APIS Project Executive summary

Project summary

The "Array Passive ISAR adaptive processing (APIS)" project was born through the framework of the Defence R&T Joint Investment Programme on Innovative Concepts and Emerging Technologies (JIP-ICET) initiative promoted by the European Defence Agency (EDA), in the topic Radar Technologies / Processing and has been implemented by the APIS consortium with the participation of 6 entities, and 4 countries; INDRA Sistemas S.A. (INDRA) (ES) acting as Project Leader, National Interuniversity Consortium for the Telecommunications (CNIT) (IT), VITROCISET SPA (VITRO) (IT), Universidad de Alcalá de Henares (UAH) (ES), MTA-SZTAKI (MTA) (HU) , University of Cyprus (UCY) (CY).

The project had a total duration of 24 months and was founded by EDA with 1,470,946.68 € from a total cost of 1.871.201,98 €.

Project objectives

The main objectives of the project were to:

- Study and analyze a multichannel, multistatic single receiver Array Passive Radar (APR) making use of digital signals of opportunity
- Develop and analyze an adaptive SAP/STAP-ISAR processing technique (Space Adaptive Processing/Space Time Adaptive Processing-Inverse Synthetic Aperture Radar)
- Realize a concept demonstrator of the APIS system

The work done in APIS

Structure and methodology of the project

The work done in APIS has been structured into nine different WPs in order to correctly address and identify the final project objectives. The total length of all the WPs was planned in 24 months with several milestones and project meetings separated by 6 months.

WP1 - Project Management (INDRA Project Leader): This WP is aimed to establish, maintain and disseminate the project structure and milestones, maintain the daily progress of the project and take the decisions in order to drive the activities of all Work Packages within the scope of the contract.

WP2 - System design analysis (UAH Coordinator): This WP analyzed the whole project from a system view to a subsystem view. As a result, it defined the block diagram of a fully capable APIS system. The outputs of this analysis provided the requirements for the rest of the elements of the system, which were the:

- Antenna requirements, that guided the selection or design of the final antenna.
- Receiver architecture, which considered the reference and target channels, including the necessary data acquisition system to implement ISAR techniques.
- Processing architecture to implement the different blocks of the receiver.

This WP also provided a baseline for the APIS demonstrator architecture, a downsized APIS system for proof of concept. Two parallel architectures were considered, as presented in ***Figure* 1**.

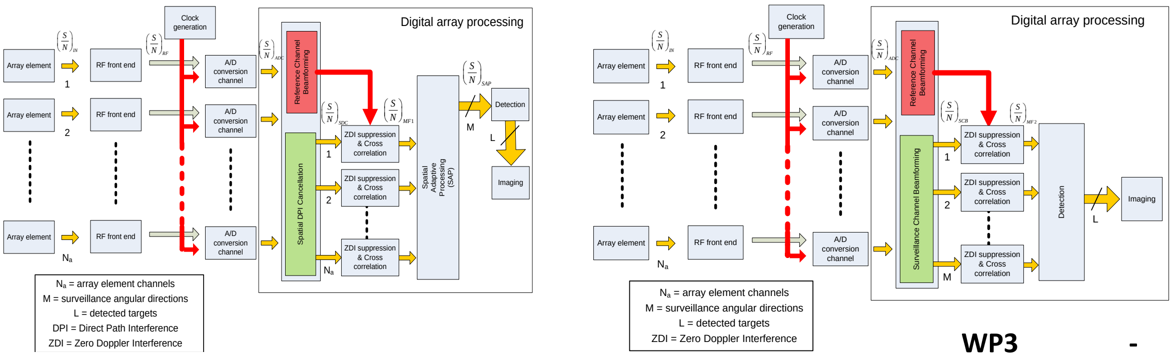

Figure 1. Architecture 1, considering Spatial Adaptive Processing (SAP) beamforming (left) and Architecture 2, considering deterministic beamforming (right)

WP3 - Waveform analysis of illuminator of opportunity (UAH Coordinator): This WP analyzed the potential use of several wide spread and available signals to be used as illuminators of opportunity for a Passive Radar. In this context, analog and digital signals were studied. This study included but was not limited to the DVB-T, FM, DAB, UMTS and military born signals. Also, the suitability and expected performances foreseen for these signals were analyzed (ambiguity function, resolution, coverage...).

WP4 - Beamforming techniques (UCY Coordinator) The objectives of this WP were to determine the beamforming strategies for the APIS system and demonstrator in order to form the direct signal beams on the direction of the transmitters of opportunity and define an adaptive beam technique for creating nulls on the beam patterns of the target channels in order to attenuate the direct signal and the related multipath as well as jammer and hot clutter (direct signal and multipath coming from other sources than the reference transmitter) on the array received signal. This WP also provided a base line SW package to be integrated in the APIS demonstrator

WP5 - Target detection and tracking techniques (CNIT Coordinator) This WP developed a new technique to cross-correlate the reference signal with the target returns in order to reconstruct the range profiles via pulse compression technique. It has defined a spatial adaptive beamforming (SAP) technique to spatially remove the spatially correlated disturbance including, direct signal and multipath interferences, jammer and hot clutter in the target channel and finally has defined a Doppler filtering technique to cancel ground clutter in the target Direction of Arrival. This WP also provided the main SW core for target detection and tracking for the APIS demonstrator.

WP6 - SAP - ISAR signal/image processing (CNIT Coordinator) The aim of this WP was to define an ISAR algorithm to implement the radar imaging functionality in conjunction to the SAP algorithm to reduce spatially correlated clutter/interference. Also the development and implementation of ISAR image processing technique to acquire information on imaged targets has been integrated into the APIS demonstrator as another SW module.

WP7 - System demonstrator (INDRA Coordinator) This WP has collected all the outputs of the previous WPs in order to build, on a low budget, the simplest architecture based mainly in COTS that can be used to show the feasibility of all the techniques and algorithms developed within the APIS project. In this context, a proof of concept system has been implemented and an on-site demonstration will be available.

WP8 - Test and assessment (VITROCISET Coordinator) The objective of this WP was to evaluate the results and performances obtained by the built demonstrator, with special emphasis on the evaluation of the algorithms as those are the most challenging area under test.

WP9 - Exploitation Roadmap (VITROCISET Coordinator) This WP intends to identify from the APIS results the critical technologies as well as the skills required to properly utilize the technologies of the future. as means to achieve a joint decision on future research and development, future skills development, and to establish a commitment to work together to address these challenges.

The following graph intends to represent the interdependency among and between WPs:

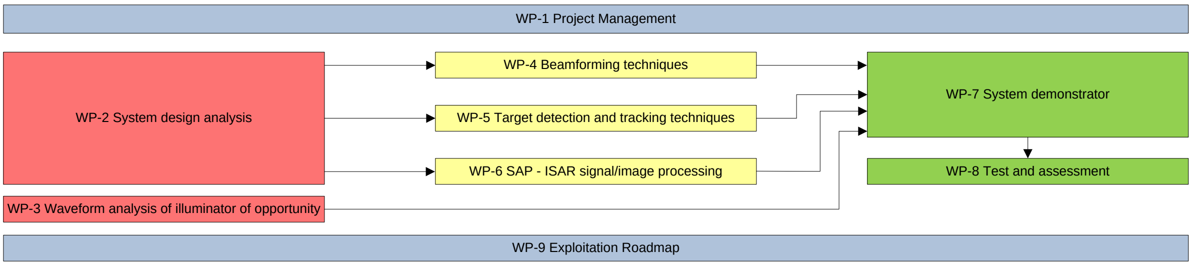

Figure 2. Interdependency WPs flow graph

Outcomes and results of the project

APIS demonstrator step by step

As stated in the original objectives of the project, one of the main three objectives of the project, and for sure the most challenging one was the build of a demonstrator to prove the concept of all the outputs of the different WPs. The outputs coming from all partners needed to be conveniently coordinated in order to coherently build a system of systems.

The scope of the demonstration was agreed with all stakeholders in the project. The main goal was to focus the problem in the assessment of the ISAR capabilities of the system and in the meanwhile to minimize the risks in order to ensure the overall results. In order to do that a potential scenario and a set of minimum requirements and capabilities for the demonstrator were agreed. The main aim was to obtain an ISAR image of a low altitude aircraft.

As stated in the contract, the System Demonstrator has been installed in Spain, Paracuellos del Jarama at a site depending of the Spanish National Civil Aviation Authority (AENA), and the designated targets were the airliners landing at Barajas Airport.

Previous to system built, several simulations and preliminary tests were performed in order to minimize risks and ensure next steps of integration. In this sense antenna and beamforming simulations were performed in order to determinate optimum antenna design.

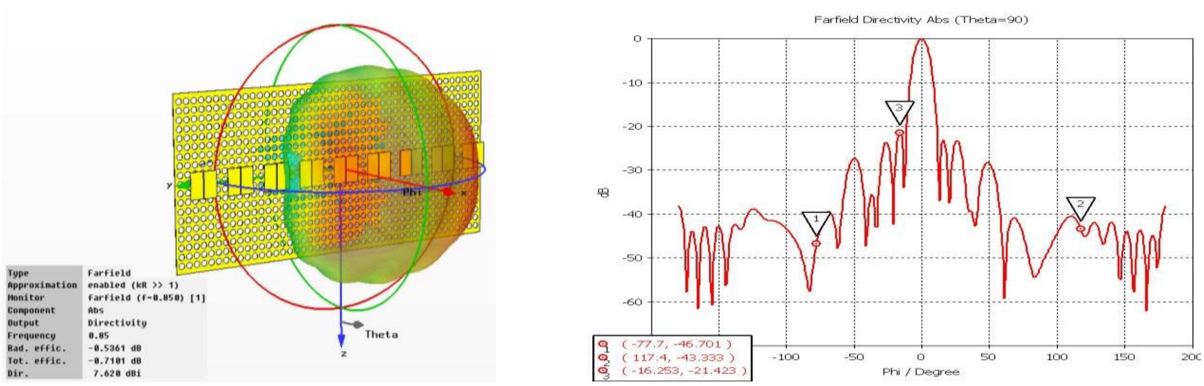

Figure 3. Antenna (left) and beamforming simulations (right) designed by ENAL

In addition, a preliminary algorithms assessment campaign was done using a very primitive system, but good enough to gather very valuable data to evaluate the main system parameters (signal levels and availability, SNR, presence of multipath effects, …).

Figure 4. Preliminary algorithm assessment

Scenario evaluation was also done in order to calculate the estimated performances and to validate the mission concepts (estimated RCS, SNR, geometry, expected dynamics, …).

Once this first risk reduction campaign was concluded, the system building phase and unit testing was conveniently initiated.

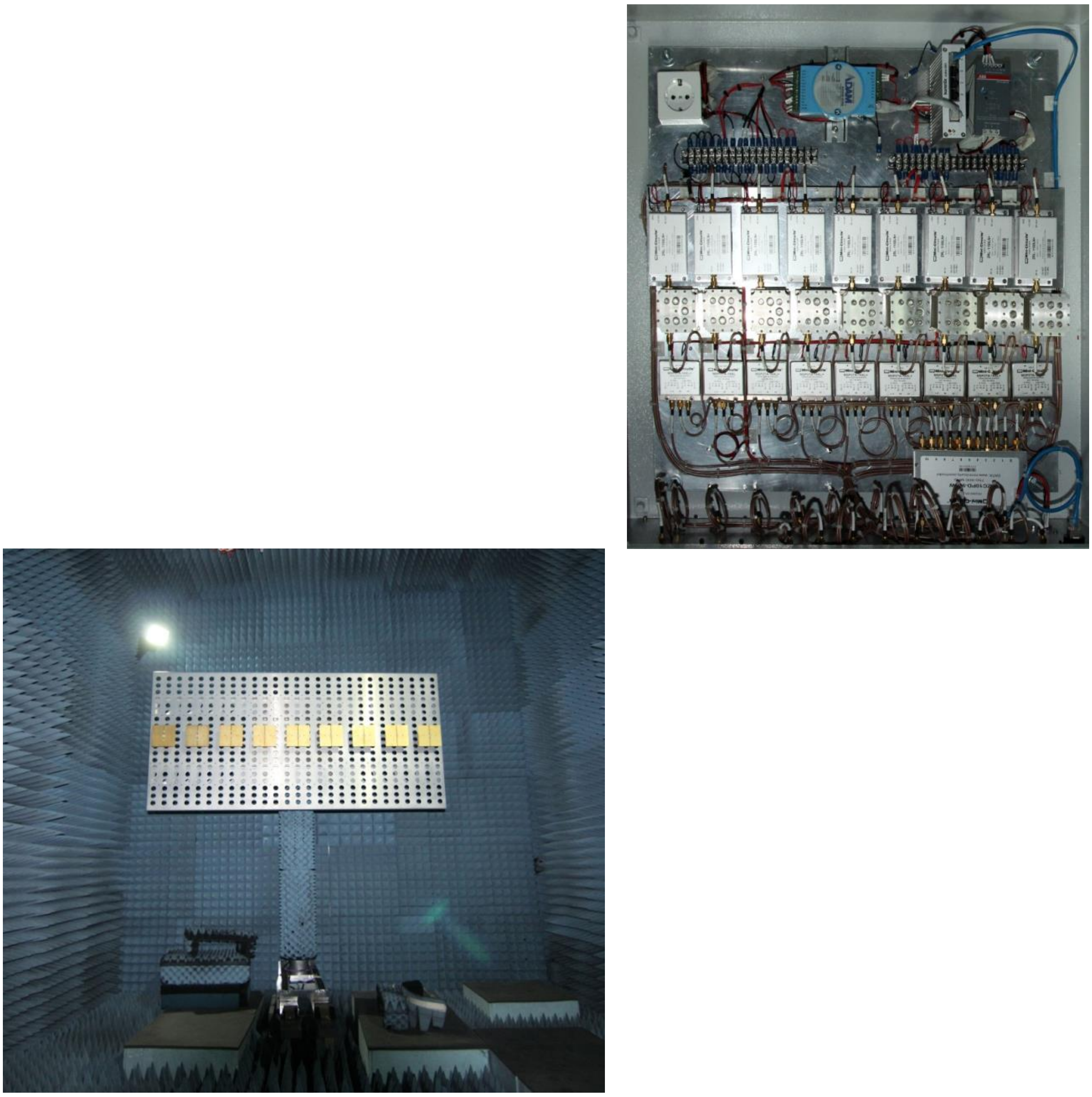

Figure 5. Antenna array (designed by ENAL) measurements in anechoic chamber (left) and calibration network (right)

After unit testing, the integration phase was initiated in order to confirm that calculations, estimations and hypothesis were aligned with real world results.

Figure 6. Field system integration tests

Finally on-site installation (Paracuellos del Jarama) was executed and exhaustive measurement sessions were performed in order to validate the capabilities of the systems as initially planned and agreed with the respective stakeholders. Results were conveniently disseminated through the production of test and assessment reports. Even thought this is not intended to be a technical document, an ISAR image is presented in ***Figure 7***.

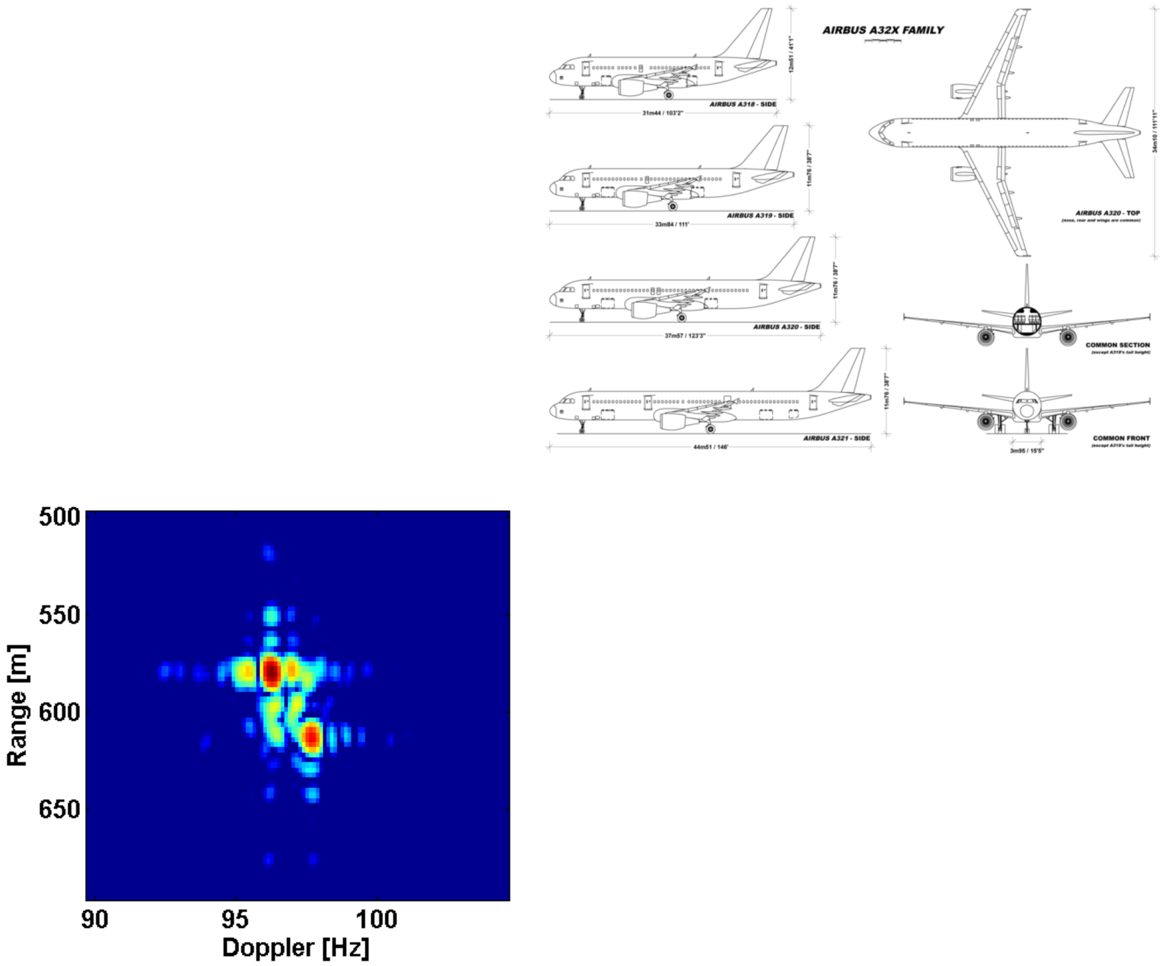

Figure 7. ISAR image using SAP of an Airbus 321

The APIS demonstrator has integrated several innovative concepts and algorithms beyond the ones initially considered in the proposal, such us MUSIC for IoO direction estimation, non-deterministic beamforming embedding SAP into beam formation, etc.

Added value

Regarding the exploitation of the results created in the APIS project, the EDA member countries get access to the produced results, deliverables and technologies, providing a basis for future system development for the presented capabilities.

The APIS Consortium Partners include defense-related industry partners with the goal of developing parts or the whole of the proposed architecture and capabilities. Research partners can also base further research on the results obtained during the project. Thus, the produced results benefit both the scientific and the industrial communities, aiding the defense industry and academics as well.

The added value for the scientific community is many-fold:

- The proof of concept of ISAR imaging through the use of a Passive Radar.
- The real world data captured and processed.

The added value for the EDA contributing members is many-fold:

- First of all, individual system components have been designed, manufactured, implemented and validated in a real world scenario.
- Secondly, APIS provides an architecture blueprint that might be exploited in similar projects or follow-on.
- Thirdly, the used test environment, lessons learned and gathered data may in future serve as a baseline for conducting proof-of-concepts of passive radar imaging.
- Fourthly the used demonstrator environment may serve as a test-bed for future extensions and enhancement not only of the APIS system but also other (commercial) sensor processing equipment.

Results produced in the project could not have been achieved without the fruitful collaboration of many Academic and Industrial partners involved in a large number of different fields and committed in bringing together expertise from both research and application/industry areas. Such collaboration is inevitable for such and similar large scale research work were various fields of knowledge and industry-driven Research & Development (R&D) is the main goal.

The consortium partners benefited during the APIS project from the collaboration with partners of different expertise. The collaboration enabled each partner to broaden its knowledge in the field of radar and had the opportunity to successfully employ their specific skill set in the demanding area of defense systems. The result was the development of the APIS system.

The knowledge gained during the APIS Research activity will be used for future collaborations.