EUCNC | 6G Summit
Antwerp, Belgium • 3-6 June 2024

Implementation of Reconfigurable 149Mbps TDC-Based PPM Transceiver

Pauls Eriks Sics, Nikolajs Tihomorskis, Sandis Migla, Jakovs Ratners, Viktors Kurtenoks, **Arturs Aboltins**

1862
RIGA TECHNICAL UNIVERSITY

eventech

Objective

Designing and **Implementing** a high-bitrate pulse position modulation (PPM) transceiver for long range / low energy applications. Use off-the shelf **event-timer** for demodulator.

Key Points:

- Target bitrate of over 149 Mbps .
- DTC/TDC-based software-defined radio approach for flexibility.

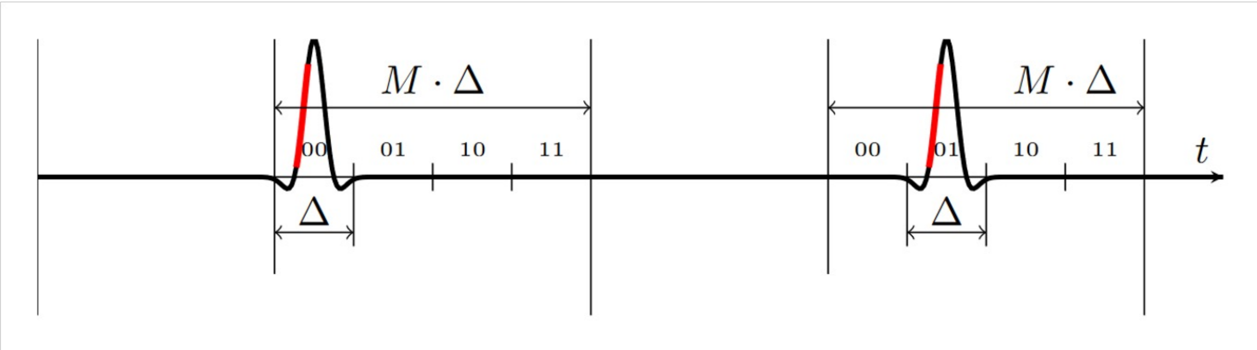
Technology Overview

EUCNC | 6G Summit
Antwerp, Belgium • 3-6 June 2024

- **Modulation Technique:** Pulse position modulation (PPM).
- **Components:**
  - Modulator implemented with software-controlled digital-to-time converter(DTC).
  - Demodulator based on high-precision time-to-digital converter (TDC).
- **Advantages:**
  - Extraordinary energy efficiency
  - Capable of handling signals with up to 100 GHz bandwidth.
  - Software flexibility allows switching between different PPM formats.

Why PPM ?

Meets the need for energy-efficient, high-speed communication in **deep space** (millions of km) applications and **IoT** (harvested power)



Structure of example PPM signal encoding **00** and **01**, where:
–D – duration of one position
–M – number of positions

Pulse width (which affects average power) does not carry information and can be minimized.

TDC & DTC

Time-to-digital converter instead of analog-to-digital converter
Digital-to-time converter instead of digital-to-analog converter

- Allows to deal with **huge numbers of positions** (our prototype supports up to 65535)
- Allows to use fully **asynchronous** processing pipeline, significantly saving power even during the data transfer.

Parameters of the modulator.

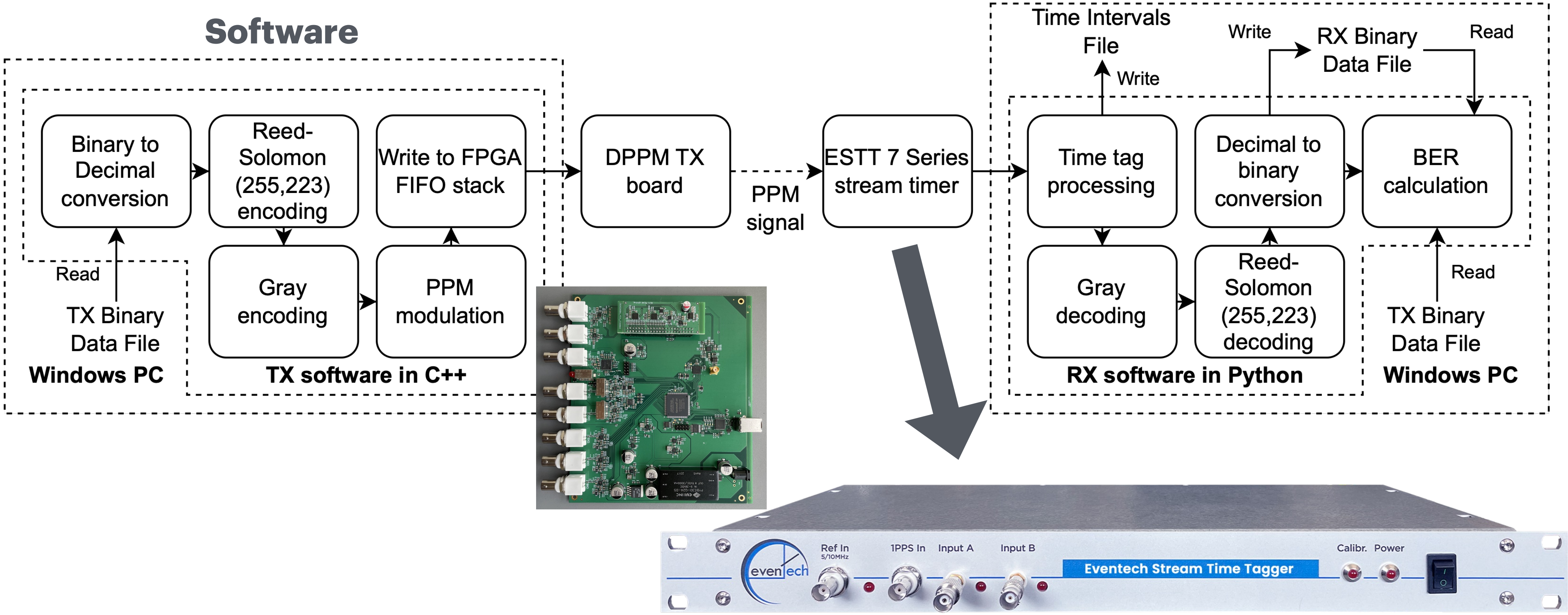
Parameter	Value
DTC granularity (minimum step)	10 ps
Maximum precision delay	10450 ps
Bits for precision delay	10
Maximal coarse delay	655.35 μs
Bits for coarse delay	16
Maximal number of pulses per second	10^6
Minimal pulse repetition interval	10 ns

Parameters of the ESTT 7 Series event timer.

Parameter	Value
Single-shot RMS resolution	2.2 – 2.3 ps (max 2.5 ps)
Dead time	40 ns
Impulse duration	$\geq$ 125 ps
Measurement rate	20 MEPS
Single input time tag drift	< 2 ps/C°
Input to input offset drift	< 0.05 ps/C°

Design and Implementation

Transceiver block diagram



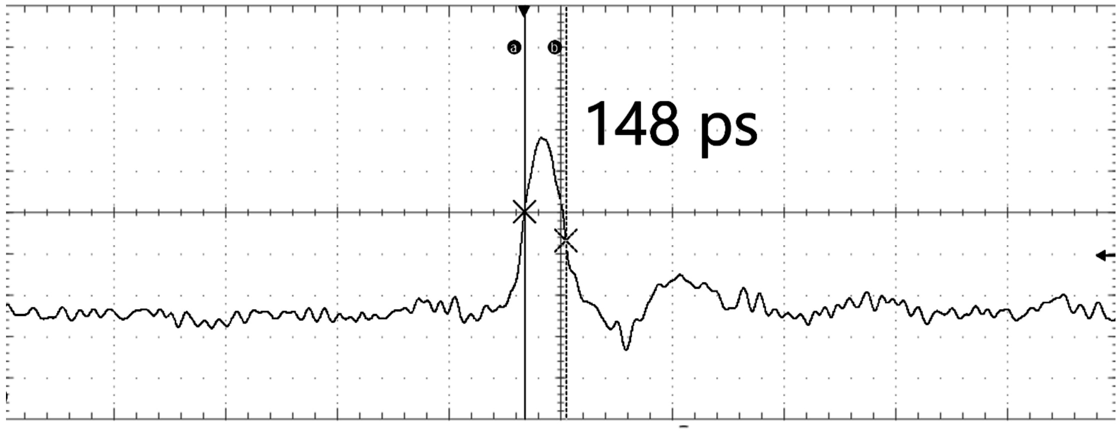
Laboratory Testing and Results

Setup

Laboratory Testing and Results

EUCNC | 6G Summit
Antwerp, Belgium • 3-6 June 2024

Transmitted signal

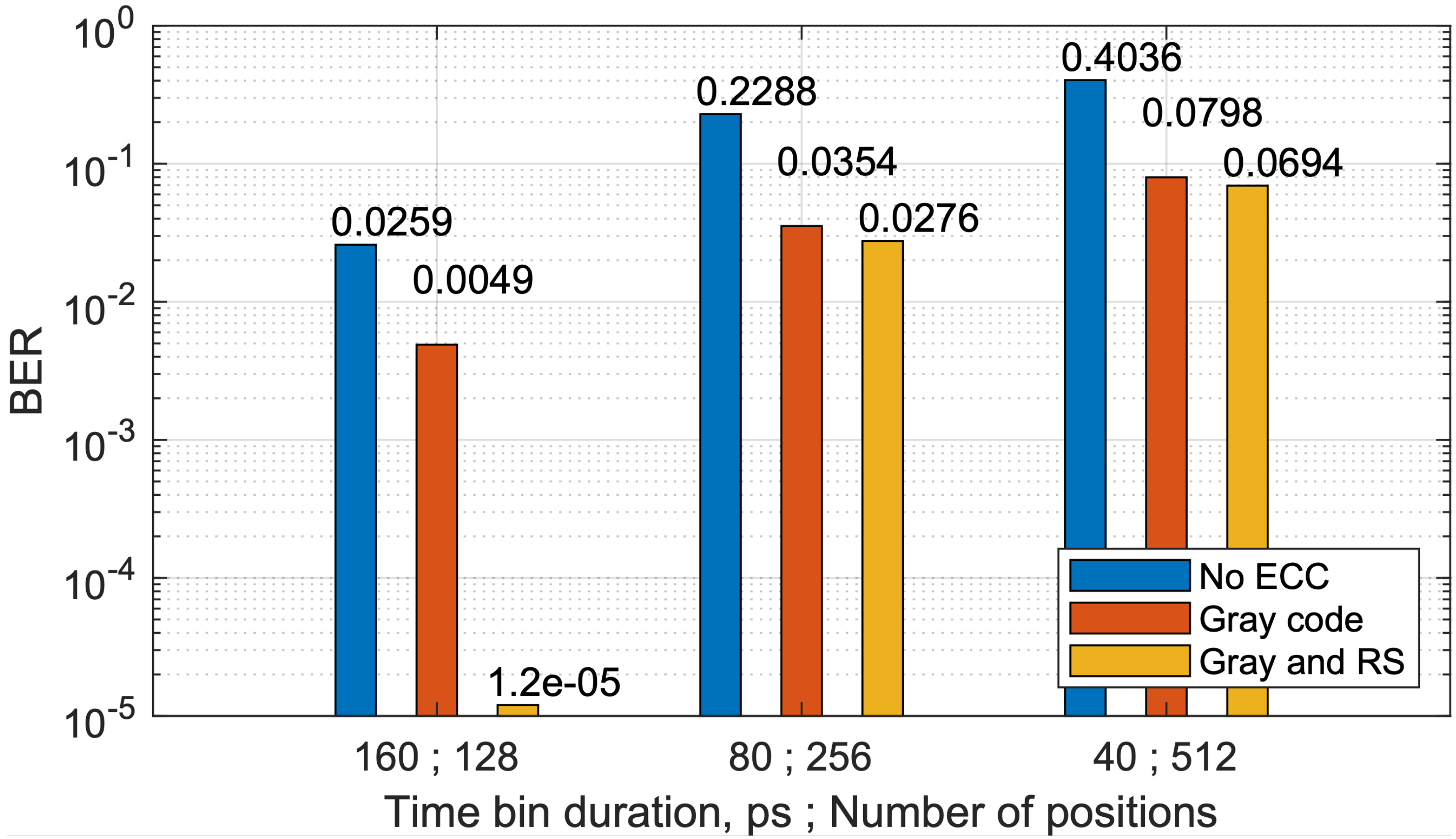


Test configuration

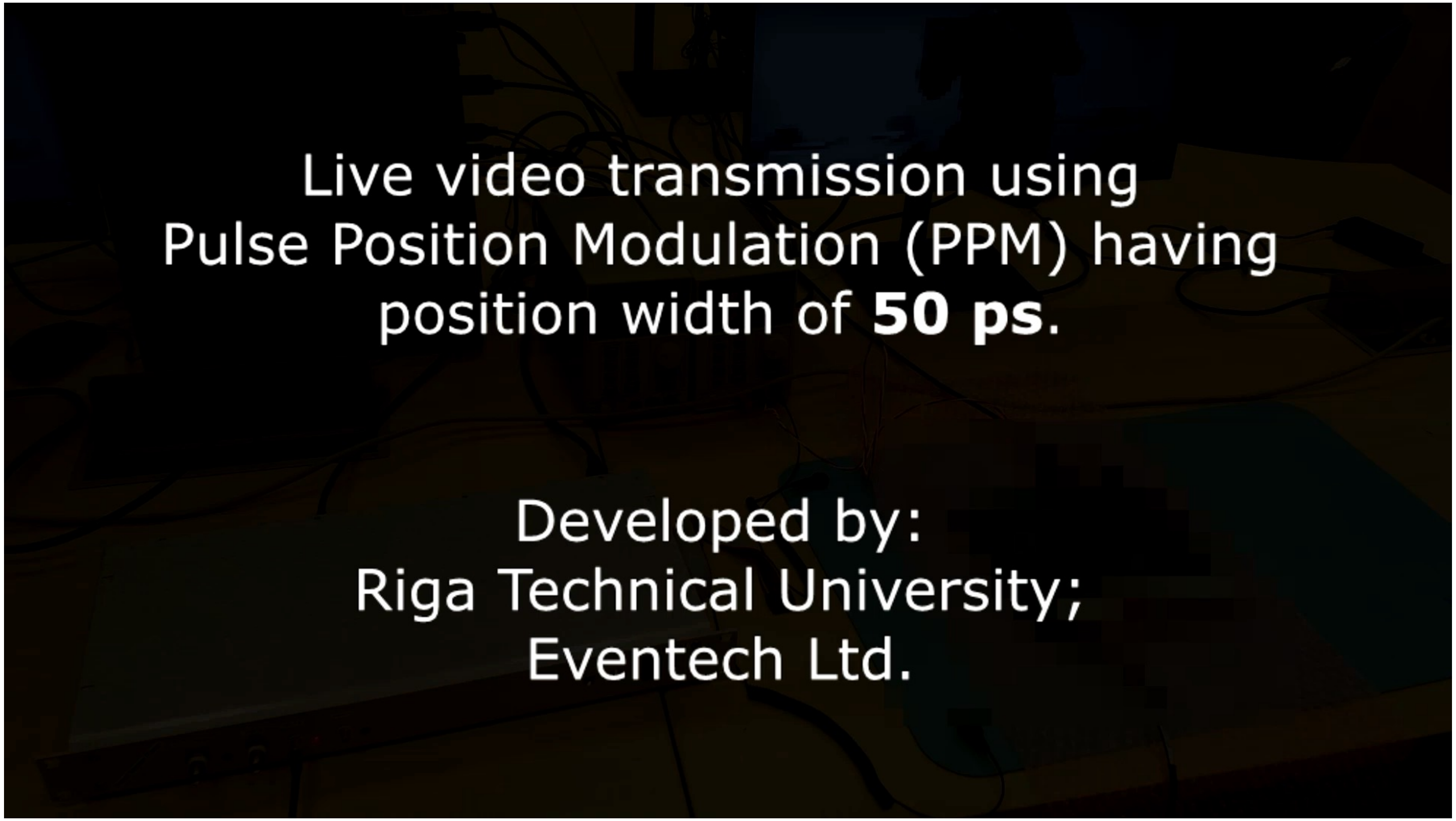
Parameter	Description	Value
Modulation scheme	Modulation scheme	DPPM [9]
Bit count	Number of bits sent	10^6
t_g	Guard time, ns	50
τ	Pulse duration, ps	150
x	Bit pattern	Pseudo-random

Laboratory Testing and Results

Test results



Demonstration



Conclusions and Future Work

- **Achievements:**
  - Prototyped a versatile, high-speed PPM transceiver.
  - Demonstrated the feasibility of using software-controlled TDC and DTC technologies in energy-efficient high bitrate data transmission.

- **Next Steps:**
  - Address software limitations to fully utilize hardware capabilities.
  - Use of TDC with lower dead time
  - Simultaneous satellite laser ranging (SLR) and communication

Acknowledgements

- **Funding:** Supported by the Latvian Council of Science grant No. lzp-2021/1-0475, "Picosecond-resolution pulse position modulation for beyond-the-limits energy efficiency of communications", Riga Technical University.

- **Collaborations (hardware):** Eventech Ltd

- **Contact Information:** http://picoppm.org