILINX SPARTAN 6; on the right, the prototype PCB of the laser current driver operating with a maximum 3.3V single supply voltage).

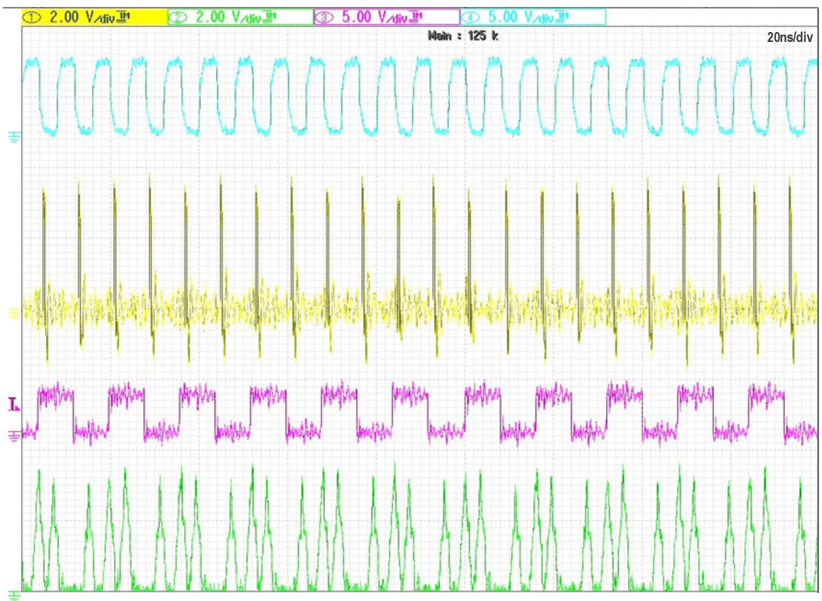

Figure 4: Experimental measurements conducted with the implemented system of Fig. 3 operating at 125Mbps: the blue trace is the main clock signal, the yellow trace is the clock (i.e., the synchronisation signal) recovered and generated by the receiver, the green trace is the received 2ns pulse train employed by the decoding circuit for clock and data recovering, the violet trace is the decoded data stream (the transmitted data stream is composed by the bit sequence: 1, 0).