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

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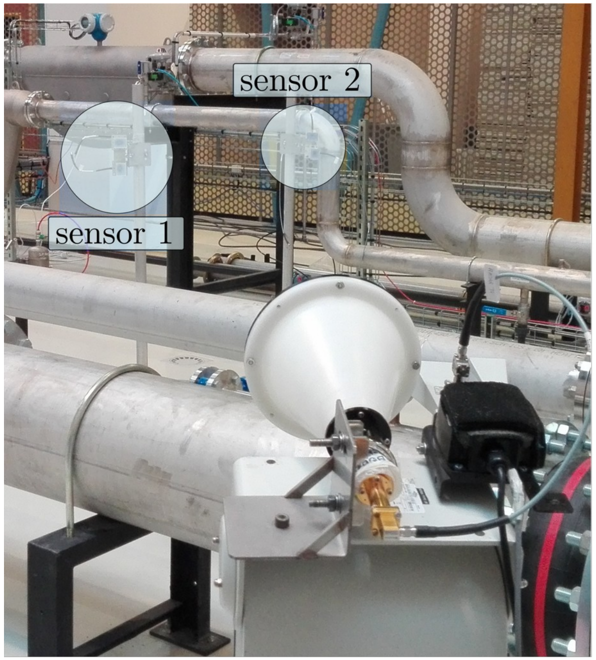
Context



- 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 ?

[1] J. Philippe,et al "In-situ wireless pressure measurement using zero-power packaged microwave sensors," Sensors, vol. 19, no. 6, 2019.
[2] D. Henry et al, "Long-Range Zero-Power Multi-Sensing in Industrial Environment using Polarization Diversity and 3D Radar Imaging ", International Microwave Symposium 2020, to be published.

Outline

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

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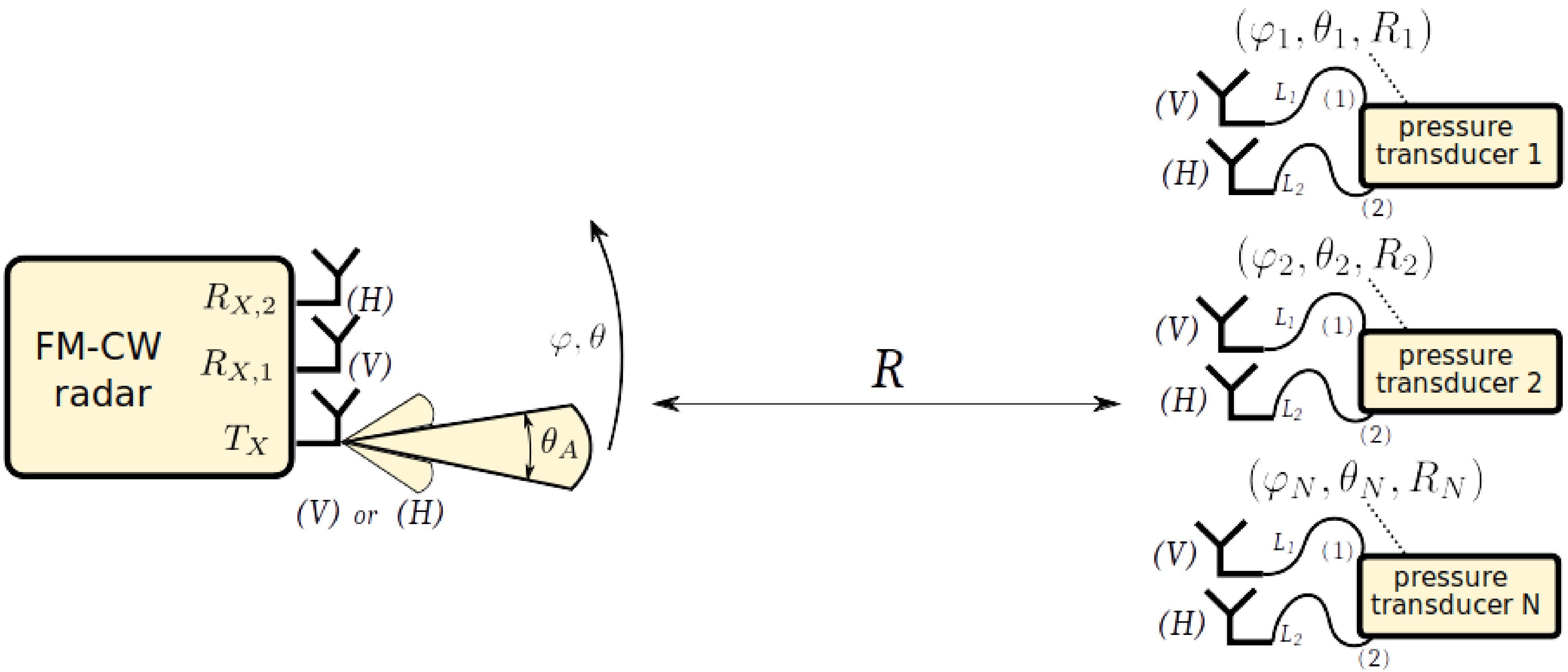
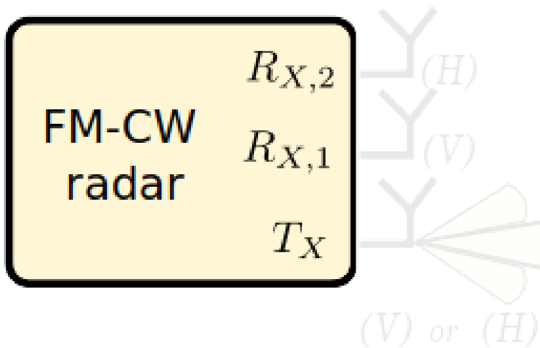
Interrogation principle



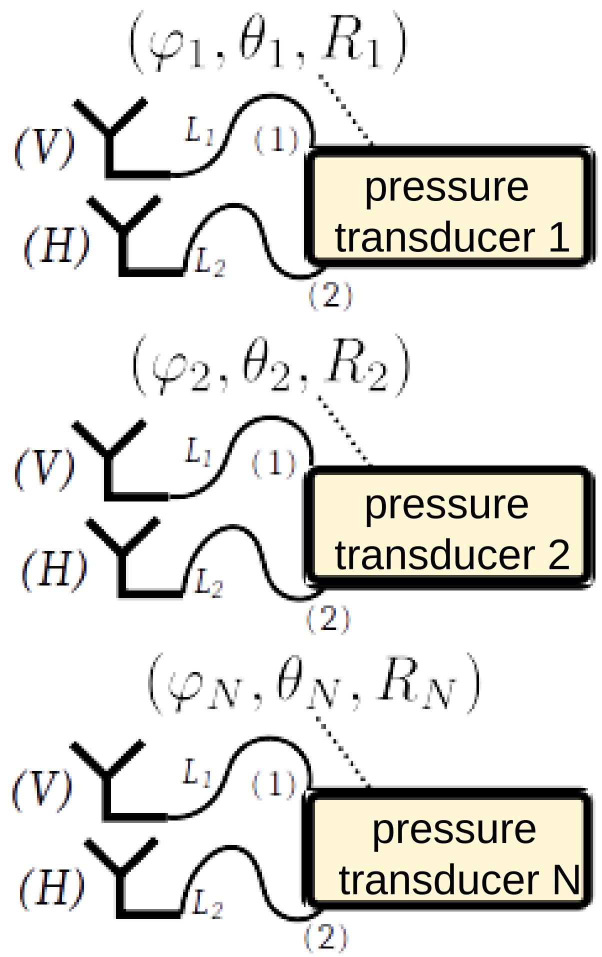
Interrogation principle



- **The reader :**
- Microwave FM-CW radar
- Carrier frequency : 23,8 GHz
- Modulation bandwidth : 2GHz
- Depth resolution : 7,5cm
- Transmitted power : 10mW

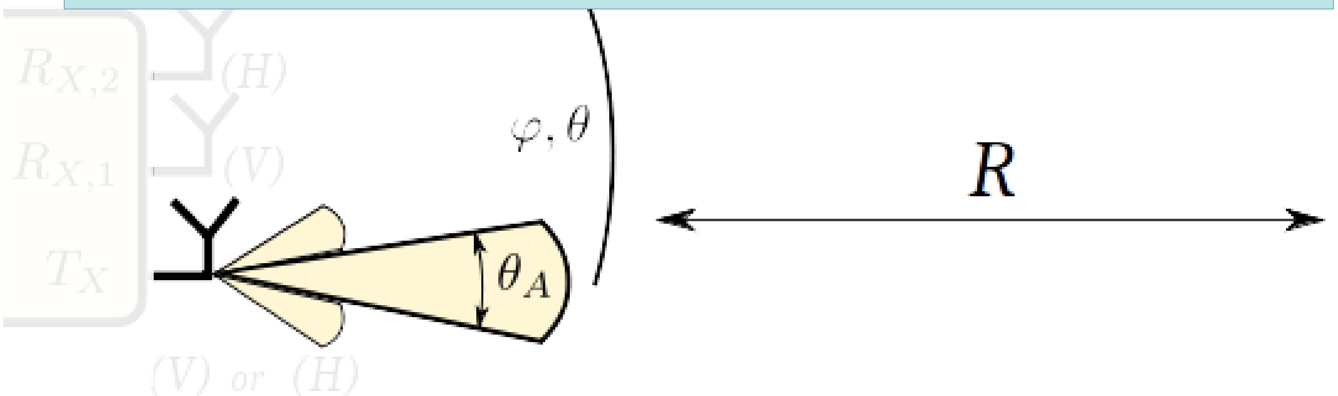
Interrogation principle

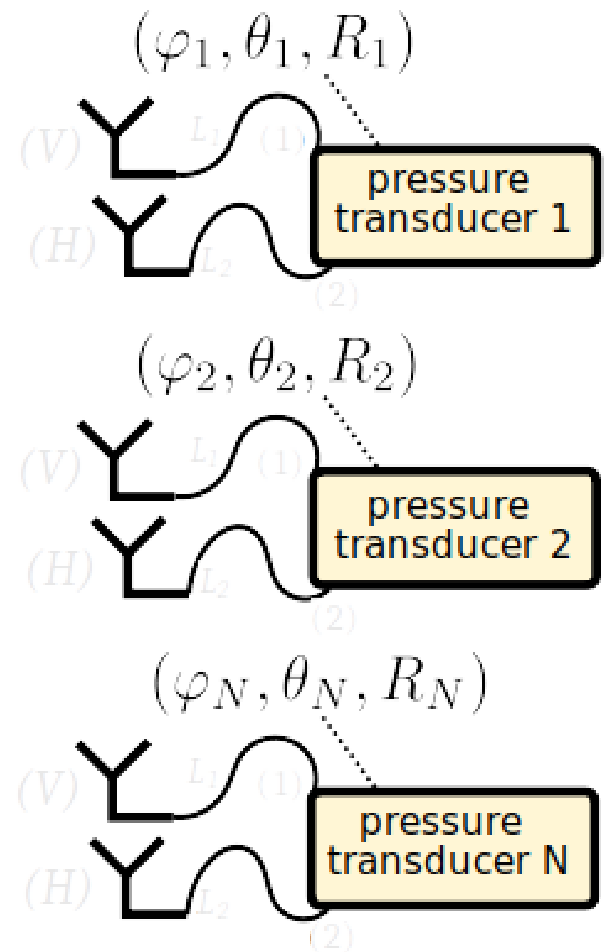
- **Multi-sensing :**
- Several chipless sensors are located in the scene
- They might be different depending on the application
- Here : two chipless pressure transducers are interrogated



Interrogation principle

- **3D beamscanning and 3D imaging:**
- Directive Tx antenna : θ_A=6°, G=28dBi
- Mechanical sweep in azimuth (φ) and elevation (θ)

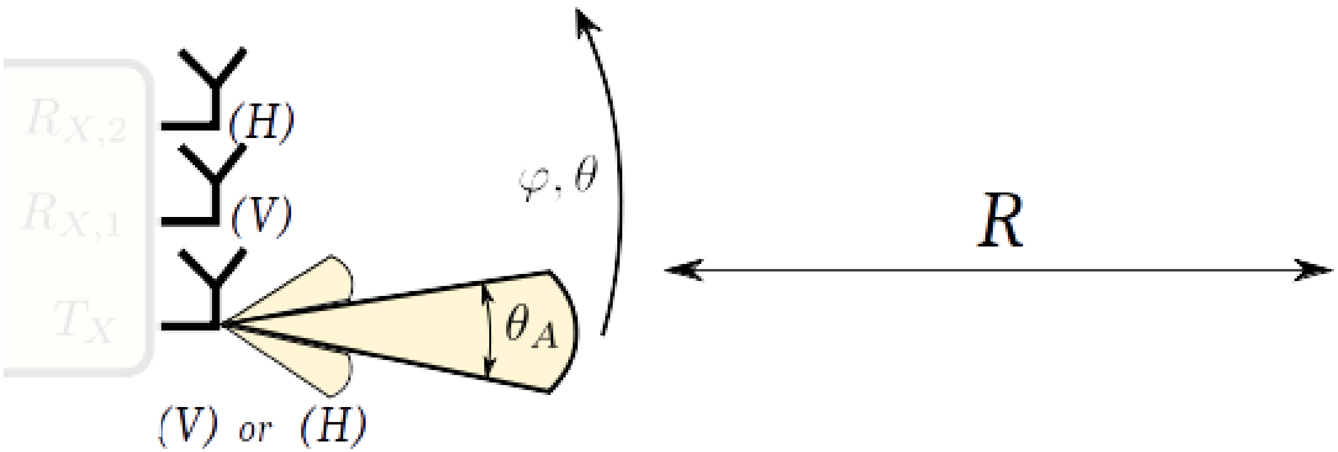


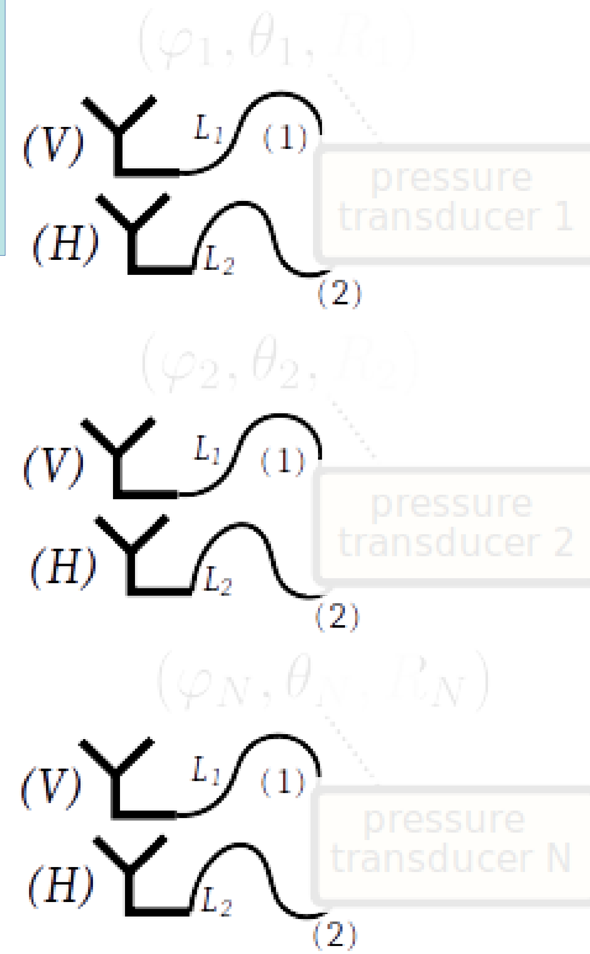


- Position of the sensors : φ,θ,R

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		Polarization of the Tx radar antenna	
		V-pol	H-pol
Polarization of the radar Rx antenna	V-pol	**VV** **R+L1**	**HV** **R+(L1+L2)/2**
	H-pol	**VH** **R+(L2+L1)/2**	**HH** **R+L1**

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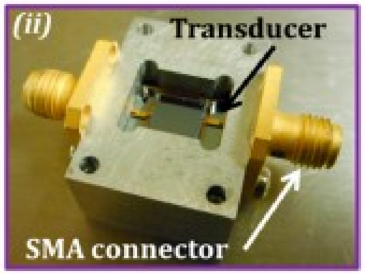
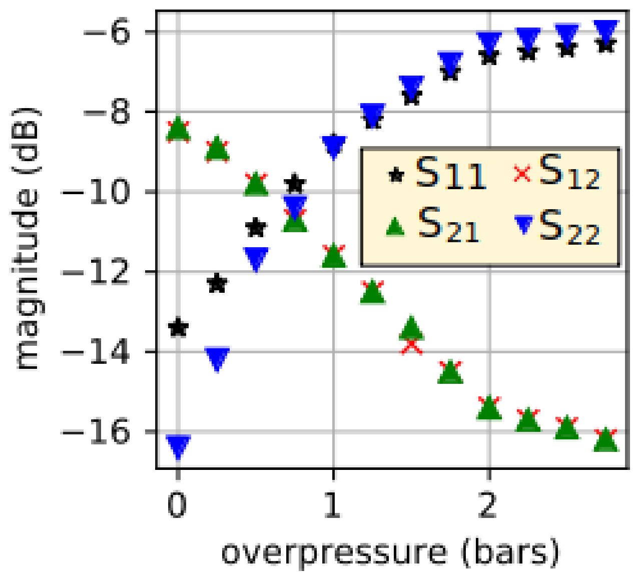
The chipless pressure transducers

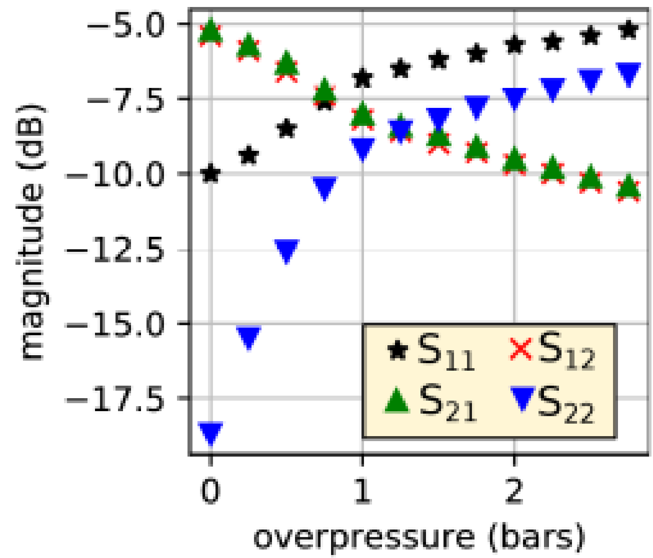
Two chipless pressure transducers are interrogated



sensor 1



sensor 2



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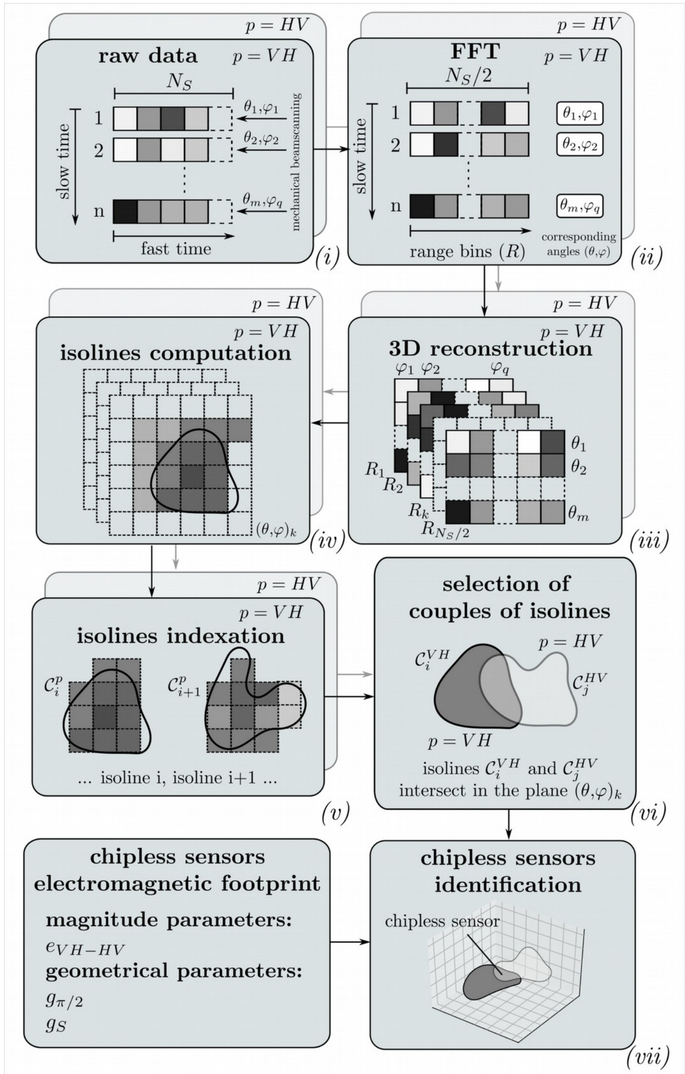
Identification algorithm



- (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

[3] D. Henry and H. Aubert, "Isolines in 3D Radar Images for Remote Sensing Applications," 2019 16th European Radar Conference (EuRAD), PARIS, France, 2019, pp. 69-72.

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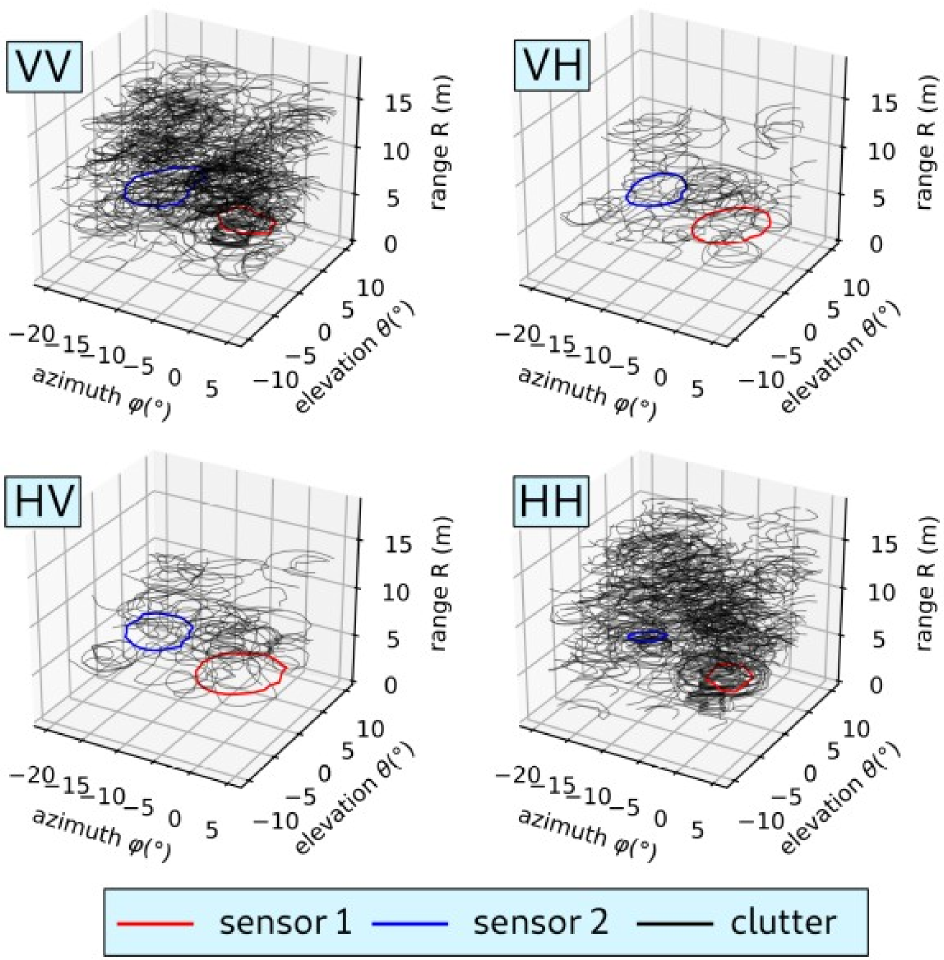
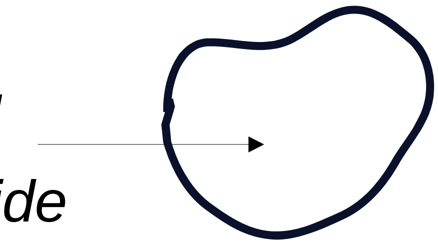
Electromagnetic footprint of the sensors

Number of isolines (radar echoes)



e_{max} : maximal echo level inside the isoline



$$\Lambda_p = \frac{N_{sensors,p}}{N_{sensors,p} + N_{clutter,p}}$$

Λ_{VV}=0,0051

Λ_{VH}=0,030

Λ_{HV}=0,027

Λ_{HH}=0,0056

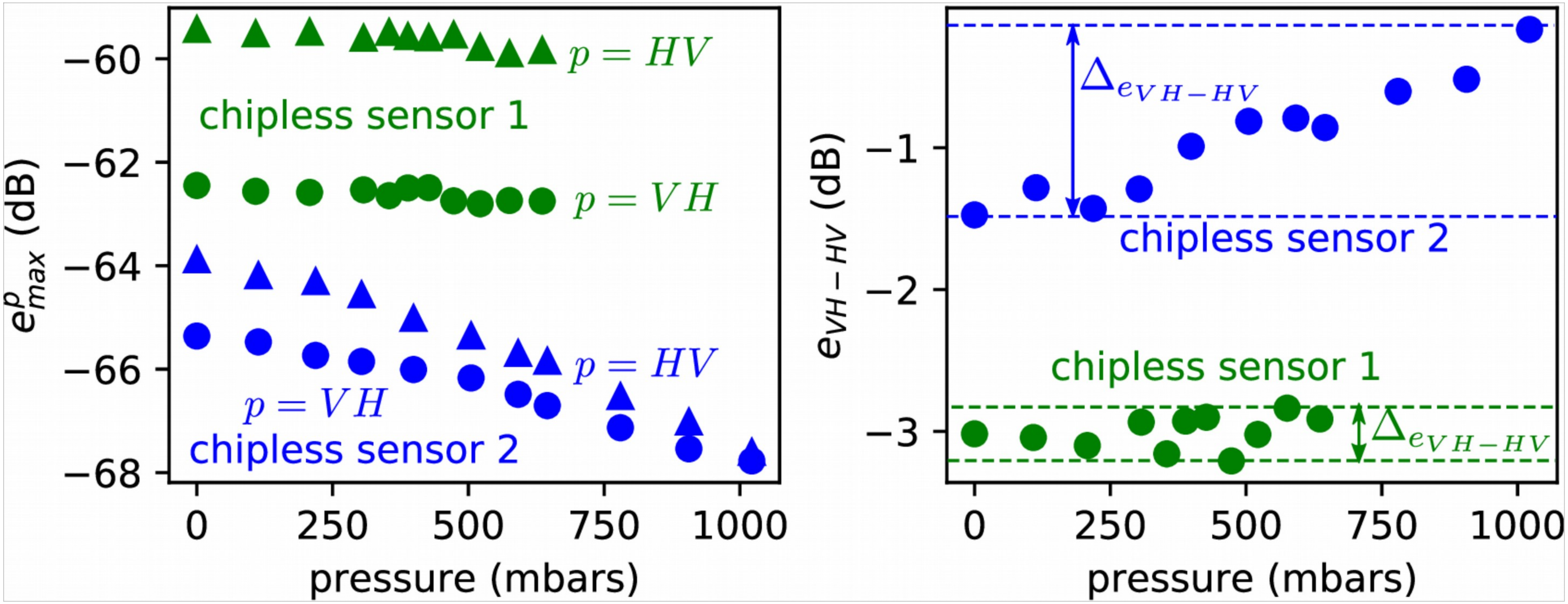
$N_{sensors}$ number of isolines generated by the sensors

$N_{clutter}$ number of isolines generated by the clutter

p : polarization configuration

Electromagnetic footprint of the sensors

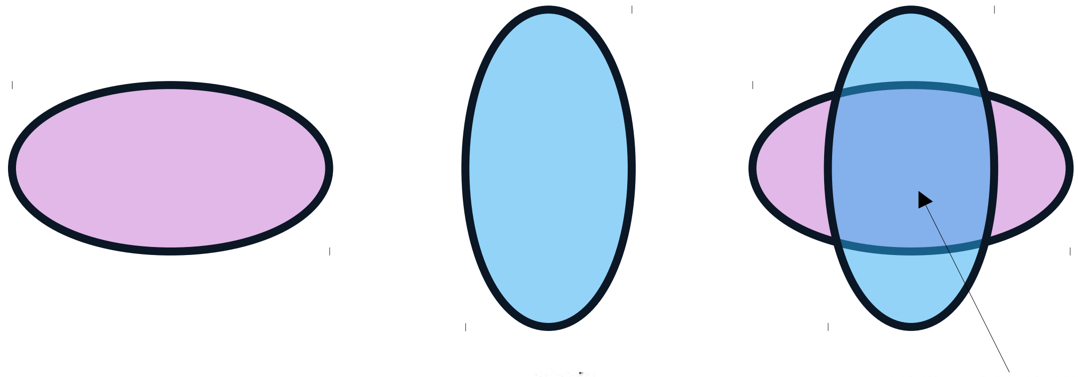
Magnitude parameters



Electromagnetic footprint of the sensors

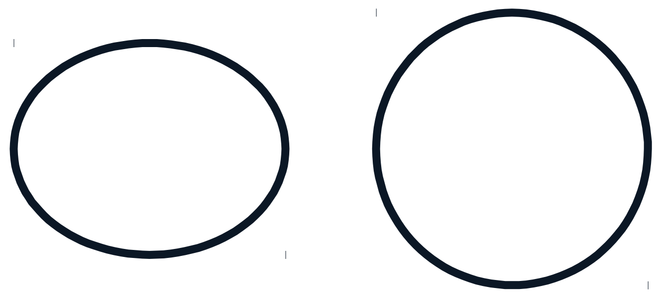
Geometrical parameters

$$g^{p}_{\pi/2} = \frac{\mathscr{A}\left(\mathscr{C}^{p} \bigcap \mathscr{C}^{p}_{\pi/2}\right)}{\mathscr{A}\left(\mathscr{C}^{p}\right)}$$



$\mathscr{C}^{p}$ $\mathscr{C}^{p}_{\pi/2}$ $\mathscr{C}^{p} \bigcap \mathscr{C}^{p}_{\pi/2}$

$$g_S = \frac{\mathscr{A}\left(\mathscr{C}^{VH}\right)}{\mathscr{A}\left(\mathscr{C}^{VH}\right) + \mathscr{A}\left(\mathscr{C}^{HV}\right)}$$

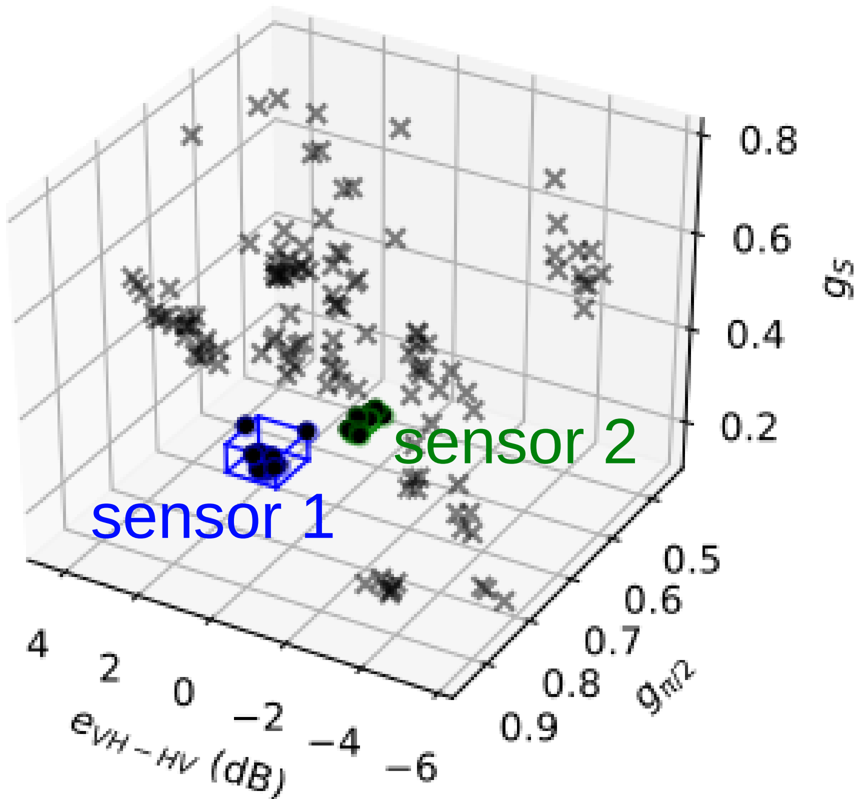


$\mathscr{C}^{VH}$ $\mathscr{C}^{HV}$

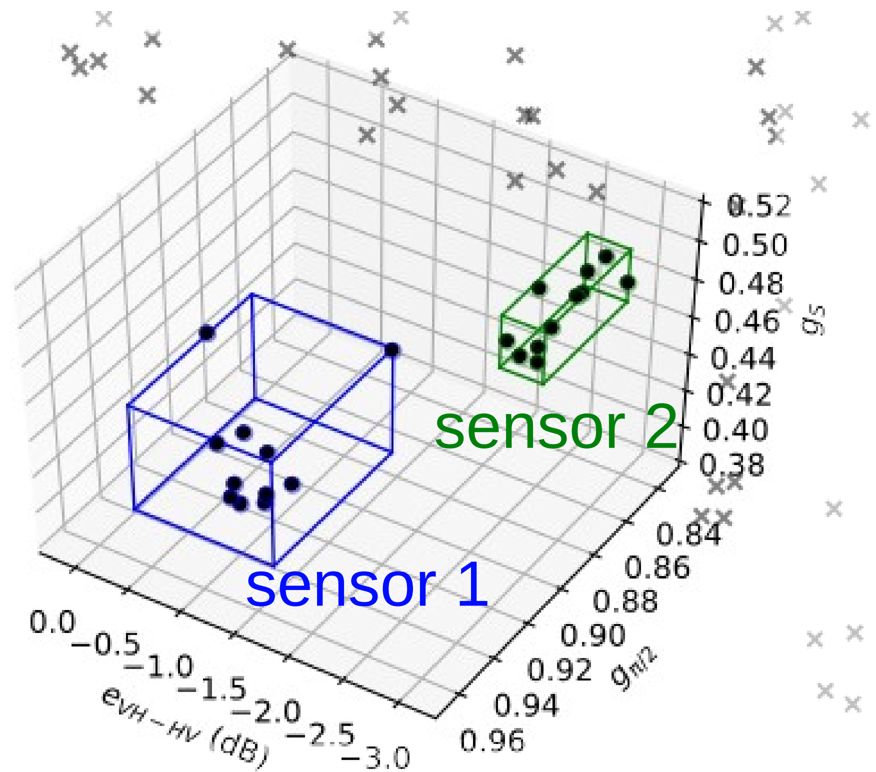
Electromagnetic footprint of the sensors

Applied pressure varying between 0 bar and bar.

identification map



zoom



x : clutter

Conclusion and perspectives

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.

Ackowledgment

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