Passive radar distributed sensor network for detecting silent aerial and maritime targets in coastal waters

Mª Pilar Jarabo-Amores, D. Mata-Moya, N. del-Rey-Maestre,
P.J. Gómez-del-Hoyo and J. Rosado-Sanz,

Signal Theory and Communications Department
Superior Polytechnic School, University of Alcalá

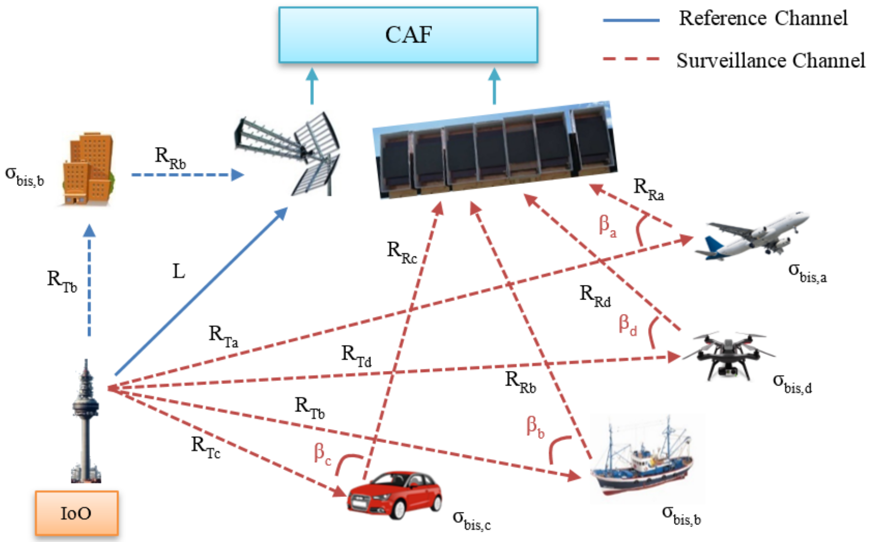
Institute of Electronic Systems
Warsaw University of Technology

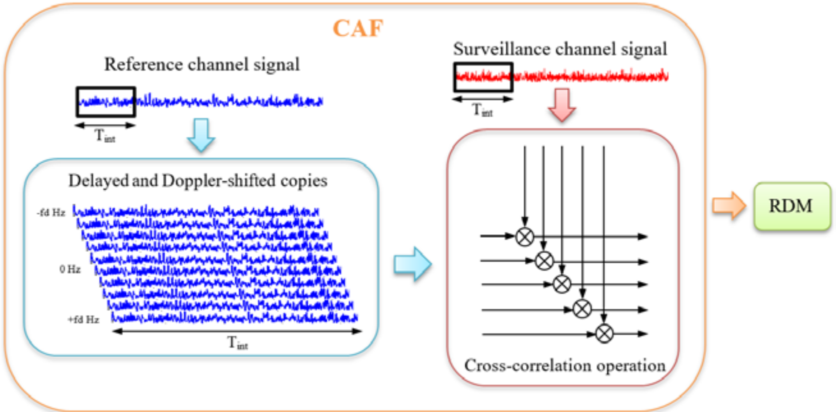
Contents

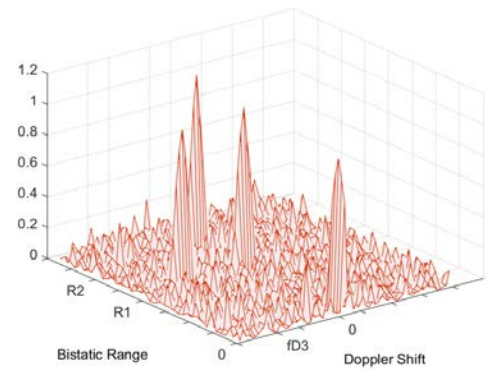
- PR Operation principle.
- Radar Scenario.
- Coverage Estimation.
- Passive radar network design.
- Experimental Results.
- Conclusions.

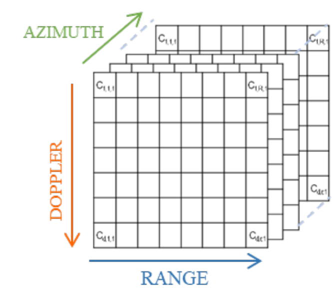
PR Operation Principle

Set of techniques to detect targets and to estimate their positions and velocities, using Illuminators of Opportunity (IoOs), rather than a dedicated transmitter.





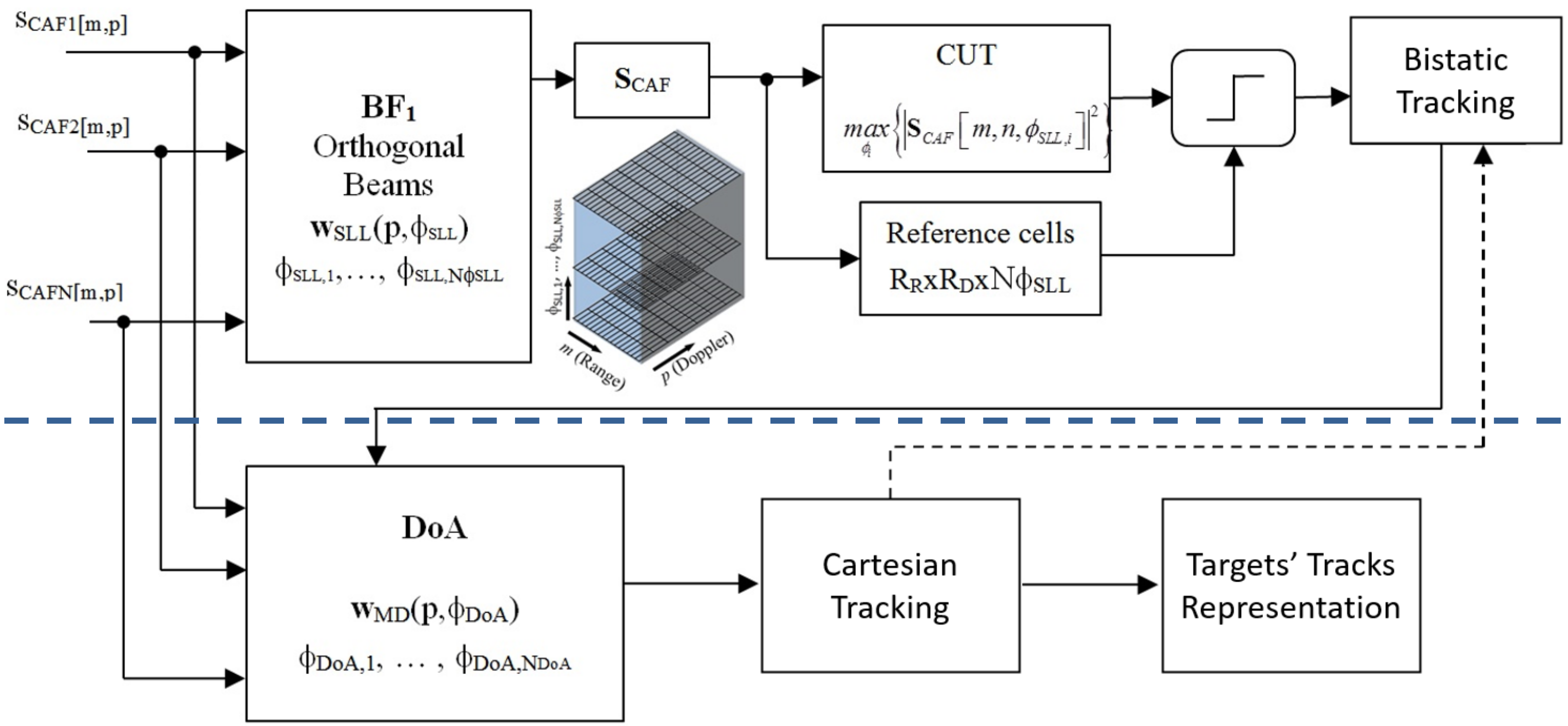




PR Operation Principle

Two stage spatial filtering processing scheme (IDEPAR demonstrator):

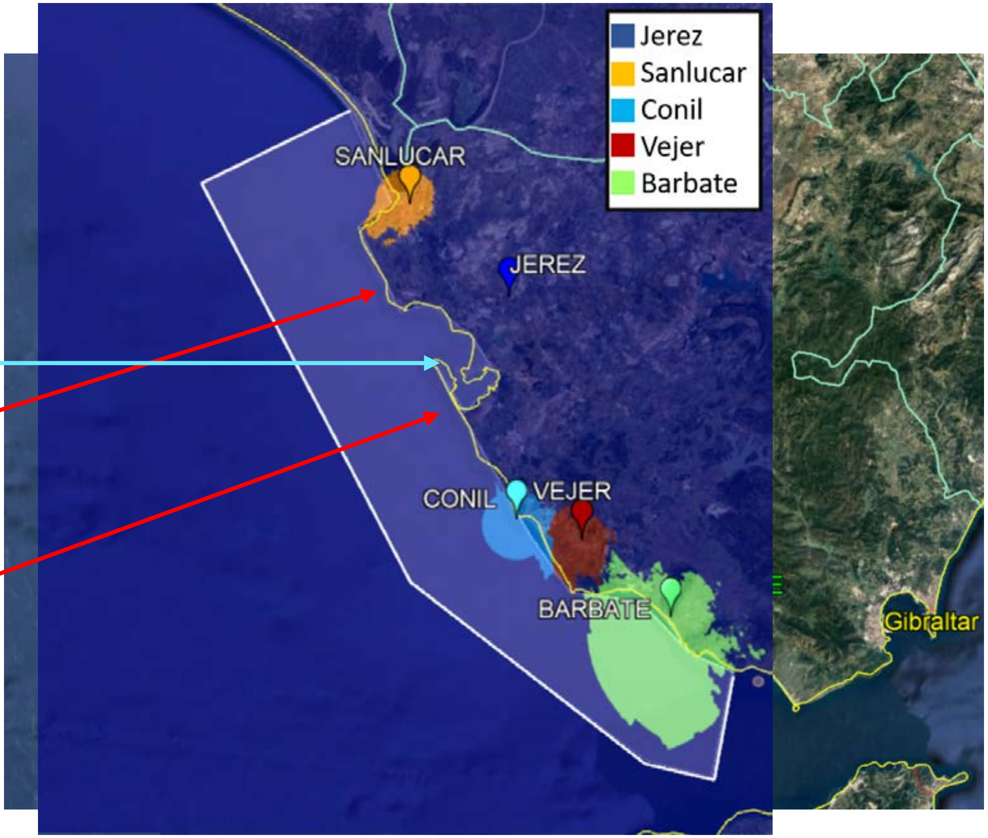
- Orthogonal beams (SLL criterium) + Bistatic tracking
- High accuracy DoA (MVDR) + Cartesian tracking



Radar scenario

Coastal scenario at the south of Spain:

- Coastal length: 150km
- IoOs: 5 DVB-T transmitters.
- Civil instalations:
  - Port of Cadiz
- Military installations:
  - Rota base
  - Torregorda test center



	JEREZ	SANLUCAR	CONIL	VEJER	BARBATE
EIRP	67.20dBm	53.91dBm	49.19dBm	40.04dBm	49.20dBm

Coverage Estimation

Reflects how well an area of interest can be tracked by the radar under certain parameters → quantify the quality of monitoring

- Radar equation for bistatic systems → Cassini ovals

$$(R_R R_T)^2 = \frac{p_T \cdot g_T \cdot g_R \cdot \lambda^2 \cdot \sigma_b}{(4\pi)^3 \cdot p_R \cdot l_{IOO-\text{target}} \cdot l_{\text{target-PR}}}$$

- Inclusion of additional losses and rearranging

$$\boldsymbol{P}_R\,(\text{x}, \text{y}) = \frac{P_{IOO-Target}\,(x,y) \cdot G_R\,(\text{x},\text{y}) \cdot 4\pi \cdot \lambda^2 \cdot \sigma_b}{L_{Target-PR}\,(x,y)}$$

- Use of electromagnetic simulators:
  - Bistatic RCS estimation
  - GIS + path modelling

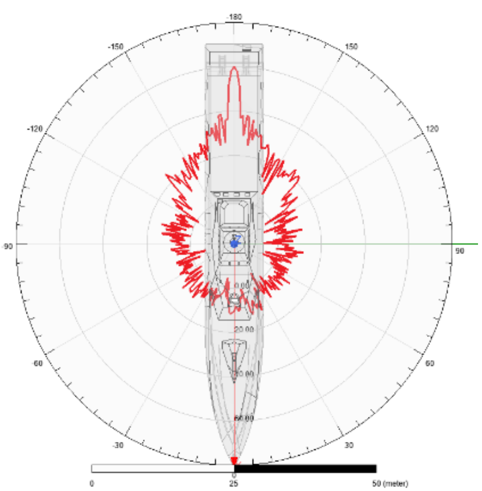
Coverage Estimation

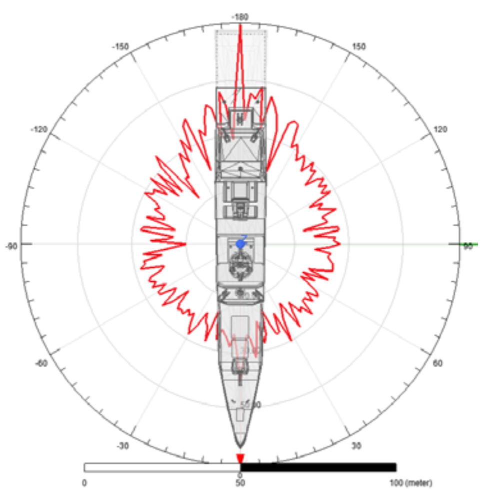
Targets BRCS estimation: maritime targets

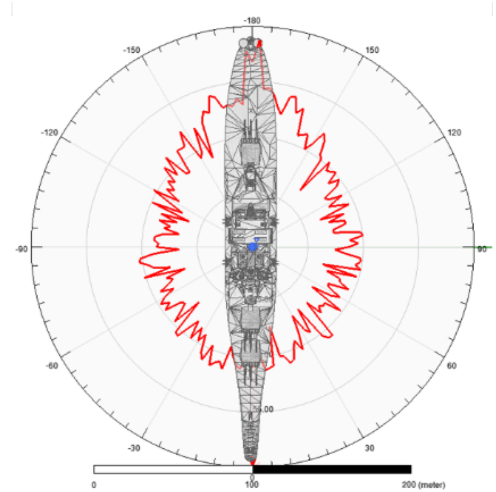
- Three size targets
- Materials: carbon fiber/steel

- Frequency: 738MHz
- Simulation step: 5º

	Size	ß =0	ß =30	ß =60	ß =90
Visby corvette	72.3x10	27.48 dBsm	**25.21 dBsm**	27.43 dBsm	25.88 dBsm
Admiral Gorshkov frigate	132x16	32.08 dBsm	31.35 dBsm	31.34 dBsm	**28.95 dBsm**
USS New Jersey battleship	270x33	50.41dBsm	48.64 dBsm	**47.84 dBsm**	47.94 dBsm





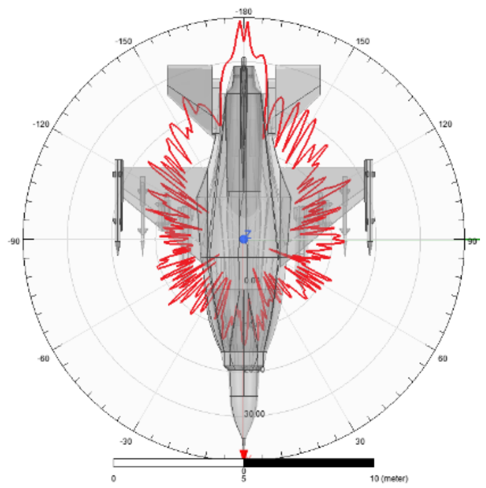


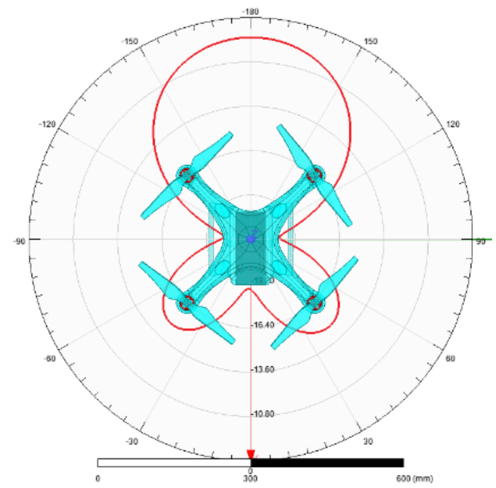
Coverage Estimation

Targets BRCS estimation: aerial targets

- Fighter and small drone
- Materials: Aluminium/lithium/copper
- Frequency: 738MHz
- Simulation step: 5º

	Size	β =0	β =30	β =60	β =90
F16 fighter	15x10	13.48 dBsm	13.97 dBsm	**12.06 dBsm**	13.39 dBsm
DJI Phantom III	0.35x0.20	-11.32 dBsm	-11.25 dBsm	**-13.69 dBsm**	-12.61 dBsm

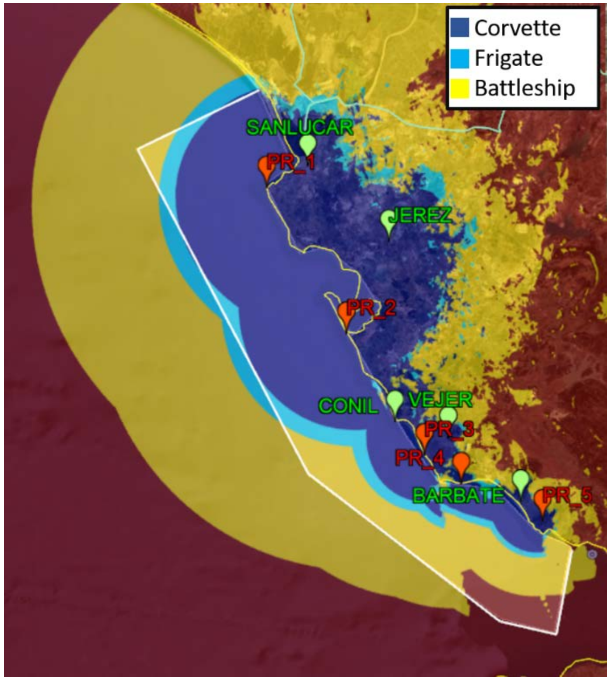




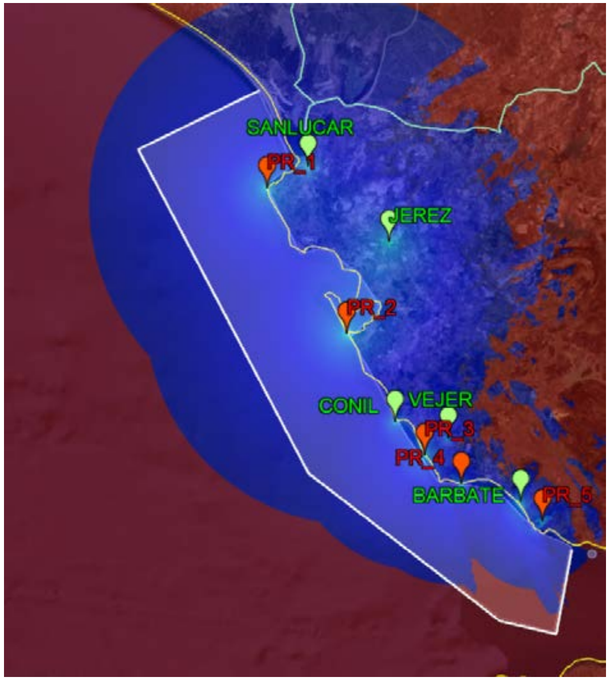
Passive radar network design

Estimated theoretical coverage:

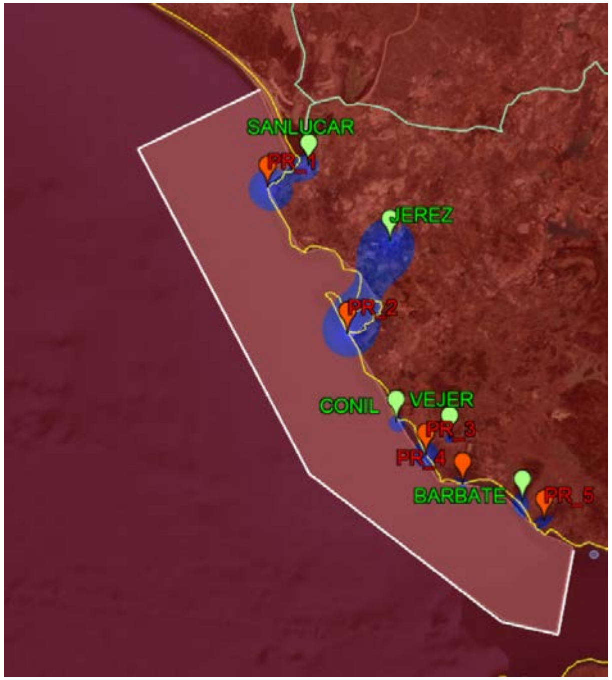
- 5 nodes (reference and surveillance array) distributed along coastline
- At least one IoO-PR pair to provide detection and 2D location



Maritime targets



Fighter



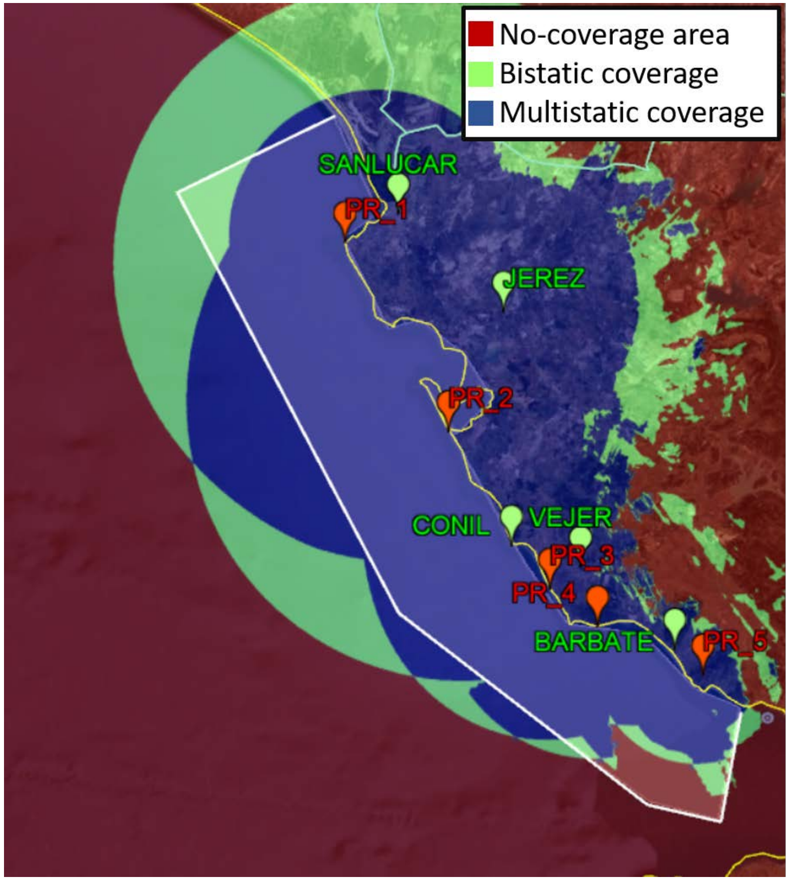
Drone

Passive radar network design

Estimated theoretical coverage:

Multistatic configuration analysis:

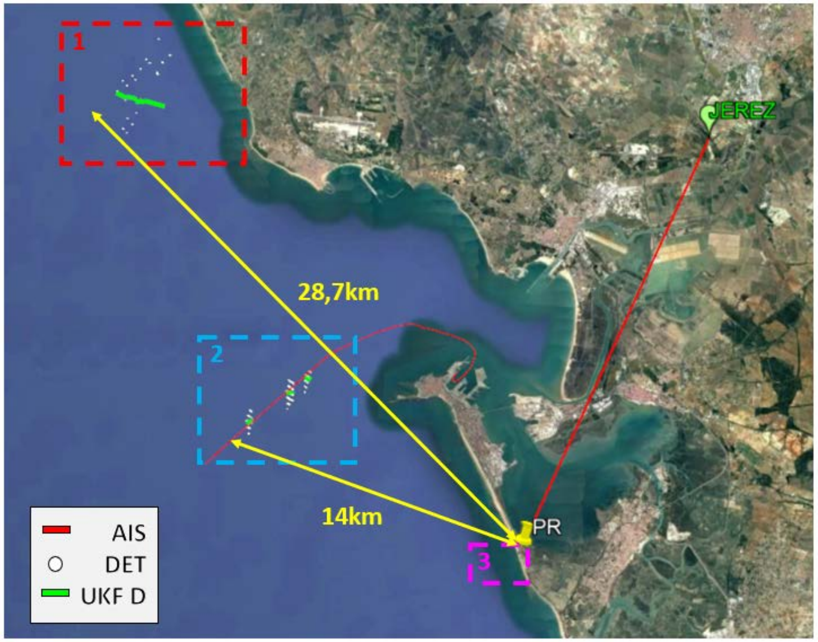
- At least two IoO-PR pairs
  - Multiple IoO-single PR: distributed processing
  - Multiple PRs: internode communication/central processing
- Increase of detection probability
- Increase of 2D location performances
- Estimation of flight altitude

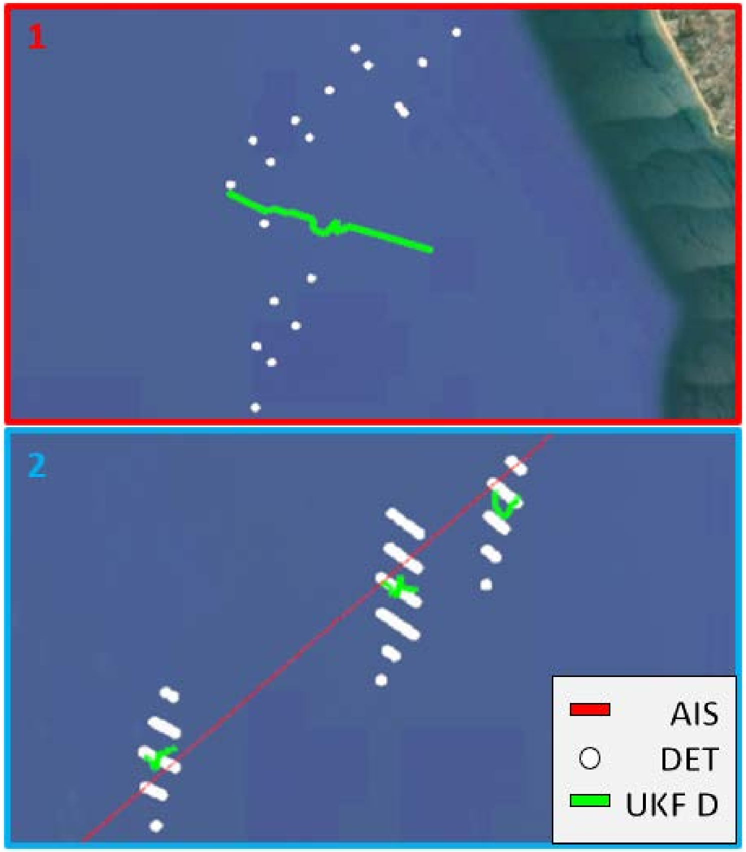


Experimental Results

IDEPAR deployment in PR location 2: Torregorda test center

- 1 reference and 7 surveillance antennas
- 40 sec acquisition per data set
- 20MHz (2 DVB-T channels)

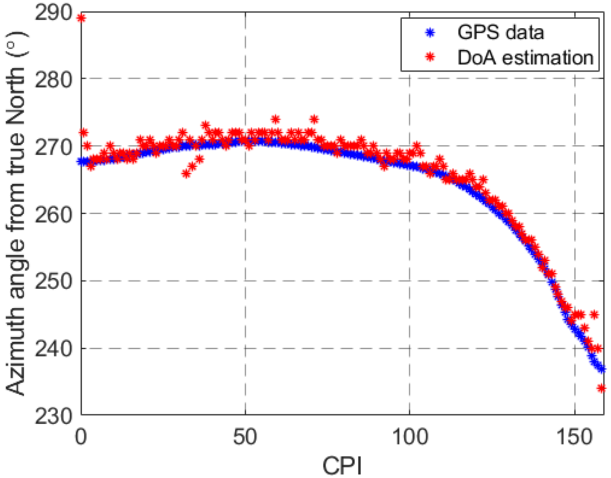


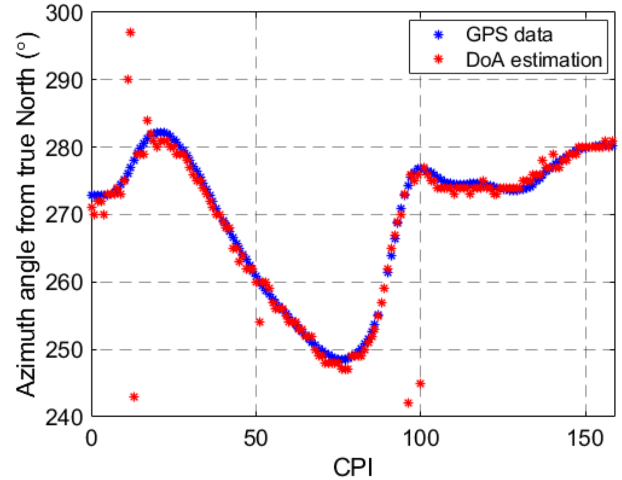


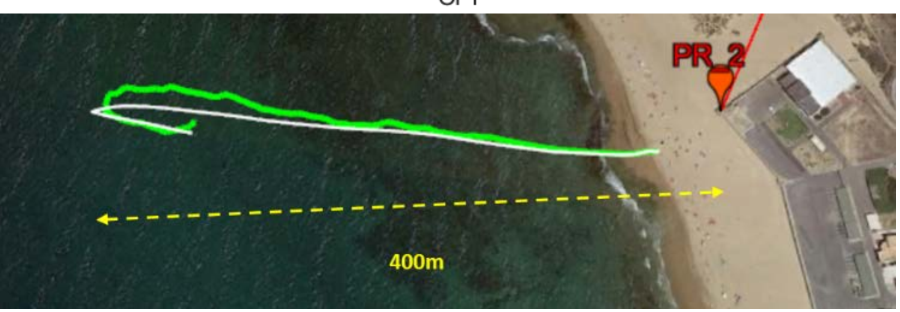
Experimental Results: Radar Processing

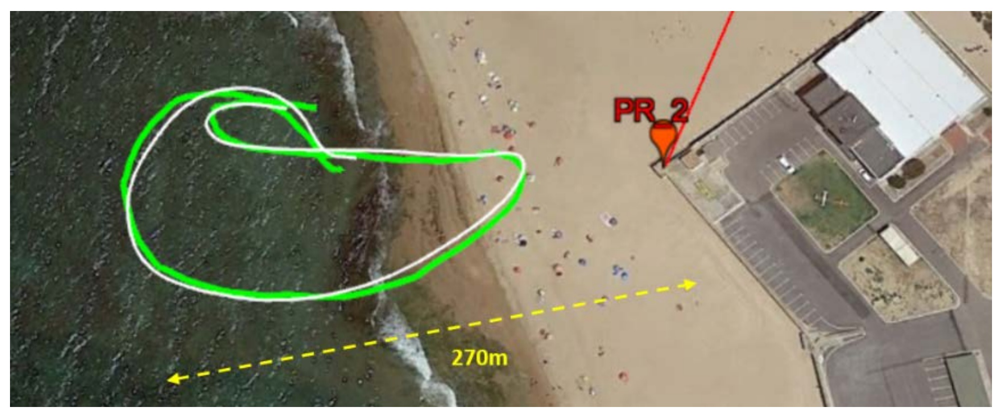
IDEPAR deployment in PR location 2: Torregorda test center

- Cooperative target: DJI phantom 3
- 2 datasets → 2 trajectories









Conclusions

- The feasibility of the use of a PR sensor network for coastal border control was studied. An area in the south of Spain was selected as AoI including: the Rota naval base and the Torregorda Test Center as military facilities.
- A sensor network composed of five PR nodes exploiting DVB-T transmitters was designed.
- A theoretical analysis based on system coverage analysis was carried out to study PR sensor network viability considering aerial and maritime target of interest. Coverage results show the viability of the PR sensor network in the selected radar scenario.
- For validation purposes IDEPAR demonstrator PR was deployed in one of the sensor network nodes at the Torregorda Test Centre where detection and tracking of different targets were carried out.
- Results confirm the feasibility of DVB-T based PRs for monitoring coastal scenarios.

Thank you for your attention

Pedro José Gómez del Hoyo

pedro.gomez@pw.edu.pl

Institut of Electronic Systems
Warsaw University of Technology