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Lyon 1

Detection of Deeply-Implanted Impedance-Switching Devices Using Ultrasound Doppler

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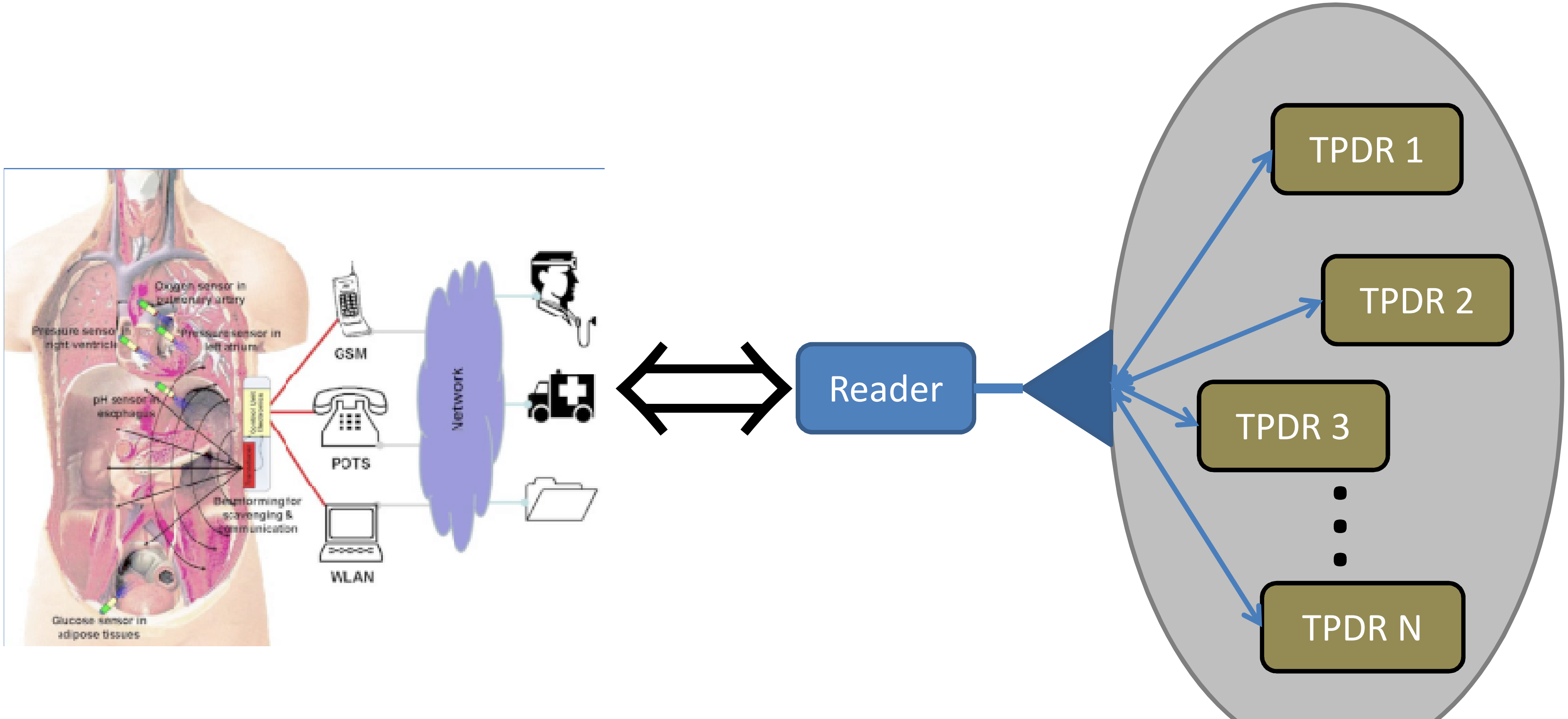
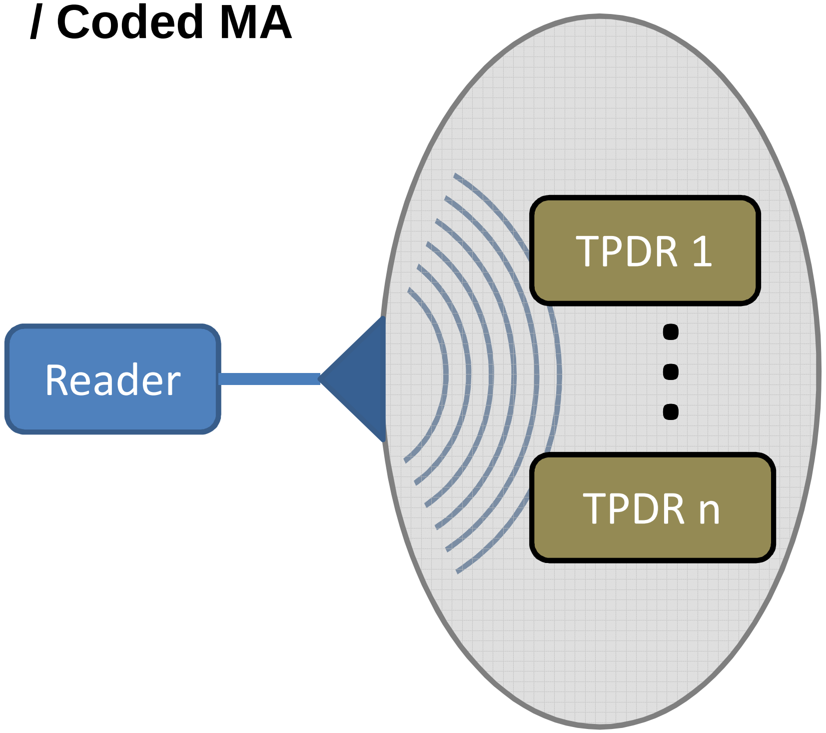
Ultrasponders and Multiple Access



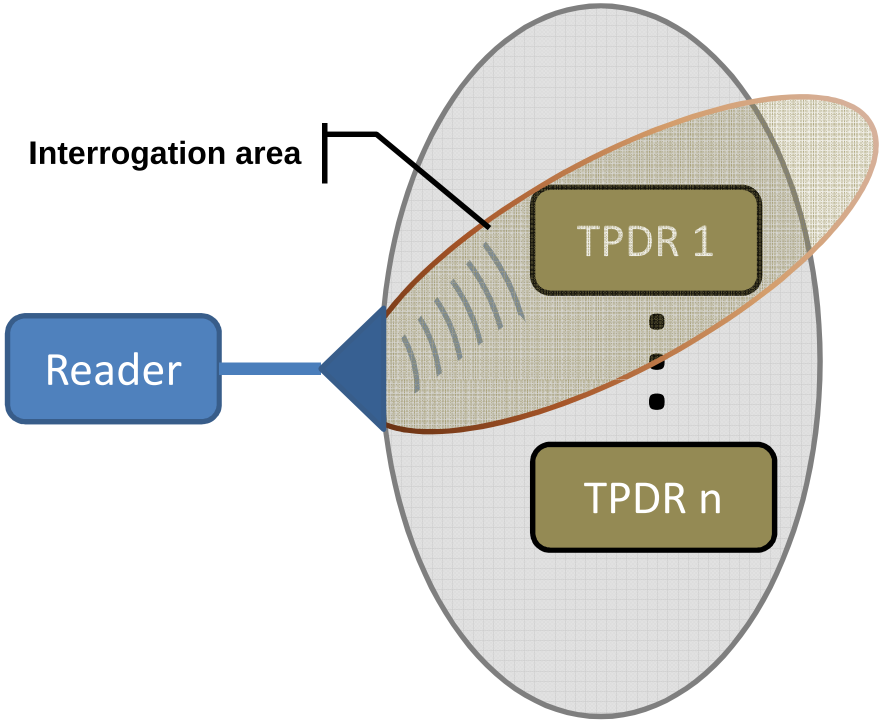
► ultimately using multiple transponders is a must.
► it implies performing RFID multiple access.
► 2 MA procedures compatible with the Ultrasponder approaches

Ultrasponder TX/RX options

→ **unfocused: Time Domain MA / Coded MA**



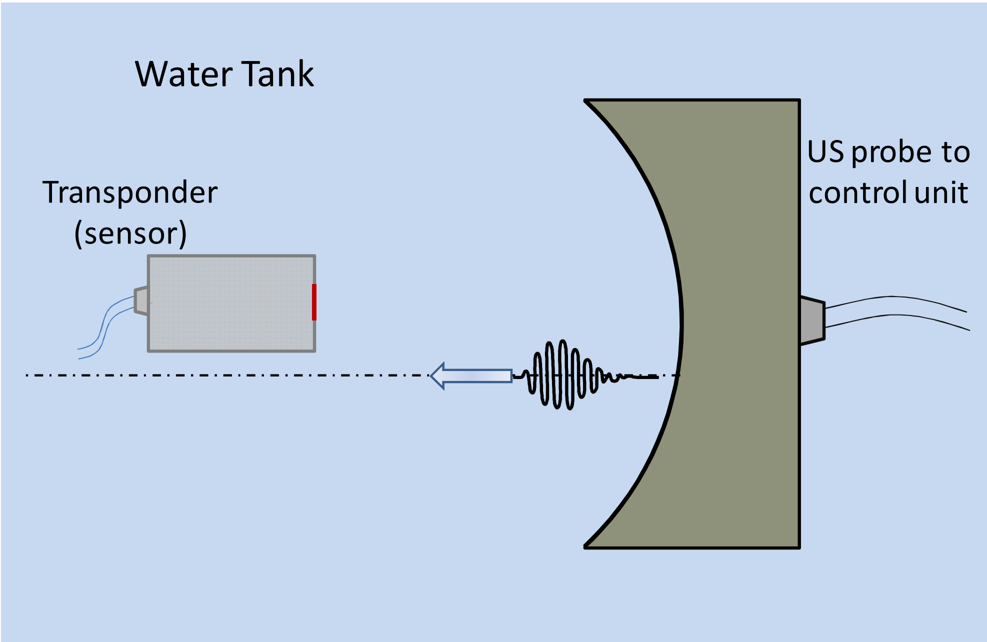
→ **directive: Space Division MA**



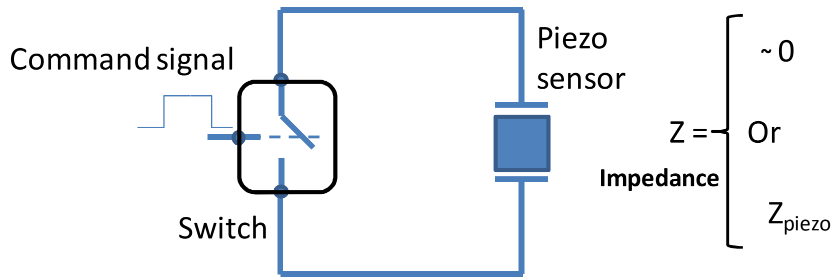
- ▶ TDMA/Coded sequences require heavier TPDR computational load.
- ▶ beam steering is natural to ultrasound imaging.
- ▶ SDMA requires scanning space with changing interrogation area.
- ▶ transponder may move.
- ▶ how to help discriminate the transponder positions from background?

Impedance switching and ultrasound

Ultrasponder communication principle based on passive impedance switching



Impedance switching:



The transponder selectively scatters ultrasound by changing the impedance of its piezo sensor.

- ► the probe can perform imaging of the search area
- ► the impedance switching is specific to the transponder.
- ► it is a discriminating criteria.
- ► how to image the flashing aspect of the transponder?
- ► idea = perform Doppler imaging

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Outline

I. **Imaging and Doppler of an impedance switching device.**

II. **Acquisitions and results**

III. **Conclusion**

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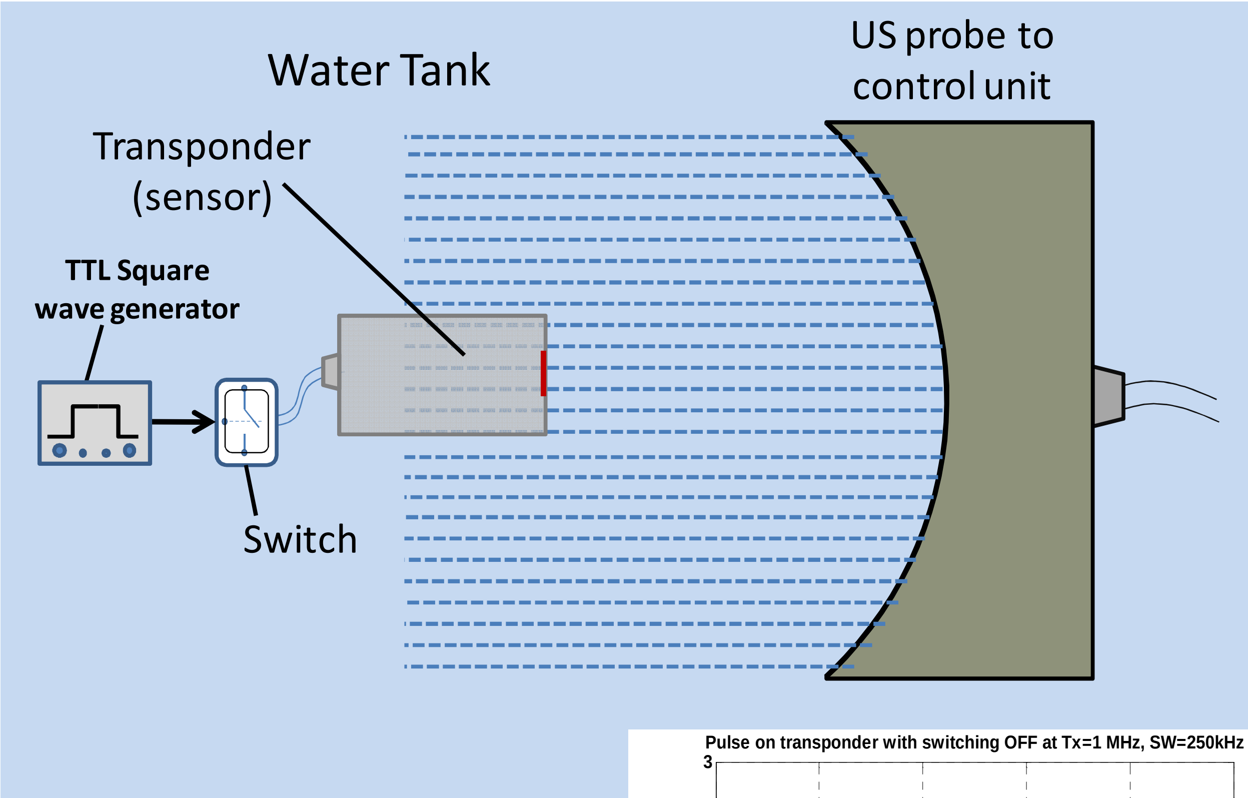
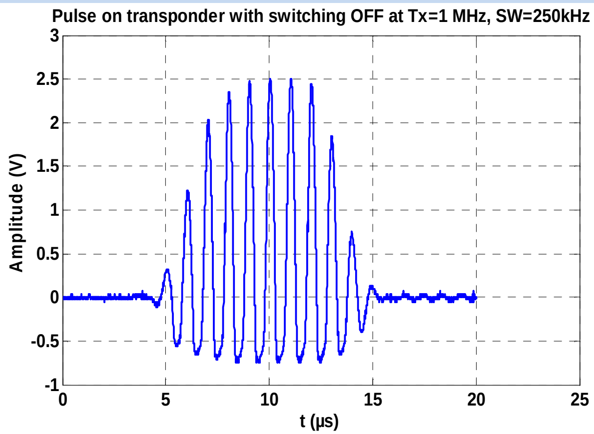
Imaging and Doppler of an impedance switching device.

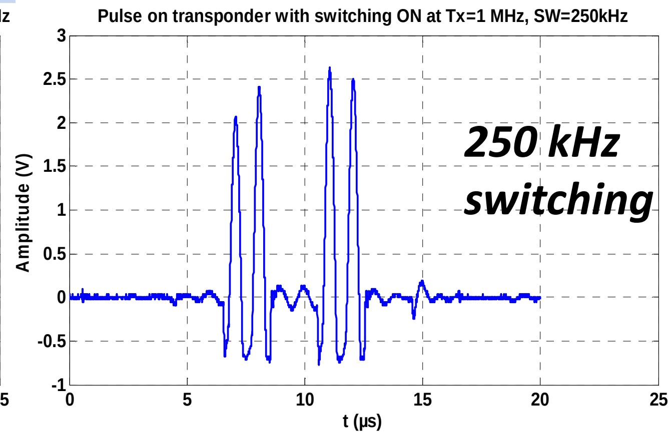


Piloted with an Ulrasonix RP 500 programmable scanner

Programming through MatlabTexo library

- T97 probe
- *64 elements*
- concave (*11 cm* radius)
- *1 MHz* (harmonics *3 &5 MHz)*
- *64 B-mode lines*
- *8* repeats of each line
- PRF fixed at 4.412 kHz





Why would it show on Doppler image?

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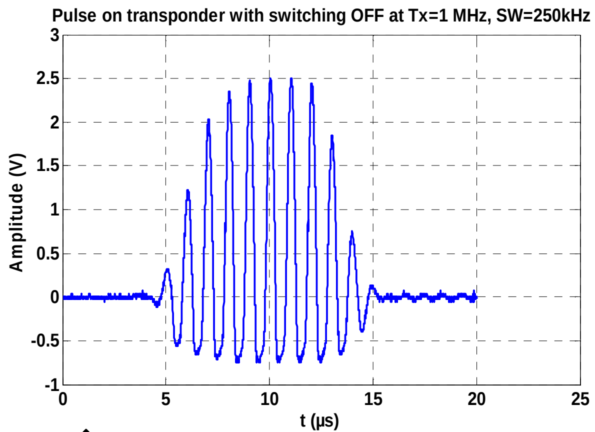
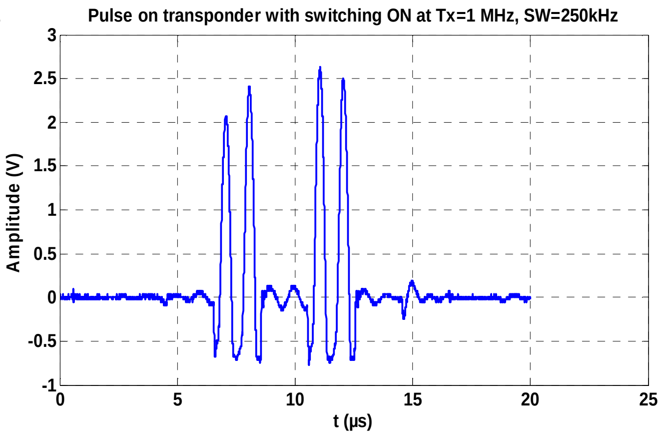
Imaging and Doppler of an impedance switching device.

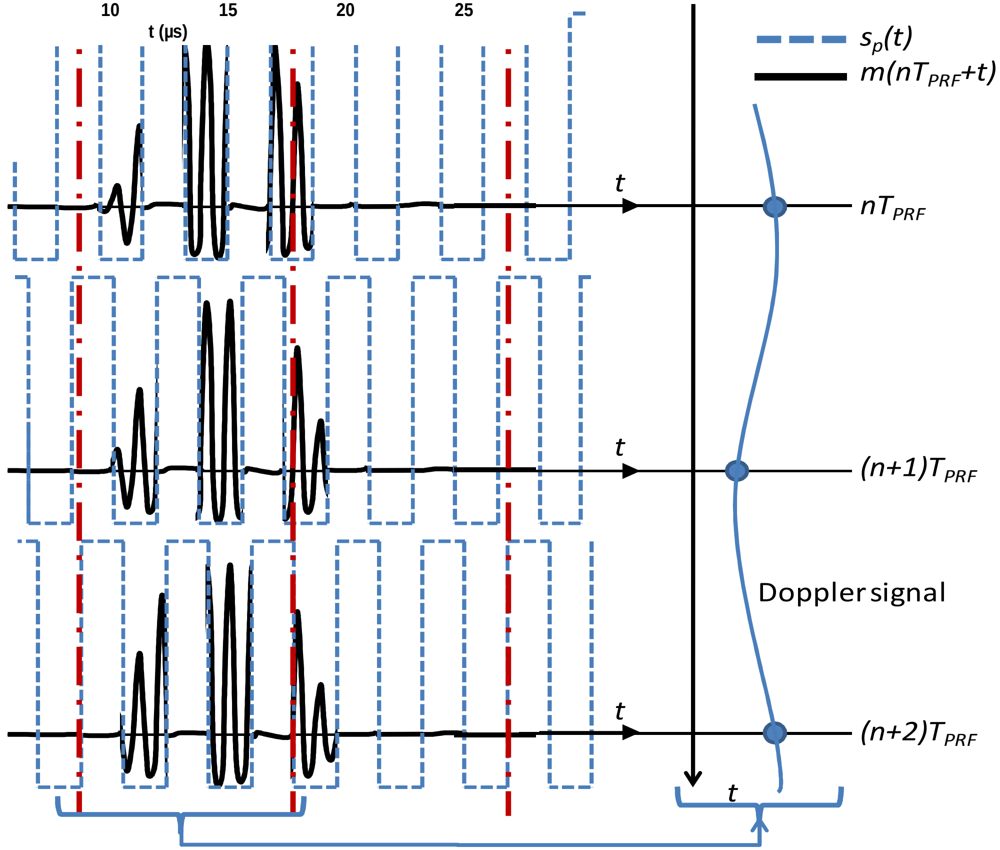




- **Switching alters the scattered pulse**
- **But switching is asynchroneous**

↑ 250 kHz switching of the transponder impedance measured on a scope

Successive observation of the same RF line ➔

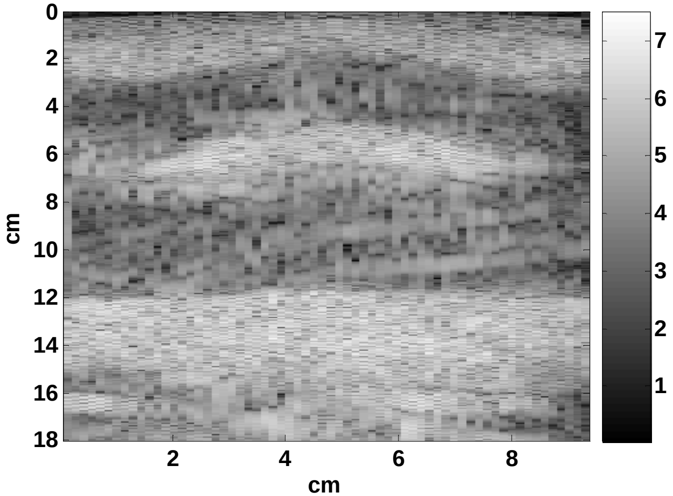


- **the non synchonicity varies the backscattered signal through time.**
- **it generates a Doppler signature.**
- **but the non synchonicity implies a varying apparent velocity.**
- **the amplitude of the Doppler signal is more reliable.**

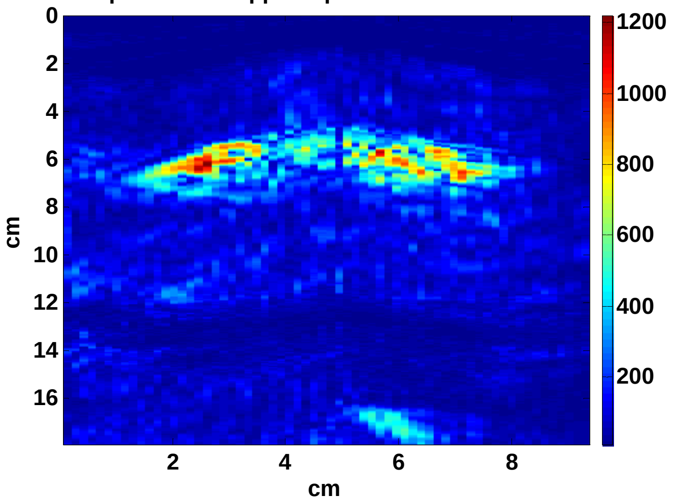
Acquisitions and results

Tests at different frequencies:

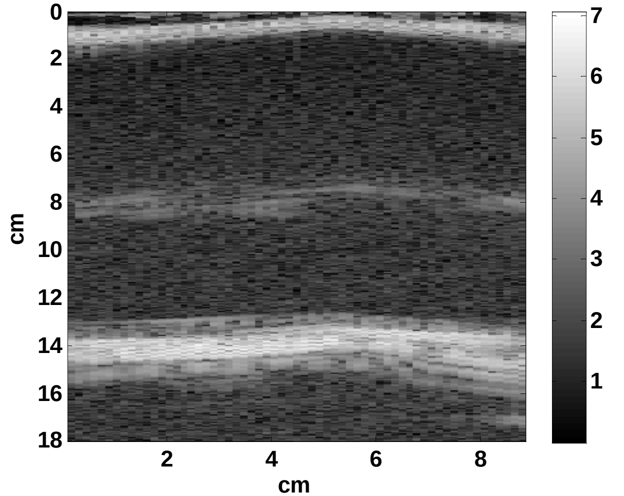
1 MHz

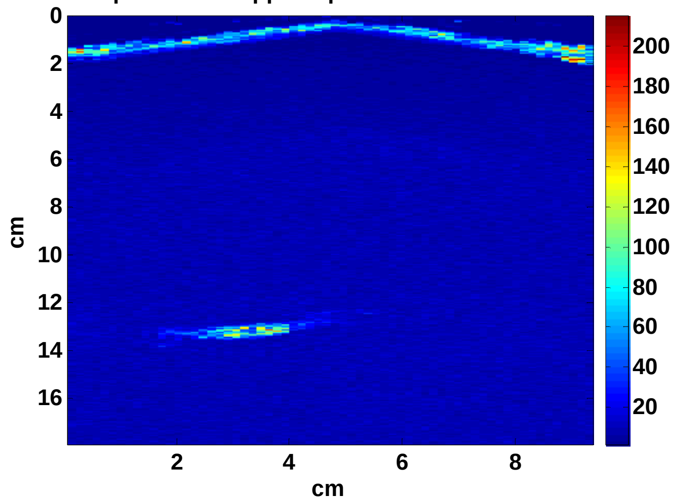


Amplitude of Spectral Doppler spectrum



5 MHz

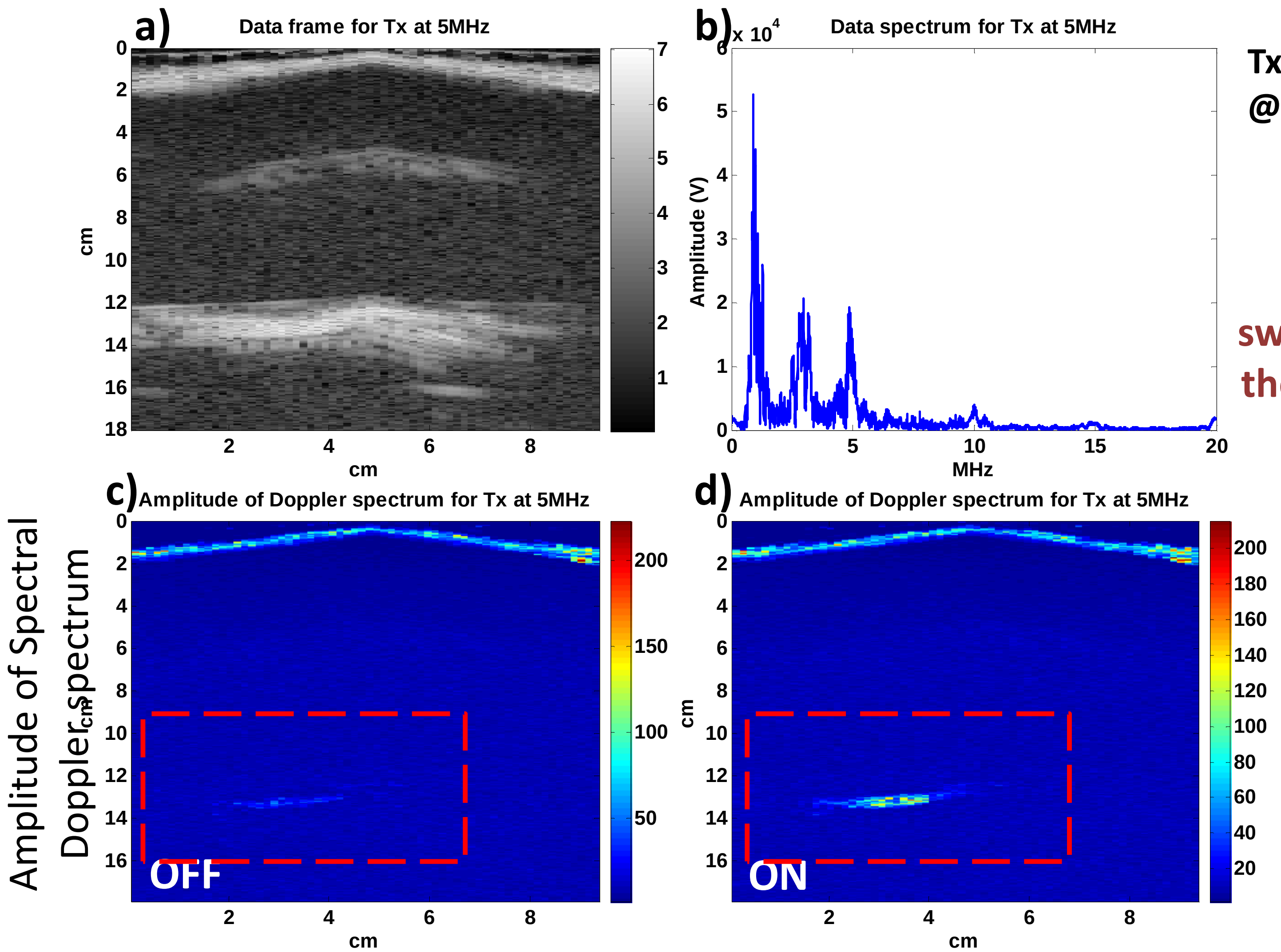




Too much reverberation at 1 MHz → work @ 5 MHz

Acquisitions and results

Complete example at 5 MHz:



Tx @ 5 MHz and switching *@ 250 kHz*

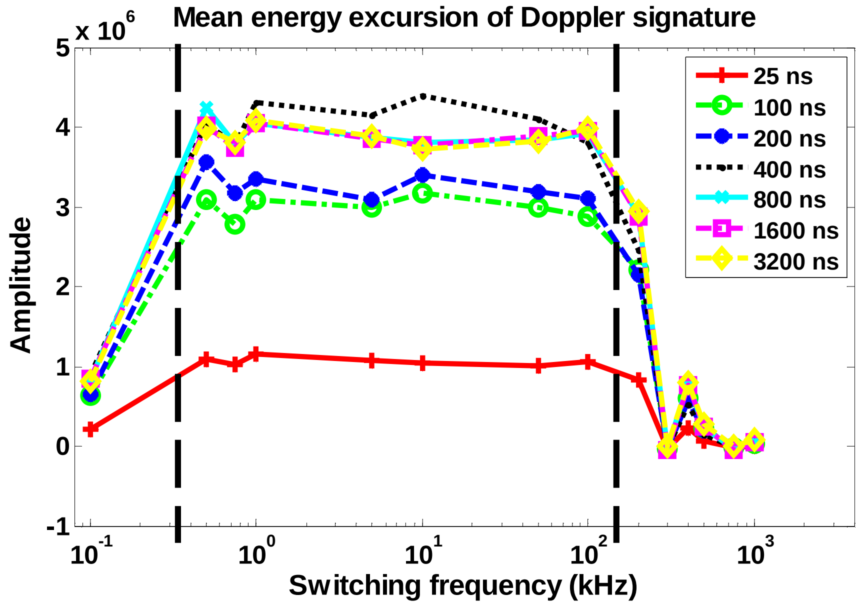
The impedance switching clearly makes the transponder visible

What are the appropriate transmission parameters to improve visibility ?
(excitation length ? Switching frequency ?)

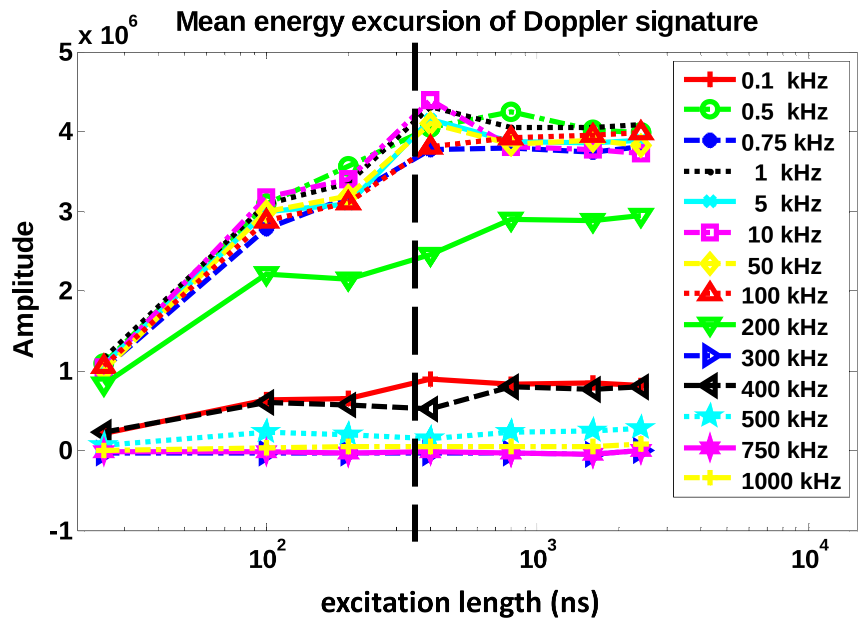
Acquisitions and results

Multiple acquisitions :

- excitation length from 25 ns to 3200 ns (min to max possible excitation)
- impedance switching from 100 Hz to 1000 MHz
- Doppler signal by 32 samples @ 40 MHz (400 ns / 616 µm windows)



Excursion is maximum between *500 Hz* and *200 kHz*



***Between 100 Hz* and below *300 kHz*, excursion increases with excitation length up to *400 ns* before marking a plateau**

► If the switching frequency is too small, successive shots image the sensor of the transponder in the same state, which makes the Doppler signal constant.

► If the switching frequency is too high, averaging/masking of several cycles.

► a longer pulse, up to Doppler window length, increases the Doppler amplitude.

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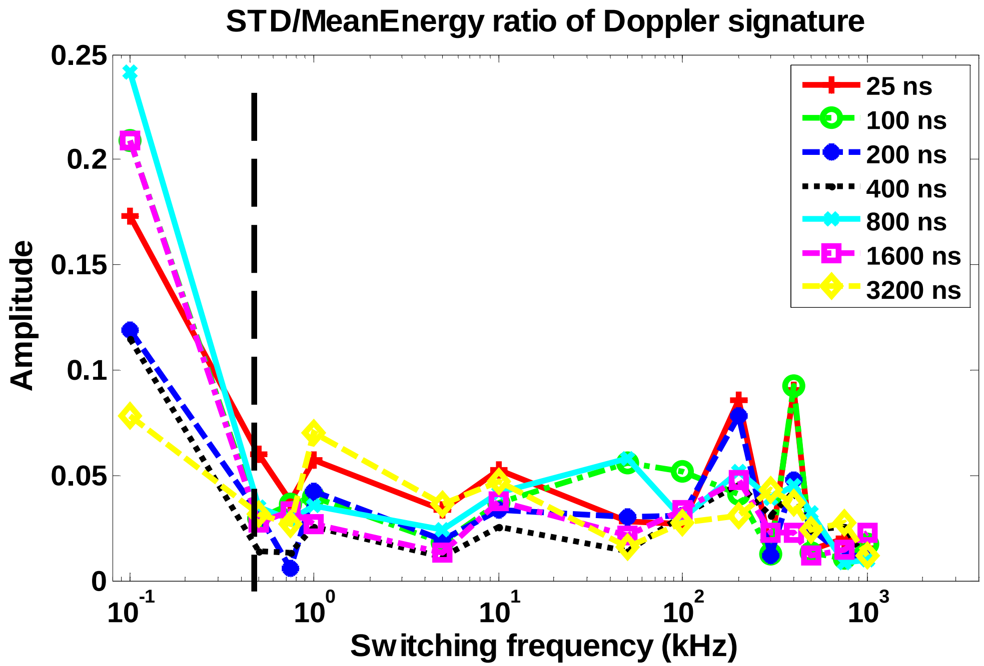
Acquisitions and results

Repeatability :

- over 5 repeats for each point.



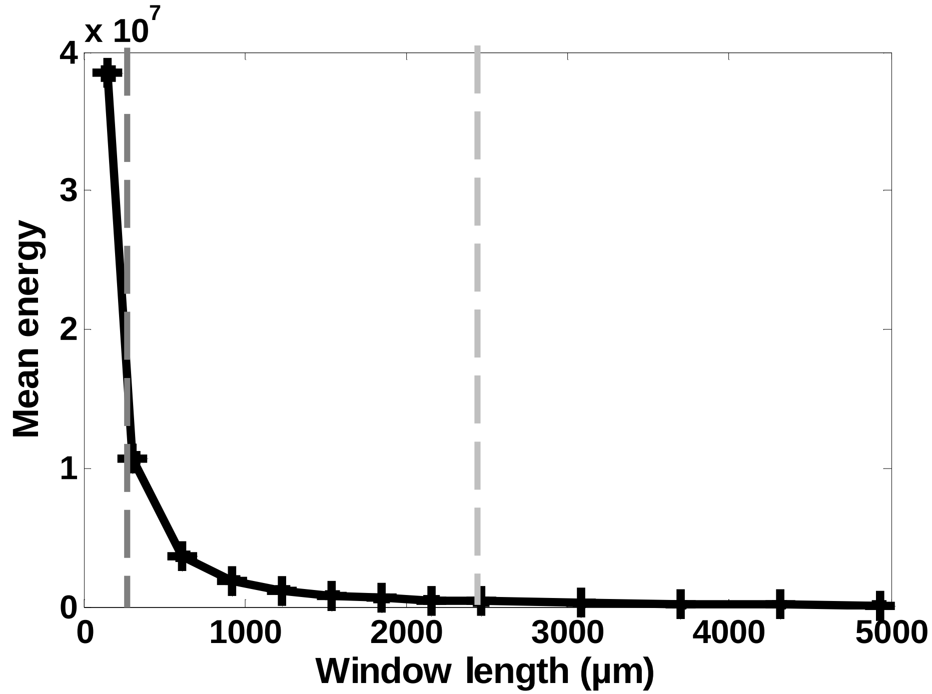
► too low/too high switching frequency reduces the repeatability

► above 0.5 kHz, the relative dispersion remains around 5 % and below 10 %

Acquisitions and results

Impact of Doppler settings (window size) :

- window size from 100 µm to 5000 µm
- switching frequency of 200 kHz
- excitation length of 1600 ns (2500 µm)

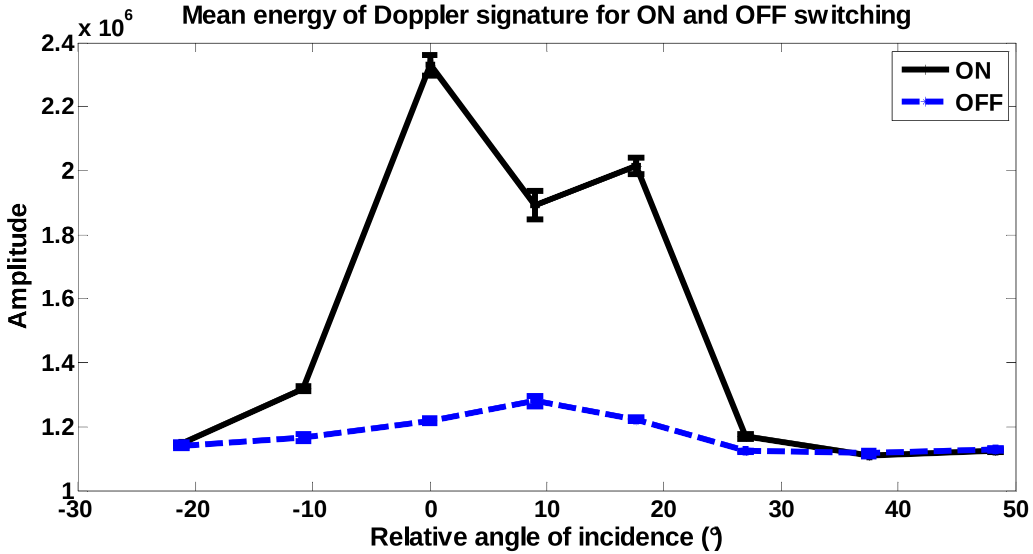


► longer windows average more cycles, decrease the Doppler signal, and thus reduce the ability to distinguish the transponder.
► smaller windows increase Doppler amplitude, but increases the sensitivity to noise and computational cost.

Acquisitions and results

Impact of incidence angle :

- switching @ 100 kHz
- 1600 ns excitation
- 5 repeats



▶ON amplitudes above the *OFF* amplitudes between *-10°* and *24°*

▶ range of ≈ *34°*

Conclusion

- A SDMA approach is explored for facilitating the transponders detection
- Ultrasound colour Doppler sequence is implemented for a custom probe imaging at *5 MHz*
- RF data are collected for different excitation lengths, flashing frequencies and incidence angles.
- Results shows that detection is optimum when
  - Spectral Doppler window is smaller
  - excitation approaches window size
  - switching frequency is in the range of *0.5 kHz* and *200 kHz*
- the device can be detected over an angle window of around *34°*.
- Doppler facilitates the detection but is not a final solution
- detection process requires advanced image processing.
- Still it allows a fast localization of – possibly multiple – TRPDs which does not require exchange of ID data (simplified transmission protocol) and random energy transmission.

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