Challenges and Practical Applications of Passive Radar

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Presentation outline

- Motivation
- Principles of PCL and Technology
- PCL demonstrators
- Limitations and research directions
- Concluding remarks

PCL objectives

Military operations scenarios are increasing in complexity

The main task of radar

<u>TO SEE AND NOT TO BE SEEN</u>,

is very difficult to fulfil.

Development of PCL technology as an additional tool to complement active radar is a very promising direction.

Passive Radar

- Do not transmit any signals
- Instead, exploit transmitters of opportunity available in a given scenario
- Huge potential interest in civil and military applications:
  - Useful in an already crowded RF spectrum
  - Enables covert and passive mode

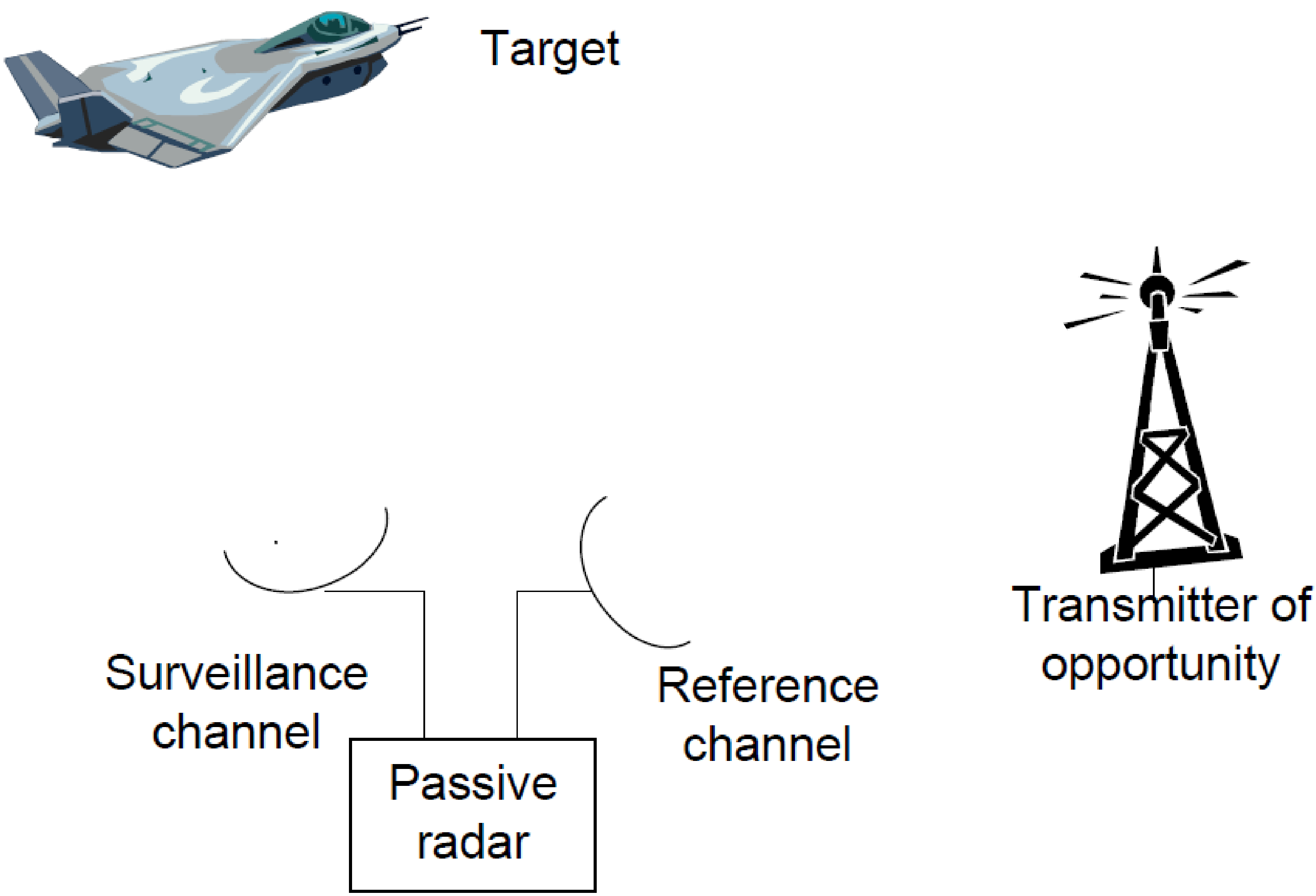
Activities sponsored by NATO STO

- Under this scope, there are several NATO STO sponsored activities:
  - SET-108, Task Group on "*Passive Sensor Trials and Analysis and the Development of Advanced Passive Radar Systems Techniques*";
  - SET-152, Task Group on "*Deployable multi-band passive/active radar for air defense (DMPAR)*";
  - SET-164, Task Group on "*Advanced Modeling and System Applications for Passive Radar Sensors*";
  - SET-177 Workshop on "*Passive Radar ECM, EPM and Critical Aspects*";
  - SET-195, Task Group on "*DMPAR short term solution verification*".

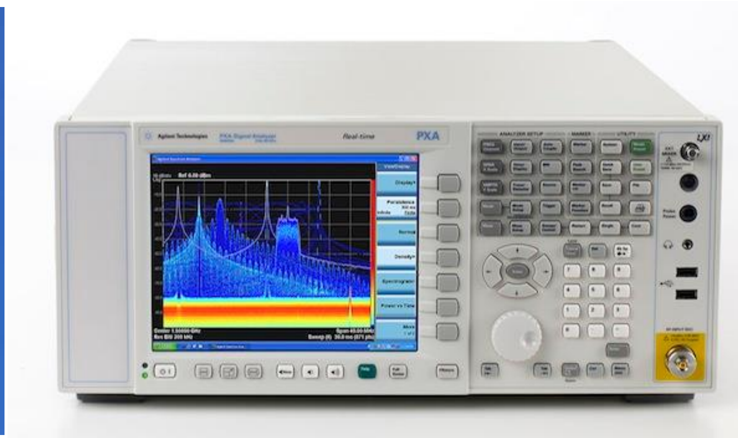
Passive Radar

TECHNOLOGY AND PRINCIPLES

Classical passive bistatic radar geometry



Technology



KMA4113 Log periodic antenna | Agilent PXA spectrum analyzer | Signal processing

→ PCL system uses illuminators of opportunity

→ Can be built using COTS equipment:

- Commercial antennas
- Amplifiers
- Spectrum analyzers
- Channel sincronization using GPS signals or sophisticated algorithms
- Signal processing with a PC

Multi-static multi-receiver localization using DVB-T

- Passive radar developed at WUT using COTS components (vector signal analyzer, amplifiers, antennas)
- Uses DVB-T transmitters to detect and track air targets
- Data synchronized using GPS signals
- Localization of targets in 3D

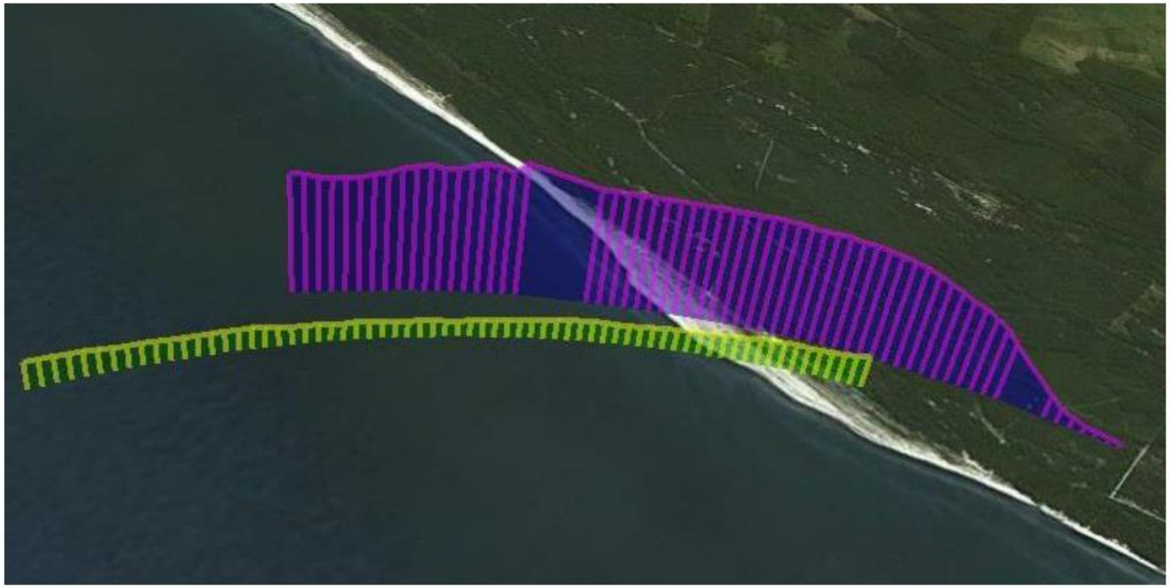
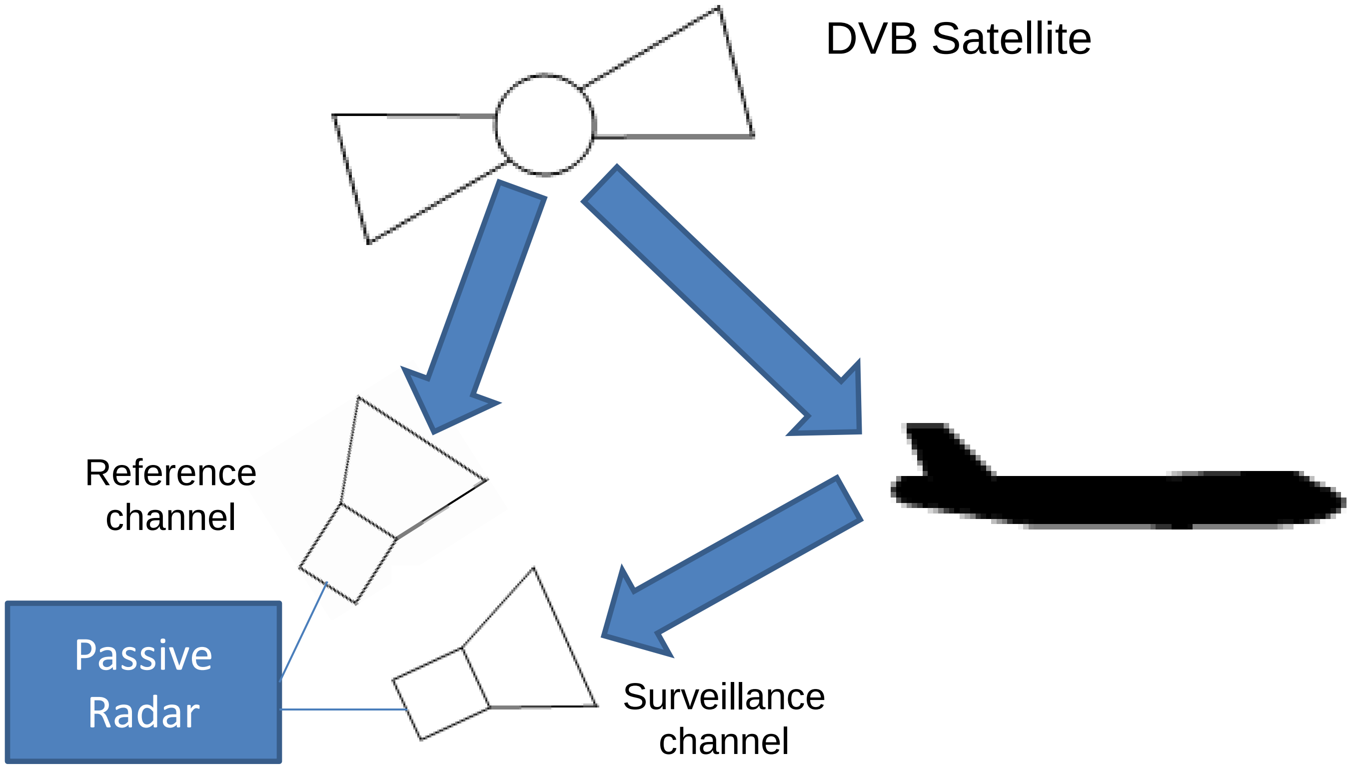


Figure 4 3D trajectory of two localized targets (visualized using Google Earth [9]).

"***Multi-static Multi-receiver Target Localization Using DVBT Transmitters***", M. Baczyk, P. Krysik, M. Malanowski. A. Gromek, J. Kulpa, P. Dzwonkowski, (WUT), POL , NATO SET-187, Szczecin, Poland, 2013

Example: Pedagogical Passive Radar using DVB-S signals



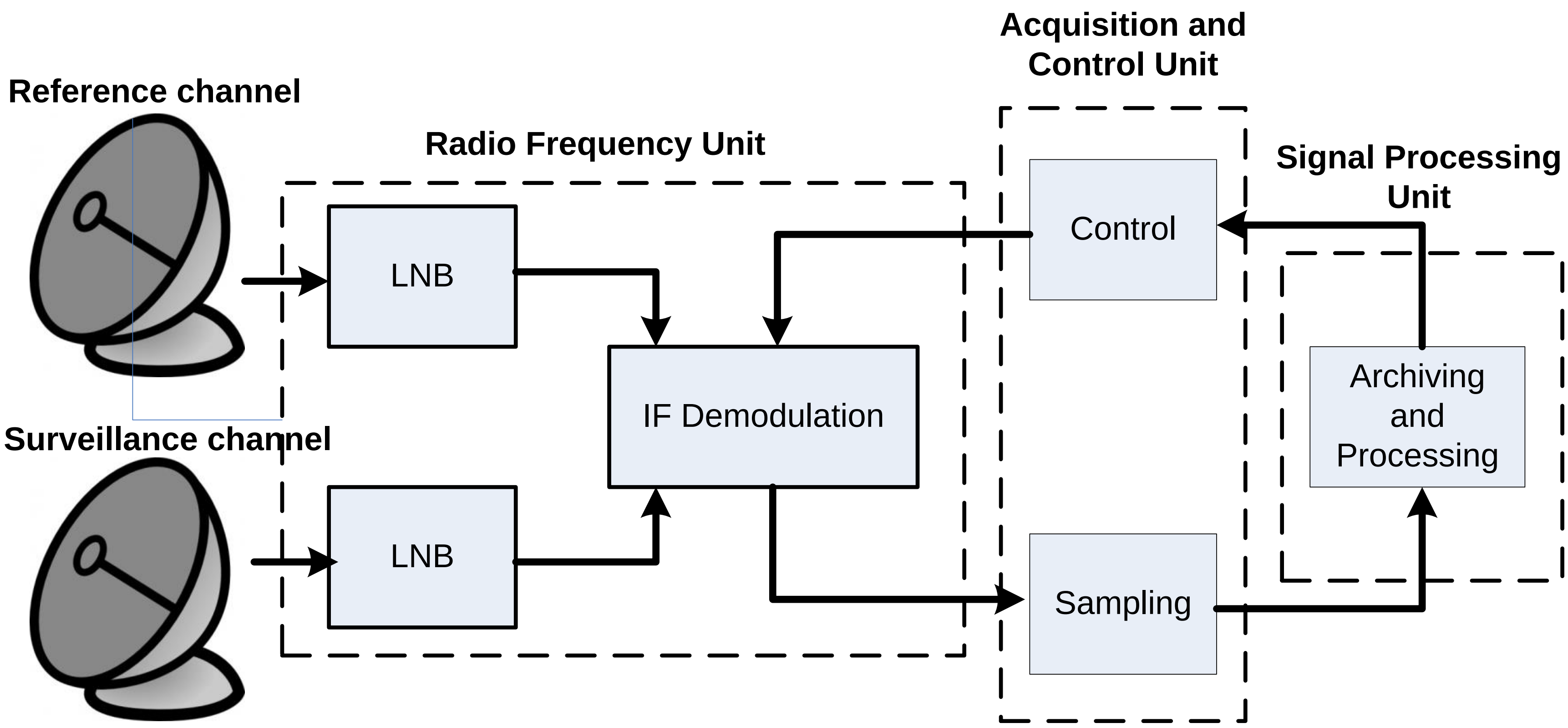
DVB-S satellites:

+ Large bandwidth and noise-like signals due to the compression and encription
+ Satellite visibility
+ Geostacionarity – no need to follow satelite motion

Challenges:

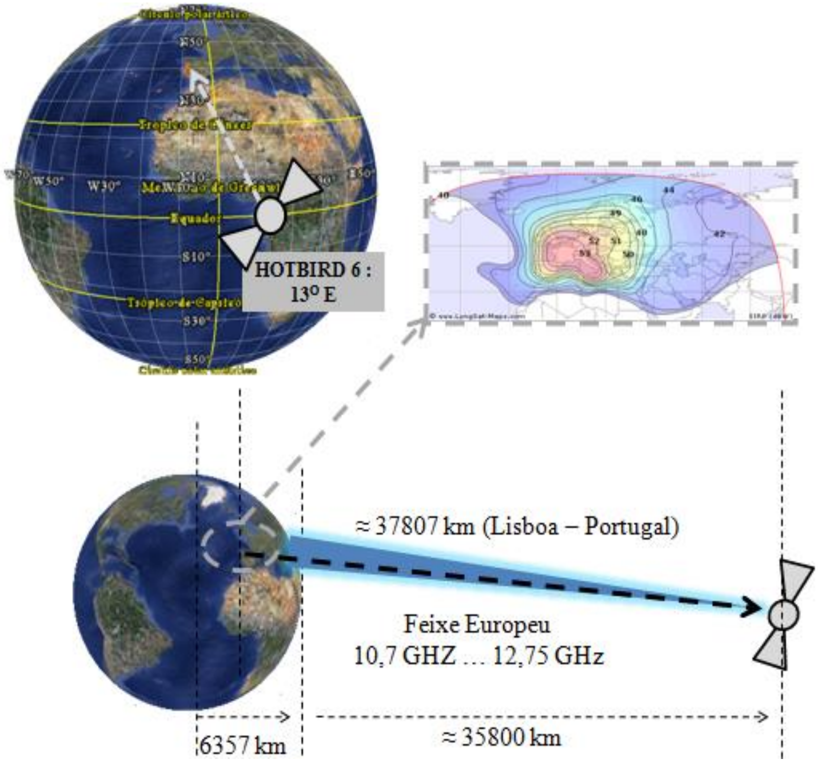
- Very weak signals
- Very low budget
- Use of low cost comercial LNB → Independent oscillators imply phase drift and frequency offset

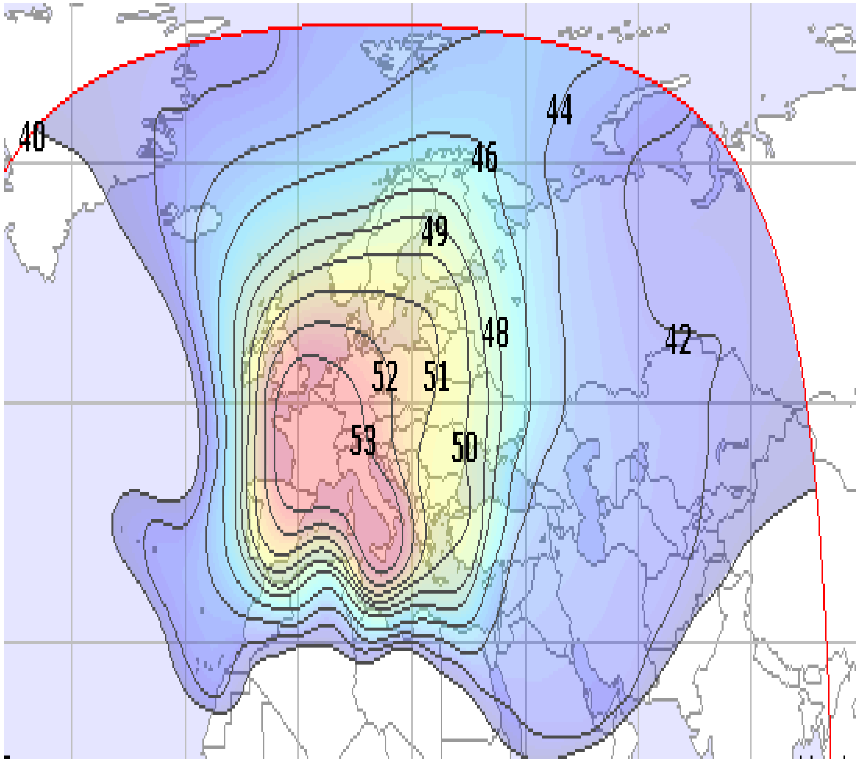
Developed system



All components, except IF demodulation, are COTS

DVB-S satellite selection





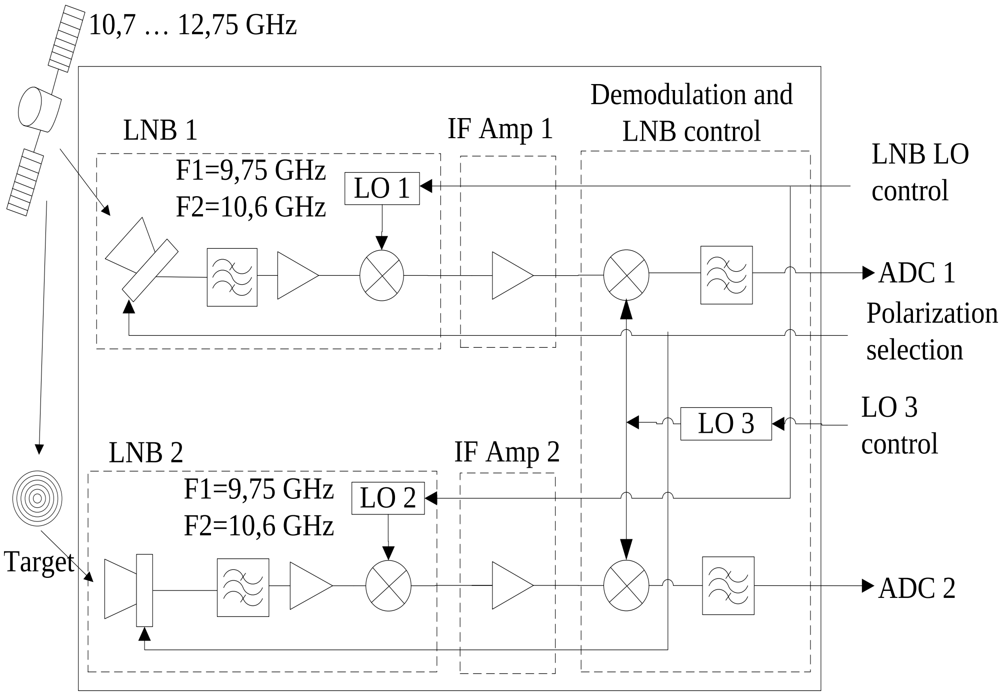
- Hotbird 6 offers visibility from test site and relatively high EIRP

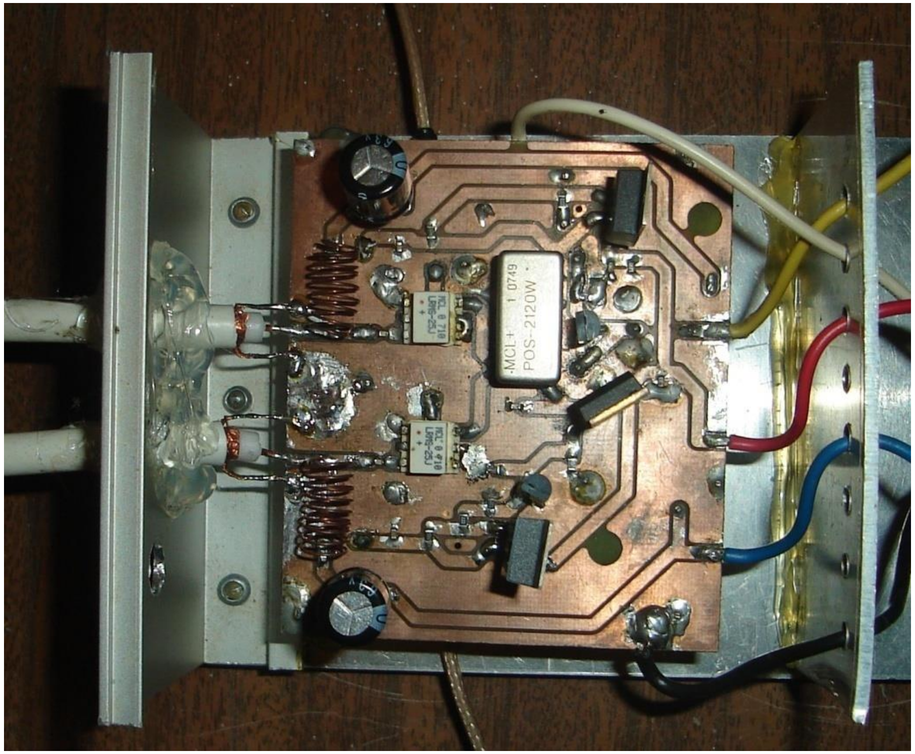
RF Unit: from RF to IF

- Demodulation from RF to IF is done by two commercial LNB (FTE LNC 54U)

- Each LNB has an independent LO → phase incoherency and frequency errors between channels

IF Demodulation and control unit

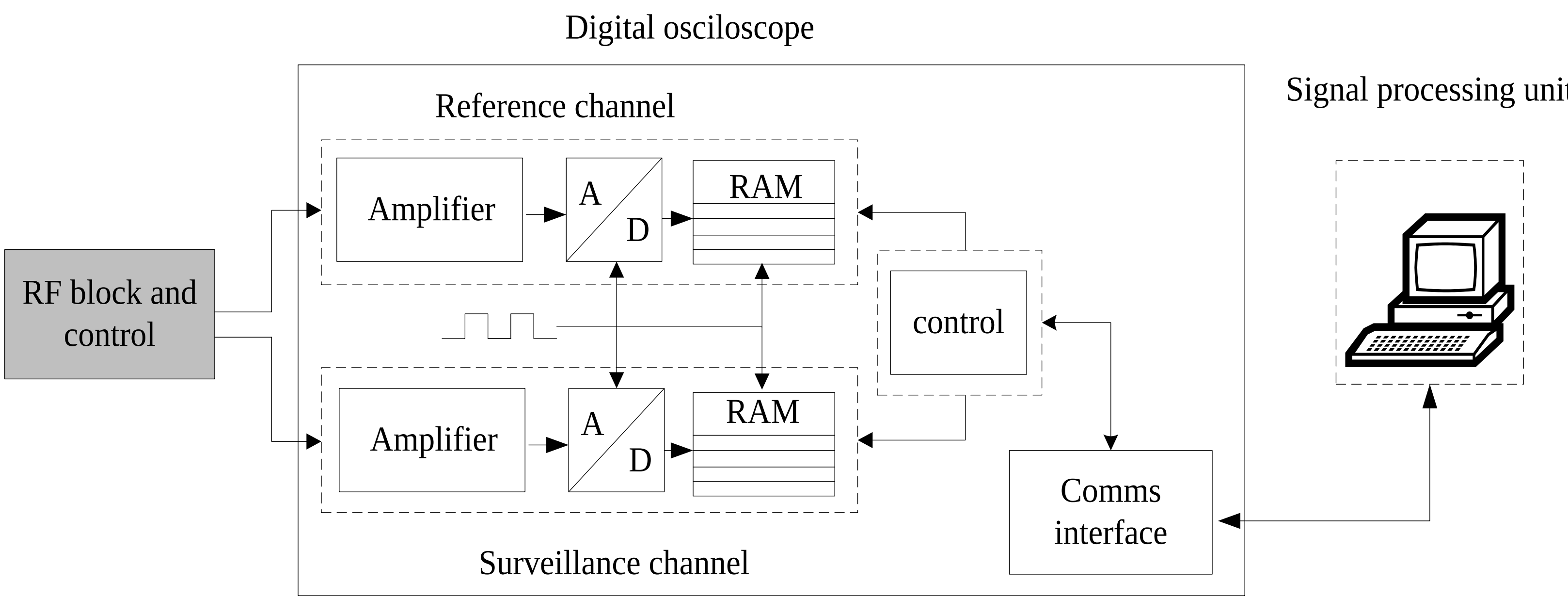




A dedicated analog circuit was developed to demodulate the IF signal to baseband using two mixers and a common LO

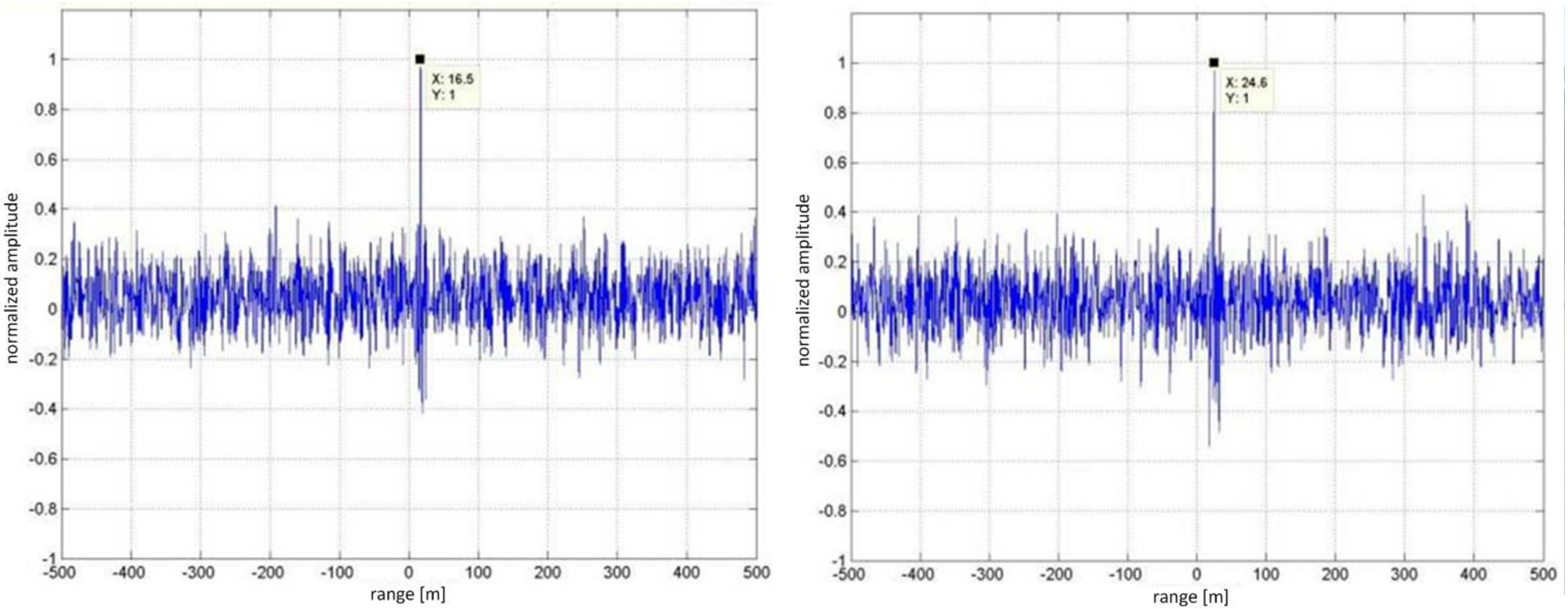
Sampling and temporary storage

Sampling and temporary storage is done by a digital osciloscope



Signal Processing unit: Windows laptop with MATLAB for signal processing

Target detection



Passive Radar

DEMONSTRATORS

Cassidian FM Passive Radar

- Stationary CASSIDIAN FM passive radar demonstrator
- In 2010 Cassidian started development of multiband passive Radar demonstrator using FM, DAB and DVB-T in real-time
- The new version of the stationary single FM sensor demonstrate good detection for commercial airliners up to 100 km

Fraunhofer FHR Parasol

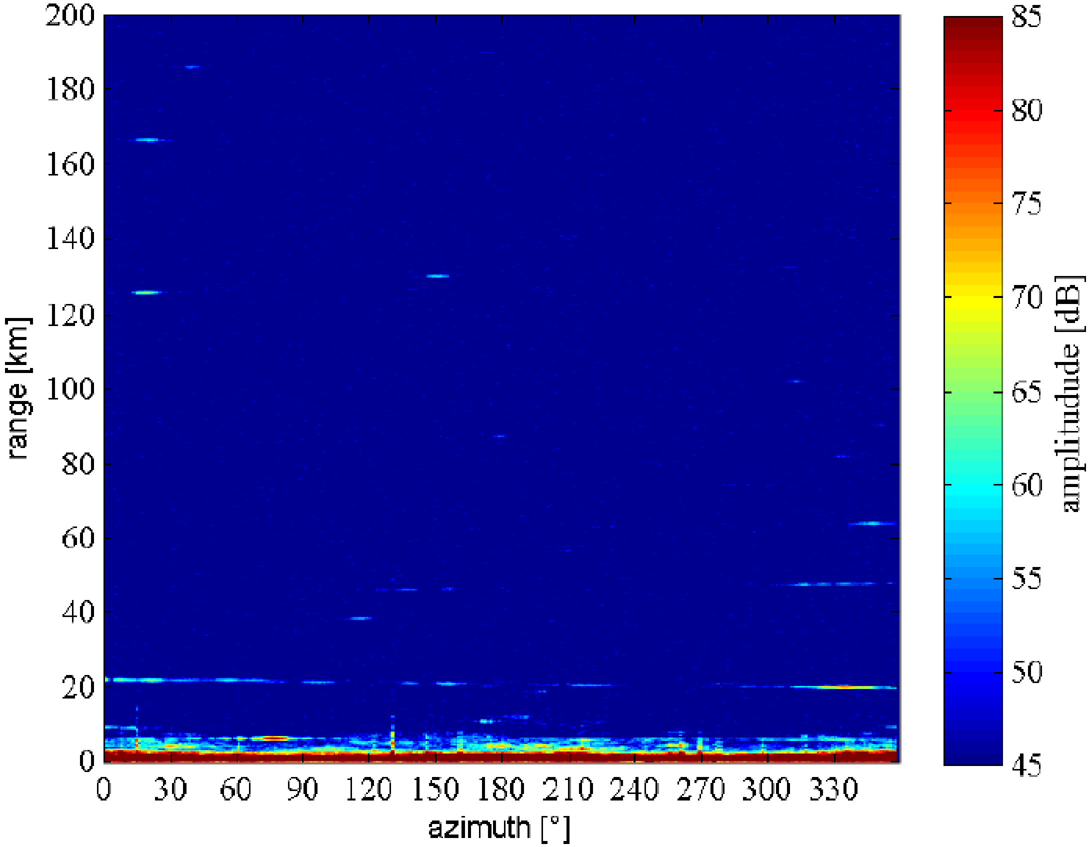
- Wind power farms are increasing in Europe
- Neighbors complain, besides noise, of the flashing lights on to warn low-flying planes
- Parasol – Passive radar that turns lights on only when low-flying planes are detected
- Uses local radio station transmitters as illuminators of opportunity

(C) Fraunhofer FHR

J. Heckenbach, H. Kuschel, J. Schell and M. Ummenhofer, "Passive radar based control of wind turbine collision warning for air traffic PARASOL," *2015 16th International Radar Symposium (IRS)*, Dresden, 2015, pp. 36-41

Passive radar using Early Warning VHF radar

- Demonstrator uses long-range pulse VHF-band active radar as illuminator of opportunity
- Uses 2 antennas on the top of a 5 m mast for reference and surveillance signals
- Using relatively simple hardware experimental results show targets at distances up to 190 km
- This approach can be used to extend the coverage of our own VHF radars or to obtain coverage using enemy's radar



"Passive Radar Utilizing Early Warning VHF Radar as Illuminator of Opportunity ",P. Roszkowski, P. Samczynski, M. Malanowski, A. Gorzelanczyk, K. Kulpa,(WUT), POL, NATO SET-187, Szczecin, Poland, May 2013

Thales Passive Radar

- Thales Homeland Alerter 100
  - Developed jointly by Thales and ONERA
  - Deployed on Bastille Day in 2010 to monitor Paris airspace
  - Uses signals from radio and TV broadcasts
  - Designed for surveillance of medium and low altitudes airspace
  - Claimed range > 100 km

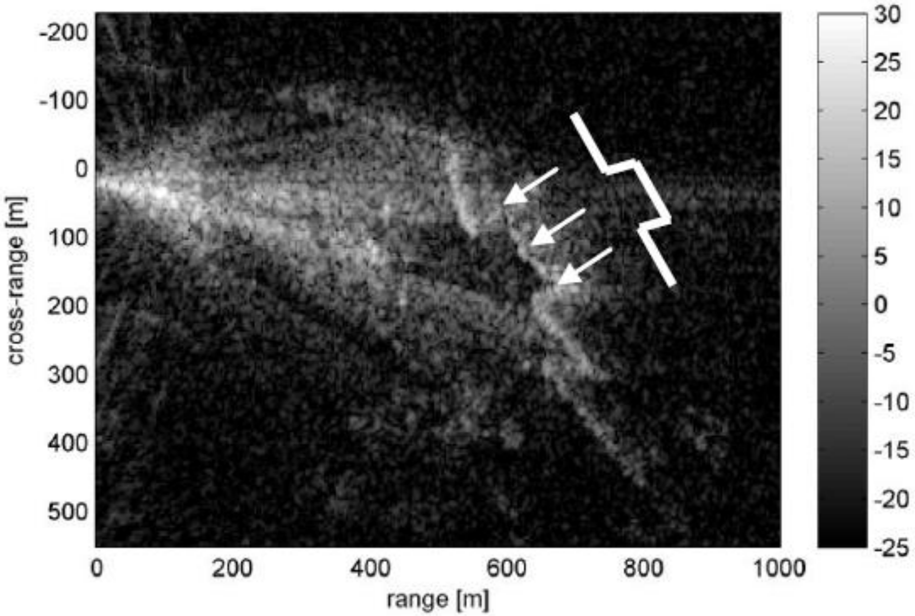
Exhibition - Demonstrators

- Several demonstrators in Exhibitions Cassidian, ERA and WUT

Passive SAR imaging demonstration

- Passive SAR imaging is a novel trend
- Imaging example using non-cooperative space-based pulse radars as illuminators

Optical image of the scene

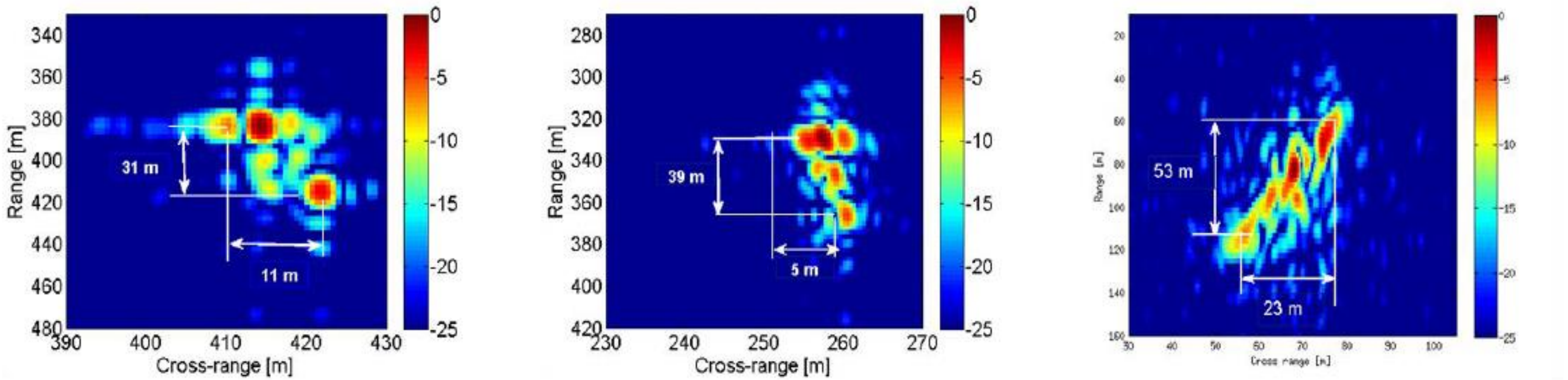


Passive SAR imaging using TerraSAR-X

“**Challenges in signal processing for passive SAR radars utilizing non-cooperative space-based pulse radars as illuminators**”, P. Samczynski, K. Kulpa;. Maslikowski, D. Gromek(WUT), POL, V. Kubica (Royal Military Academy), BEL, NATO SET-187, Szczecin, Poland, May 2013

Array Passive ISAR (APIS) Project

- Array Passive ISAR (APIS) demonstrator was shown (supported by EDA)
- Able to detect targets and generate ISAR images by exploiting DVB-T transmitters



(a) Airbus 320 (37m length, 34m width)

(b) Airbus 321 (44m length, 34m width)

(c) Airbus 340 family (63-75m length, 60-63 m width)

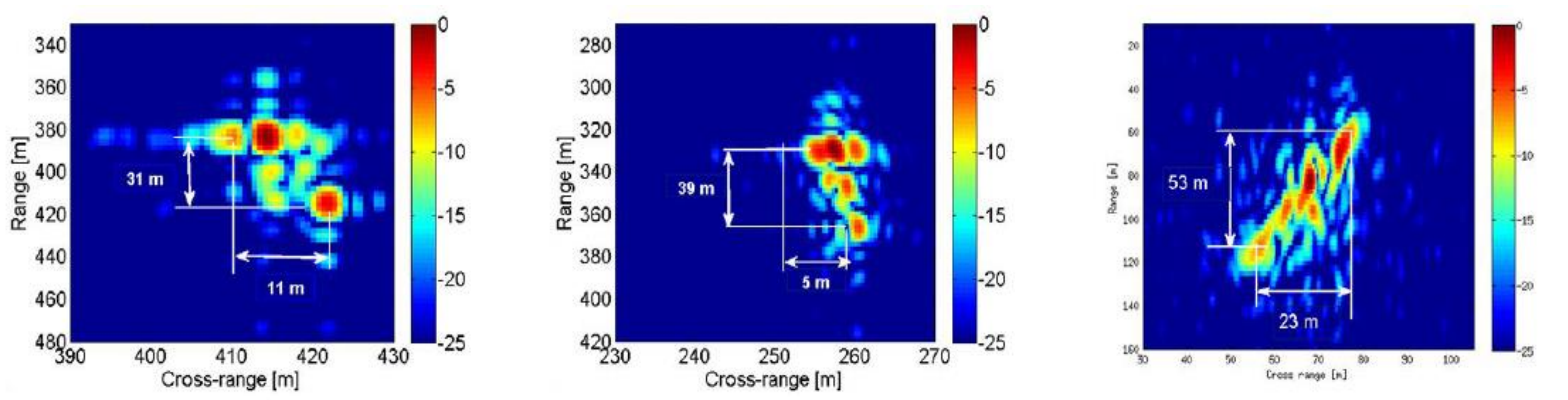
RF Front-End #1 and Calibration Network

ISAR images of diferent airplanes

APIS demonstrator

"***Array passive ISAR adaptive processing (APIS) Project: an overview***", J. Alvarez, J. Gaitán(Indra SISTEMAS) ESP, F. Berizzi, A. Capria, M. Conti, E. Giusti, M. Martorella, C. Moscardini, D. Olivadese, D. Petri,(RaSS), CNIT, Pisa) ITA J. L. Bárcena , D. De La Mata, P. Jarabo, M. Rosa(U. de Alcalá)ESP, A. Podda, A. Sulis(VITROCISET), ITA, C. Benedek, T. Szirányi (MTA SZTAKI), HUN, G. Georgiou, A. Papanastasiou, C. Topping, (U. Cyprus), Cyprus, NATO SET-187, Szczecin, Poland, May 2013

Passive ISAR



(a) Airbus 320 (37m length, 34m width)

(b) Airbus 321 (44m length, 34m width)

(c) Airbus 340 family (63-75m length, 60-63 m width)

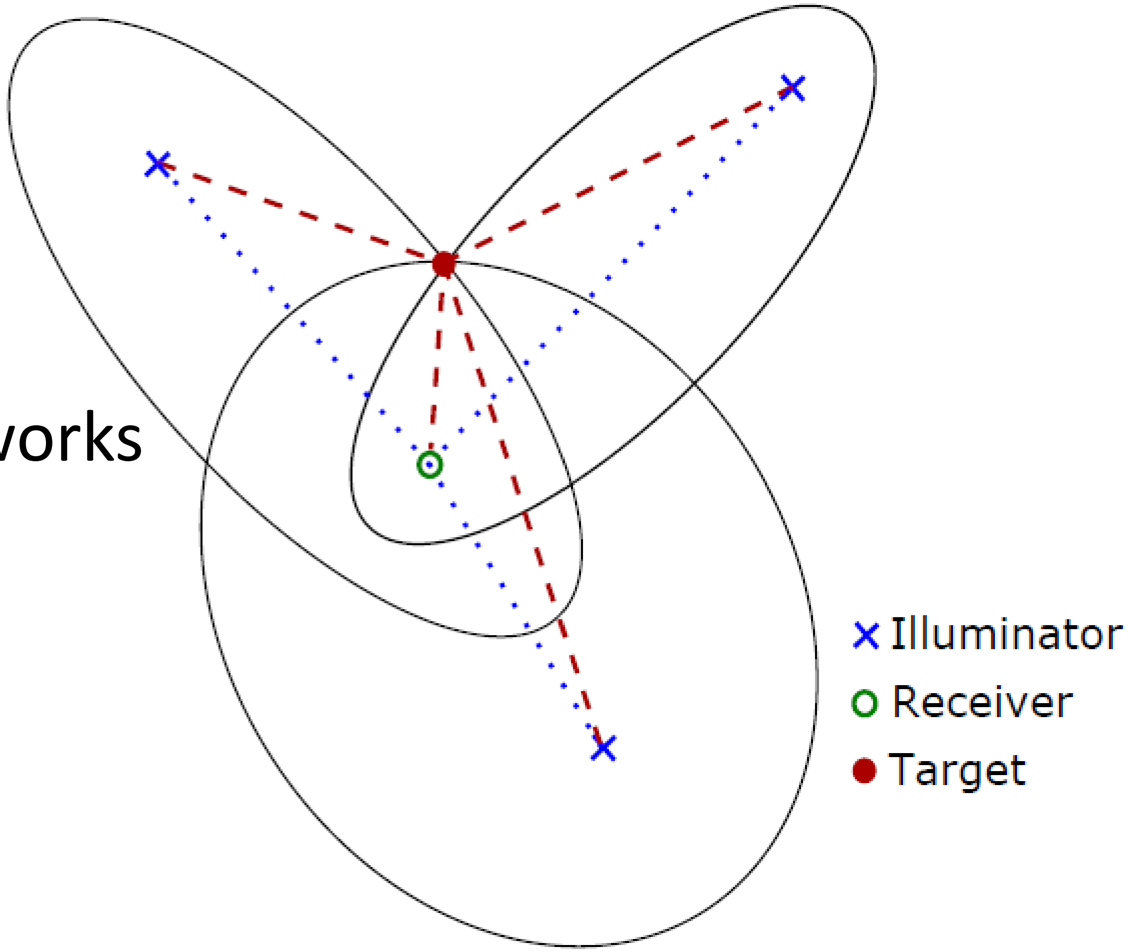
Some notes:

- Results obtained with current demonstrator cannot compete with those obtainable with a active ISAR system
- However, system allows to form bistatic ISAR images at those frequencies where it is usually forbidden to transmit, such as VHF and UHF.
- Finer resolution images may be formed by adjoining more DVB-T channels.

Research Directions

Measurements association in SFN

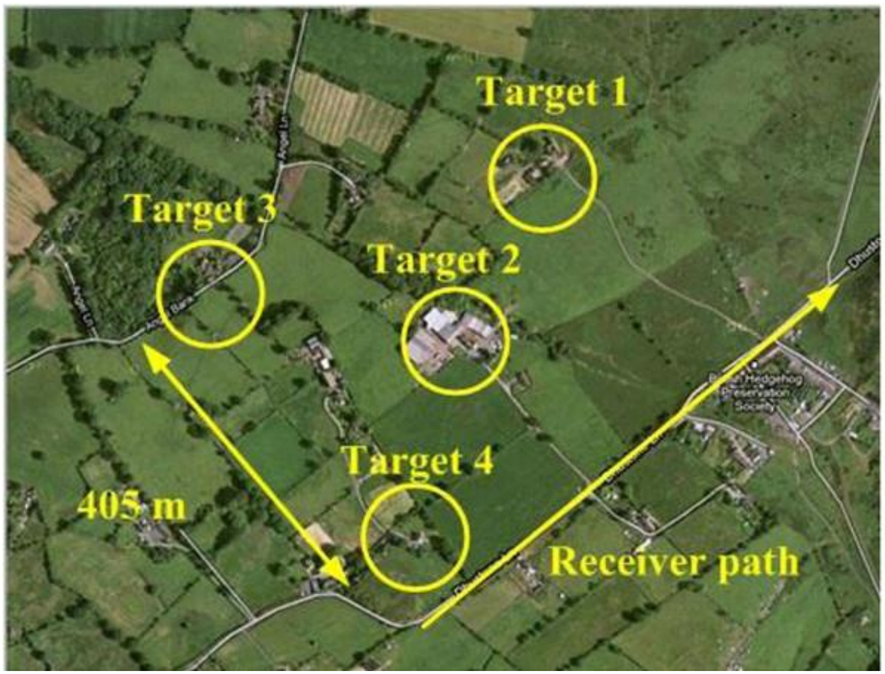
- Single Frequency Networks in DVB-T:
  - All transmitters use the same frequency band
  - Can lead to geolocation ambiguities

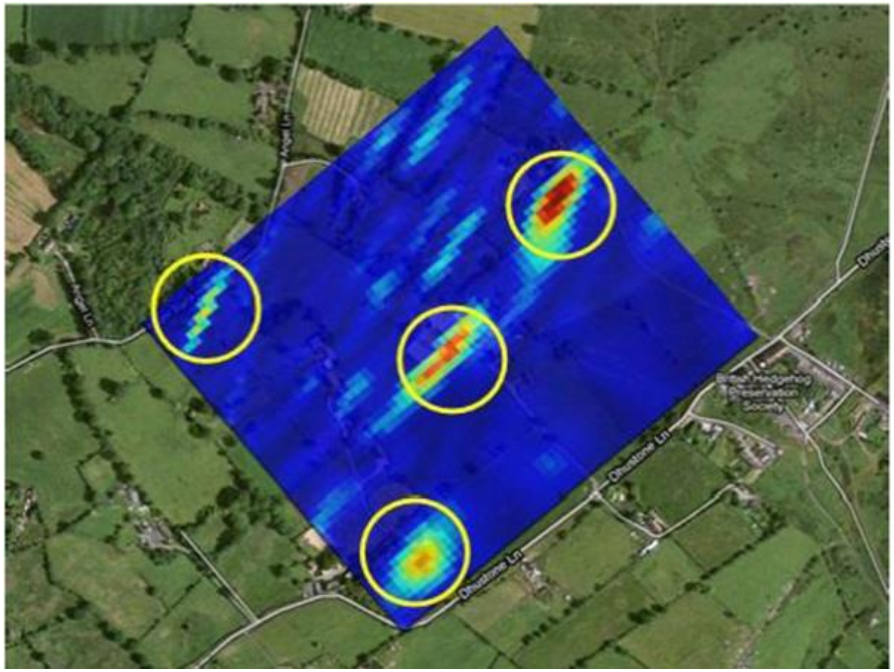


Extracted from K. Polonen and K. V., “Measurements association in SFN passive radar systems,” IEEE Intl. Radar Conference, 2015

Transmitters not available

- In some scenarios the necessary terrestrial transmitters may not be available
- Possible alternative: satellite borne illuminators
- Example: imaging using Galileo signals





Extracted from M. Antoniou and M. Cherniakov, “GNSS-based bistatic SAR: a signal processing view,” EURASIP Journal on Advances in Signal Processing, vol. 2013, no. 1, p. 98, 2013.

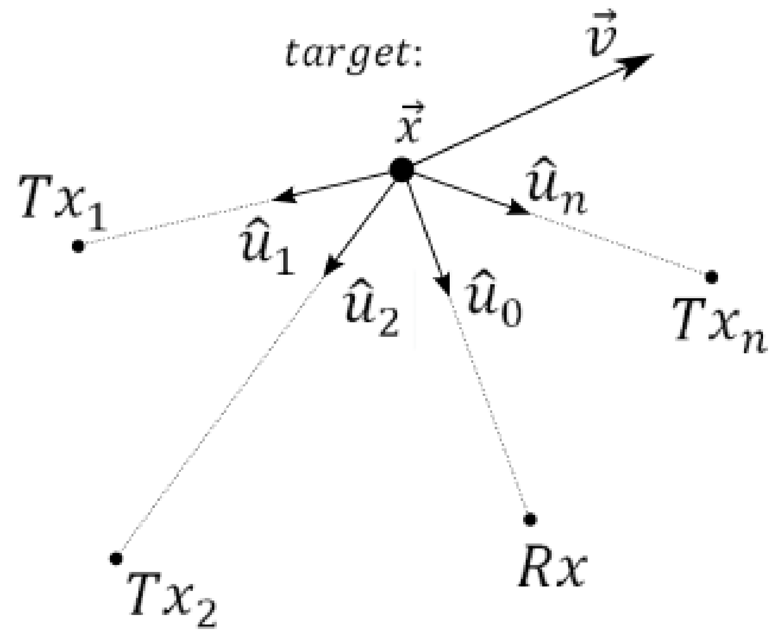
Impact of wind-farms on passive radar

- Wind turbines number in Europe is increasing
- They significantly influence the operation of passive radars causing false alarms or covering real targets
- Using DVB-T transmitter as illuminators of opportunity:
  - Lack of detection in masked regions
  - Doppler spread on echoed signals can be large due to blade rotation causing false alarms

"Impact of Wind-Farms on Passive Radar Operation", K. Kulpa, P. Samczynski, M. Malanowski, J. Misiurewicz. M. Baczyk, J. Kulpa, (WUT), POL, NATO SET-187, Szczecin, Poland, 2013

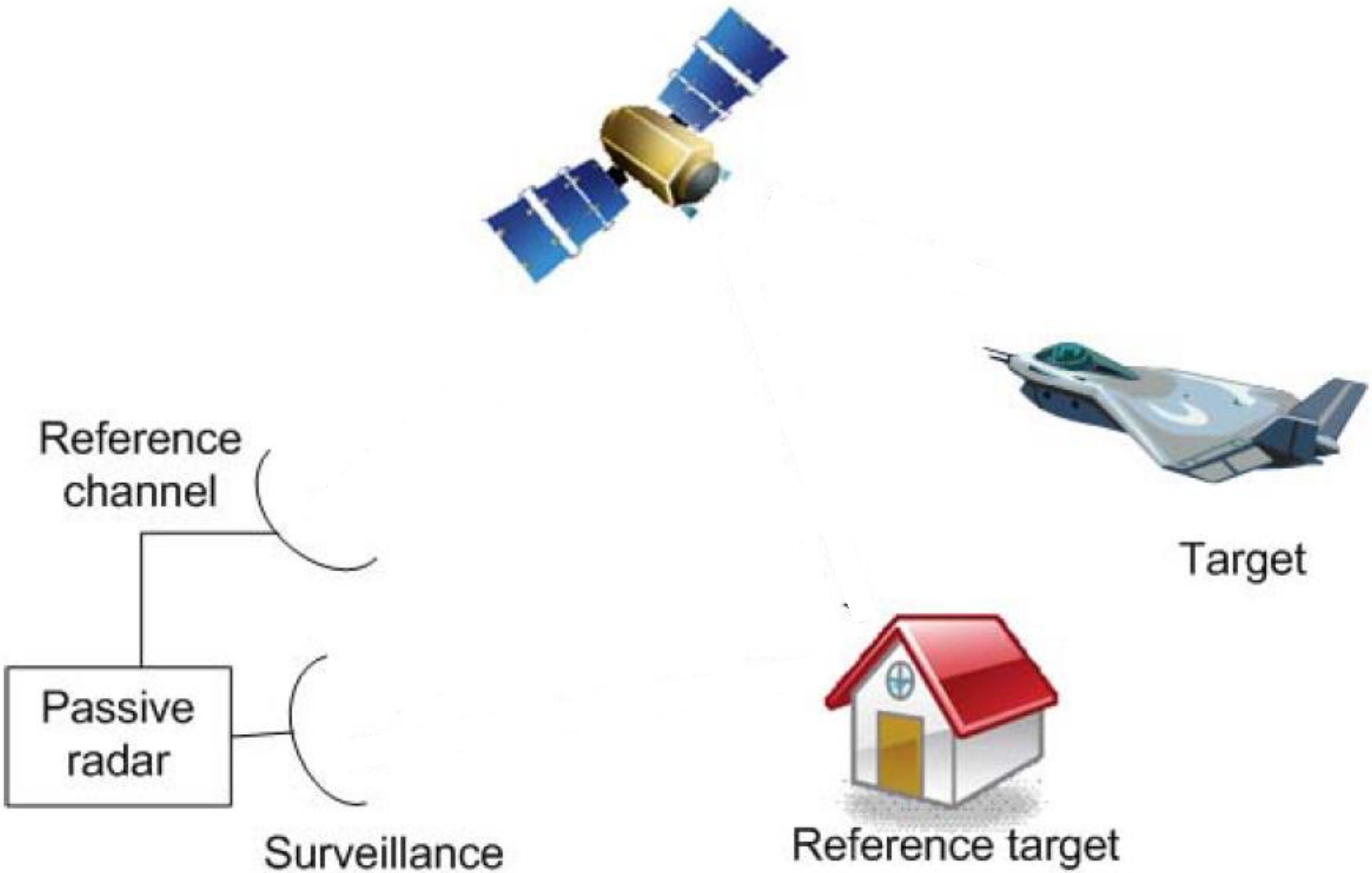
Doppler-only localization and tracking

- Passive Radar – long integration times
  - → Good Doppler estimation accuracy
  - → Doppler-only locatization and tracking may be possible
  - → Advantage: does not need sinchronous sensors
  - → Open questions: achievable performance



M. Wielgo, P. Krysik, J. Misiurewicz, and K. Kulpa, “Doppler-only localization problem solution for PCL radar,” in International Radar Symposium (IRS), 2015.

Opportunity targets for channel synchonization



P. Marques, Opportunity Targets as References for Phase Correction on Passive Radar Channels, International Radar Symposium, Germany, June, 2015

Data fusion between PCL and PET

- PET – Passive Emitter Tracking
  - 2 receiving stations process the signal coming from a target onboard transmitter (communications, IFF or radio navigation systems)
- PCL – Passive coherent localization
  - One station receives a direct signal from a non-cooperating emitter (FM, DVB-T, GSM, …) and the same signal reflected by the target
- Fusion between PCL and PET minimizes the errors that are problematic in each subsystem

"***The Benefits of Data Fusion from PCL and PET Passive Sensors***", T. Brenner, P. Kasprzak, L. Lamentowski (BUMAR ELEKTRONIKA S.A), K. Kulpa, M. Malanowski (WUT), POL, NATO SET-187, Szczecin, Poland, May 2013

Passive Radar

MAIN CONCLUSIONS

Main conclusions

- High potential military use of passive radar technology to detect enemy targets due to its portability and invisibility to anti-radar systems.

- Passive radars can provide covert air volume reconnaissance during peace time: not recognized by a potential enemy and it can warn of possible hostile action.

- Increasing maturity of PCL makes transition from research to application a reality

Main conclusions

- PCL are a different class of sensors than active radars...
  - They will not replace active radars
  - Instead, they can fill the gaps or deficiencies of active radars
- Both types of activities have to be supported