TCAR, the Transatlantic Cooperative AGS Radar: a programmatic and technical overview

Peter Hoogeboom[1], Hans Hommel[2], Giorgio Canafoglia[3], Jim Hausle[4], Jan Hubeek[5], Luis Lopez[6], Robert Nachman[7], Jean-Paul Neuville[8]

[1]TNO Physics and Electronics Laboratory, The Hague, Netherlands, email hoogeboom@fel.tno.nl
[2] EADS, Ulm, Germany, [3] Galileo Avionica, Milan, Italy, [4] Raytheon, El Segundo, California, USA, [5] Dutch Space, Leiden, Netherlands, [6] Indra, Aranjuez, Spain, [7] Northrop Grumman, Baltimore, Maryland, USA, [8] Thales Airborne Systems, Elancourt, France

Abstract — **In view of the NATO Air to Ground Surveillance requirement a feasibility study on the development of an advanced SAR/MTI radar system has been conducted by a group of industries from 6 nations (FR, GE, IT, NL, SP, USA). The architectural design of the system is based on knowledge from currently ongoing radar programs in these countries. A programmatic and technical overview of the TCAR program will be presented in this paper.**
Furthermore a discussion is presented on global requirements, platform configurations and scalability aspects, technical approach to simultaneous SAR and MTI operation, global radar configuration, processing aspects, radar mode developments.

I. INTRODUCTION

The North Atlantic Treaty Organization (NATO), or members thereof, are considering the development of an airborne ground surveillance radar system, known as the NATO Alliance Ground Surveillance (AGS) System. The operational need for an AGS capability, as defined by the NATO Staff Requirement (NSR), is based on a military requirement stated by the NATO Military Authorities (NMA) and a subsequent tasking by the North Atlantic Council (NAC) to the conference of National Armament Directors (CNAD) in 1993 and reconfirmed by the Reinforced NAC in September 2001.

The AGS system will consist of a NATO owned and operated capability, consisting of radar-equipped aircraft, Operation and Control stations, datalinks and ground stations. The advanced radar system TCAR (Transatlantic Cooperative AGS Radar) will form the heart of the system. This radar sensor will be developed by industries of 6 nations and will leverage technology from existing programs. The program will be managed by a dedicated management structure.

The TCAR radar sensor will satisfy AGS Core requirements as specified in the AGS NSR and the Concept of Operations (CONOPS), and satisfy as well, the need for national applications of the TCAR technologies. The requirements are detailed in the Technical Requirement Document (TRD). The TCAR system will be an advanced airborne ground surveillance sensor based on modern AESA (Active Electronically Scanned Array) antenna technology.

The objective of the TCAR program is the development and manufacturing of this next generation SAR Imaging/ MTI radar sensor, and its integration into a manned and an unmanned airborne platform, including its support in operation, to satisfy the AGS requirements. The TCAR concept is based on a modular, scalable and open system architecture. The modularity and scalability ensure the adaptation to various aircraft platforms, such as Midsize-Jets, Business-Jets and HALE-UAVs, with maximum commonality.

The performance of each radar solution will mainly be determined and limited by the specific platform constraints, e.g. available platform prime power, cooling, space and payload weight allocation.

The TCAR is an advanced side looking, wide area surveillance (WAS) multi mode radar. The radar is characterized by:

- long processed range,
- concurrent SAR and MTI-functions,
- an X-band active electronically scanned array (AESA) antenna,
- high reliability and antenna graceful degradation,
- high effective radiated power (ERP) by modern generation of active transmit/receive modules (TRM),
- wide- instantaneous bandwidth,
- low antenna side lobes,
- COTS digital signal processing,
- built-in calibration and measurement.

II. TCAR CONSORTIUM OVERVIEW

The US and European governments (Germany, France, Italy, Spain and The Netherlands) have tasked their industries with AESA experience to initiate an AGS Radar (TCAR) Feasibility Study. The following American and European radar industries jointly performed the TCAR study:

- European Aeronautic Defence and Space (EADS)	GE
- THALES Airborne Systems	FR
- Galileo Avionica	IT
- Indra Sistemas	SP
- Dutch Space	NL
- Northrop Grumman	US
- Raytheon	US

III. RADAR ARCHITECTURE

The architecture proposed for the TCAR is based on a modular, scalable and open radar system design. In characterizing the system, there are several requirements that drive the architecture. Some key points are:

- a multibeam capability and a high aperture power product to enable high revisit rate of moving targets in a large area at long range,
- independent hardware to enable concurrent modes, e.g. SAR and MTI,
- a large antenna along with multiple receivers and STAP (Space Time Adaptive Processing) processing to enable high positioning accuracy in MTI modes and to achieve a small minimum detectable velocity (MDV) of moving targets,
- time delay networks and small element spacing in the antenna to allow for large squint angles, in order to cover large areas,
- wide-band waveform generators and other components to allow for high resolution in imaging and non-imaging modes.

The application of scalable antenna design techniques enables the re-use of technology in TCAR radar designs that range from relatively small sized short antenna HALE UAV systems to large-size, powerful mid-size jet systems that employ a very long antenna. These systems will use the same T/R modules.
The scalable radar system hardware architecture, shown in Figure 1, consists of:

- Antenna Group,
- Central Electronics Group,
- Radar Processing Group.

These elements are internally connected via a radar control Local Area Network (LAN). Data is internally transported via specific interfaces to accommodate fast transport requirements (not shown in the figure). Connections to the AGS Mission Subsystem will be established via specific interfaces for radar output data and for radar control, tasking and navigation data.
The Antenna Group, the Central Electronics Group and the Radar Processing Group are described in more detail in the following sections.

A. Antenna Group

For each of the platforms the radar antenna will be an AESA, mounted with a one axis gimbal to the fuselage of the platform (it could be positioned underneath or on top of the fuselage). This gimbal orientation allows radar pointing to the left or the right side of the platform. In azimuth, an electronically scanned beam achieves a wide angular coverage. In elevation, the electronic scan capability allows full illumination of the Ground Reference Coverage Area (GRCA).
A high transmit power is achieved by the use of a large number of transmit receive modules (T/R modules). The AESA inherently supports high system availability enabled by graceful degradation of radar performance. Liquid cooling is applied in the Antenna Group to support the high power dissipation requirements.

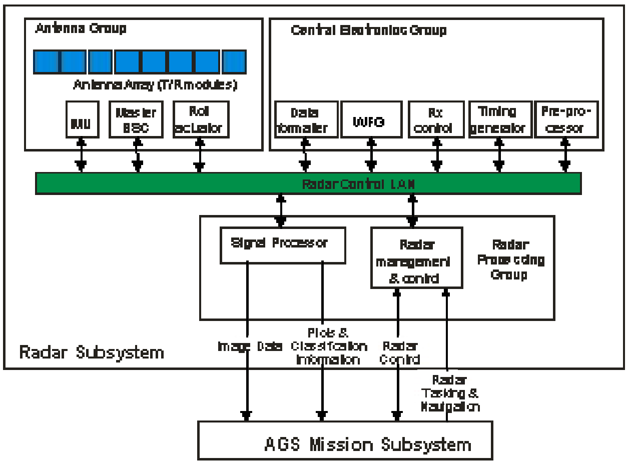

Figure 1: Overview of the radar system architecture

The Antenna Group is composed of:

- On Axis and Off Axis Antenna structure and frame,
- Antenna-panels, planks (basic building block of the scalable AESA antenna, with a predefined elevation structure) and sub arrays,
- Separate manifolds for transmit and certain receive modes,
- Beamformer, RF interface and RF converter,
- Harness, Beam Steering Computer, Time Delay networks, DC power supply and IMU,
- Antenna Gimbal.

B. Central Electronics Group

The Central Electronics (CE) Group (Receiver/ Exciter) is based on a modular and configurable design, in order to provide opportunities for technology insertion for future applications and upgrades. The CE supports a variety of different modes including concurrent SAR/MTI modes.

The Central Electronics Group includes:

- The Exciter, which generates the different waveforms for the SAR, MTI, HRR (High Range Resolution) and simultaneous modes. Furthermore, all reference Local Oscillator signals for up, down conversion and timing base will be generated and distributed.
- The multi-channel digital receiver supports the down conversion with fixed LO and de-ramping techniques. Multi-beam-on-receive and STAP techniques are also supported. The receivers support advanced signal pre-processing, including digital I/Q conversion, digital down-conversion and data formatting.
- Calibration support to adjust gain and noise levels in the AGC attenuators.
- The power conditioner for filtering and providing the power forms for the Antenna Group.
- Handling the information from the IMU in the Antenna Group and distributing these data to the Radar Processing Group.

C. Radar Processing Group

The Radar Processing Group includes:
- The Radar Management and Control processor,
- The Radar Signal Processor (COTS based processor).

Figure 1 shows the control data flow within the radar and between the radar and the AGS Mission Sub-system.

For the HALE-UAV system, the COTS based components and boards will be ruggedized to survive the extreme, high altitude environments.

The Radar Management and Control processor will manage proper operation of the radar subsystem and handle the control and tasking between the Radar and the AGS Mission Sub-system.

The Radar Management and Control Unit will perform the following operations within the radar:
- Verify that the actions commanded by the AGS Mission Sub-system to be performed by the radar are properly received and understood.
- Distribute the orders received from the AGS Mission Sub-system to the different radar components involved in their execution.
- Generate the proper commands for the rest of the radar elements, including beam control and antenna pointing and selection of the proper waveform parameters for the radar modes to be applied at the Central Electronics Group.
- Collect status, built-in test reports and relevant radar diagnostic information from the different radar elements. This information is transferred to the AGS Mission Sub-system.
- Supervise data flow between the AGS Mission Sub-system and the Radar.
- Monitor the requested radar tasks to insure that they are being performed according to the expected operational capabilities of the radar.
- Perform periodical housekeeping and monitoring tasks of the different radar activities.
- Collect GPS and navigation data from other platform sensors and provide them to the radar system.

A separate radar control capability will enable radar stand-alone operation (e.g. during radar integration, test, radar validation and in-field maintenance). This radar control capability can generate radar tasks.

The radar signal processor handles digitized data that will come from the receiver together with all the radar setup information (time, PRF, frequency, etc.). These data are processed in real time. Separate processing sections take care of the concurrently available SAR and MTI data streams.

The COTS based Radar Signal Processor will process all the digital channels implemented at the receivers. This processor will provide the different radar products required by the AGS Mission Sub-system.

Due to the high data rate involved in the signal processing, it is expected that the data will be sent over a dedicated high-speed data network to the AGS Mission Sub-system.

IV. Radar modes

The following operational radar modes will be implemented:
- **Moving Target Indicator** (MTI): The MTI mode is used to detect moving targets. Individual targets within convoys or groups will be resolved with sufficient accuracy for targeting. A high resolution ground MTI mode (HRR WAS), a medium resolution ground MTI mode and a medium resolution maritime MTI mode will be provided. A wide area is covered with these MTI modes with a high revisit rate. The plots generated by the MTI modes will be delivered to the AGS Mission Sub-system, which will perform the target tracking.
- **Classification modes**: The classification modes (terrestrial ISAR, maritime ISAR, HRR and Spectral Classification (SPC)) are used to generate data for the support of the classification of designated targets. The SPC mode provides Doppler spectra of designated targets. The classification will be done by the AGS Mission Sub-system and may include the ability to discriminate between wheeled and tracked vehicles, slow flying helicopters and ground rotating antennas.
- **Swath SAR**: The Swath SAR mode is used to image long-range swaths at selected image resolutions for the surveillance of fixed targets.
- **Spotlight SAR**: The Spotlight SAR mode is used for imaging of small areas at selected high resolutions to provide detailed images of the targets.
- **Open Sea**: The Open Sea mode is used for vessel detection in the open sea and will operate in high sea states.

The MTI modes will cover the whole GRCA (area of interest) on a continuous basis. All other modes can operate in any (squinted) area within the GRCA.

V. Development approach

The industrial consortium that carried out the feasibility study will develop the TCAR radar. The radar will be delivered to the AGS System consortium. Integration and testing will be jointly done in a cooperative effort of both consortia.

The program will start with a Design and Development (D&D) phase. A detailed design will be made by a joint engineering team. TCAR will be based on knowledge and technology from US and European AESA programs. The manned aircraft radar and the HALE-UAV version will, as much as possible, be developed, integrated, qualified and flight-tested concurrently.

The first prototype radars will be flight-tested on the target aircraft for the Mid-size jet and on a suitable surrogate manned aircraft for the HALE-UAV radar.

The development of software for the radar modes occurs in parallel with the hardware development. A spiral approach with three software builds is proposed, where the single modes are delivered first, followed by the

concurrent modes. Based on test flight results and further development, new versions will become available. The concurrent modes will be tested after the successful completion of the single mode validation.
The production phase will start under a subsequent contract. The Initial Operational Capability will be available in the year 2010 as required by NATO.

VI. Conclusion

In this paper the design of a state-of-the-art SAR/MTI radar for ground surveillance has been presented. This radar will be designed by 7 industries of 6 nations and based on technology and knowledge from US and European AESA programs. The radar is designed at the request of 6 NATO countries and should provide NATO and the nations with an initial state-of-the-art Ground Surveillance capability in the year 2010.

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