Radar sensor technology developments at CSIR DPSS in support of Persistent, Ubiquitous Surveillance Systems

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Abstract

South Africa, like other countries, faces the challenge of protecting its territory and its people from activities such as illegal border crossings, weapons trafficking, smuggling, piracy, poaching, organised crime, and terrorism on land, at sea and in the air. The country's assets available for monitoring and securing its large land and maritime territory are relatively small, resulting in an unfavourable force-to-space ratio.

Since 2003 the Council for Scientific and Industrial Research (CSIR) has been involved in developing some of the key elements of an S&T capability based on international technology trends in persistent, ubiquitous surveillance. The ultimate aim of this programme is to develop and produce a series of South African innovations that can be used by departments and agencies of the State to enhance national security. The operational concept would be to enhance their real time situation awareness and thereby achieve a force multiplication effect to overcome challenges caused by the low force-to-space ratios in their areas of responsibility.

The CSIR system engineering team on the programme identified radar as the primary sensor for such security related surveillance systems. Reasons include radar's potential to provide long range coverage (tens to hundreds of kilometres), scan 360° with high update rates (several times per minute), low latency (less than 30 seconds) under most environmental conditions of interest (day and night, and under low visibility conditions caused by high humidity, salt spray, fog or rain) and monitor large numbers of objects of interest (up to 10 000) virtually simultaneously. Also, radar operation is not dependent on active cooperation by the object of interest (e.g. by transmitting beacon or transponder signals) or on it radiating communication or navigation signals.

This paper highlights:

a) Some of the key functional and performance requirements of this type of radar.

b) Recent results obtained in a number of directed research projects undertaken at the CSIR to develop radar technologies required for this type of radar.

c) The CSIR technology roadmap for the development and/or acquisition of the radar and other sensor subsystems, the data fusion subsystems and the elevated platforms leading to fully integrated surveillance systems of increasing performance.

d) Progress with the development of operational scenarios, employment doctrines and system level requirements for these types of systems.

1. General introduction

The Radar and Electronic Warfare Competency Area at CSIR DPSS has been active in applied research and technology development (R&D) in its field of expertise since the late 1960's, mainly in support of the Department of Defence. One of its best-known achievements as part of the National System of Innovation is the development of modern pulsed Doppler tracking radar technology in South Africa. During the late 1990's this technology was transferred to Reutech Radar Systems (RRS), a fully South African owned radar company. RRS based the development and production of the RTS 6400 Optronic Radar Tracker (ORT) on this technology transfer. The ORT is currently operational on the SA Navy's Valour Class Frigates as the primary target tracker in their anti-air and anti-surface fire control systems. This is the culmination of a fully South African developed innovation that saved the country R 350 million in foreign exchange.

Reaching the end of this successful technology transfer in 2002, the question was asked what new class of radar-based solutions were required in future South African security related systems. The challenge was to find a class of problems that affects the quality of life of the people of South Africa at the national level and that could be solved with a family of creative, radar based innovations. If, in addition, the innovations could be manufactured in South Africa by the existing aerospace sector of the country's Science, Engineering and Technology (SET) capability, it could provide a family of new innovations to these national resources and thereby enhance their wealth creating potential.

Furthermore, an opportunity was sought requiring a solution at a high level of the systems hierarchy – a so called Tier 1 solution. This means that, if successful, not only technological capabilities at the subsystem, component and material levels would be developed, but also technologies at the user systems level. It ensures that the design authority and intellectual property of the system that is eventually delivered to the end user reside in South Africa. This ensures South African control over the choice of subsystems, suppliers and export clients.

Lastly, an opportunity was sought that would contribute to the development a knowledge based economy in South Africa with the accompanying opportunities for human capital development and the creation of employment and wealth as foreseen in the Department of Science and Technology's Ten Year Innovation Plan.

2. The identified top level requirement

One of the important challenges faced by South Africa today is the perceived inadequate level of safety and security. This is true both at the personal or small scale level where people and small businesses feel unsafe due to the high levels of violent crime, but also at the national level where organised crime is conducted by increasingly larger and better organised groups.

Activities such as the poaching of marine resources including abalone, crayfish and fish and national border violations by groups involved with smuggling, weapons and people trafficking, stealing of cattle or game, illegal immigration, etc. are regularly reported in the public media. This leads to South Africa being perceived by the outside world as well as by many South Africans as an unsafe country. It also influences perceptions about South Africa's ability to host major events such as the 2010 FIFA Soccer World Cup.

One of the ways to help counter this type of crime is to provide innovations specifically optimised for their missions and concepts of operation to government departments and agencies tasked with ensuring national level safety and security.

Turning to South Africa's role in the sub-Sahara African region, the New Programme for Africa’s Development (NEPAD) identifies the establishment and maintenance of peace, safety and security as prerequisites for sustainable development in Africa.

This motivates the South African government to deploy its security forces not only inside South Africa, but also in various countries in Africa as part of peace support operations mandated by the African Union (AU) and the United Nations (UN). These types of missions often tend to degenerate from UN Chapter 6 (peace keeping) to Chapter 7 (peace enforcement) operations. To execute these types of missions with maximum effectiveness while providing maximum protection to personnel engaged in them, some specialised equipment and doctrine are required, creatively conceived to give our forces a competitive edge against the asymmetric threats they encounter.

Considering the required capability in more detail, it becomes clear that crime and instability need to be prevented and fought on land, at sea and in the air. It is often difficult to detect and monitor perpetrators and act against them as they usually choose to operate at night, in conditions of bad visibility or in areas not under surveillance. Others conceal themselves amongst private or commercial traffic in order to gain an advantage on their victims and/or the security forces.

As illustrated in fig. 1 below, South Africa has a land area of 1,2 million square kilometres, a maritime economic exclusion zone (EEZ) of 1,5 million square kilometres and an air space covering both these areas. The land borders span 4862 km and the coastline 3924 km. However, the country's assets available for monitoring and securing this vast area and its borders are relatively small, resulting in an unfavourable force-to-space ratio. This situation makes it relatively easy for criminals and hostile forces to carry out their plans undetected and with impunity.

In South Africa, the members of the Justice, Crime Prevention and Security Cluster (JCPS) of government are collectively responsible for ensuring national safety and security. This cluster includes police, defence, intelligence and other

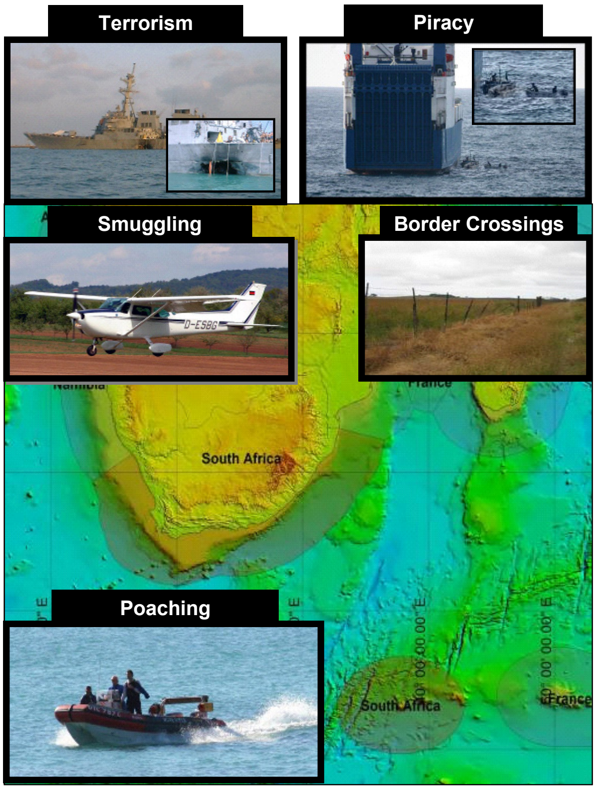

Figure 1: Some threats of interest in Africa and in South Africa's border zones, including its maritime economic exclusion zones. Efficient and effective surveillance is required over all important parts of the South African land border areas, air space and maritime zones.

departments with national security responsibilities. To increase their efficiency, South Africa needs to deploy national capabilities that transcend the responsibility and focus of any one department and that can be deployed in a wide variety of national roles.

These challenges provide opportunities for innovations that can help members of the JCPS improve the quality of life of the people of South Africa, while creating new jobs and wealth in our industry through the development and production of new knowledge based products and services. In addition, success may contribute to a change in public perceptions about South Africa: both its willingness to prevent and fight crime, and its ability to do so with indigenously developed technology. It would also contribute to the international marketing of the products involved, since they would have been proven under actual operational conditions in a developing country.

3. Relevant technological solutions

Progress in aerospace technology and specifically in the fields of aerial platforms, sensors and ICT, makes it possible to conceptualise systems capable of providing real time situational awareness. This in turn can provide a force multiplication effect that would greatly enhance the efficiency and effectiveness of intelligence agencies and security forces.

These technologies make it possible to provide persistent (“all the time”) and ubiquitous (“everywhere at once”) surveillance. Situational awareness is enhanced by means of an integrated system of systems. The ultimate objective of these systems is to provide real-time information with unprecedented richness and reach. The richness is achieved by tightly integrating a variety of new-generation, high-performance sensors mounted on elevated platforms in order to provide wide area coverage. This forms an information network, fusing sensed data and extracting enriched information regarding the situation and the way in which it is developing. It combines the individual strengths of various types of sensors deployed at optimum positions in the area of interest. The reach is achieved by segmenting the resulting information into classes of interest to various user groupings. Only that part of the real-time information that is important to each user group is provided to them in a way designed to optimise its assimilation and use by commanders. In this way optimum decision making is enabled regarding the actions to be taken by their respective services and forces.

Figure 2 below indicates the functions required in an ideal persistent ubiquitous surveillance system to provide a "recognised area picture" with the proposed qualities of richness and reach.

Performance that was previously limited to the domain of science fiction, films and computer games is becoming feasible by exploiting the exponential increase in performance of modern digital information and communications technology (ICT) and digitized sensors. For this reason this type of system is being referred to as “digital surveillance” in the civilian security environment or as the information, surveillance and reconnaissance (ISR) part of the Command, Control, Communications, Computers, Intelligence, Information, Reconnaissance and Surveillance

(C^{4}I^{2}RS) functions of the "digital battlefield" in the military world.

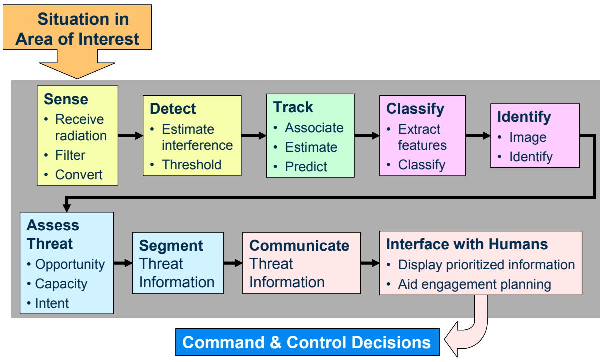

Figure 2: Sensing and information processing functions required to provide persistent and ubiquitous surveillance over large areas with richness and reach and thus support the maintenance of quality situational awareness.

4. The AwareNet R&D Programme

AwareNet is the name given to the CSIR's applied research and experimental development programme in persistent, ubiquitous surveillance systems. It was formulated in 2003 as part of a strategy planning process where the challenges and opportunities summarised in the previous section were recognized. Since then, AwareNet R&D activities steadily increased as more funding was obtained and as the R&D team involved in it continued to grow.

In 2002, CSIR DPSS performed a study to identify potential sensors and platforms that may be used as part of a national scale maritime surveillance system. It was found that radar and/or electro-optical and signal intelligence sensors deployed on spacecraft, manned aircraft, UAVs, aerostats and airships and also networks of terrestrial and ship-based microwave radars as well as terrestrial HF surface wave and sky wave radars are currently used in other countries for applications akin to those described in sections 2 and 3. This study came to the preliminary conclusion that for Southern African conditions and currently perceived threats, a system with a high performance, elevated microwave radar as its primary sensor may be a cost effective solution.

During the first phase of the AwareNet programme, six main technologically defined subsystems were identified as important for this type of solution. These were:

- Elevated, semi-geostationary, long endurance platforms such as unmanned, stratospheric airships, tethered aerostats and long endurance unmanned aerial vehicles (UAVs).
- Long range microwave surveillance radars with automatic target detection, multiple target tracking and target recognition functions.
- Multi-spectral electro-optical sensors.
- Radio frequency surveillance sensors.
- Data fusion, intent estimation and threat estimation algorithms, data interfaces and communication systems.
- Human machine interfaces, properly designed based on cognitive task analyses.

Further development of the concept later indicated that a seventh subsystem may be required in many cases. This is an airborne, high resolution electro-optical sensing system to provide real time imagery of the activities on and around a selected object of interest. This may be based on manned platforms, but also, increasingly, on small, quiet UAVs.

First indications of the technology readiness of subsystems that may be incorporated in the overall AwareNet surveillance system were obtained and in the light of these, adjustments were made to the overall objectives and the long term road map for the AwareNet system. (Please see section 9.1 for a description of the concept of technology readiness).

Regarding the platform that may be used for semi-geostationary operation, it was found that globally, the technology readiness of stratospheric airships and their subsystems were still at levels 1 to 4, indicating that the technology roadmap should not rely on such capabilities in the short to medium term. This insight caused a shift in focus towards masts, mountain tops, aerostats and, possibly, long endurance UAVs as the more likely short to medium term platforms.

In the fields of the sensor and data processing subsystems, important (and feasible) avenues of scientific inquiry and technology development were identified as being:

- Remote sensing of objects of interest over wide areas of coverage under naturally occurring propagation conditions, at sea, in the air and on land.

- Automatic detection of entities of interest while suppressing unwanted clutter and false target detections.
- Automatic tracking of all detections and the estimation of the positions and movements of the entities of interest with the required resolution, accuracy and update rate to ensure continuity of tracking and sensing of the joint behaviour of entities without swapping track identification.
- Semi-automatic estimation of the class and, if possible, the identity of each tracked entity.
- Semi-automatic analysis of the behaviour of each classified entity over time and in relation to other entities and resources in the vicinity in order to estimate the probable intent of each entity.
- Semi-automatic determination of the level of threat posed by each entity based on its proximity to resources that may be exploited, its ability to exploit such resources and its intent to do so.

Slowly changing information from geographic information systems, intelligence databases, weather sensors, etc. needs to be seamlessly integrated with each track to provide the context and thereby enhance the extraction of meaning from the real time sensed information. If data are available from external sources such as beacons, telemetry systems and satellite-based sensors, these should be solicited, integrated and fused in a way that enhances the situational awareness of commanders.

5. Radar related progress and impact

Phase 2 (2007 – 2009) of the AwareNet programme started with proposals for CSIR competitive funding for more detailed R&D work being formulated in all the non-platform related subsystems identified in section 4. Unfortunately, the only CSIR funding awarded for this phase was for the overall AwareNet system requirement analyses and concept development and for a number of important radar subsystem level directed research tasks. Some co-funding for the radar tasks was also secured from the Department of Defence's DERI funding. This allowed the CSIR to make good progress in some important radar related topics and achieve impact at technology readiness levels 1 to 4 that will be described in the following sub-sections.

In order to achieve the type of surveillance system defined in the previous section, a radar with high performance in each of the functions of sensing, detecting, tracking and classification is required. Early investigations indicated that a radar with long coherent integration times along with a wide sensing bandwidth would probably be required to obtain enough energy on the targets for detecting small targets at long ranges, for obtaining enough Doppler resolution to distinguish targets from clutter, and for achieving the range and Doppler resolution as well as the sensitivity required for target classification. The requirement is to achieve this, while at the same time having high enough update rates to track and estimate the maneuvering behaviour of a large number of maritime, air and land objects of interest with a radar sensor with low enough mass and high enough reliability to be carried on a long endurance airborne platform.

These challenging requirements may potentially be satisfied with a multi-channel agile or staring beam array radar with a large aperture. It was therefore decided to continue the radar part of the programme by postulating such a radar concept and asking what the required waveforms, signal processing algorithms and the performance limits would be for each of these functions. The answers to these questions are required to define the requirements for the antenna, transmitter, receiver waveform generation, signal and data processing subsystems of such a radar. To this end, R&D tasks on each of the topics in the following subsections were carried out during the past 3 years.

5.1 High range resolution radar processing

The current capability in this field at the CSIR has its roots in work carried out on an X-band SAR by a joint CSIR/UCT team. They developed a stepped FM technique to provide high range resolution (HRR) over the full radar range. The new technique suppresses the usual problems with stepped FM of forming “ghosts”. This work was published in an IEEE conference paper (NEL W.A.J. et al., 2002). The CSIR subsequently implemented the stepped FM technique in both the Fynmeet and MECORT radar R&D facilities and through the development of some creative calibration techniques, improved it to achieve -35 dB spurious free dynamic range.

In order to increase the unambiguous Doppler interval over which high range resolution measurements can be made, a second technique had recently been developed and implemented on the Fynmeet radar. It is referred to as "de-chirp on receive" and is a technique that allows high range resolution to be obtained within a single radar pulse repetition interval (rather than with a series of pulses as is required with the step FM technique). Following a detailed mathematical analysis of this technique and the various non-idealities typically present in a radar waveform generator/receiver chain, a setup and calibration procedure was developed that again enabled -35 dB spurious free dynamic range to be achieved in the Fynmeet Radar system (DE WITT J., NEL W.A.J., 2008).

The CSIR HRR capability has already been used to form high range resolution radar images of various ships and aircraft as well as test targets (see figure 3 for an example). An important application is its use as a diagnostic tool to determine the relative magnitude of radar scattering centres on "stealthy" ships and aircraft. It can be used to identify the main contributors to the radar cross section (RCS) of such platforms, the first step in a program to reduce a platform's RCS in order to enhance its survivability when attacked by radar guided weapons.

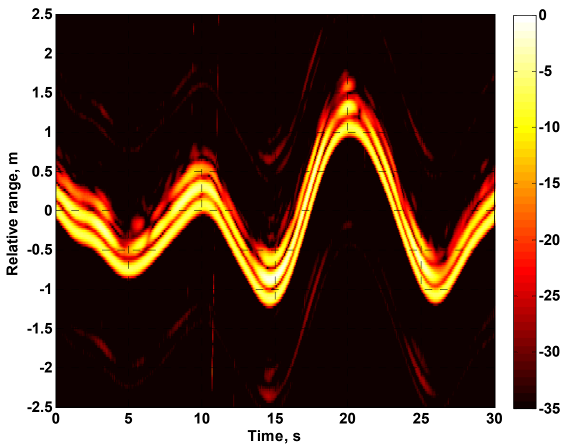

Figure 3: MECORT HRR measurements on a sphere suspended from a weather balloon above the sea. Range resolution of about 12 cm allows the reflections received via the direct, single and double bounce propagation paths to be resolved, enabling the measurement of the temporal statistics of these radar reflecting mechanisms.

On the AwareNet programme this capability underpins radar target recognition techniques that make use of the relative radial positions of target scattering centres on targets, those that only use the length and width of the target and those that make use of Inverse Synthetic Aperture Radar (ISAR) techniques to obtain a target image that may be used for target classification.

5.2 Small boat detection in sea clutter

The focus of this part of the AwareNet radar research is the automatic detection and tracking of small boats at all ranges from very close to the radar to the radar horizon and under all sea states and weather conditions under which these boats may be used. CSIR researchers considered a part of the problem space currently not well covered in available radar literature, namely the characteristics of the radar echoes from small boats as well as from the surface of the ocean that become measurable with high range resolution and with long radar dwell times. The hypothesis is that a staring beam array radar will be able to exploit these characteristics to achieve significantly better detection and classification performance than is possible with current maritime surveillance radar technology.

Addressing this gap in the available knowledge base, the CSIR DPSS performed an extensive measurement campaign near Cape Agulhas, the southernmost tip of Africa, during the winter of 2006, using the wideband Fynmeet radar measurement facility. Calibrated radar reflectivity measurements were recorded along with measurements of the prevailing weather conditions, the wave heights and directions and the positions and orientations of three different types of small boat. Hundreds of data sets were recorded over a period of two weeks and under a wide variety of weather and ocean conditions.

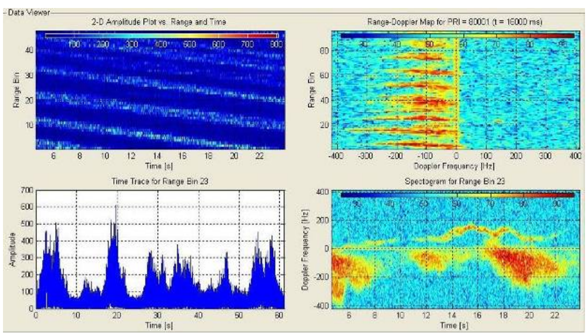

Figure 4: One of the July 2006 datasets processed to show the amplitude and spectral characteristics of sea clutter and a small boat as a function of time. In the bottom right quadrant, note the difference in the spectral signature of breaking waves and that of a small rigid hull inflatable boat. This is the basis of the new type of CFAR detector that is being developed as part of the AwareNet radar programme.

The CSIR processed this rich set of data in collaboration with the University College London (UCL) and the University of Cape Town (UCT). A number of identified research questions in the fields mentioned above were answered. These represent important inputs to the AwareNet radar concept definition.

In addition, following the suggestion of radar specialists in the UK who considered the recorded dataset to be one of the best of its kind in the world, the CSIR decided to make it accessible via a website portal www.csir.co.za/small_boat_detection). The CSIR first announced the availability of the dataset at the IET International Conference on Radar Systems in October 2007. It was again mentioned by Dr. Simon Watts, a prominent UK radar researcher, in his keynote address at the IET Radar Clutter Modelling Seminar held in London in February 2008 and again in his keynote address at the IEEE International Radar Conference held in Adelaide, Australia in September 2008. It has already been accessed and used by at least 20 registered researchers from a number of countries (including the United Kingdom, the Netherlands, France, Italy, Korea, China and the USA). It resulted in an increased international visibility of the radar R&D capability at the CSIR and in a number of international collaborative interactions.

During November 2007, the higher sensitivity and larger look-down capability of the MECORT radar facility were used to record another dataset from a high location on Signal Hill above Cape Town. Sea clutter measurements were recorded over a larger range of grazing angles, a wider range of angles relative to the wind and with different range resolutions over deep water and around the shores of Robben Island. A different set of small boats were also instrumented and measured along with a wide variety of other targets of opportunity.

Figure 5: MECORT deployed on Signal Hill overlooking Table Bay and Robben Island during the November 2007 measurement campaign.

These measurements enabled the CSIR to develop a number of validated mathematical models of the amplitude, temporal and spatial statistics of the radar reflectivity of small boats as well as of sea clutter under conditions relevant to those that can be expected in some of the application domains of the AwareNet system in Southern Africa. In the case of clutter, the measured data in South African littoral waters were found to compare well with generalized models from the literature. Measured data were subsequently used to evaluate the latest constant false alarm rate (CFAR) target detection algorithms published in the international radar literature and to propose further improvements to them. This work is ongoing, but has already resulted in a number of conference and journal publications (HERSELMAN P.L. et al., 2007), (HERSELMAN P.L. et al., 2008), (HERSELMAN P.L. et al., 2008).

The future will see continued exploitation of the current datasets, additional measurement campaigns, as well as the realization of an AwareNet radar technology demonstrator based on these results.

In the mean time, the CSIR had been approached by a number of institutions to utilize the knowledge and skills already developed as part of the AwareNet programme:

- UCL and UCT requested the CSIR to assist them in a sea clutter measurement campaign to be conducted in South Africa during 2009 using their netted radar measurement system in a bistatic configuration.
- The SA Navy prioritized a small boat detection function to be developed for one of their operational radars as part of its continuous improvement programme
- Reutech Radar Systems (RRS) and the SA Navy included the CSIR in a workshop to develop a user requirement definition for a proposed new type of maritime surveillance radar. A crucial requirement for this radar is an ability to detect and track small boats in littoral sea clutter.
- RRS requested the CSIR to study their new surveillance radar, the RSR 940 Spider and propose improvements to its small boat detection performance. This was done and a proposal to develop new waveforms and signal processing algorithms was developed.

- RRS requested the CSIR to develop a small boat detection capability for their new pulse Doppler surveillance radar that is being developed for a foreign client.

5.3 Target classification using ISAR

Inverse Synthetic Aperture Radar (ISAR) is a coherent radar processing technique that is used to generate a target image from which at least the class of target, and in some cases even its identity may be estimated, even at long ranges and under conditions of bad visibility. This is done by sensing the Doppler shifts caused by differing radial motions of parts of an extended target in the cross range direction while resolving it in the downrange direction using a HRR technique such as those discussed in section 5.1

Most published ISAR imaging algorithms are based on the assumptions that the target is rotating around a fixed axis of rotation and at a constant angular rate. However the motion of small boats in rough seas violates both these assumptions most of the time, leading to significant distortion and/or blurring in the resulting ISAR images.

Recent research at the CSIR focused on understanding the effects that cause blurring, specifically for smaller vessels at sea, both through theoretical analyses and through practical measurements. Fig. 6 illustrates some early results of this work. The research has generated significant insights into the algorithms used to generate ISAR imagery and their limitations.

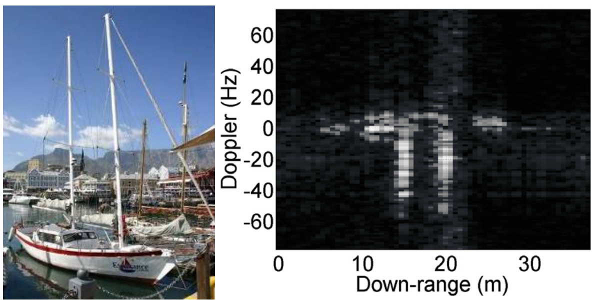

Figure 6: The yacht "Esperance" measured during the Nov 2007 measurement campaign using the MECORT radar deployed on Signal Hill in Cape Town. On the right is one of the ISAR images formed from this data. From such images the boat's length, width and the fact that it has two masts can already be determined. It is foreseen that further research will further improve the quality of these types of images and thereby the amount of information that may be extracted from them.

Important elements of this work form part of the research sponsored by a CSIR PhD studentship. Results had been published as conference and journal publications (LORD R. et al., 2006), (ABDUL GAFFAR M.Y. et al., 2007), (ABDUL GAFFAR M.Y. et al., 2008).

It is expected that this work will contribute significantly the target classification function of the AwareNet radar sensor. In the mean time, some of the mathematical models and simulations as well as the measurement techniques developed as part of this research are already finding application in a number of other CSIR radar R&D projects.

5.4 Target classification using micro Doppler

The fine grain Doppler spectrum centred around the mean Doppler offset caused by the radial velocity of a complex platform such as an aircraft or a ship is often referred to as micro Doppler in the radar literature. This is caused by moving structures on the platform such as the main and tail rotors on a helicopter, propellers on fixed wing aircraft, turbine blades in jet engines, rotating antennas on ships, wheels or tracks on vehicles and swinging arms and legs on people.

A CSIR research team recently developed the first “successful” radar recognition technique in South Africa using micro Doppler techniques. They developed the technique outlined in fig. 7 to identify the make and model of a helicopter using a pulse Doppler radar with long dwell times. They partially validated the technique using data measured on nine different types of helicopters using the MECORT radar facility. This work led to the publication of a conference paper presented at a recent international radar conference in Australia (CILLIERS et al., 2008) where the presenter who is currently working on a MSc (Eng), funded by a CSIR studentship, won the award for the best student paper.

This research will be continued by upgrading the MECORT facility to enable it to measure higher Doppler shifts unambiguously. An application to the DOD for funding for this upgrade was approved early in 2008 and the upgrade is expected to be completed before the end of 2008. This will enable the capability underpinning this technique to be applied to investigate other sources of characteristic micro Doppler signatures and the extension of this form of NCTR to other classes of targets.

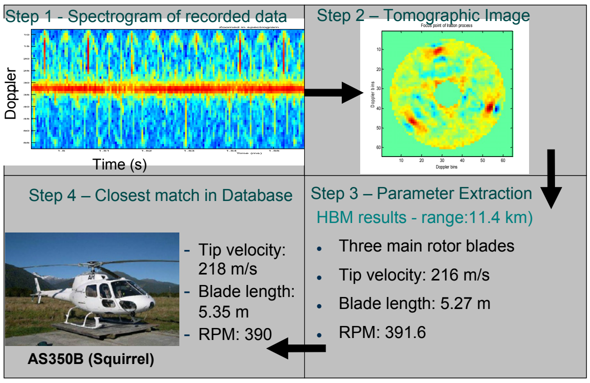

Figure 7: Steps in the non-cooperative recognition of a helicopter. The echoes received by a pulse Doppler radar with a long dwell time are processed to form a spectrogramme of the received Doppler spectrum. This is processed into a tomographic image by means of an inverse Radon transform. From this the number of blades, the blade length and the rotor rotation rate can be estimated. Comparing this to information in a helicopter database yields the helicopter type.

Although this work has only progressed to the proof of concept level (TRL 3), both major radar industries in South Africa as well as the South African Navy already expressed interest in it. A contract is currently being negotiated with RRS to develop a helicopter detection and recognition mode for their new export radar. They are also interested in collaborating with the CSIR on research into the classification of land targets.

6. The AwareNet system concept development

The level of situational awareness that AwareNet persistent, ubiquitous surveillance innovations aim to provide to commanders is currently unknown amongst potential users in South Africa. In order to realise the potential of such an innovation in a command and control system, appropriate doctrine needs to be developed by potential users, each in their own application domain, making creative use of this new capability. Only when both the technological innovation and the appropriate user doctrines are developed synergistically with each other, will the emerging properties and the value of such a system of systems become visible and measureable. And only when this has happened sufficiently, will non-technically oriented decision makers consider the risk low enough to budget for it as part of a funded acquisition project. The requirement is therefore to raise the technology readiness level of the technology developed so far to levels 5, 6 and 7, i.e. working through breadboard validation in a relevant environment to the demonstration a prototype system in an operational environment. To achieve this, there are two main challenges:

a) Find sponsors willing to fund the development of a technology demonstrator with enough of the foreseen functions and performance that it can be used in a sufficiently realistic programme of experimentation and demonstration in an operational environment.

b) Find and develop early adopters of the concept amongst the potential user communities who would be willing to collaborate in such a programme. They should be able to help define typical operational scenarios, user requirements and draft application doctrines and then take part in experimentation to develop these as part of a spiral technology development process including elements of requirements pull and technology push.

Responding to the requirements of potential sponsors of a fully functional AwareNet radar technology demonstrator, a radar technology roadmap was developed. It was found useful to think of the roadmap as a three dimensional "radar evolution plan" as shown in fig. 8. Along the X-axis is shown the development of the system functions (sense, detect, track, classify, identify, estimate threat level), first for maritime, then for air and then for land based targets and environments (Y-axis). The Z-axis shows that when this has been done for a short range, mountain top based system, it can be upgraded to one that can be flown on a medium sized aerostat, then to one with a longer operating range on the same aerostat and then to a long range sensor on a large platform flying at high altitude. It is foreseen that this plan will provide a clear path for the technology development programme with measureable milestones and with technology demonstrators that can be deployed and experimented with in realistic and operational environments. The plan is described in much more detail in a number of project proposals prepared for potential sponsors both in South Africa and overseas.

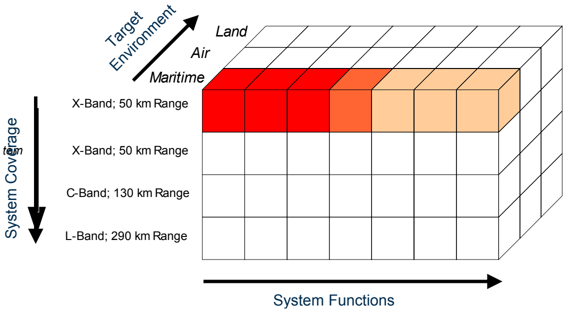

Figure 8: Radar evolution plan

Regarding potential application domains with interested early adopters, two have been identified as described below:

6.1 Soccer World Cup 2010 Security

The command and control centres tasked with managing this interdepartmental responsibility require situational awareness of the nature defined in the AwareNet programme. It is foreseen that by applying some of the technology already developed to upgrade existing sensors like the RSR 940 Spider radar and the MECORT experimental radar facility, a first demonstrator of this kind of capability can be ready for the final exercises planned for late in 2009 and for use during the World Cup matches in 2010.

As a first step in this direction, the RSR 940 radar was deployed during the joint security exercise called Operation Shield 1 in Port Elizabeth in July 2008. A joint CSIR and RRS team integrated the radar with the experimental command and control system built around the Integrated Development Environment (IDE), a fledgling new generation command, control, communication and computer system being developed at CSIR DPSS for the Department of Defence.

Valuable lessons were learned regarding challenges to overcome in this type of operational environment and useful radar data were recorded. The relative importance of the functions and characteristics defined for the AwareNet system could be assessed. The qualities of persistent and ubiquitous surveillance, low false alarm rates, no false tracks and automatic target classification were found to be of decisive importance for this type of system.

6.2 Anti-abalone poaching operations

SANParks recently expressed their interest in becoming involved in the type of joint experimentation described above. The application will probably be anti-abalone poaching operations in Marine Protected Areas in Algoa Bay, False Bay and Table Bay. Negotiations to register a joint R&D project with SANParks are well advanced. In preparation for this, two in-depth planning sessions had already been held with crime investigation officers involved in these types of operation.

7. Conclusions

R&D performed at the CSIR over the past four years confirms that exciting trends in several technologies allow new concepts for persistent and ubiquitous surveillance to be turned into realisable radar-based innovations. The resulting richness and reach of information available from these types of systems can satisfy many surveillance requirements and provide an edge to commanders of real time operations. Results obtained to date confirm that persistent and ubiquitous surveillance systems have the potential to develop into a range of Tier 1 innovations for the South African Aerospace Industry.

The proposed medium term plan for the AwareNet programme is to embark upon a full scale technology demonstration programme on the radar part of the concept while re-starting R&D projects at lower levels of technology readiness in several of the other subsystem technology areas identified in Phase 1 of the AwareNet programme.

Such a full scale technology demonstration programme involving the Universities of Stellenbosch and Cape Town, RRS, CSIR DPSS and their suppliers of components, materials and services in the South African industry may be the launch project of a South African industrial cluster or a Centre of Competence as the Department of Science and Technology refers to it.

8. References

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9. Footnotes

9.1 Technology Readiness Levels

Applying the concept of Technology Readiness Levels (TRLs) in technology management is currently considered best practice by leading aerospace and defence companies. It was in general use by NASA and the US Air Force Research Laboratory by 1999 and was subsequently adopted by the US and UK Departments of Defence. Readiness levels are measured along a scale of one to nine, starting with paper studies of the basic concept, proceeding with laboratory demonstrations, and ending with a technology that has proven itself on the intended product. The Air Force Research Laboratory considers TRL 6 an acceptable risk for a weapon system entering the program definition stage, the point at which the US DOD launches its weapon programs, and TRL 7 an acceptable risk for the engineering and manufacturing development stage to ensure that the gap between product requirements and the maturity of key technologies is closed sufficiently to avoid cost and schedule overruns while satisfying the product performance requirements.

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