Passive SAW tags and sensors operating in Ultra-Wide frequency Band

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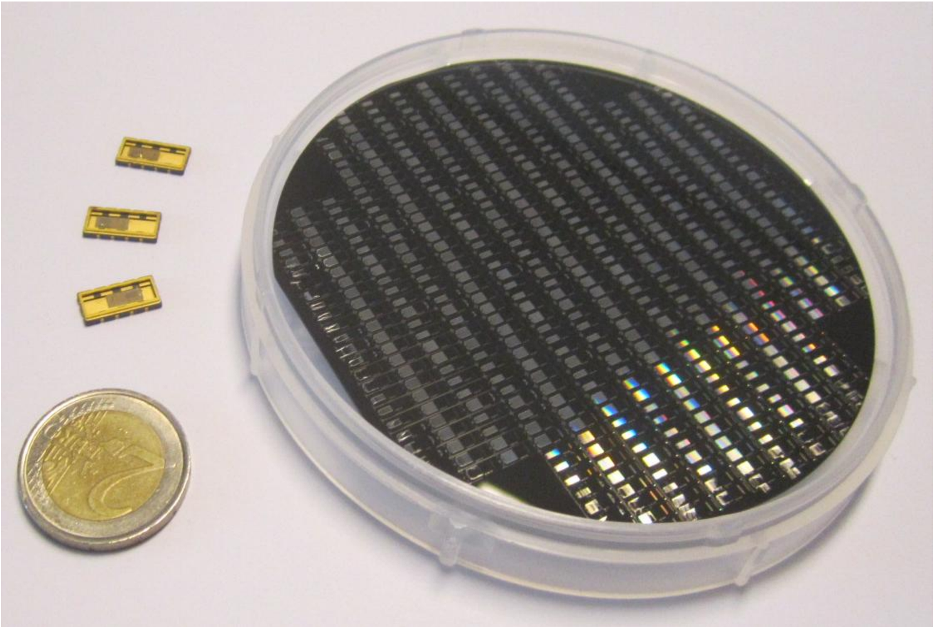


<u>Ultra Wide Band *(UWB)* :</u>

Ultra Wide Band (UWB) brings many advantages:

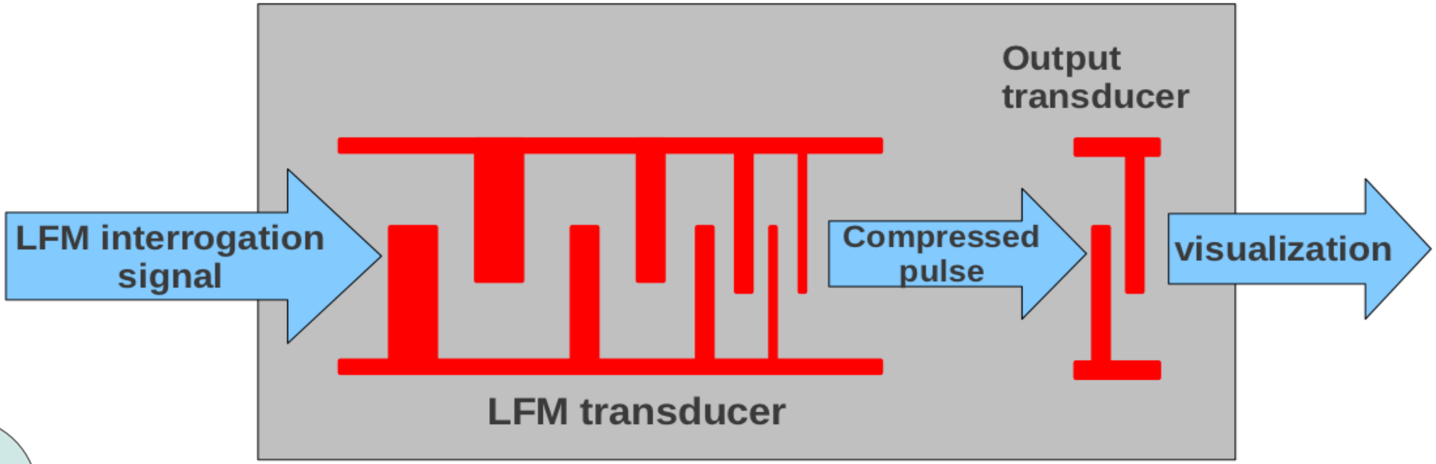
- Wider frequency spectrum ***B*** allows encoding more information (because of shorter compressed pulses)
- The signal can be processed inside the tag/sensor
- Reduce the size of the sensors and therefore their price
- Extremely low average power levels emitted by the reader allows operating sensors in an environment where the low EM radiation level is demanded.

- We have developed a UWB prototype temperature sensor operating in a lower frequency bands 200 MHz to 400 MHz.

- The system for the US UWB standard, (the power must not exceed 41.3 dBm/MHz, on a 500 MHz frequency band) is under development.

Prototype 1: Signal processing

- The transducer consisting of pairs of electrodes whose periods corresponds to generation of Linear Frequency Modulated (LFM).

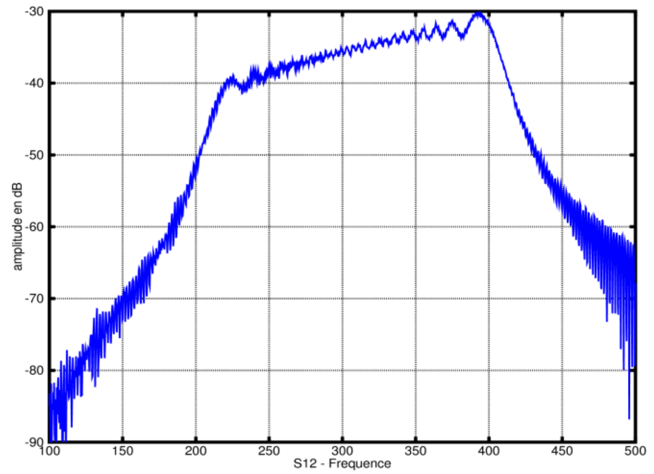


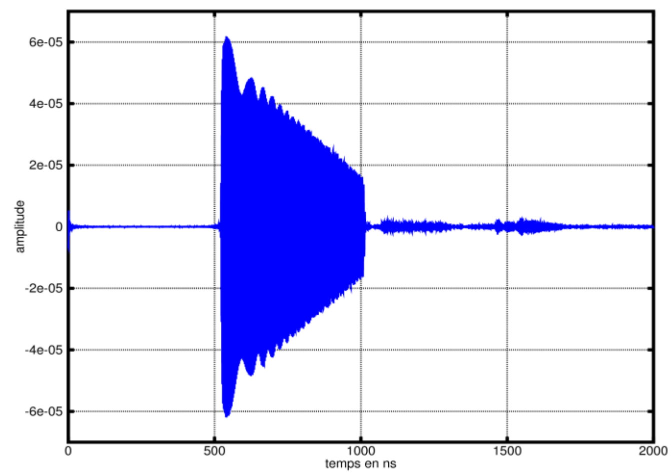
This first prototype has been designed and realized to observe and understand how works the pulse compression and how to measure precisely the pulse delays.

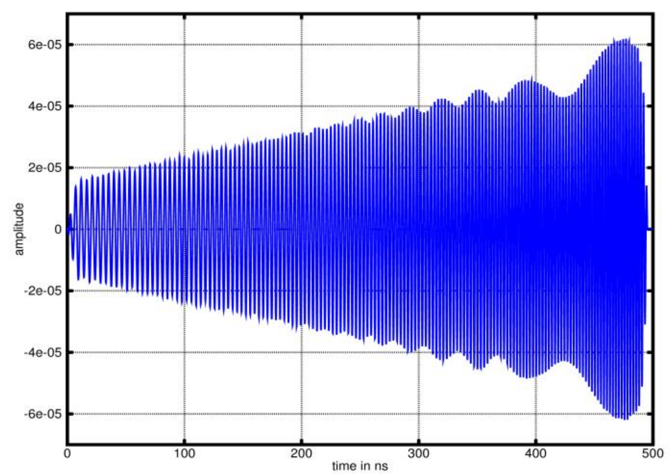
UWB prototype 200-400 MHz :

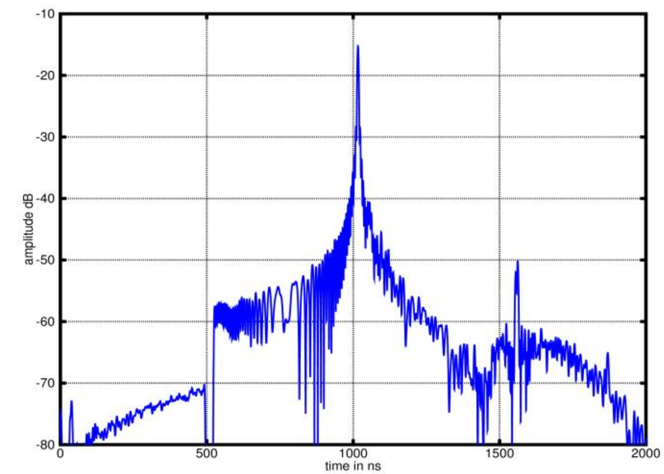
Build a compressed pulse.

Time reversal signal processing.









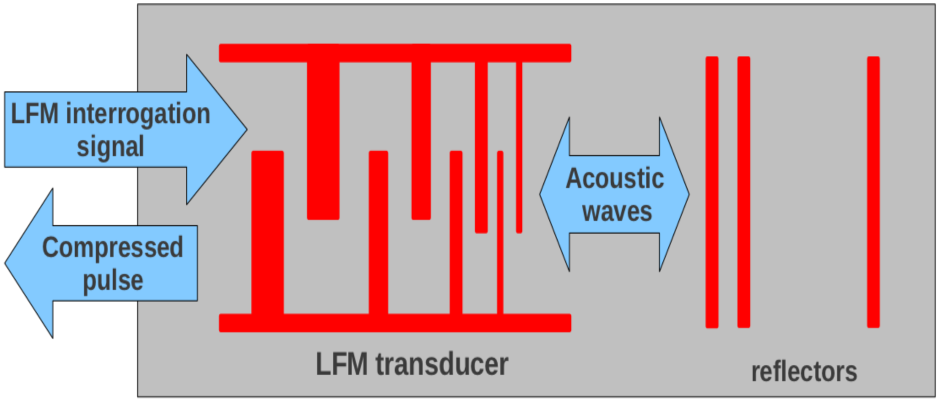
UWB prototype 200-400 MHz :

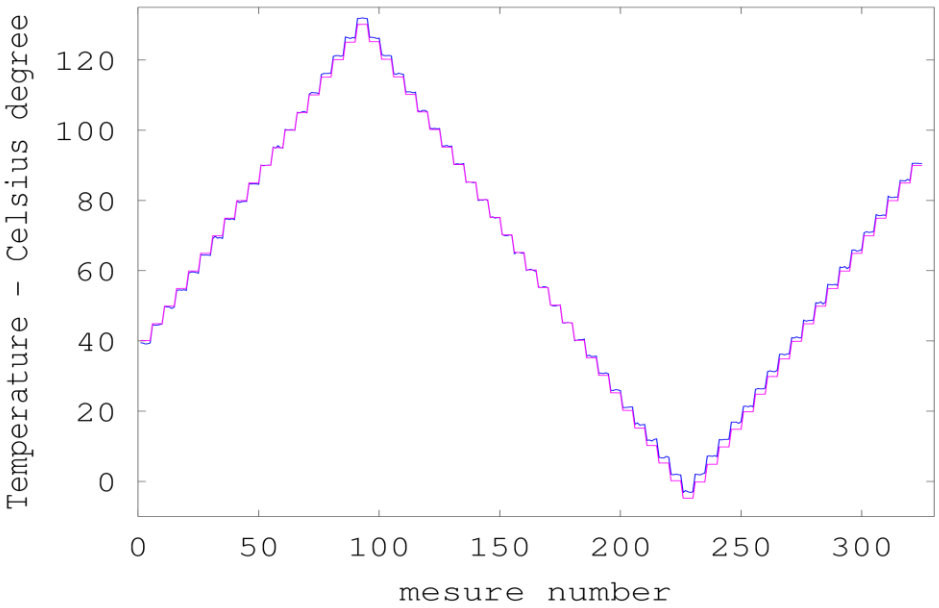
-Temperature Measurements

- Compressed pulse has been used to code the reflectors positions.

- The time variation between the second and the third pulse gives temperature. The first pulse code the sensors ID.

-Sensors have measured temperature step between -5° C to 130° C with 0,2° C precision.





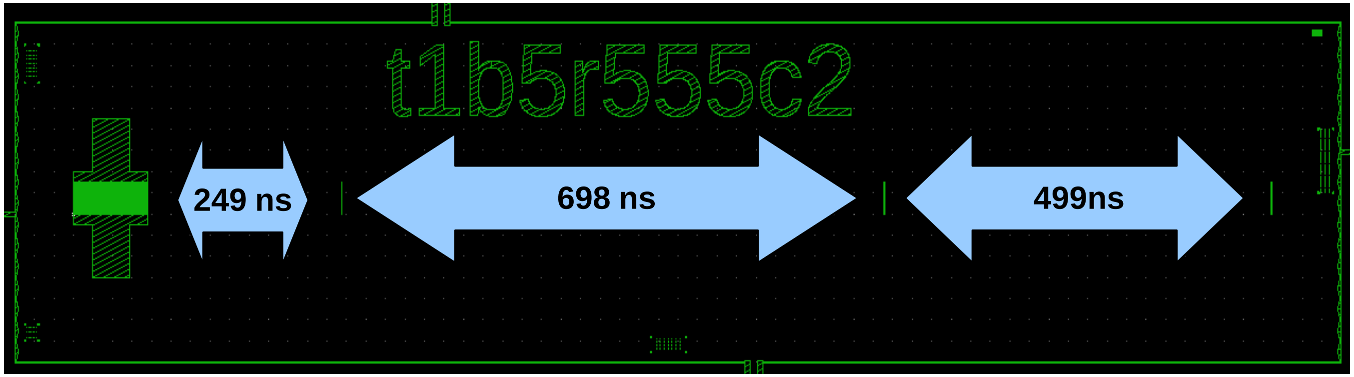
-Blue curve : The prototype mesure

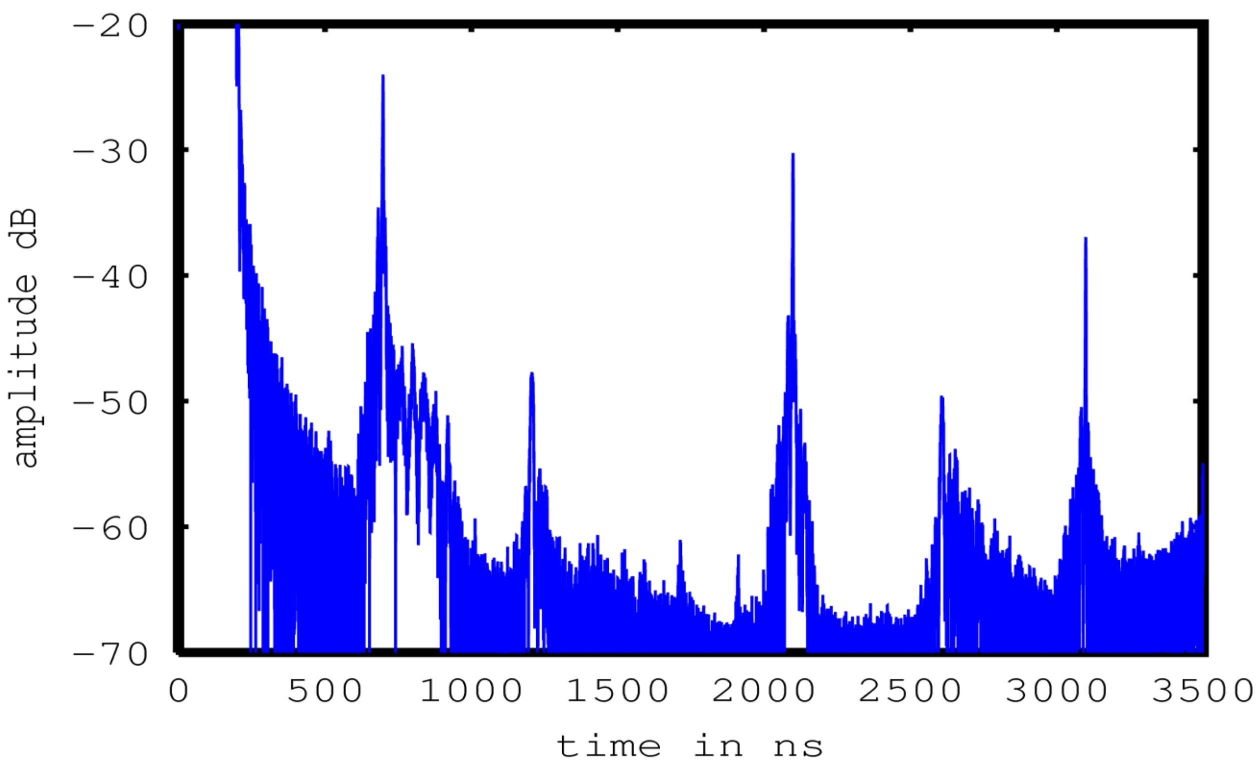
-Red curve : PT100 reference mesure.

UWB 2-2,5 GHz :

- LFM transducer, B*T=50

- 2 ns compressed pulses



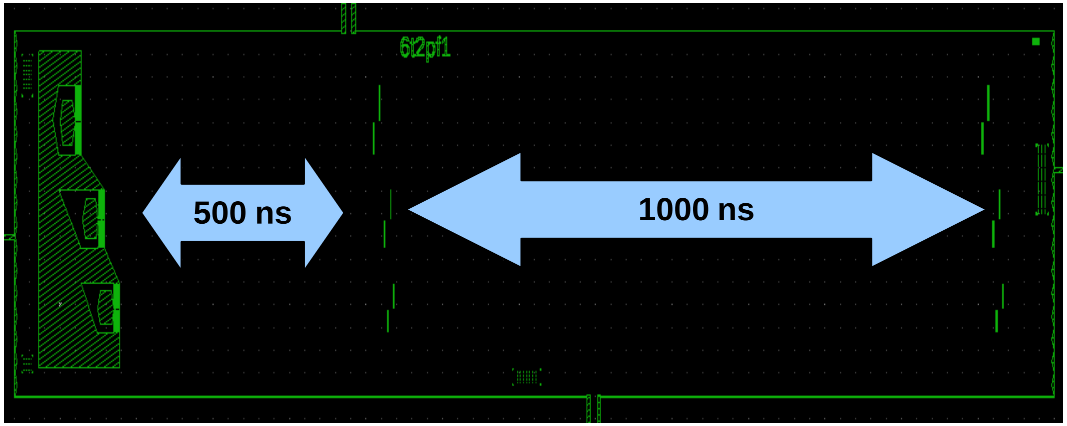


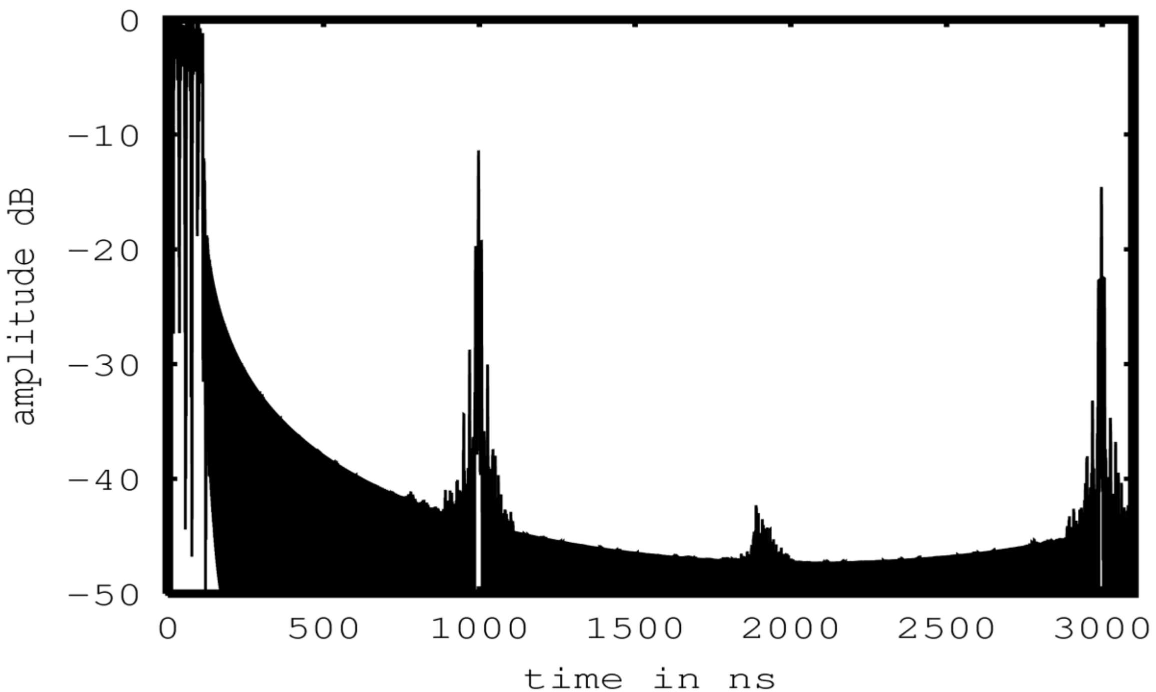
UWB 2-2,5 GHz :

- Constant transducer connected in parallel.

- The transducers operate on bandwidths of 100 MHz.

-Each channel (transducer and reflector) is sized for his operating frequency.





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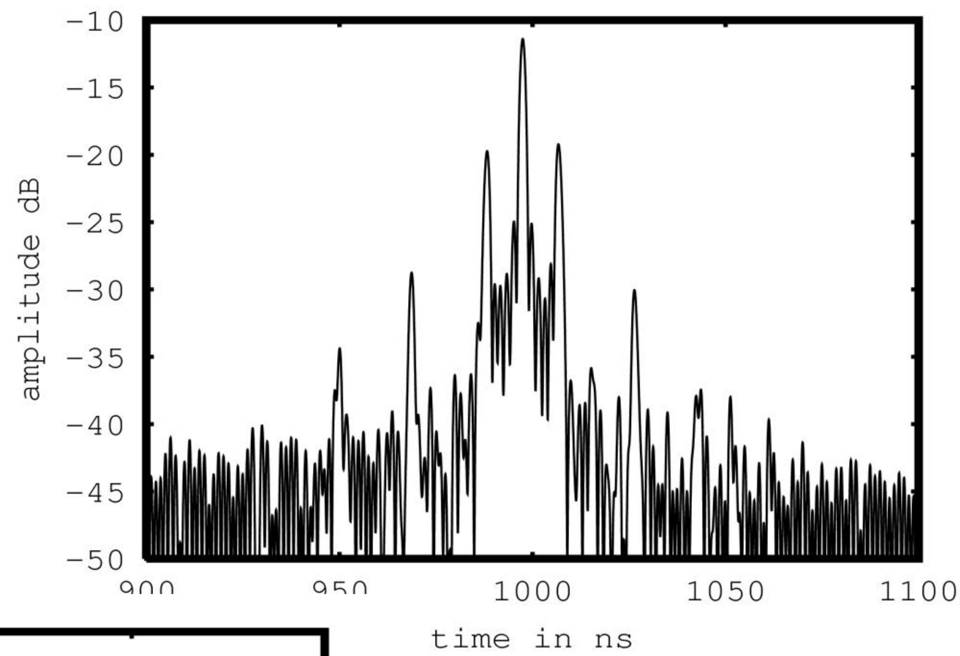
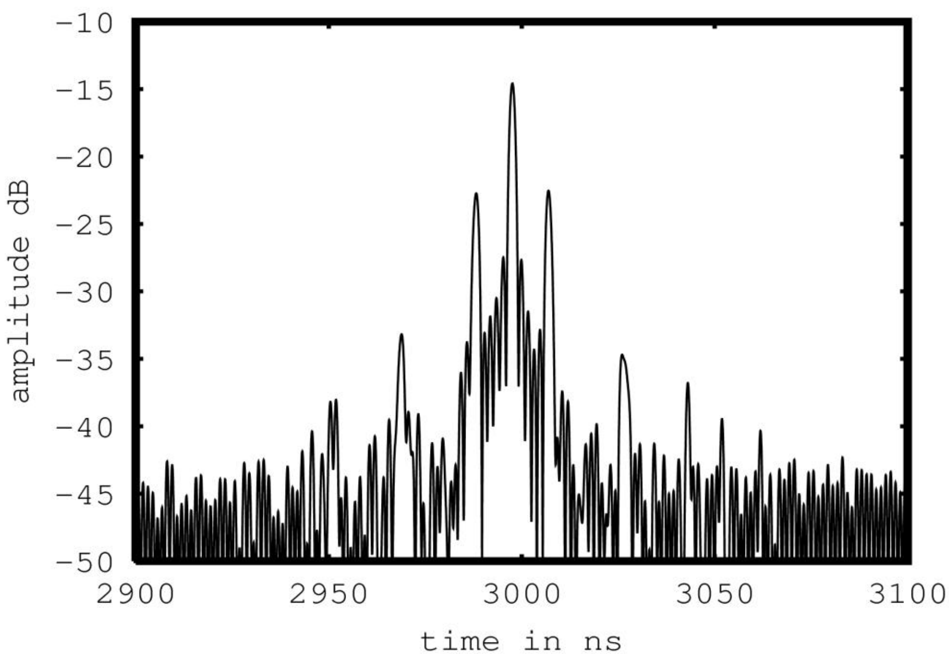
UWB 2-2,5 GHz :

- The energy levels for compressed pulses are better than for the transducer LFM.

- Sides lobes energy is too high therefore there is difficult to use it for sensor networks.





Top : First pulse with 2ns compression (-12 dB)

Left : Second pulse with 2ns compression (-15 dB) femto-st sciences & technologies

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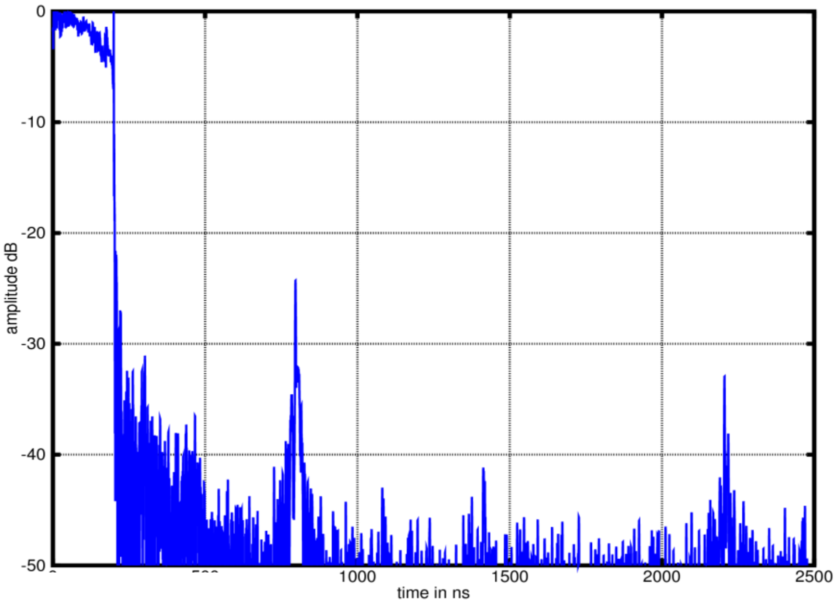
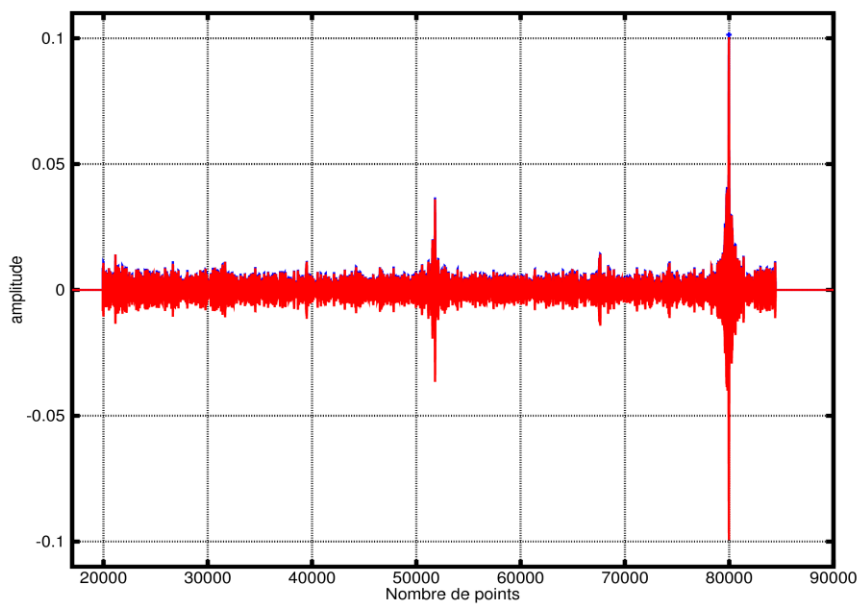
Correlation technique :

- Measuring the elapsed time between two echoes by using a method of cross-corelation.

- The first pulse is used as reference vector for the cross-correlation with all the signal.

- Inter-corelation must be made on the real and imaginary part of the signal.





Top : response of a LFM UWB sensors, 2 compressed pulses.

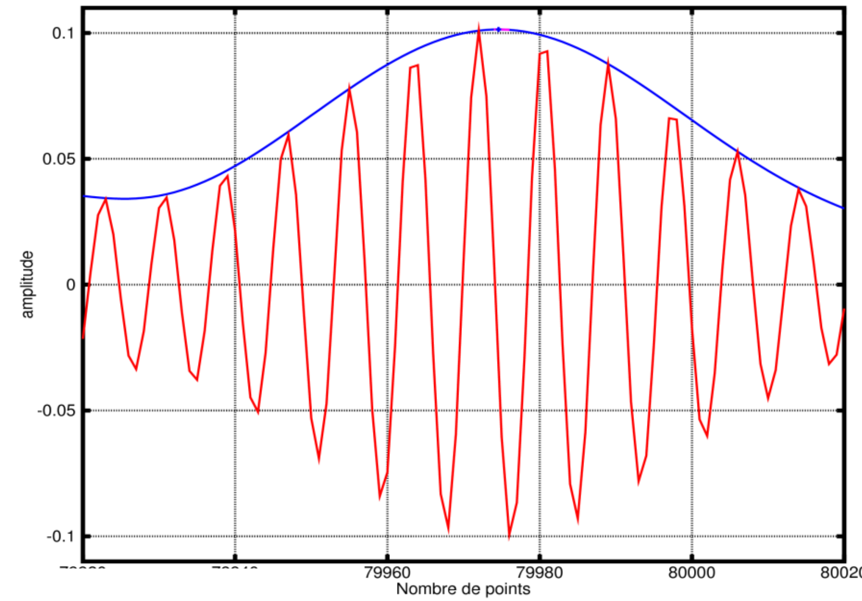
Left : Cross-correlation between the first pulse and the full signal.

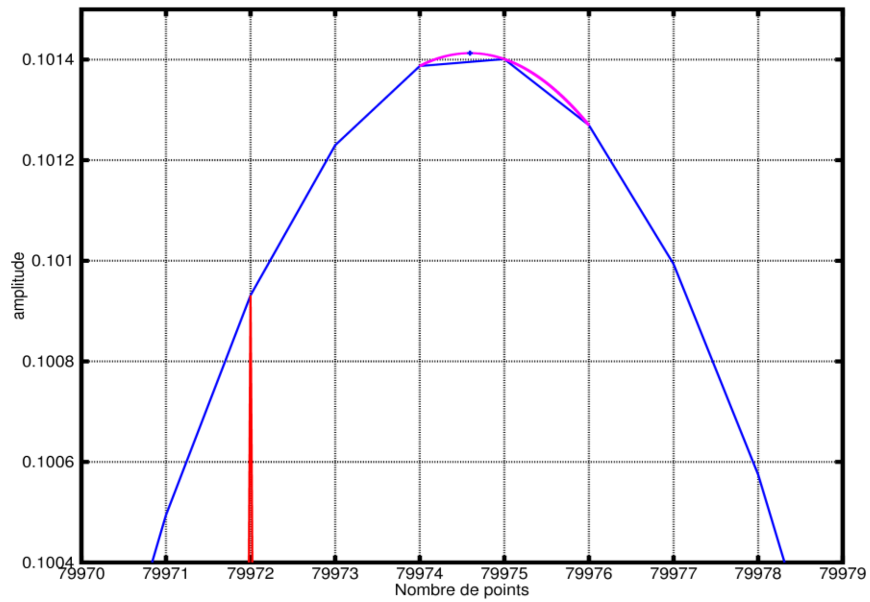
Correlation technique :

- On the cross-correlation response, the maximum should be found on the signal envelope.

- This technique is still sensitive to the phase and it avoids making an measurement error of 1 period.

-Three maximum points are used to refine the measurement

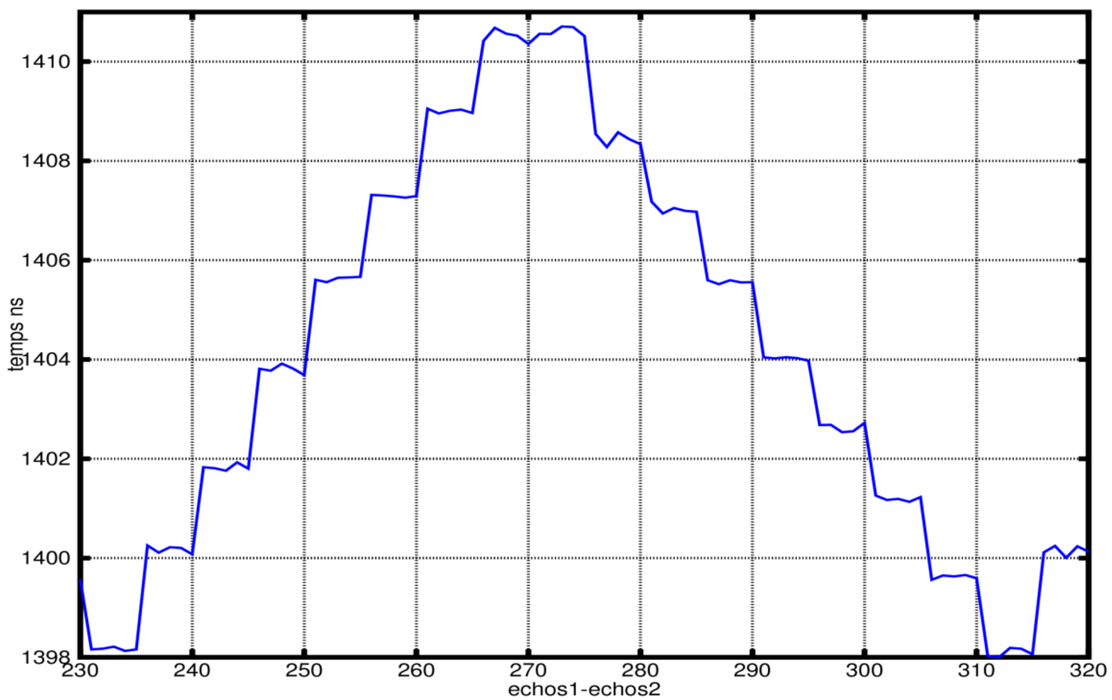




Top : enveloppe on the cross-correlation result.

Left : Curve in magenta passes through the three maximum points.

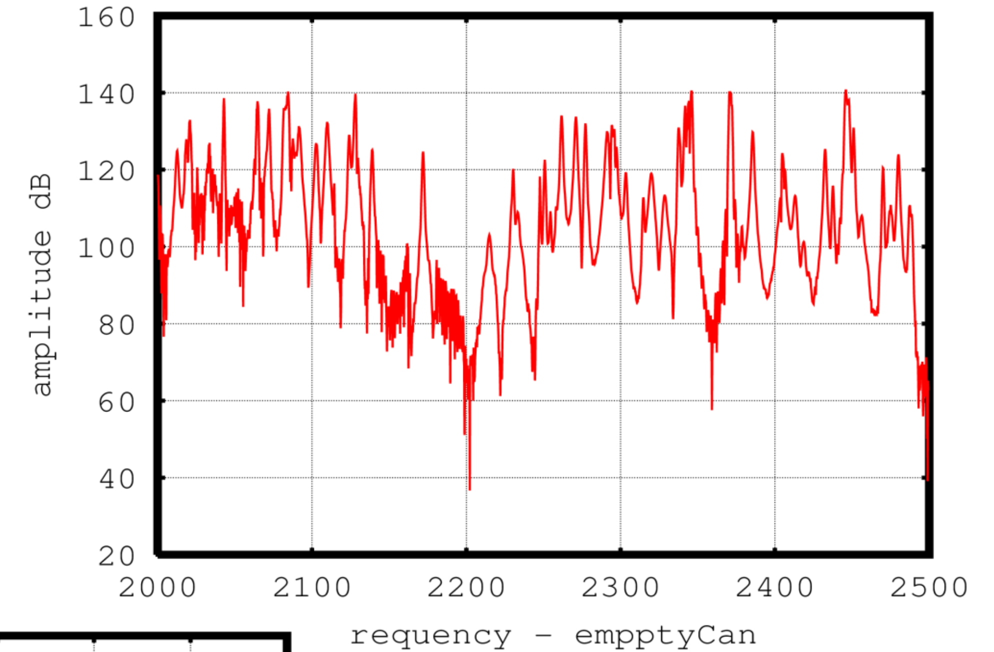
Correlation technique :

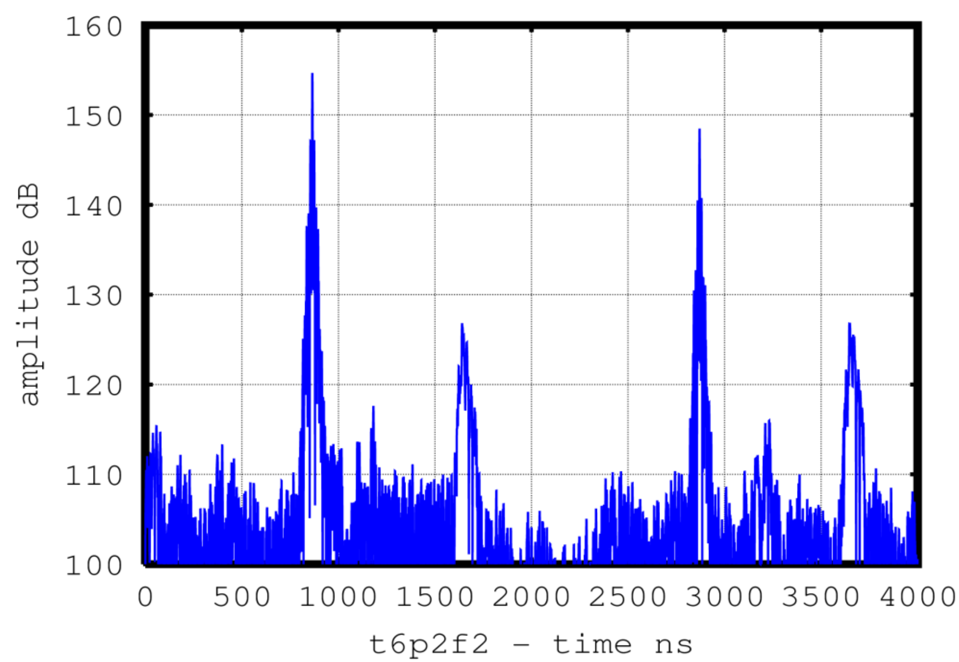


Reflective environment :

-Measurement of UWB sensor (2-2,5GHz, 6 transducers connected in parallel) in a reflective environment (here a iron can with diameter of about 60 cm).

-Metal can has 1 µs resonance duration.





Top : Spectral response of the empty metal can.

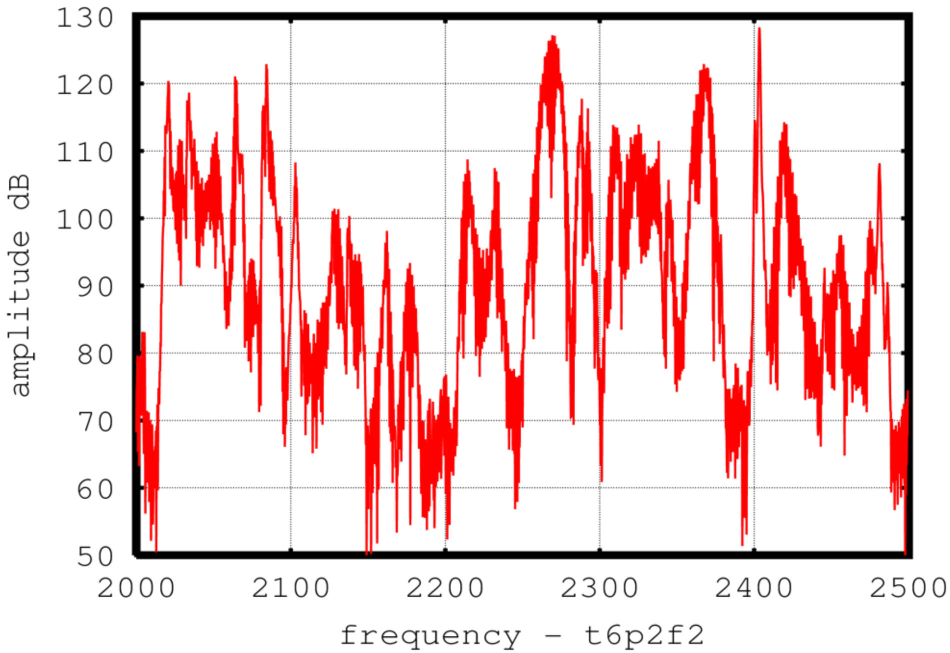
Left : Wireless interrogation of the sensor in a non-reflective environment.

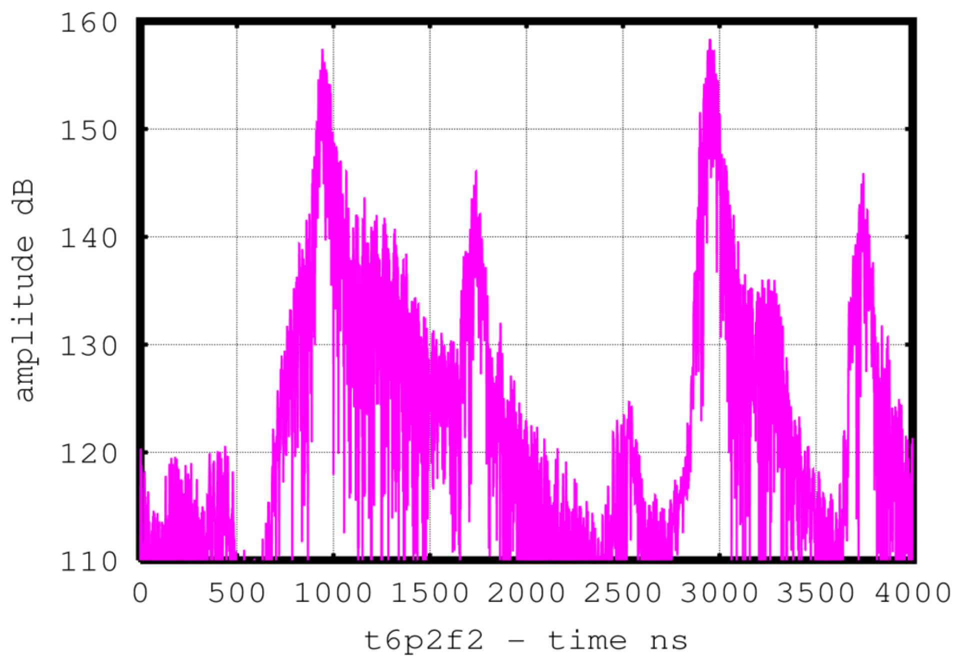
Reflective environment :

-The sensor is placed in the metal can and its spectral response is measured.

-The step of spectrum processing is the same as previously, with the use of time-reversal technique

- Sensor response is visible, compressed pulses are wide and noisy but they are still identifiable.





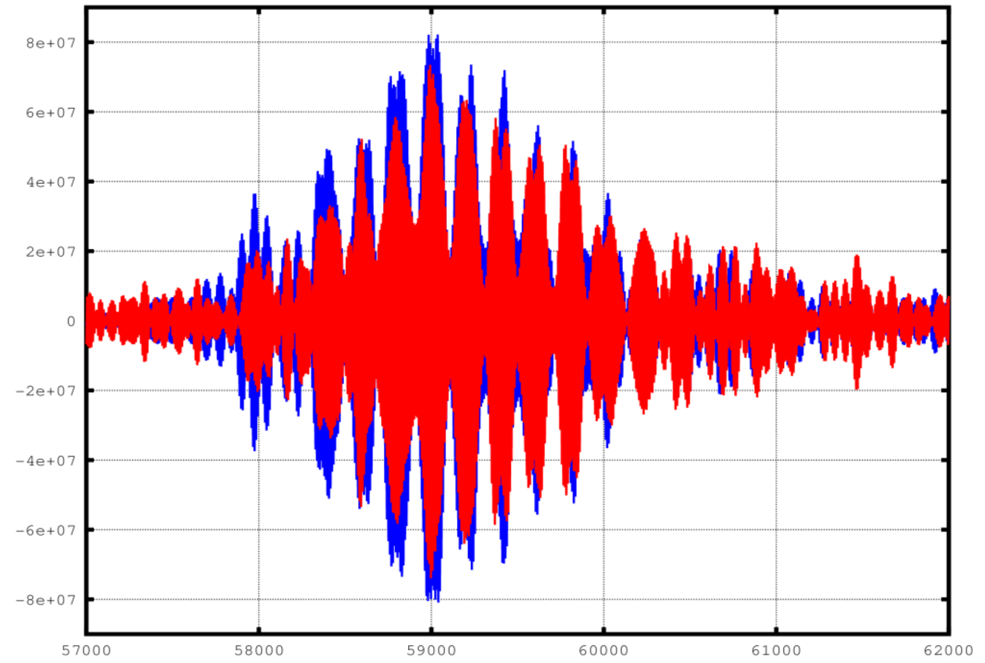
Top : Spectrum response of the can with the sensors inside.

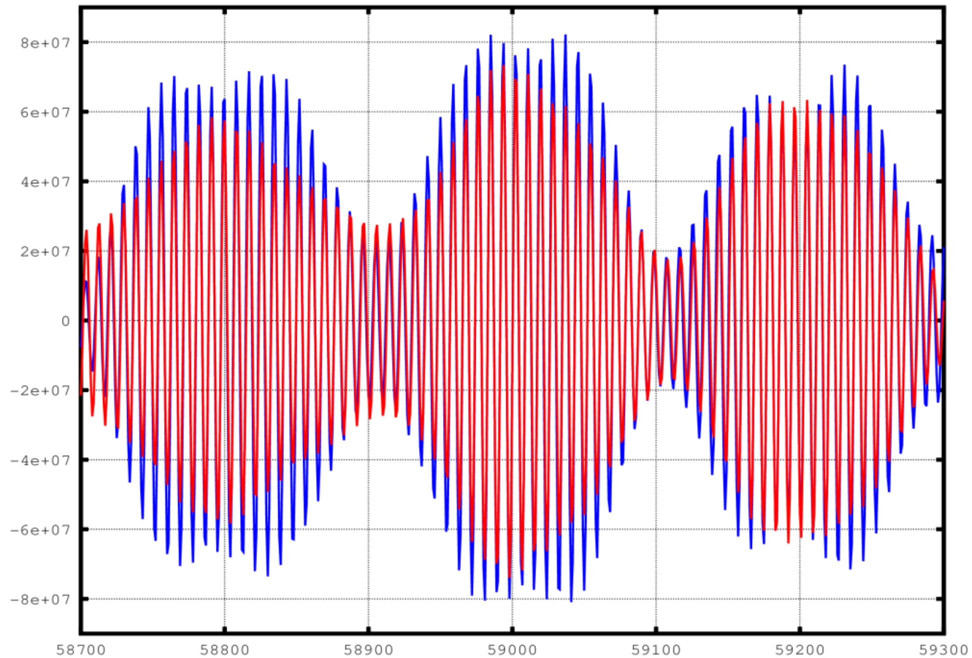
Left : sensor response, compressed pulses are noisy but they are still identifiable.

Reflective environment :

-In red the first echo is superimposed on the second echo in blue.

-In a reflective environment even if the pulses are distorted, it remains the same and therefore the cross-correlation technique can be applied.





Top : Red the first compressed pulse, blue the second compressed pulse.

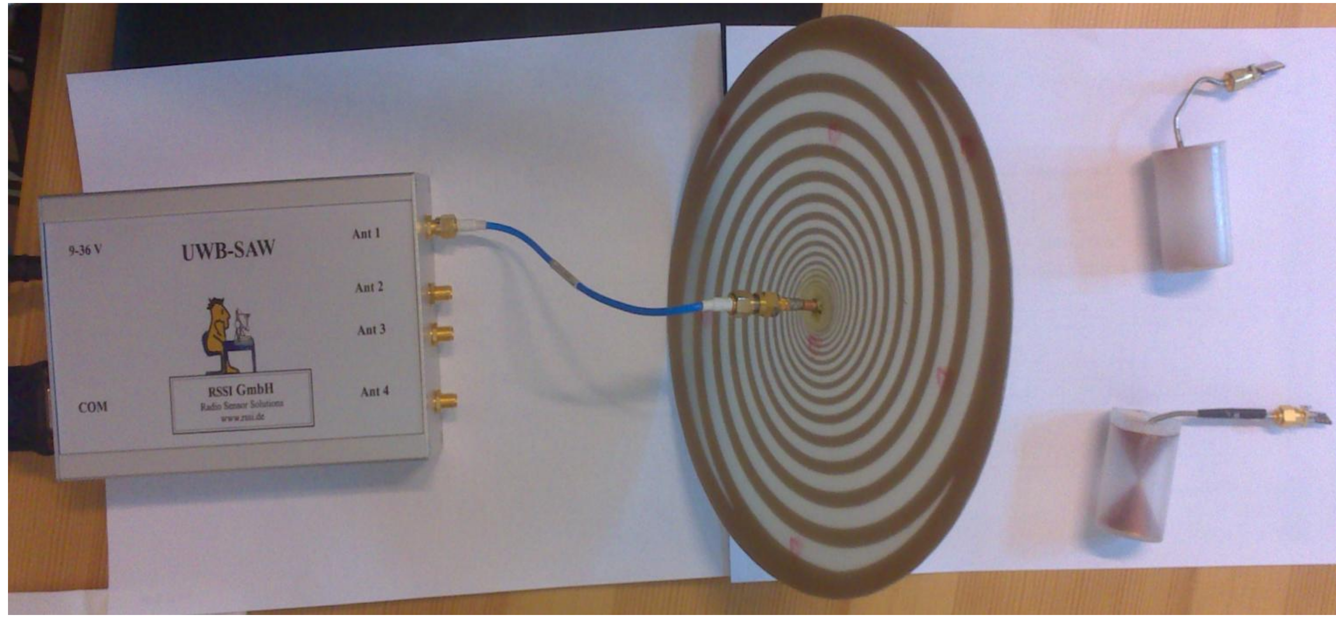
Left : the pulse are superimposed using the algorithm described in the previous section.

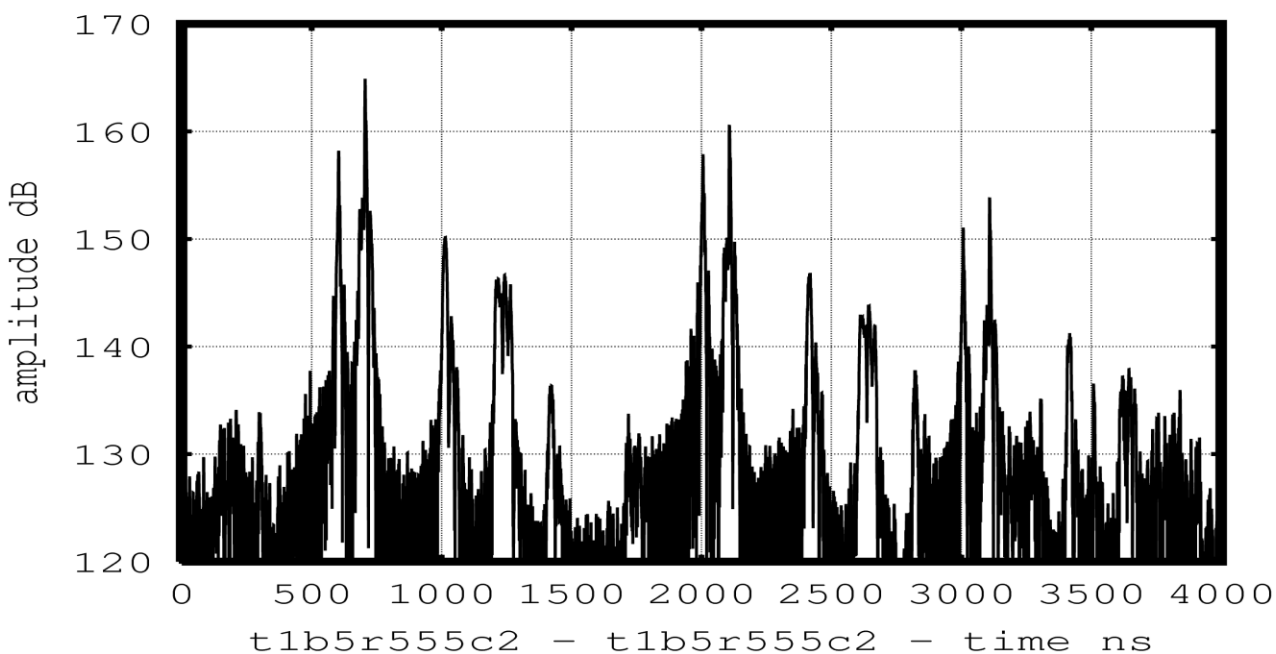
Remote measurement :

- Each frequency are read separately.

-Two UWB LFM sensors are measure in the same time.

-There is no colision algorithm, Sensors responses are simply separate in time domain.





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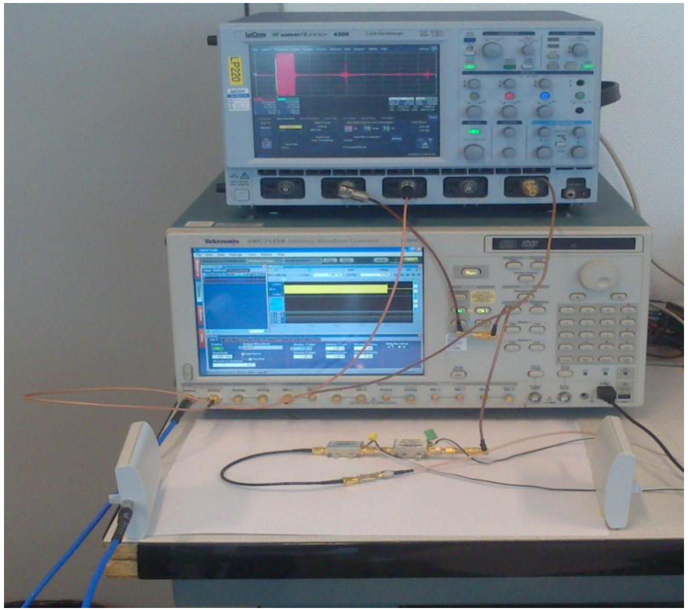
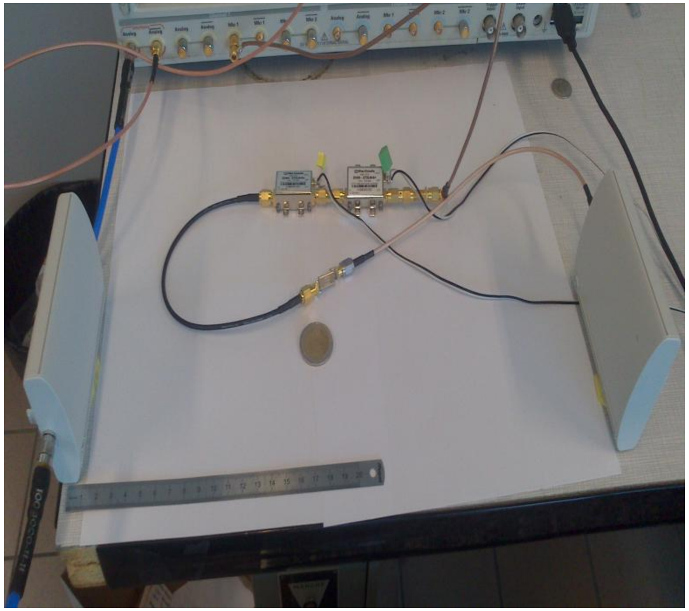
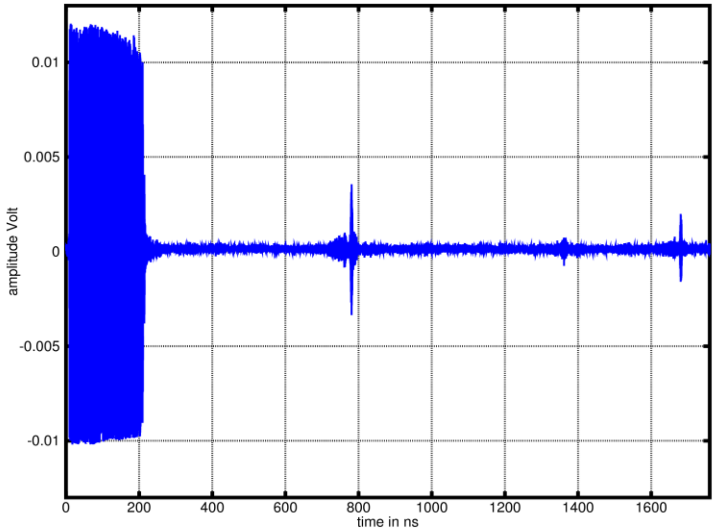
Remote measurement :

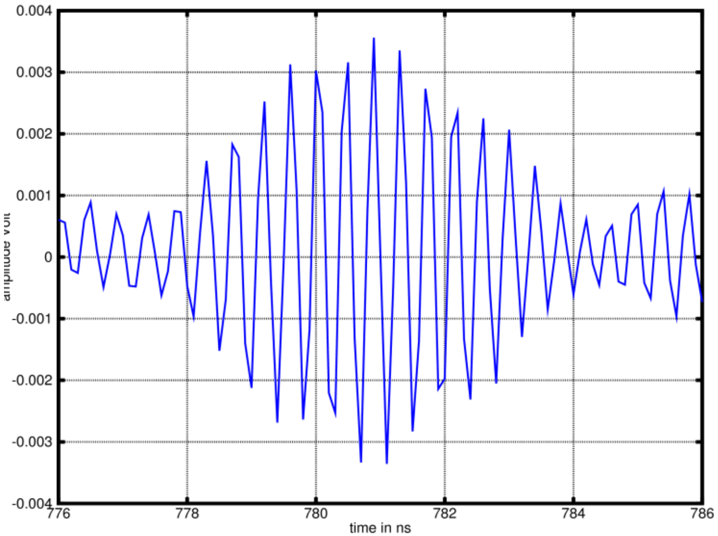




-Transmission measurement directly using time reversal technique as interrogation signal.

This techinque use the transducer gain B*T.





Conclusion :

- The prototype have validated the technique of narrow compressed signals.

- For SAW-tags, extremely narrow compressed signals open possibility of radical increase of the code capacitance and radical reduction of chip size of the device.

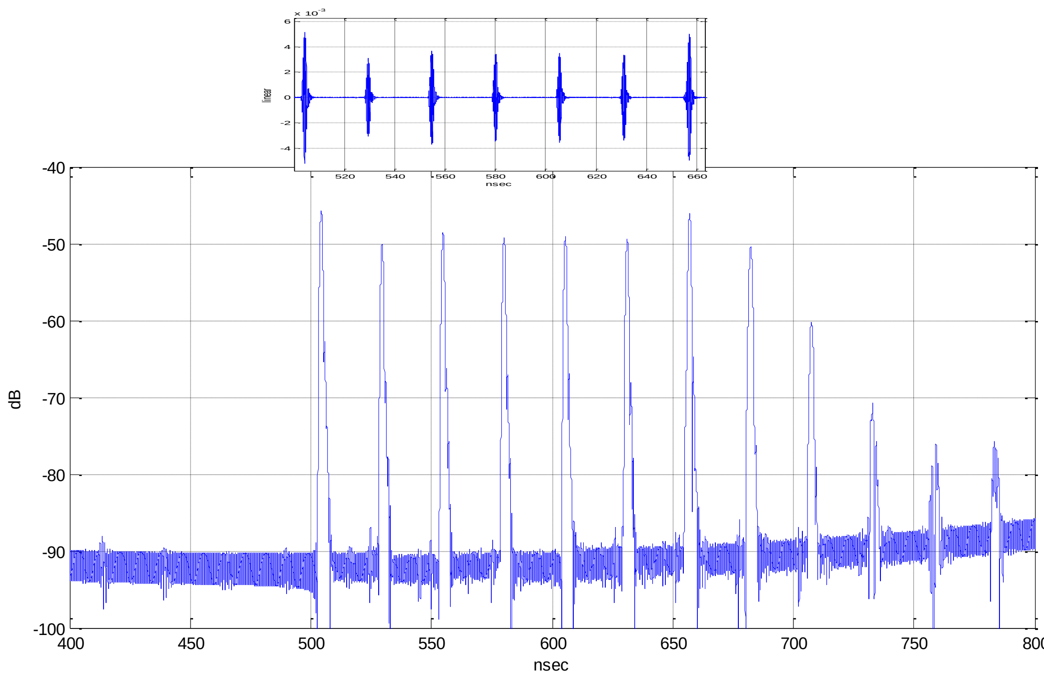
-The SAW-tags measured temperature with an accuracy of 0,2° C.

-This work allows us to better understand the processing signal with LFM transducer.

_The main part of the work has been done in frames of SAWTAG project , "Chaires d'excellence,2010-2012" , ANR, France

6GHz SAW tags

1. Frequency range 5650MHz-6425MHz , B=750 MHz, is available in some countries. In Russia the power of transmitter can up to1 Watt and antenna gain factor +23dB.The operation radius up to 20 km is permitted
2. The propagation loss strongly increases , proportional to f^2 , but the size decreases. Finally the increase of loss can be not so dramatic.



Layout, Chip 2.0 x 0.94 mm2
Pitch = 0.313μm for Al electrodes
Loss < 50dB