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# Ultra Wideband Sensor Network for Industrial IoT



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## Objective

Development of UWB sensor network for data collection (industrial IoT).

Different sensors of engine (7):

6 UWB transmitter for 6 thermal sensors;

1 UWB transmitter for 2 frequency sensors, thermal sensor, 2 pressure sensors .

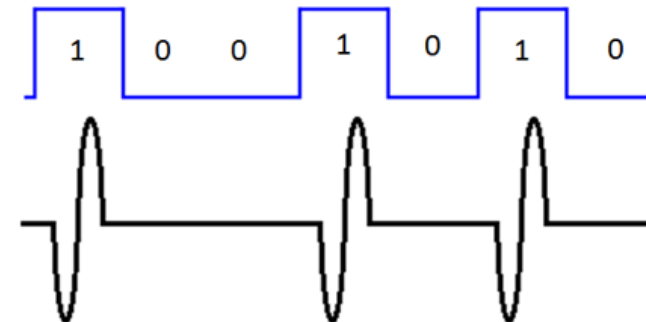
The automatic control and operating engine unit:

- 1) Receiving information from the sensors and controls, processing the information received.
- 2) Measurement of the engine parameters using multiple sensors.

Requirements :

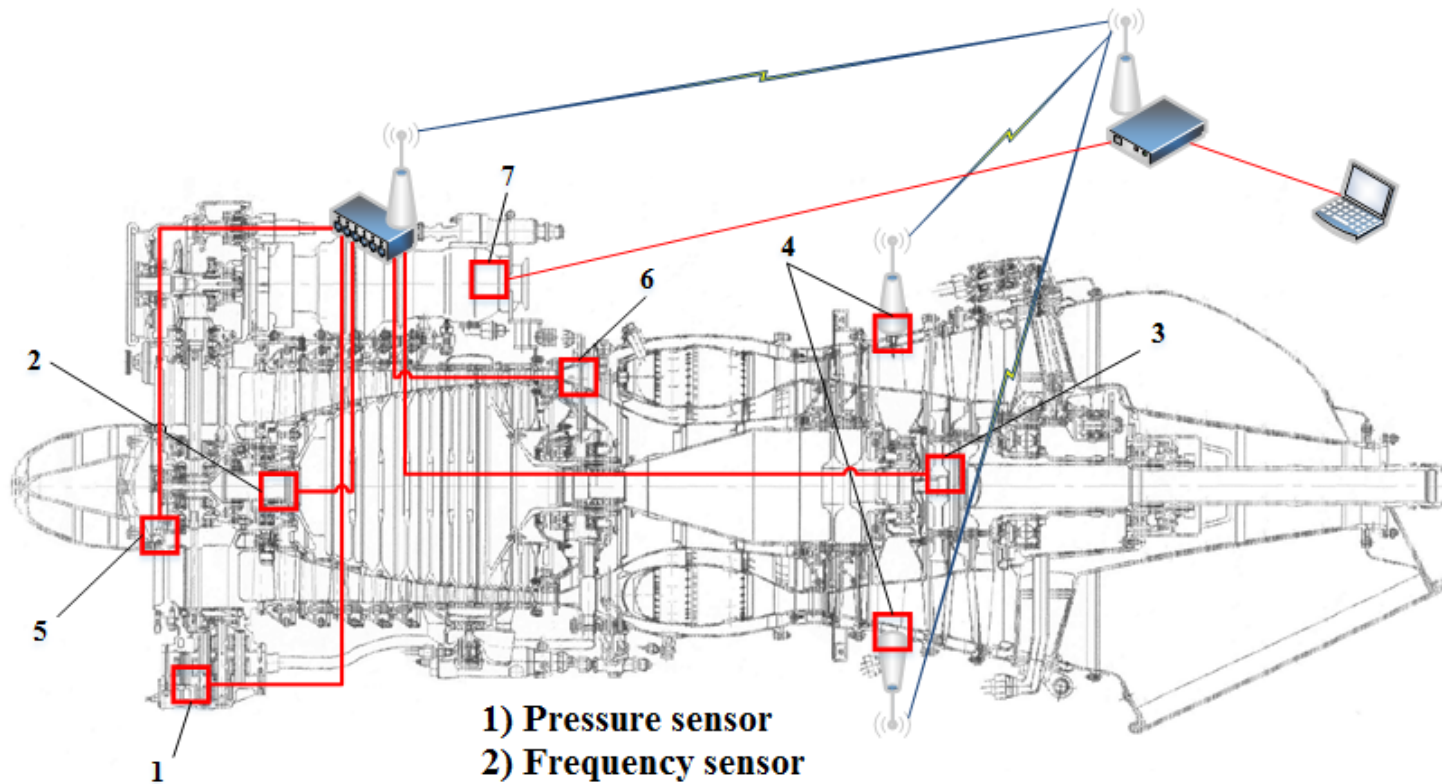
- Extreme low-power wireless data transmission technology operating in conditions of high interference. Harvesting energy from heat radiated by the engine.
- Transmitters implementation on controllers.

**Modulation «On-Off Keing»,  
asynchronous transfer.**





## Objective



- 1) Pressure sensor
- 2) Frequency sensor
- 3) Frequency sensor
- 4) Thermal sensor
- 5) Thermal sensor
- 6) Pressure sensor
- 7) Controller



## **Why UWB signals?**

**Many metal surfaces:**

- **Interferences,**
- **Reflections.**

**Low signal-to-noise ratio.**

**Requirements of extreme low-power transmitters**

**(energy harvesting by thermal gradient).**

**Narrow-band systems (Bluetooth, ZigBee, etc) not very effective in such conditions => UWB signals.**



## Physical layer packet and data link frame

Data link frame (max 61 bits)		
ID	Data	CRC
4 bits	max 49 bits	8 bits
$N_b$ bits		



Spread sequence application (32 elements)

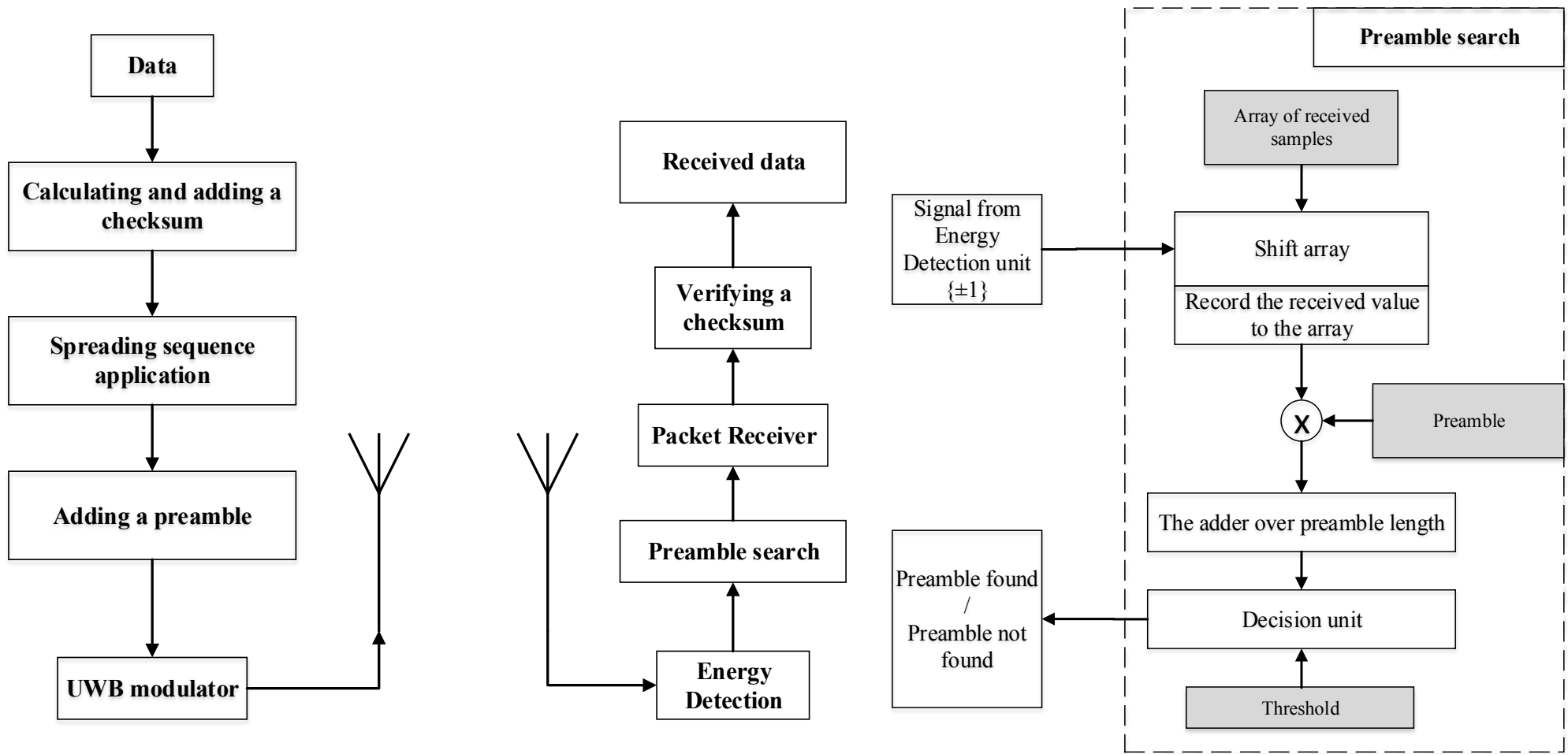


Physical layer packet	
Preamble	Data
$L$ elements	$32N_b$ elements
$(L + 32N_b)$ elements	

Repetition of each physical layer packet of up to 4 times with a random pause between repetitions!

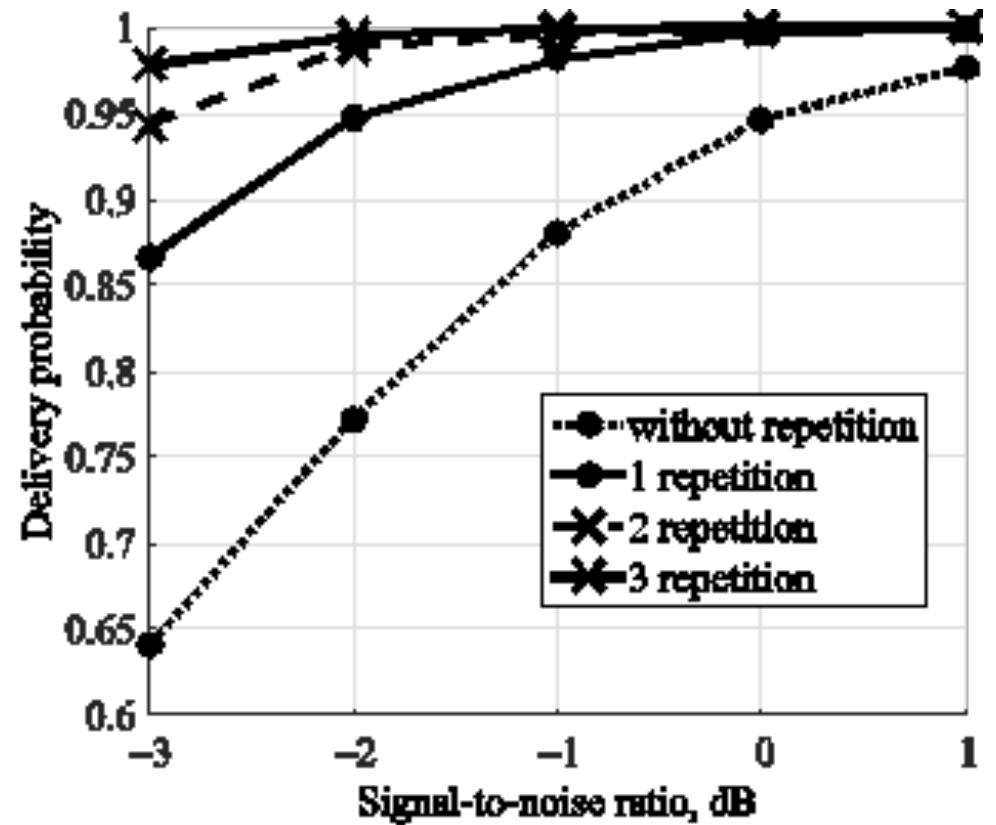
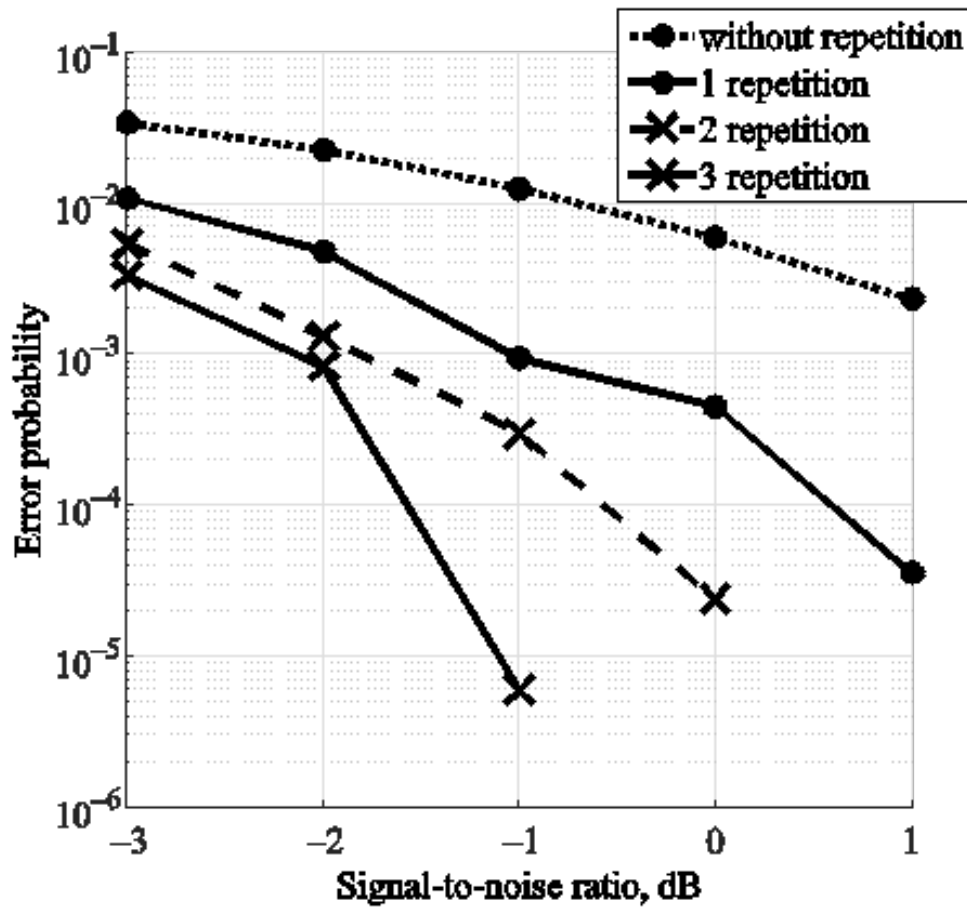


## Simulation model





### Simulation results

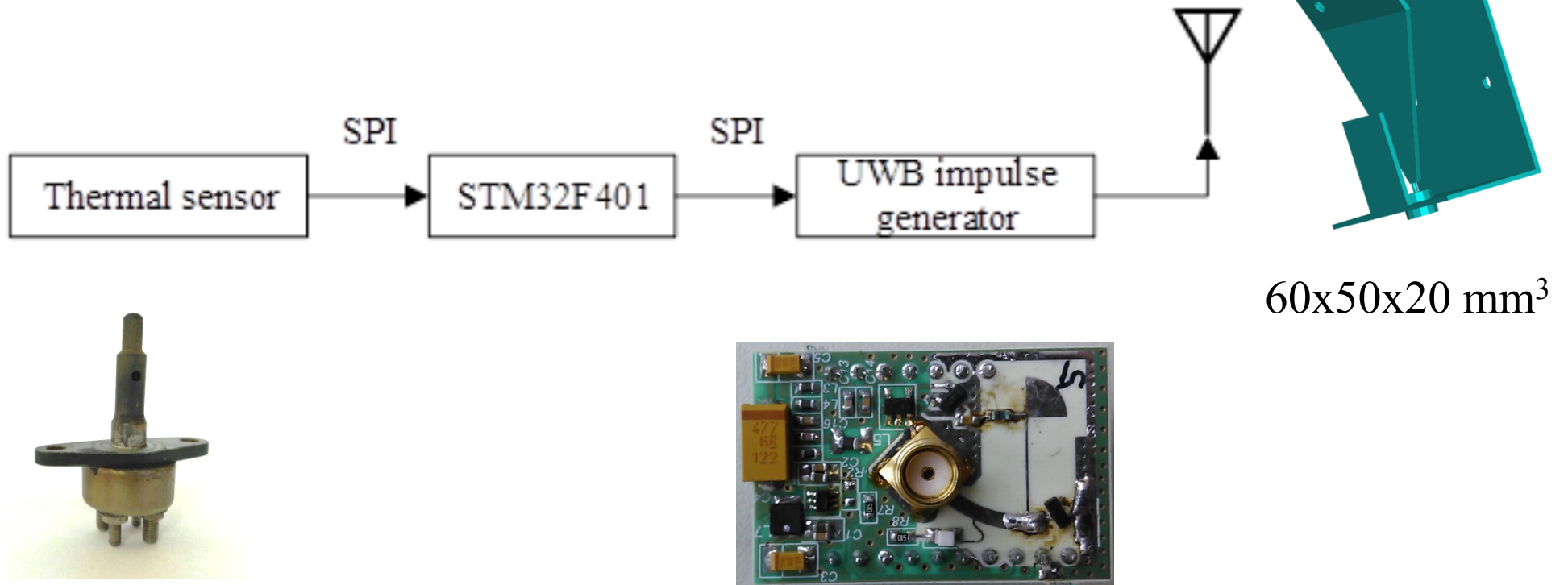


The preamble in this case is 1000 elements long



## Experimental setup

UWB transmitter: microcontroller STM32F401.  
The period of the UWB pulses = 1 microseconds.

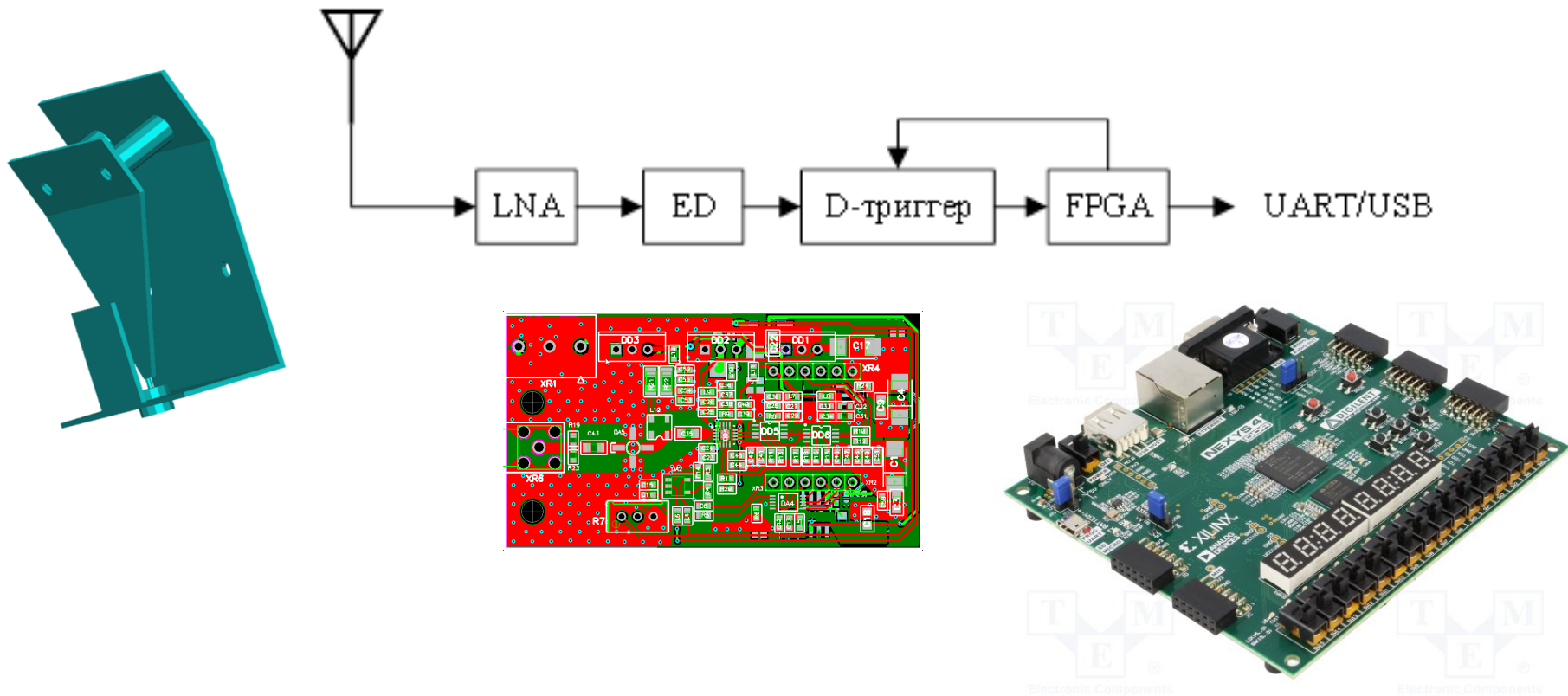






## Experimental setup

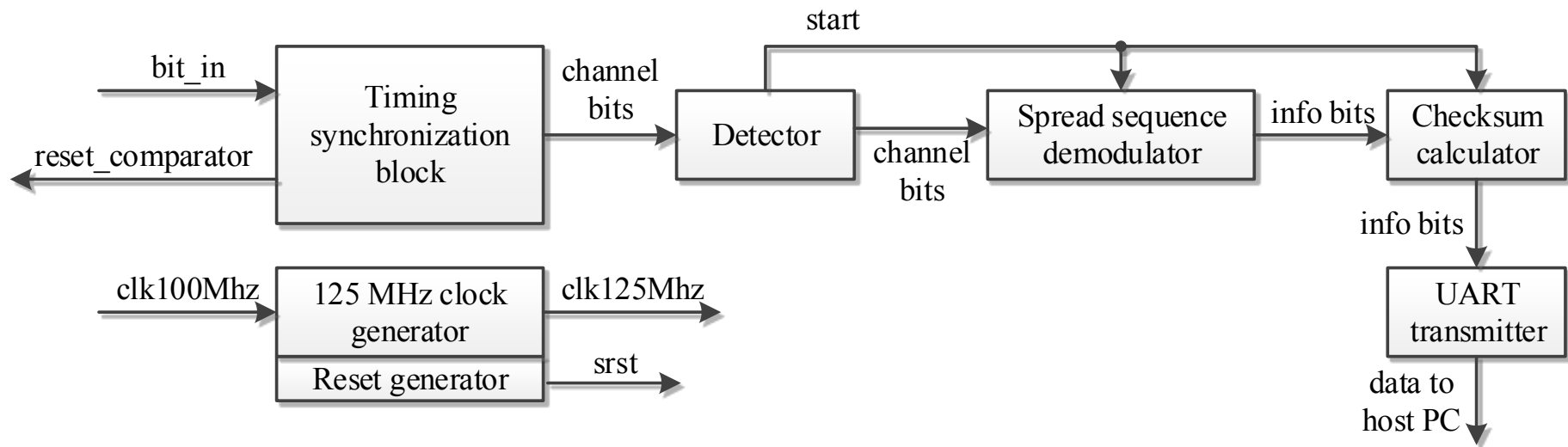
Signal recording: oscilloscope Agilent Technologies DSO9104A.  
Receiver: Nexsys4 DDR board.





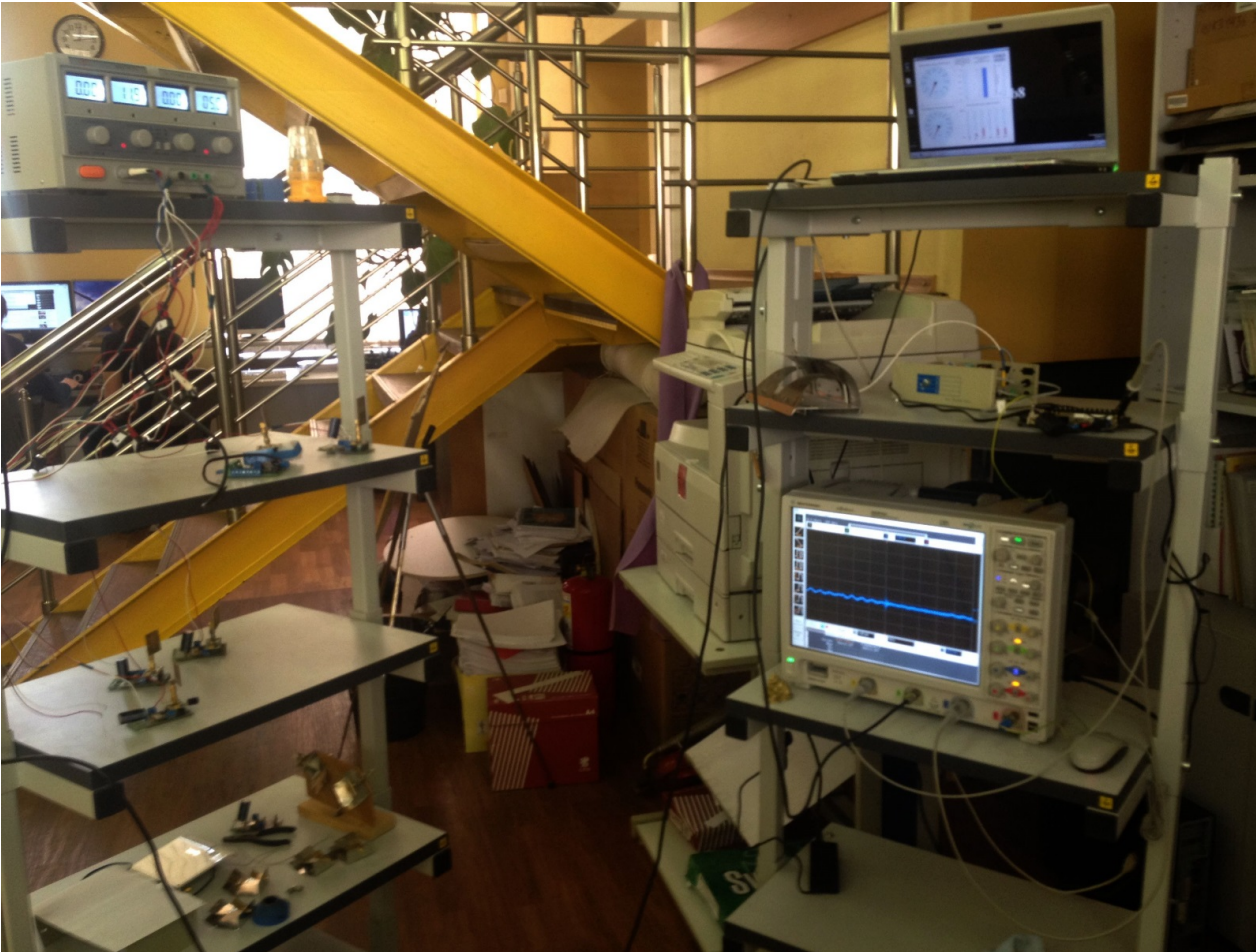
## Experimental setup

FPGA part of UWB receiver on the Nexsys4 DDR board based on the latest FPGA Artix-7.





## **Experimental setup (Laboratory)**

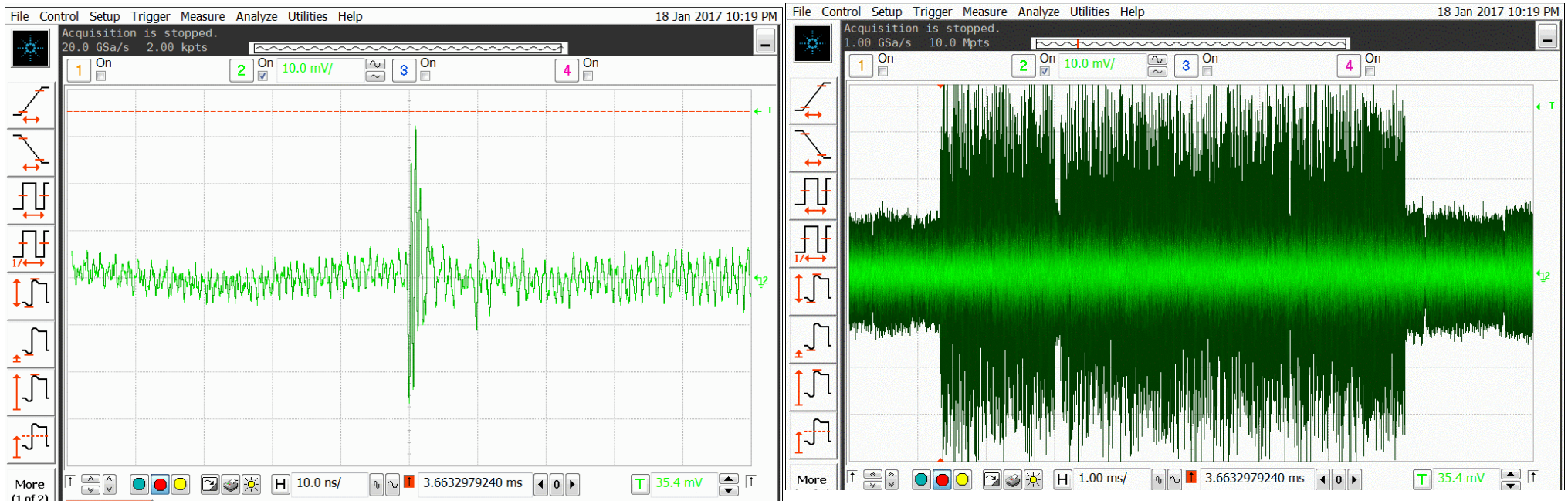


- Power source.
- 6 UWB transmitter for thermal sensors + antennas.
- 1 UWB transmitter for: 2 frequency sensors, thermal sensor, 2 pressure sensors + antenna.
- Oscilloscope Agilent Technologies DSO9104A.
- Receiving antenna + LNA, ED, D-trigger.
- FPGA Artix-7.
- PC.
  
- Distance: 1 meter.



## Experimental results

Distance 1 meter. 7 UWB transmitters. 3 repetition of each packet.  
Processing records in Matlab simulation model .



UWB transmitter	1	2	3	4	5	6	7
Received packets (correct CRC)	4/4	2/4	1/4	2/4	2/4	1/4	2/4



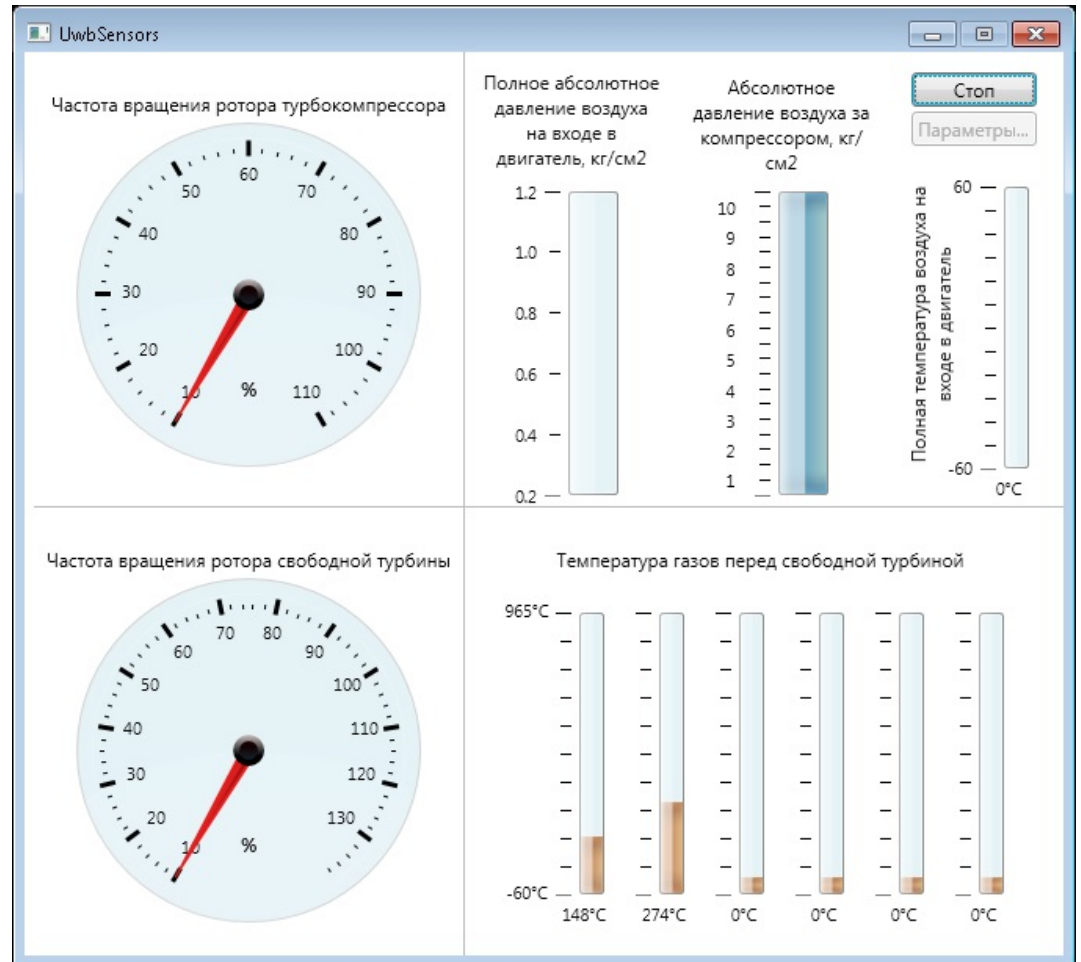
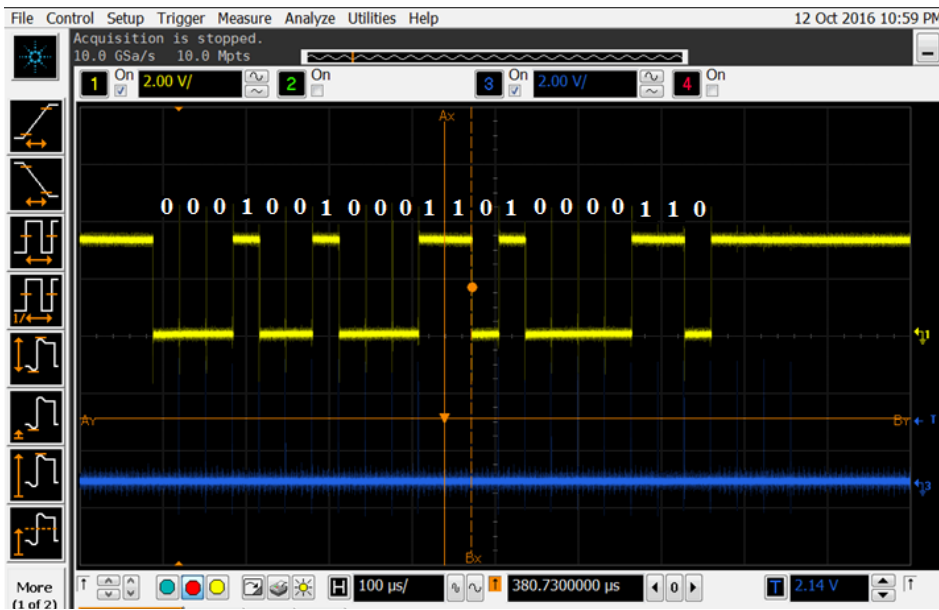
# Ultra Wideband Sensor Network for Industrial IoT

## Experimental results

ID = «0001».

Data = «001000110».

CRC = «10000110».





## Experimental results

7 UWB transmitters.3 repetition of each packet.

Processing in FPGA

Real engine

Distance 1 meter		
<u>Thermal sensor №1</u> <b>Total packets: 143345</b> <b>Packets with errors: 0</b> <b>Missing packets: 0</b>	<u>Thermal sensor №4</u> <b>Total packets: 92486</b> <b>Packets with errors: 1</b> <b>Missing packets: 1</b>	<u>1 UWB transmitter for: 2 frequency sensors, thermal sensor, 2 pressure sensors</u>  <b>Total packets: 26487</b> <b>Packets with errors: 0</b> <b>Missing packets: 0</b>
<u>Thermal sensor №2</u> <b>Total packets: 138911</b> <b>Packets with errors: 0</b> <b>Missing packets: 1</b>	<u>Thermal sensor №5</u> <b>Total packets: 128684</b> <b>Packets with errors: 1</b> <b>Missing packets: 0</b>	
<u>Thermal sensor №3</u> <b>Total packets: 142456</b> <b>Packets with errors: 0</b> <b>Missing packets: 0</b>	<u>Thermal sensor №6</u> <b>Total packets: 95616</b> <b>Packets with errors: 1</b> <b>Missing packets: 0</b>	



## Problems and Directions of development

**Increasing number of sensors (32).**

**Transition to a distributed UWB sensor network:**

- **Network layer?**
- **Routing rules?**
- **Performance requirements for routing nodes?**
- **Resulting network performance?**

