JOURNEES TECHNIQUES ROUTE 2024

NDT Techniques for Roadways Inspection by Using Ground-Based Synthetic Aperture Radar Imaging Approaches

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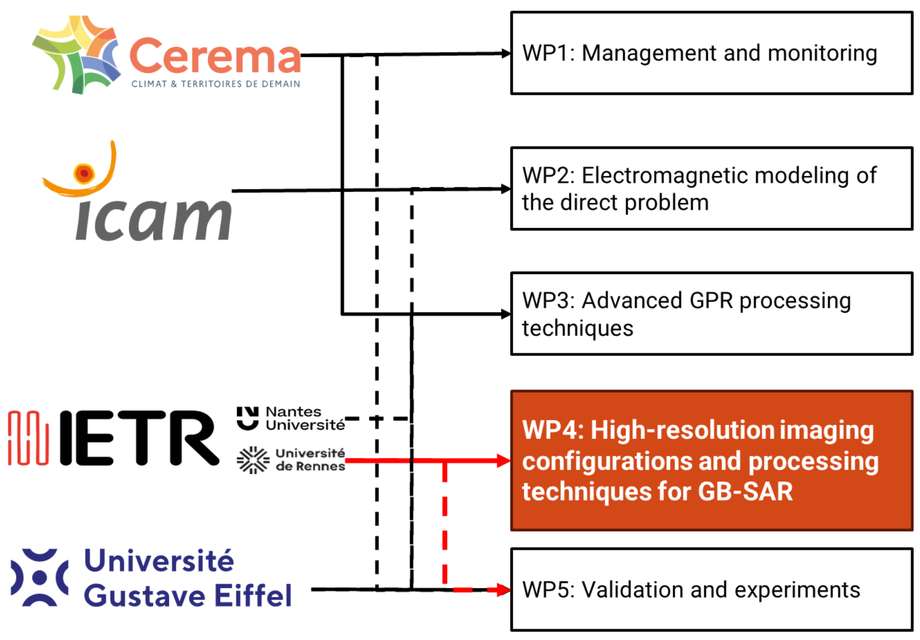
Introduction – ANR ACIMP project

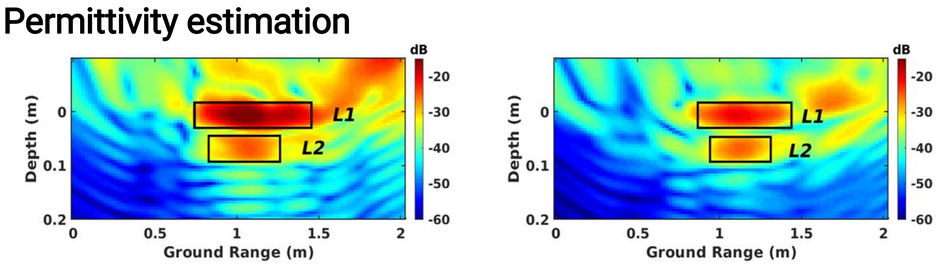
anr agence nationale de la recherche

Roadway structural diagnosis for underground defects is a challenge.
Non-destructive detection and evaluation methods are needed.

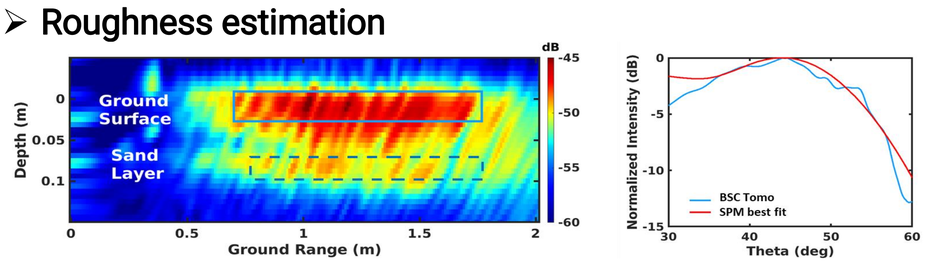


Advanced features analysis with angular and polarimetric diversities

➢ Permittivity estimation



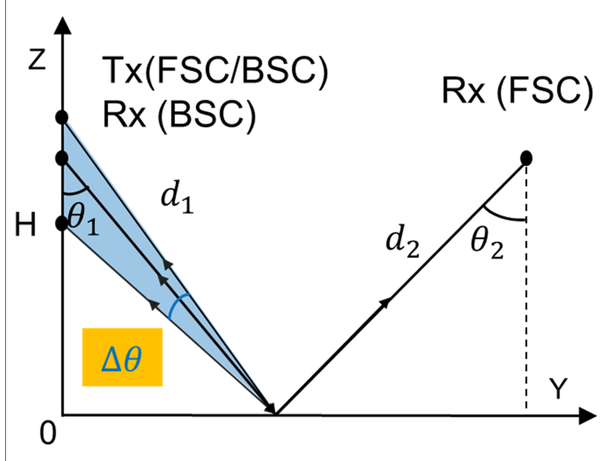
➢ Roughness estimation



	Ground-Asphalt	Defect-Sand
Permittivity ε_r	5.8	9.5
Roughness kl *	3.5	4

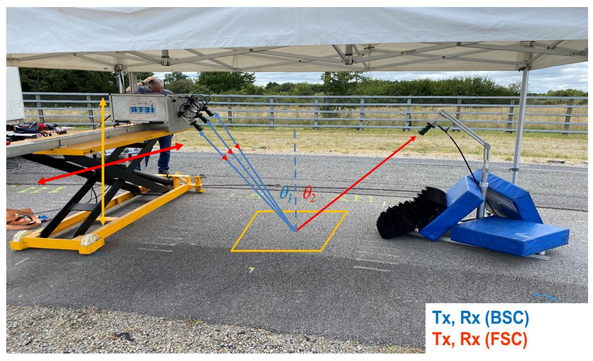
*Roughness is indicated by the correlation length kl

Bistatic FSC TomoSAR Imaging [1] [2]

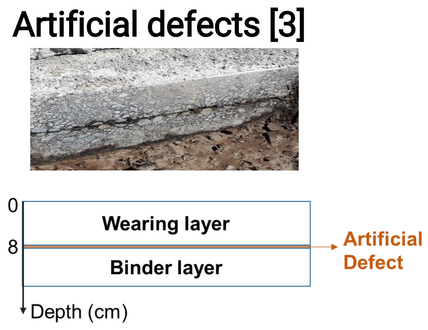


- **Back-scattering (BSC)**
  Good δy , roughness sensitivity
- **Forward-scattering (FSC)**
  Native high SNR and good δz
- Tomographic resolution:
  $\Delta\theta$ **depends on** array length

➢ GB-SAR system operated in BSC and FSC modes



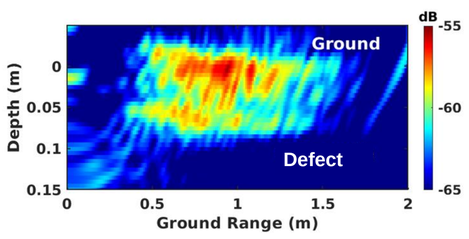
Artificial defects [3]

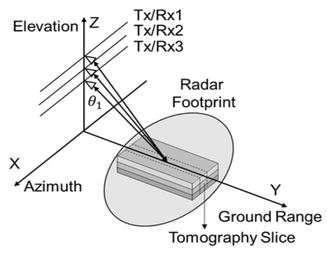


Fatigue Carousel at UGE-Nantes

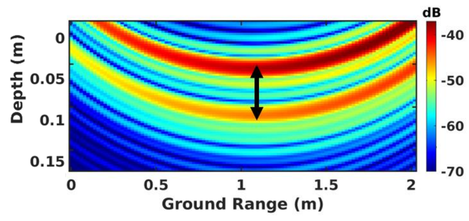
➢ Experimental results

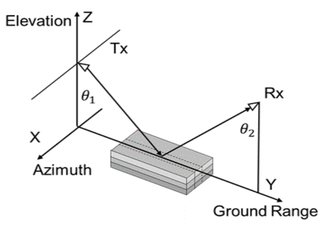
BSC Tomo



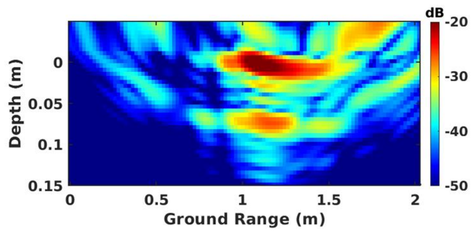


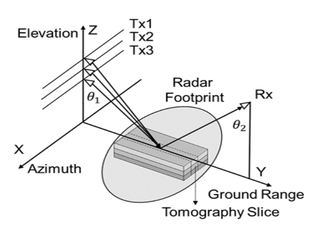
FSC Single-Channel





FSC Tomo

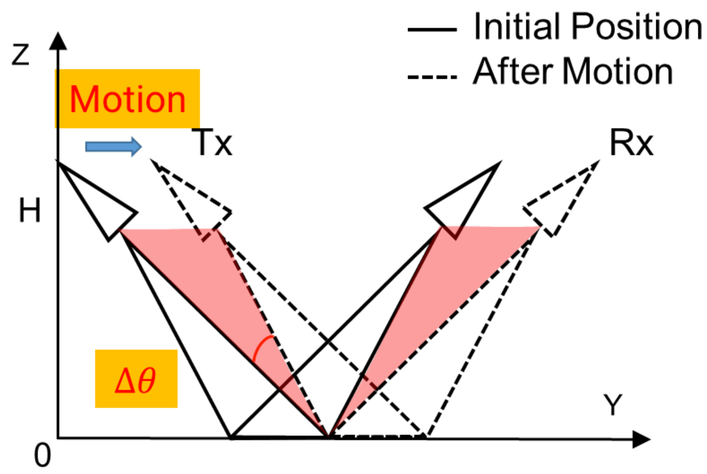




Reference

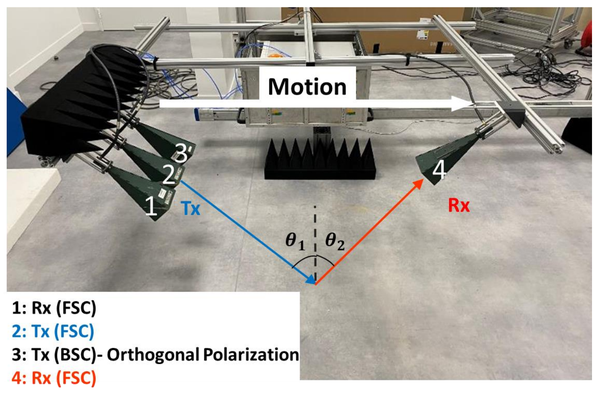
[1] MD, Wu, et al. "Comparison of Imaging Radar Configurations for Roadway Inspection and Characterization", Sensors 23.20 (2023).
[2] MD, Wu, et al. "Comparison of radar imaging configurations for the characterization and diagnosis of roadways", 2021 IEEE IGARSS.
[3] D, Xavier, et al. "GPR Monitoring of Artificial Debonded Pavement Structures Throughout Its Life Cycle During Accelerated Pavement Testing", Remote Sensing 13.8 (2021).

Sliding FSC TomoSAR Imaging [4] [5]



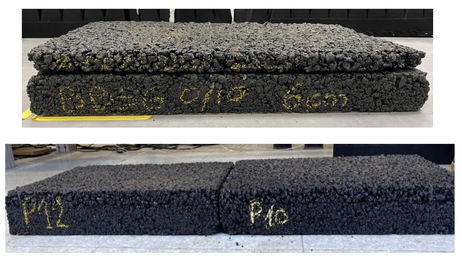
- Horizontal resolution:
  $\Delta\theta$ **depends on motion**
- **Minimal complexity**
  1 Tx and Rx
- Unlimited imaging range

➢ Constant Offset Sliding Bistatic (COSBis) SAR system



1: Rx (FSC)
2: Tx (FSC)
3: Tx (BSC)- Orthogonal Polarization
4: Rx (FSC)

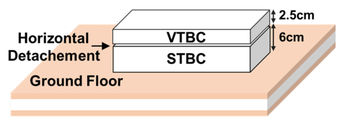
Pavement slabs with air-void cracks



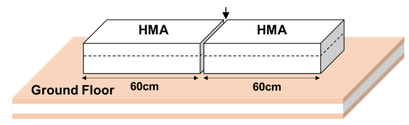
CEREMA, Angers

➢ Experimental results

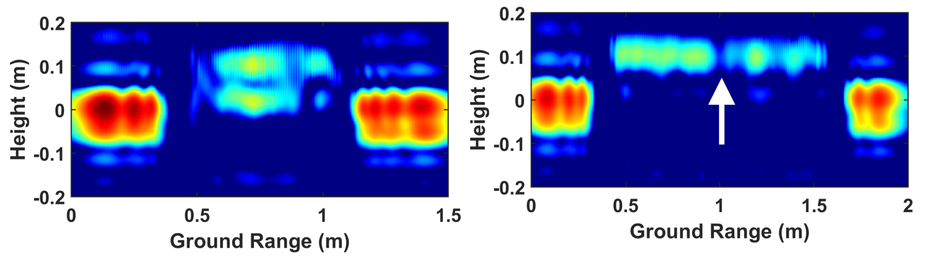
Horizontal crack



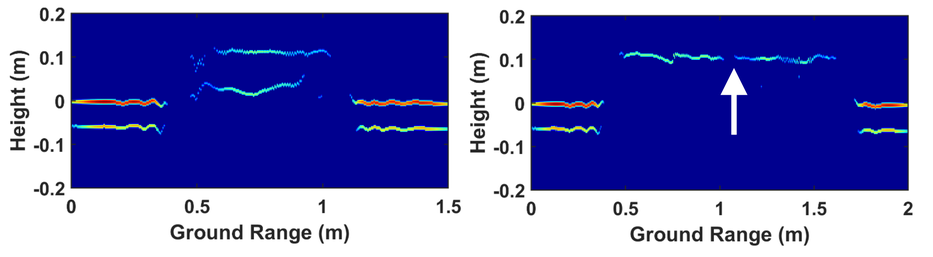
Vertical crack



Focused images



High-resolution images



Reference

[4] MD, Wu, et al. "A New Ground-Based SAR Technique for Roadway Characterization and Deterioration Inspection", 2023 EuRAD, EURAD Prize Finalist.
[5] MD, Wu, et al. "A New Approach of Constant Offset Sliding Bistatic SAR System for Pavement Inspection and Characterization" (submitting).

Conclusion

- FSC TomoSAR is presented for roadway diagnosis and detailed features analysis.
- Sliding FSC is proposed with minimal complexity and achieving good horizontal discrimination.
- High-resolution method is applied to enhance vertical discrimination and prove effective in complex scenarios.