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Purpose and Scope for a Multi Configurable Active Phased Array Test-Bed

Åse Jakobsson and Scott Capon

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Surveillance Systems Division
Electronics and Surveillance Research Laboratory

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ABSTRACT

It has been proposed that SSD develop a multi-configurable experimental active phased-array microwave radar for carrying out research on advanced architecture and signal processing concepts. This document defines the purpose and the scope of a Multi-Configurable Active Phased Array Test-bed (MCAPA). A number of system and software concepts are discussed, their merits are evaluated and rated against each other. Finally, the way ahead for the development of the MCAPA test-bed is proposed based on the trade-off discussions.

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Executive Summary

In private industry, microwave radar system design is currently undergoing a revolution. Solid state active phased arrays are at last appearing in operational systems, and, at the other end of the system, dedicated signal processors coded in assembly language are being replaced by Commercial-Off-The-Shelf (COTS) equipment coded using modern high order languages. Much of these recent developments have arisen from leverage off the civilian communication and information technology sectors. SSD has a need to maintain and develop skills in understanding the advanced technologies and processing techniques now achievable for radar, as well as providing hands on experience in microwave phased arrays radar design for our staff. Considering that microwave radar is the primary tactical surveillance and targeting sensor, this is an essential objective for SSD.

The purpose of DST 00/175 is to define a phased development of a multi-configurable active phased array microwave radar (MCAPA) test-bed suitable for analysing and developing advanced architecture and signal processing concepts. The objective with this first stage of DST 00/175 is to ensure that the longer term DST task is well defined and its purpose and objectives are understood and viable.

The purpose of the MCAPA is to provide a test-bed suitable for analysing and developing advanced architecture and signal processing concepts. The primary purpose is to develop SSD expertise in the area of phased array technology both for conventional electronically scanned array (ESA) and for digital beam forming (DBF) concepts. The secondary purpose is to provide, within the division, expertise in implementation aspects of radar system and subsystem design that cannot be gained by algorithm development, modelling and simulation alone. Finally, a test-bed is needed that will compliment rather than just repeat work in other TTCP countries, such that marketable research results can be achieved.

The MCAPA test-bed will provide the raw data to develop and prove ESA and DBF concepts considered desirable to explore such as:

- Advanced signal processing concepts requiring digital beamforming capabilities and a flexible waveform generation capability.
- Exploration of bistatic / multi static radar operation – particularly the receive function of bistatic operation.
- Explore the combination of novel waveforms and adaptive beam control.
- Investigation of advanced radar scheduling algorithms.

The technology areas that relate to microwave radar and in particular phased array radar have been rated in accordance with their future applications for the ADO. The outcome of this analysis indicates that the three highest priority technology areas that need to be developed as part of this test-bed program are:

- Monostatic electronic scanned array,
- Bistatic receive functionality and,
- Digital beam forming on receive.

The next three steps are:

- to develop a research program for electronically scanned array applications.
- to write a task-plan for the development of the test-bed and identify staff.
- to write a system requirement specification for the test-bed

Strategically, the test-bed program should lead to applications or spawn further highly desirable research topics. Some ideas for future research that could be implemented through CTDs include:

Low interference radar – the frequency spectrum is being sold off and previously military frequency bands now may have commercial primary users. The issue of who is allowed to use the spectrum and when has become very important. Radar with a very wide tunable range can be applied to transmit at frequencies not being used for anything else in a particular geographical environment. This would mean that the system has to "sniff" the environment before transmitting. In addition, the wide frequency range can also be used for shared aperture purposes and to promote better multi-functional performance as well as exploiting ducting effects for naval applications. Finally, with a wide tunable range and a "sniff" capability, the system could also be used on receive only to perform bi-static operations utilising transmitters of opportunity.

Covert Bistatic Radar Demonstrator. All three services have acquired or are acquiring surveillance radar systems that operate in the radar L-band part of the spectrum. It would seem logical to demonstrate a capability to use these soon-to-be in-service systems to illuminate targets for passive detection by a forward-deployed sensor. The research conducted under this task could form the basis for such a concept.

This process will lead to a comprehensive program for SSD to develop the necessary expertise required for providing relevant science and technology advice on future capabilities employing microwave radar. In addition, the program allows follow-on development of CTDs in areas of great opportunity and importance to ADF.

Authors

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Åse graduated from Chalmers University of Technology, Gothenburg, Sweden in 1984 with a M.Sc. in the school of Electrical and Electronic Engineering. She worked for Ericsson Radar Systems AB for 10 years including a 3 year posting at DSTO, Salisbury under an MoU between Australian and Sweden. Her area of work during this time includes microwave antenna design, adaptive sidelobe cancelling for phased array, target detection processing and adaptive ESA radar control as well as requirements analysis, specification and system test specification. She worked for AWA Defence Industries 94 -97 with radar warning receiver system design and systems engineering. In 1997 Åse joined DSTO and works at the Surveillance Systems Division with microwave radar systems, tactical data-link interface to multi-sensor integration and multi-platform multi-sensor integration and requirements analysis.

Scott Capon

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Scott graduated from The University of Adelaide, South Australia in 1990 and received a Bachelor of Engineering with Honours in Electrical and Electronic Engineering. Since graduation he has been employed by DSTO on a variety microwave radar related tasks and is currently managing the SSD program to support Project Wedgetail, the Australian AEW&C Capability acquisition project. Scott is a joint holder of an international patent for a Radar Return Signal Simulator developed at DSTO and was awarded the 1999 ESRL Director's award for Best Contribution to Defence Outcomes for his work on AEW&C.

Contents

Glossary

COTS	Commercial Off The Shelf
DBF	Digital Beam Forming
EMC	Electro Magnetic Compatibility
EMI	Electro Magnetic Interference
EP	Electronic Protection
ESA	Electronically Scanned Antenna
ESM	Electronic Support Measures
IF	Intermediate Frequency
MCAPA	Multi-Configurable Active Phased Array microwave radar
RF	Radio Frequency
Rx	Receive
STAP	Space Time Adaptive Processing
Tx	Transmit

1. Introduction

In private industry, microwave radar system design is currently undergoing a revolution. Solid state active phased arrays are at last appearing in operational systems, and, at the other end of the system, dedicated signal processors coded in assembly language are being replaced by COTS equipment coded using modern high order languages. Much of these recent developments have arisen from leverage off the civilian communication and information technology sectors. SSD has a need to maintain and develop skills in understanding the advanced technologies and processing techniques now achievable for radar, as well as providing hands on experience in microwave phased arrays radar design for our staff. Considering that microwave radar is the primary tactical surveillance and targeting sensor, this is an essential objective for SSD.

The purpose of DST 00/175 is to define a phased development of a multi-configurable active phased array microwave radar (MCAPA) test-bed suitable for analysing and developing advanced architecture and signal processing concepts. The objective with this first stage of DST 00/175 is to ensure that the longer term DST task is well defined and its purpose and objectives are understood and viable.

Section 2 defines the research and technical purpose and scope of a Multi-Configurable Active Phased Array Microwave Radar Test-bed (MCAPA) to be developed at SSD. Section 2 also develops the importance of the second purpose, to develop hands on experience in radar design within the Division.

Section 3 outlines the design drivers drawn from the trade-off discussions and develops the progression of the MCAPA test-bed. The context of the test-bed in a research program is briefly developed.

Finally, section 4 concludes the document.

2. Purpose and Scope

The purpose of the MCAPA is to provide a test-bed suitable for analysing and developing advanced architecture and signal processing concepts. The primary purpose is to develop SSD expertise in the area of phased array technology both for conventional electronically scanned antenna (ESA) and for digital beam forming (DBF) concepts. The secondary purpose is to provide, within the Division, expertise in implementation aspects of radar system and subsystem design that cannot be gained by algorithm development, modelling and simulation alone. Finally, a test-bed is needed that will complement rather than just repeat work in other TTCP countries, such that marketable research results can be achieved.

The MCAPA test-bed will provide the raw data to develop and prove ESA and DBF concepts currently considered desirable to explore such as:

- Advanced signal processing concepts requiring digital beamforming capabilities and a flexible waveform generation capability.
- Exploration of bistatic / multi static radar operation – particularly the receive function of bistatic operation.
- Explore the combination of novel waveforms and adaptive beam control.
- Investigation of advanced radar scheduling algorithms.

In order to foster innovation within these areas, a sound technology base is needed to understand how the technology can be exploited in new ways. The act of performing part of the design and in particular the system design will allow our staff to understand the state of the art technology being developed for future phased array systems, regardless of whether we use state of the art technology for our test-bed. The test-bed should be developed further in several stages if not all the desirable concepts can be included in the first stage.

The following sections outline areas within system technology and subsystem skills, which can be obtained and developed through the development of a test-bed. The merit of each area is briefly described and a discussion provided. The purpose of these tables is to provide input to a trade-off process for the system requirements on the test-bed. The trade-off is discussed and documented within each section. Decisions regarding priorities and design for the first stage are made based on these trade-off discussions.

2.1 System Technology

The system and software concepts listed below have been given a rating of importance within a scale of one to ten, where ten is the highest rating available. The reason for the rating is given in the comments column.

Table 1. Concept Trade-off discussion

Concept	Rating	Merit	Discussion
Digital Beam-forming (DBF)	10	STAP, adaptive beam-forming, super-resolution processing, multiple simultaneous beams. Synergy with other Branches and Divisions.[1]	Costly but performance enhancing technology. May be the way ahead for Bistatic use to allow adaptivity in the receive function. There is a need to develop an understanding of critical effects of phenomena such as antenna mutual coupling, channel match, and component tolerances on digital beam-forming. This architecture concept received a high rating because a) DBF is an important ingredient in achieving a number of novel radar capabilities b) DBF is not commonly operational for microwave radars – it is state of the art and may soon be achievable for a reasonable cost. Consequently, if DSTO wants to develop expertise for the future this is one area, which is feasible, but still in the future and certainly not exploited.

[1] Wide Area Surveillance Branch, SSD, EWD and CD are currently working with Digital Arrays at other frequencies and for other applications.

Concept	Rating	Merit	Discussion
Shared Aperture	2	Potential cost or space effectiveness. Opportunistic use of apertures for multiple purposes such as radar, ESM, jamming and data-link.	Challenging system architecture and performance trade-offs to achieve good performance for different purposes. This concept received a low rating, because the application does not promote novel microwave radar capabilities or improved microwave radar performance. Although shared aperture is an interesting application, the ability of collecting measurement data with a test-bed would not further the concept as effectively as would an actual concept demonstrator. Consequently, shared aperture is a topic that should be addressed outside this task.
Very Wide Operational Bandwidth	5	Frequency can be selected to suit the function. Frequency band selectable to cause less interference with commercial applications. Shared aperture applications possible.	The frequency spectrum is being sold off and consequently some of the traditional military radar applications frequencies are not always available for use. To sample or "sniff" the environment and then operate in bands not being used would solve this problem. As a counter measure to sea-skimming missiles, very wide-band radars can be used to select frequency bands where the ducting effect can be exploited. A wide operating frequency band gives the opportunity to select the band most suitable for the function, eg high frequency for accurate targeting data, low frequency for longer range search and through rain patches. This is probably more suitable for a CTD than a test-bed.

Concept	Rating	Merit	Discussion
Electronically Scanned Radar	10	Improved track initiation, effective energy management and flexibility through optimisation of radar resources to radar tasking, beam and waveform scheduling.	Application of artificial intelligence and other advanced technologies to the problem is ongoing research within DSTO. This test-bed would allow researchers to investigate the practical applications of their work. The combination of adaptive beam and waveform scheduling has not been exploited fully. In order to implement adaptive beam scheduling, real-time signal processing must form part of the test-bed. ESA radar is now becoming "conventional". There are a number of operational systems and the technology required for implementation is established. However, in particular for high performance tactical microwave radar systems, the ability to focus the transmit power in one direction cannot be neglected. DSTO still needs to develop expertise to understand the technology within this area and cannot rely on only the DBF as DBF doesn't necessarily require phased array techniques for the transmit function. Further more, we can expect to have to support a number of ESA radars such as TPS 117 and Wedgetail. In addition, any AIR 6000 platform is more than likely to have an ESA radar. The ESA concept therefore received a high rating.

Concept	Rating	Merit	Discussion
Advanced Waveform	9	Specialised capabilities such as identification, detection by matched illumination or low probability of intercept radar.	This is an area of ongoing research in the radar community. However, it does not require phased array or DBF technology. May have significant impact on the design of the phased array front-end technology because of wide instantaneous band consideration generally assumed for advanced waveforms. To be able to tailor the waveform to a particular measurement adaptively delivers higher performance and may not necessarily require wide instantaneous band implementation. The bandwidth should be selected as the one optimum from bandwidth and dynamic range perspective. The concept received a high rating because advanced waveforms are considered important to combine with concepts such as DBF and ESA to allow adaptivity and capability enhancements of the radar function. When developing new waveform and signal processing techniques to support the waveforms measured data is invaluable.
Bistatic Operation	10	Covert receiver operation, counter low-observable performance, lower space weight and power requirements for receiving system.	Synchronisation between transmit and receive systems is a design challenge that warrants investigation. If a modular design is applied in addition to selecting the digital beamforming option, bistatic operation for a test-bed should not add too much complexity. Transmit sources of opportunity, such as digital TV broadcast, could be investigated if the right frequency band is selected for the test bed. This concept received a high rating because it is considered operationally important. A test bed could be developed for mono-static operation and either allow for a modular and separate transmit and receive function (including antenna aperture) or a test-bed which can operate as receive only and subsequently arrange a separate transmit function.

Concept	Rating	Merit	Discussion
Multi Static	1	Lower transmit power. Difficult to jam	Multi-static concepts can be proven by a bi-static test-bed, hence the low rating for this concept.
Conformal Array	1	The physical characteristics are attractive to platform design.	Not suitable for a test-bed. Not necessary for electronically scanned antenna concepts research.
Sparse Array	5	Provide a large aperture and thus good resolution without the cost of a fully populated array.	With a Multi-Configurable array, there is potential for exploring this concept, provided that modules can be separated and placed at differing distances. The caution is that tactical microwave radar most often needs the power output of all elements to achieve tactical range.
Simultaneous Polarisation Diversity	2	Polarisation can be used to provide discrimination of man made objects from natural terrain, as an EP transmitting a polarisation orthogonal to the jamming signal, and can supply additional information for target identification.	This concept does not require digital beamforming. Dual polarisation ability adds considerably to the complexity of the design. Need to establish whether require dual transmit and receive modules, or can satisfy requirement with transmitting one polarisation, simultaneously receiving two. For accurate measurement of polarisation matrix, requires stringent antenna design. This is an interesting area of research, but should be developed elsewhere, as polarisation diversity introduces significant additional design complexity and cost. Research into this area may be conducted more cost effectively by using a mechanically steered antenna.

Table 2 Software Development Trade-off discussion

Software	Rating	Merit	Discussion
Space-Time Adaptive Processing (STAP)	9	Improved detection range through reduced clutter and noise jamming.	Exploration of STAP requires multiple receiver and antenna channels. Implementation of STAP involves development dependent on the radar system, its application and the environment in which it operates. Consequently, supporting measurement data is vital to fully understand the signal processing technique. To fully explore STAP performance the test-bed must be airborne. The US has collected substantial amount of data for STAP research and TTCP discussions indicate that not all of it can be processed by US researchers. Consequently, data may be obtained to use for STAP research without needing our own test-bed.
Super-resolution	7	Multi-path resolution, raid-count and improved track association performance.	The theory is not well tested for microwave radar applications as signal processing capacity has not been available to implement in real time systems. However, in the communications and in the sonar domain, super-resolution has been worked on for some time, since real-time applications within these areas allow for longer processing times. Consequently, a broad base of theory is available to draw on. The access of real measurement data is necessary to understand the implementation of radar system parameters, environment and application on the advent of low cost DSP technology will allow implementation in the microwave radar applications.
Detection and Estimation	9	Improved detection and track range though the use of novel signal processing such as wavelet transform and track-before-detect. Identification through new waveforms and processing techniques. Hardness against sophisticated electronic attack.	This process does not necessarily require phased array or DBF technology. The test-bed is likely to be able to support software concept within this area and no special consideration will need to be observed. If the test-bed is designed to allow Advanced Waveforms, it will be able to support novel ideas for this concept. For a bistatic application, novel detection and estimation concepts are necessary. However, exploration of the synergies between track-before-detect and electronic scan scheduling does require phased array technology.

Software	Rating	Merit	Discussion
Array Hardware Control and Calibration	10	Improved performance.	Exploration of realistic hardware and design issues never encountered through algorithm development and concept development. Additionally, experience in this area is not readily obtainable through computer based simulation. However, lessons learned on calibration realisations will assist in the simulation of other radar systems. This is an essential software function, which cannot be dispensed with – consequently it should form part of the test-bed design. Whether the test-bed will actually be used to conduct research within this area can be considered at leisure.
Sophisticated Display function	1	Provide marketing value of concepts by allowing real time demonstration.	When selling new technology concepts it is important to be able to demonstrate results in a format understandable and visible to a client. SSD may well wish to obtain sponsorship for further development of concepts explored through this test-bed. An advanced display including a sophisticated HMI would presuppose real-time signal processing. This option should probably be delayed in the first stage and therefore receives a low rating.
Simple Display function	10	Provide visibility of system operation or test and evaluation and convenient control parameter input.	To test and evaluate the test-bed a rudimentary display function will be required. This could be in the form of the capability to display the analogue signal from one receiver channel. A simple display may also provide the control input interface and display of BIT data. This may be necessary for ease of operation and therefore receive a high rating. Necessary to provide operators with a check that the data being collected will be accurate and suitable for purpose.

2.2 Subsystem Skills

This table summarises the benefits of doing in-house design of a subsystem.

Table 3. Subsystem Skills Acquisition Trade-off

Subsystems	Benefit
Microwave Antenna Design	Understand microwave propagation and how antenna performance such as sidelobe levels, gain and beam-shape impact system performance. Understand how sidelobe performance requirements etc are translated into hardware design. An appreciation of antenna design is fundamental to radar systems expertise.
Transmit/Receive (Tx/Rx) RF technology	Potential for understanding low cost development of Tx/Rx technology, employing commercial communication technology. Tx/Rx RF subsystem is often the most expensive hardware part of an ESA radar. For frequency bands such as X-band the number of elements and the output power desired have long been a show-stopper for realisable ESA radar. Accurate control of gain and phase of T/R modules is critical to array performance and needs to be well understood. Performance of RF filtering, transmit amplifier design and module topology on spectral control, spurii, EMI and EMC are further issues.
Digital Receiver Technology and Digital Waveform Synthesiser	These subsystems include down-conversion to IF, sampling, de-modulation and digitisation. Understanding modern radar receiver design. Reasonable to do in-house, because of abundance of COTS or dual-use technology. Developments in low-cost, COTS, direct digital frequency synthesis and arbitrary waveform generation could be exploited. These could allow wide tuning frequency range, facilitating multi-functional arrays, optimal use of the spectrum and shared aperture arrays. Understanding of non-linear effects on radar performance and trade-off between complexity and performance.
High Speed Data Distribution	In high-bandwidth digital radar systems, data reticulation is a limiting factor that needs to be understood.
Timing and Control	Understanding of real time systems implementation. Particularly critical in Bistatic applications.

3. MCAPA Test-bed Recommendations

The purpose of the test-bed is to explore techniques and technologies associated with phased array microwave radar. SSD has a strategic need to develop technology expertise and system expertise within this area, since the majority of future military microwave radar systems will be either electronically scanned or use digital beam forming.

3.1 Design Drivers

The trade-off discussions in section 2 give rise to the design drivers below.

Essential characteristic of the test-bed design are:

1. Monostatic electronic scan
    a. Provides focus of transmit energy – essential for tactical microwave radars.
    b. Monostatic electronic scan is the core concept in operational systems for the foreseeable future.
2. Bistatic / multi-static receive function
    a. To counteract Low Observable technology
    b. To protect the shooter by not emitting
    c. Difficult to jam,
    d. CW transmit is possible – increasing the average power,
    e. No experience of this new technology in the microwave frequency band for tactical surveillance applications
3. Digital beam forming on receive
    a. required for bistatic operation
    b. permits investigation of advanced processing
4. Self-calibration
    a. Forms part of all operational ESA systems – understanding the technology is vital.
5. Simple display function

Important characteristics of the test-bed are:

6. Advanced waveform generation
    a. Not essential of understanding ESA technology, but can provide performance and functionality improvement in synergy with ESA.

7. Real-time signal processing
    a. Essential to allow development of advanced detection and scheduling functions but off-line processing is sufficient for the initial stage.
8. Designed for airborne operation
    a. Advanced signal processing concepts such as STAP becomes of minor interest if the radar is stationary.
    b. Airborne clutter environment is significantly more challenging than for ground-based systems.

Desirable characteristics are:

9. Very wide operational bandwidth
    a. gives freedom in spectrum usage
    b. can explore ducting effects
    c. supports multi-functional concepts better than narrowband
10. Wide instantaneous bandwidth

The preceding analysis of the system and software concepts serves as an input to the definition of the system requirements. This work will lead to the MCAPA test-bed system context and technical system requirements specification in accordance with the task plan.

3.2 Progression

This section outlines an activity plan for the MCAPA test-bed, which will provide input to a well-defined task plan. A schematic team structure is developed in Figure 3.1.

The MCAPA test-bed development need to be teamed with a research program and in addition, synergies with existing and planned research collaborations, such as the track and data fusion research funded by DSTO at CSSIP, need to be explored. A Multi-Functional Phased Array Research Program or a "federation" of research tasks across SSD, EWD and CD should be explored to understand the Systems-in-Systems synergies such as multiplex use of wide band arrays for radar, communication, electronic attack and ESM. The three Divisions are all in need of ongoing technology expertise in the digital / phased array area and EWD already has expertise in some vital technologies such as MMICS and photonics. The cells of technology expertise should cover different areas in each of these three Divisions and cross-Division collaboration can be used to carry out research while the critical mass also can be maintained.

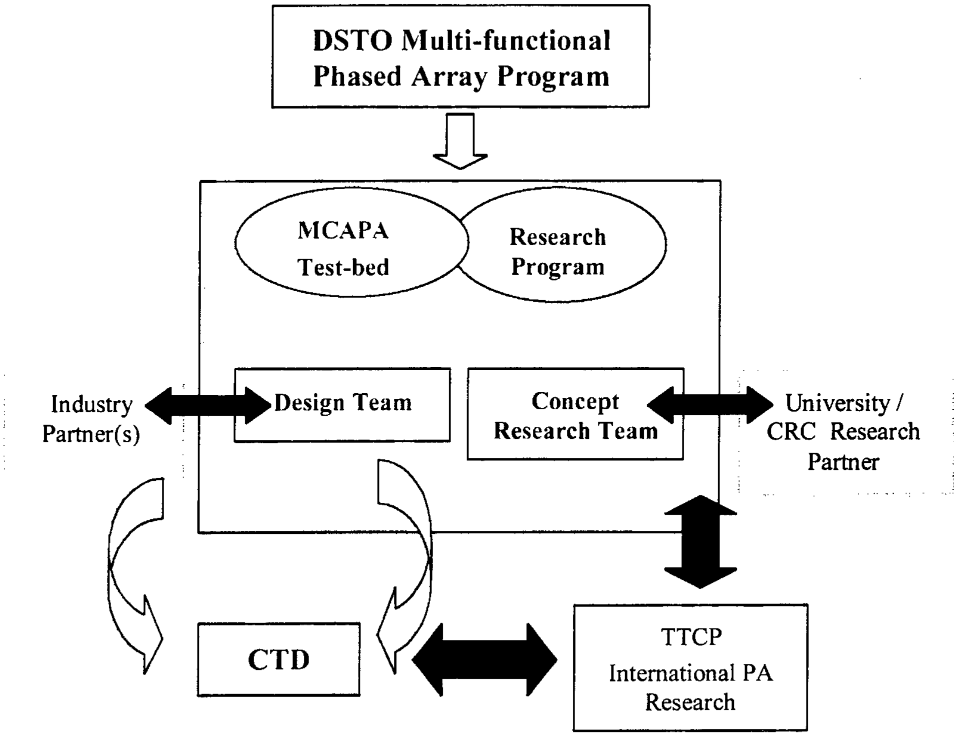

Figure 3.1 SSD Microwave Phased Array Program.

To advance the MCAPA test-bed task, the activities and documents considered necessary in the activity plan are described below. They are selected by substantially tailoring activities and documents that would have been conducted and produced in the course of system design in defence industry, based on the authors' experience.

Research Program for Microwave Phased Array Technology Applications

The research plan is essential and will provide more detailed user requirements than those outlined in section 2. A user of the plan would refer to the theoretical research that will make use of the test-bed for validation and evolvement of the research. The plan would contain a description of the concepts to be investigated through data-collection with the test-bed. The plan would also describe connections to other research tasks where synergy may be obtained. Finally, the plan should contain a section describing some visions of research topics and technology concepts that could be pursued in a larger framework and longer time-span - ie strategic planning of the phased array topic.

Examples of research areas that could be detailed in this plan are:

a. experimentation in and validation of Level 4 data fusion (sensor control) research;

b. acquisition of technology domain knowledge – specifically with a view to the following:

(1) support to acquisition of ESA radar based capabilities,

(2) capability definition studies,

(3) leveraging from COTS communications technologies, and

(4) validation of ESA radar modelling and simulation research.

c. signal processing theory – particularly in application to:

(1) innovation and the validation of innovative radar signal processing concepts,

(2) performance enhancement and the investigation of optimisation of existing signal processing concepts, and

(3) support to acquisition through the ability to brass-board contractor proposed algorithms for risk-reduction purposes.

System requirements specification

This document will define performance boundaries and operational and user system requirements for the test-bed, based on the design drivers identified in section 3.1 and the identified research program. This ensures that the test-bed will be able to support future research goals within this technology area.

Requirement analysis will be driven by analysing the purpose of the test-bed rather than performance requirements, such as what is normally the case for an operational radar system, since it is a test-bed. However, it is still important to ensure that functions and performance necessary for the selected research areas can be satisfied by the test-bed. It may also be likely that we want to proceed towards a CTD in the future and the test-bed development should then consider this.

System design document

The system design document will describe the design decisions and the outcome of the system and sub-system trade-off analysis. It provides the input to the sub-system specifications, which will be used to acquire hardware and software or lead to internal design activity.

System and sub-system trade-off analysis

This includes cost/benefit analysis of different system concepts and technology options for sub-systems. Examples may include:

1. paper design[2] of transmit/receive modules to understand the sensitivity of design parameters and technology choices,
2. system architecture concepts involving the number of array elements and their configuration, and
3. determining adequate system performance, such as demonstrable detection performance.

Test Planning

The test planning consists of defining options for validating and testing the performance and functionality of the test-bed. The test planning should be documented in a Test-plan.

Sub-system design

This will include acquisition and/or sub-system design activities.

3.3 Test-Bed Program

The primary purpose of this program is to develop SSD expertise in the area of microwave phased array technology for both ESA and DBF concepts. We also want to achieve marketable research results so that we can provide value when trading know-how with, for example, other TTCP countries. Finally, we think it is important to achieve some practical use for and output from the test-bed in a short time-span. Consequently, we have decided that the best approach is a test-bed program in stages. Two major stages have been outlined in Table 4 and they are described below.

The object of Stage A is to gain hands-on experience in the design issues relating to performance that is impossible to gain from modelling and simulation only. The test-bed would be a ground-based application only and consist of a small number of elements. The performance criteria are set to give a useful test and evaluation performance, but will not attempt to push for technology limits. The reason for this is to keep the costs down, and therefore design for test-bed purpose only. The implementation of a simple ESA will still provide experience in the calibration aspects necessary to achieve good sidelobe performance as well as the control and timing of

[2] EWD has acquired advanced microwave design software

advanced microwave radar. Finally the ESA can be used for research related to rapid track initiation, track before detect, detection, estimation and other areas. With at least three receiver channels, some experience in DBF can be gained as well.

The object of Stage B is to add some tradeable research results. Full DBF is not yet a common occurrence for active solid-state microwave radar. Adding digitisation on both transmit and receive and in particular do away with the phase-shifter on transmit would be novel. Another option is to design a T/R module with down conversion via photonics, i.e. RF to photonics to IF on receive. Introducing this technology in our test-bed would make the test-bed itself a research topic. We could potentially attempt to use photonics on transmit as well. EWD has experience in photonics and there is a photonic CRC with members across Australia including industry such as Filtronics Australia and Tenix. EWD is confident that we have the expertise on the receive part[3]. This would be a good opportunity to leverage from EWD's expertise and ensure that we are prepared for the future front-end technology of phased arrays. Photonics received significant attention during the Phased Array Conference 2000 and is considered a very promising technology for these applications. Advantages include better EMI, optical signal processing, very wideband applications with True Time Delay. If new technology for the T/R module is selected as a goal, the T/R module design should be started at the same time as stage A.

Table 4 Test-bed Program Stages

Stage		Outcome
A.	In-house System Design of ground-based test-bed. Small number of elements. At least 3 receiver channels for sum-channel and mono-pulse in azimuth and elevation. Re-configuration of auxiliary receiver channels to single element possible.	Design experience – eg. design influence on gain and phase characteristics. Calibration – eg. real world issues to achieve sidelobe performance in a realistic operational environment and with design constraints. Scheduling – research topic for first stage test-bed Limited DBF – adaptive sidelobe cancelling possible research topic.
B.	Introduction of new technology in the test-bed design, eg, use of photonics in the T/R module or digital T/R without phase-shifters. Fallback: digitising each element for full DBF on receive by proven components.	Provide marketable research results. The design becomes the research topic. Full DBF Tx and Rx. Bi-statics, super-resolution and adaptive DBF possible research topics

[3] Reference discussion with Steve Winnall, EWD

3.4 Strategic Discussions

A research program generally should lead somewhere. The goals for the two first stages of the MCAPA test-bed are to gain DSTO expertise so that we can support future ESA systems and to obtain research results that we can barter to gain further knowledge from the international community.

The research results should preferably lead to applications or spawn further highly desirable research topics. Some ideas for future research that could be implemented through CTDs include:

Low interference radar – the frequency spectrum is being sold off and previously military frequency bands now may have commercial primary users. The issue of who is allowed to use the spectrum and when has become very important. Radar with a very wide tuneable range can be applied to transmit at frequencies not being used for anything else in a particular geographical environment. This would mean that the system has to "sniff" the environment before transmitting[4]. In addition, the wide frequency range can also be used for shared aperture purposes and to promote better multi-functional performance as well as exploiting ducting effects for naval applications. Finally, with a wide tuneable range and a "sniff" capability, the system could also be used on receive only to perform bi-static operations utilising transmitters of opportunity[5].

Covert Bistatic Radar Demonstrator. All three services have acquired or are acquiring surveillance radar systems that operate in the radar L-band part of the spectrum. It would seem logical to demonstrate a capability to use these soon-to-be in-service systems to illuminate targets for passive detection by a forward-deployed sensor. The research conducted under this task could form the basis for such a concept.

[4] Discussions with Angus Massie, CD

[5] Discussions with Dr Gordon Frazer, SSD

4. Conclusion

This analysis has been undertaken to provide the top-level trade-off discussions and the top-level definition for the development of a microwave phased array test-bed. The results generate a framework for the task of developing the test-bed.

The technology areas that relate to microwave radar and in particular phased array radar have been rated in accordance with their future applications for the ADO. The outcome of this analysis indicates that the three highest priority areas that need to be developed as part of this test-bed program are:

- Monostatic electronic scanned array,
- Bistatic receive functionality and,
- Digital beam forming on receive.

The most opportunistic technology area to be pursued within the development of the test-bed is the front-end transmit / receive subsystem, where we can leverage off the expertise and excellence within the EWD and CD.

The next three steps are:

- to develop a research program for electronically scanned array applications.
- to write a task-plan for the development of the test-bed and identify staff.
- to write a system requirement specification for the test-bed

Strategically, the test-bed program should lead to applications or spawn further highly desirable research topics. Some ideas for future research that could be implemented through CTDs include:

Low interference radar – a radar system with a very wide tuneable range and a "sniff" capability can be applied to transmit at frequencies not being used for anything else in a particular geographical environment. In addition, the wide frequency range can also be used for shared aperture purposes and to promote better multi-functional performance as well as exploiting ducting effects for naval applications.

Covert Bistatic Radar Demonstrator - demonstrate a capability to use the soon-to-be in-service L-band systems to illuminate targets for passive detection by a forward-deployed digital receive array for bi-static operation.

The process described in this document will lead to a comprehensive program for SSD to develop the necessary expertise required for providing relevant science and technology advice on future capabilities employing microwave radar. In addition, the program allows follow-on development of CTDs in areas of great opportunity and importance to ADF.

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19. ABSTRACT

It has been proposed that SSD develop a multi-configurable experimental active phased-array microwave radar for carrying out research on advanced architecture and signal processing concepts. This document defines the purpose and the scope of a Multi-Configurable Active Phased Array Test-bed (MCAPA). A number of system and software concepts are discussed, their merits are evaluated and rated against each other. Finally, the way ahead for the development of the MCAPA test-bed is proposed based on the trade-off discussions.