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

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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

- 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

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

I. Imaging and Doppler of an impedance switching device.

II. Acquisitions and results

III. Conclusion
Imaging and Doppler of an impedance switching device.

- 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?
Imaging and Doppler of an impedance switching device.

- Switching alters the scattered pulse
- But switching is asynchronuous

250 kHz switching of the transponder impedance measured on a scope

Successive observation of the same RF line

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

Tests at different frequencies:

**1 MHz**

Data frame for Tx at 1 MHz

Amplitude of Doppler spectrum for Tx at 1 MHz

**5 MHz**

Data frame for Tx at 5 MHz

Amplitude of Doppler spectrum for Tx at 5 MHz

Too much reverberation at 1 MHz → work @ 5 MHz
Acquisitions and results

Complete example at 5 MHz:

The impedance switching clearly makes the transponder visible

Tx @ 5 MHz and switching @ 250 kHz

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

- 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.

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.
Impact of incidence angle:
- switching @ 100 kHz
- 1600 ns excitation
- 5 repeats

\[ \text{ON amplitudes above the OFF amplitudes between } -10^\circ \text{ and } 24^\circ \]
\[ \text{range of } \approx 34^\circ \]
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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