Identification of Chipless Sensors in Cluttered Environments
From 3D Radar Imagery and Polarimetry

D. Henry¹, T. Marchal¹, J. Philippe¹, P. Pons¹ and H. Aubert¹

¹LAAS-CNRS, Université de Toulouse, CNRS, INPT, Toulouse, France
Objective: measuring physical quantities wirelessly in electromagnetic reflective or harsh environment.

- Chipless (zero-power) sensors are good candidates. [1]
- An estimation of the pressure was remotely performed using polarization diversity [2]

Is it possible to mitigate the clutter identify sensor radar echoes and in such environment?

Outline

- Interrogation principle
- The chipless pressure transducers
- Identification algorithm
- Electromagnetic footprint of the sensors
- Conclusion and perspectives
Outline

- Interrogation principle
  - The chipless pressure transducers
  - Identification algorithm
  - Electromagnetic footprint of the sensors
  - Conclusion and perspectives
Interrogation principle
Interrogation principle

- **The reader:**
  - Microwave FM-CW radar
  - Carrier frequency: 23.8 GHz
  - Modulation bandwidth: 2 GHz
  - Depth resolution: 7.5 cm
  - Transmitted power: 10 mW
Interrogation principle

- Multi-sensing:
- Several chipless sensors are located in the scene
- They might be different depending on the application
- Here: two chipless pressure transducers are interrogated
Interrogation principle

- **3D beamscanning and 3D imaging:**
- Directive Tx antenna: $\theta_A = 6^\circ$, $G=28\text{dBi}$
- Mechanical sweep in azimuth ($\varphi$) and elevation ($\theta$)

- Position of the sensors: $\varphi, \theta, R$
Interrogation principle

- Polarimetry
- Using cross-polarization for increasing the SNR

- (H) : horizontally polarized electric field
- (V) : vertically polarized electric field
### Interrogation principle

- **Polarimetry**
- Using cross-polarization for increasing the SNR
- (H) : horizontally polarized electric field
- (V) : vertically polarized electric field

#### Sensing mode position

<table>
<thead>
<tr>
<th>Polarization of the radar Rx antenna</th>
<th>Polarization of the Tx radar antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-pol</td>
<td>V-pol</td>
</tr>
<tr>
<td>H-pol</td>
<td>H-pol</td>
</tr>
<tr>
<td>V-pol</td>
<td>VV ( R+L_1 )</td>
</tr>
<tr>
<td></td>
<td>HV ( R+(L_1+L_2)/2 )</td>
</tr>
<tr>
<td>H-pol</td>
<td>VH ( R+(L_2+L_1)/2 )</td>
</tr>
<tr>
<td></td>
<td>HH ( R+L_1 )</td>
</tr>
</tbody>
</table>
Outline

- Interrogation principle
- The chipless pressure transducers
- Identification algorithm
- Electromagnetic footprint of the sensors
- Conclusion and perspectives
The chipless pressure transducers

Two chipless pressure transducers are interrogated

Outline

- Interrogation principle
- The chipless pressure transducers
- Identification algorithm
- Electromagnetic footprint of the sensors
- Conclusion and perspectives
Identification algorithm

- (i) raw data acquisition
- (ii) beat frequency spectra
- (iii) 3D reconstruction
- (iv) isolines computation (line along which the echo level is the same) [3]
- (v) isolines indexation
- (vi) intersection of isolines for clutter mitigation
- (vii) identification from electromagnetic footprint

Outline

- Interrogation principle
- The chipless pressure transducers
- Identification algorithm
- Electromagnetic footprint of the sensors
- Conclusions and perspectives
Electromagnetic footprint of the sensors

Number of isolines (radar echoes)

\[ \Lambda_{VV} = 0.0051 \]
\[ \Lambda_{VH} = 0.030 \]
\[ \Lambda_{HV} = 0.027 \]
\[ \Lambda_{HH} = 0.0056 \]

\[ e_{\text{max}} : \text{maximal echo level inside the isoline} \]

\[ \Lambda_p = \frac{N_{\text{sensors},p}}{N_{\text{sensors},p} + N_{\text{clutter},p}} \]

- \( N_{\text{sensors}} \): number of isolines generated by the sensors
- \( N_{\text{clutter}} \): number of isolines generated by the clutter

\( p \): polarization configuration

Sensor 1 | Sensor 2 | Clutter
Electromagnetic footprint of the sensors

Magnitude parameters

![Graphs showing electromagnetic footprint of sensors.](image)
Electromagnetic footprint of the sensors

Geometrical parameters

\[
g_{\pi/2}^p = \frac{\mathcal{A}(\mathcal{C}_p \cap \mathcal{C}_{\pi/2}^p)}{\mathcal{A}(\mathcal{C}_p)}
\]

\[
g_S = \frac{\mathcal{A}(\mathcal{C}_{\mathcal{VH}})}{\mathcal{A}(\mathcal{C}_{\mathcal{VH}}) + \mathcal{A}(\mathcal{C}_{\mathcal{HV}})}
\]
Electromagnetic footprint of the sensors

Applied pressure varying between 0 bar and bar.

Identification map

Zoom

Sensor 1

Sensor 2

x : clutter
Conclusion

- Two chipless sensors have been identified wirelessly in a reflective environment.
- The clutter can be mitigated and sensors can be identified by defining specific electromagnetic footprints based on magnitude and geometrical parameters of radar echoes.
- Cross-polarization configuration increases the SNR and facilitates the identification of the chipless sensors.
Conclusion and perspectives

Perspectives

- Classification of radar echoes will be performed to analyze the feasibility of the identification for different scenarii of measurements and at different ranges of interrogation.

Acknowledgment

- Occitanie Region (CARANUC Project) and EDF (Electricité de France) for financial support.