Island Air Defence:

Challenges, Novel Surveillance Concepts and Advanced Radar System Solutions

ABSTRACT

The present-day air defence surveillance system is designed to detect threats originating from external airspace in a conventional military conflict, such as one involving multiple fast-flying fighters, helicopters and missiles. However, the operational environment has evolved to be far more challenging and complex over the past decade, with the emergence of stealthier targets that make better use of terrain to avoid detection. At the same time, there is always a desire to see further than the enemy and to obtain more information about the target. This paper aims to identify the inadequacies of the present-day air defence radar system and to propose some novel sensor solutions which include Ultra High Frequency/ Very High Frequency radar, bi-static/multi-static and passive radar, elevated sensors, High Frequency surface wave radar and non-cooperative target recognition techniques. The advantages, challenges and cost effectiveness of these advanced techniques will be analysed to develop a picture of future surveillance systems.

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INTRODUCTION

It is a never-ending race between those who want to locate their enemies and those who strive to avoid being detected, as advances in one technology inevitably lead to the development of its countermeasures. During World War II, the British Chain Home air defence radar system, which consisted of a series of 300-feet tall towers lining the south and east coast of Britain, was the first radar to be used in wartime operations (Neale, 1985). This primitive radar was able to provide early warning of approaching German fighters in daylight, but it relied on the pilot's eyes to correct for the several-mile error range inherent in the system (Buderi, 1996). However, the Luftwaffe was quick to switch to bombing at night and in bad weather to take advantage of the reduced visibility. For more than a month, the Royal Air Force (RAF) pilots could do little to take down these intruders. The bombing was finally deterred when the group led by British physicist Edward Bowen invented the magnetron, which enabled the development of a radar small enough to be carried by RAF fighters. That marked the beginning of the ongoing contest between surveillance radar and detection avoidance technologies.

More than half a century has passed since the end of World War II and the surveillance radar operational environment has grown increasingly complicated over the decades. Stealth aircraft and ships have become more common in modern armed forces, while terrain-hugging and non line of sight (NLOS) targets continue to pose problems for the conventional surveillance system. On top of that, there is also a great desire to improve the operational range of the existing system and to incorporate advanced features such as target recognition.

LIMITATIONS OF THE CONVENTIONAL RADAR SYSTEM

1. Stealth Targets

The current air defence sensor systems of many nation-states are designed for use against conventional threats such as multiple fast flying military aircraft, helicopters, and missiles that have a relatively significant radar cross-section (RCS). Figure 1 shows the typical RCS of different targets at microwave frequencies. Advancements in stealth technologies, as demonstrated by the very low RCS of stealth aircraft such as F-117, B-2 and F-22, make such targets extremely difficult to detect.

2. Physical Limitations

The operational range of ground-based radar is physically limited by terrain, as radio waves cannot penetrate obstacles such as mountain ranges. This has been exploited by helicopters operating in terrain-masking mode, as well as cruise missiles which can be programmed to fly as low as 20m above ground level (Department of the Army, 2000). The presence of buildings, which scatters radio waves, remains a challenge for detecting low-flying air targets over built-up areas.

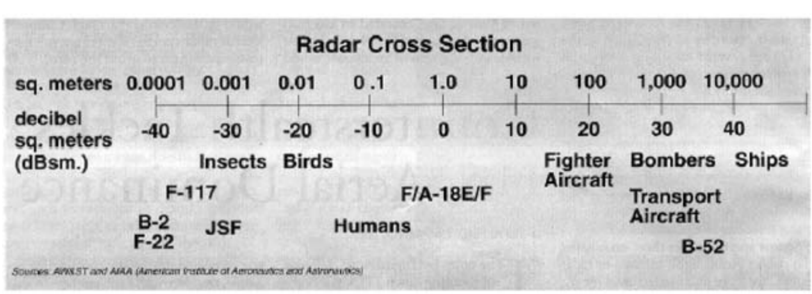

Figure 1. Examples of radar cross-sections at microwave frequencies[1]

Another fundamental limitation in the detection range of conventional ground-based radar is the inability to see over the horizon due to the curvature of the earth. In order to double the horizon distance, the radar height needs to be increased four times (Sinnott, 1988), but there is a limit to how much a radar can be elevated. For example, stability considerations will restrict the height of ship-borne radar used for maritime surveillance.

3. Low Observable Targets - Unmanned Aerial Vehicle

Unmannned Aerial Vehicles (UAVs) include drones which have pre-programmed flight paths, and remotely piloted vehicles which are controlled by ground-based operators. Each can perform a variety of missions ranging from reconnaissance and battlefield surveillance to attack and electronic warfare. UAVs are characterised by their small RCS, low speed and small thermal signature, making them difficult to detect and engage. Mission-dictated flight profiles can take full advantage of terrain to minimise the probability of detection.

Existing air surveillance systems are not designed to deal with the operating speed and altitude of UAVs. For example, the radars of Airborne Warning and Control System (AWACS) and Joint Surveillance and Target Attack Radar System (JSTARS) early warning aircraft intentionally eliminate slow-flying targets in order to filter out false targets such as birds. A mini-UAV flying at an altitude of 100m with a speed of 100km/h looks "more like a bird on the radar screen than the cruise missile of a potential adversary" (Miasnikov, 2005).

Due to its relative low cost and ease of acquisition, UAVs present concerns on its potential use for terrorism. UAVs may be exploited to attack targets that are difficult to reach by land (e.g. cars loaded with explosives). They may also be used to launch chemical or biological attacks in highly urbanised areas. The potential damage achievable by UAVs demands the special attention of future air surveillance systems.

4. Identification and Classification of Targets

Today's air defenders rely mainly on Identification Friend or Foe (IFF) systems to distinguish between enemy and friendly forces operating in the vicinity. However, the use of co-operative systems to identify targets has its limitations. For example, a hostile aircraft can be equipped with a transponder meant for civilian airliners and use it to mask its identity. Moreover, if the IFF interrogation loop is interrupted for any reason, such as transponder malfunction, the target may be misinterpreted as hostile, leading to catastrophic elimination of friendly forces or civilian aircraft.

There is also high strategic value in being able to identify the types of enemy targets. The ability to distinguish between a transport helicopter from an attack helicopter, for example, can provide valuable information about the intent of enemy forces and help the commander decide the best course of action. With the advanced processing power of modern computers, it is now possible to carry out complex target classification algorithms within a reasonable amount of time.

FUTURE SENSOR SYSTEM SOLUTIONS

Considering the above threat analysis, operational shortfalls in effective target identification and the desire to enhance the range and coverage of today's radar systems, the challenges for future surveillance systems can be broadly categorised into three main areas of: (1) Detection of stealthy or low observable (small RCS) targets, (2) Detection of low altitude, NLOS targets such as helicopters, cruise missiles and UAVs due to obscuring terrain or their being beyond the horizon and (3) Reliable classification and identification of non-cooperative targets.

To meet these future challenges, novel sensor system solutions, techniques, and key enabling technologies are proposed in the following sections.

COUNTER-STEALTH TECHNIQUES

1. Very High Frequency / Ultra High Frequency Radars

Radar-absorbent materials (RAM) and Radar-absorbent structures (RAS) are physically limited in their ability to absorb incoming electromagnetic energy. This is because the thickness of RAM required is driven by the wavelength of the incoming signal (Dranidis, 2003). For example, the most basic Jaumann absorber, which works on the principle of using interference to cancel reflected waves, required a minimum thickness of half the wavelength. To counter the majority of tracking and fire control radars in service today, which are generally in the high frequency band of 5GHz to 200GHz, RAM or RAS can easily be applied onto an aircraft since the wavelengths are on the order of a centimetre or less. However, if relatively low frequency (long wavelength) Very High Frequency (VHF) or Ultra High Frequency (UHF) radars are used to illuminate the target, the thickness of the absorber material required will be in the order of metres, rendering its application impractical on aircraft.

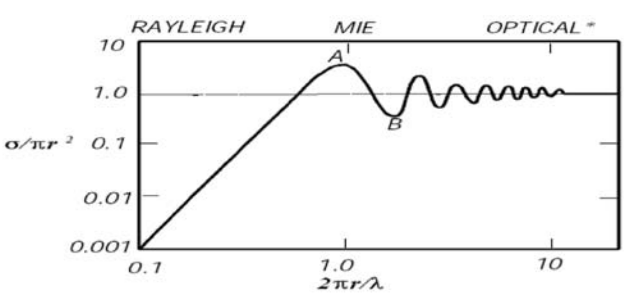

Figure 2. Normalised RCS of conducting sphere[2]

Figure 3. The "faceted" F-117A deflects incoming radar waves (Dranidis, 2003)

The effectiveness of low frequency VHF/UHF radar against targets with low RCS also relies on the resonance effect between the direct reflection from the target and scattered waves which "creep" around it. This resonance effect occurs most prominently when the wavelength of the incident electromagnetic (EM) wave is comparable to the physical dimension of the object, which results in large amplitude oscillations in the RCS. Figure 2 shows the wavelength dependence of the RCS of a conducting sphere. Maximum RCS of the sphere occurs when the wavelength is equal to its circumference.

The development of a low frequency (long wavelength) VHF/UHF radar for counter-stealth application has its limitations and issues that need to be addressed. The size of the antenna aperture has to increase in proportion to the wavelength so as to maintain a narrow beam for adequate resolution. Another constraint of VHF/UHF radar is that these frequency bands are already heavily used for commercial communication and broadcasts. Mutual interference will be a major challenge to operating the radar in such a dense EM environment.

2. Bi-static / Multi-static Radars

Besides using RAM to reduce the reflectivity of the airframe, stealth designers also make use of geometric design to deflect the majority of the incoming radar energy to less threatening directions, leaving very little to be reflected directly back to the radar receiver as illustrated in Figure 3. This is because in traditional mono-static radars, the transmitter and receiver are co-located and hence designed to receive target echoes that are returned along the same direction it transmits. Designers take advantage of the fact that the most threatening radar wave will illuminate the aircraft from a point that is much more distant horizontally than vertically. Since the forward cone is of the greatest interest in this case, most contemporary stealth aircraft are designed to direct large returns out of this sector into the broadside directions.

However, the deflected and scattered energy may still be picked up by bi-static or multi-static radars, as the receivers are separated from the transmitters over a considerable distance (shown in Figure 4). When the received signals are accurately correlated with the emitted signal from the transmitter, the point of reflection can be located. Additional transmitters and receivers can improve the accuracy of target localisation through triangulation and regression techniques, and at the same time increase the chances of intercepting reflected energies.

Separating the receiver from the transmitter in a bi-static/multi-static system, however, creates a more complex geometry compared to the mono-static radar. First, it is necessary to provide some form of synchronisation between the transmitter and the receivers in terms of transmitter azimuth angle, instant pulse transmission, and transmitted signal phase so that the received signal can be accurately correlated with the transmitted signal. Second, for the bi-static / multi-static radar to detect the target, line of sight (LOS) is required between the transmitter and the target and also between the receivers and the target. The placement of both the transmitter and receiver must be carefully considered to provide the desired coverage. To further complicate the issue, a received signal may arrive from different directions other than the true position of the target, as a result of multi-path or anomalous atmospheric propagation. It is necessary to sort out the direct distance signal from the unwanted ones before an accurate estimate of the target location can be computed.

DETECTION OF LOW ALTITUDE AND NON LINE OF SIGHT TARGETS

1. Elevated Sensors

Since incoming threats will likely fly at low altitudes to avoid detection by surface-based air defence systems, one possible solution to overcome this LOS limitation is to elevate the sensors and integrate them with surface-based weapon systems. Apart from aircraft and UAVs, elevated sensors can be carried using low life-cycle cost and long endurance "lighter-than-air" aerostats or airships which can be remotely

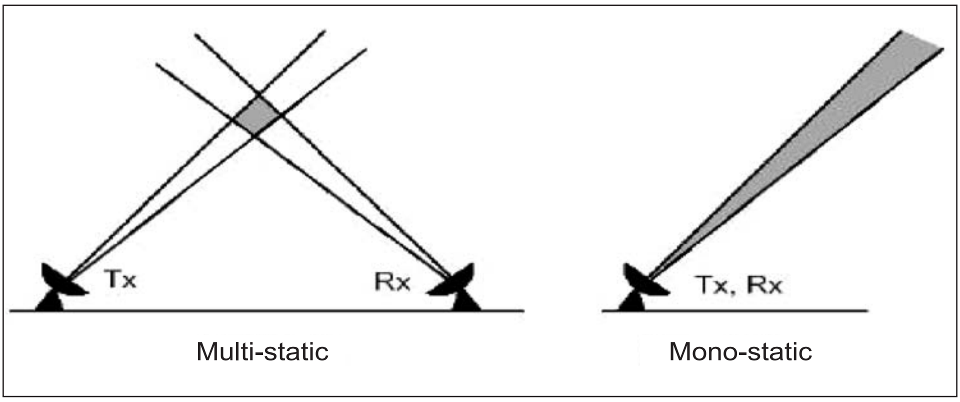

Figure 4: The transmitter and receiver are co-located for a mono-static radar, but are positioned separately in multi-static configuration. (Dranidis, 2003)

Platform	Type	Cost/flight hour (USD)	Endurance without unrefuel
AWACS / JSTARS	Conventional aircraft	$20,000	11 hours
E-2C Hawkeye	Conventional aircraft	$18,700	4.7 hours
Global Hawk	UAV	$26,500	35 hours
Predator	UAV	$5,000	40 hours
420K TARS	Aerostat	$300-500	15-30 days
Zeppelin	Airship	$1,800 (1 yr lease)	Few days

Table 1. Cost/Endurance comparison for persistent surveillance platforms

piloted, or flown autonomously. Table 1 shows a cost and endurance comparison between different elevated surveillance platforms (Naval Research Advisory Committee, 2005).

Elevation of these sensors enables the air defence weapon system to look down at the battlefield at extended ranges unhampered by terrain masking or earth curvature. To illustrate the advantage of elevated sensors, it can be calculated that the LOS range of a low flying cruise missile at 50m altitude is extended from 42km to 160km when a ground-based sensor is elevated to an altitude of 1km as shown in radar height-elevation-range chart of Figure 5.

In addition, the information provided by elevated sensors can be distributed simultaneously to all cooperative air defence weapons on the battlefield. This would provide a single integrated air picture for the air defence systems, as illustrated in Figure 6.

When using aerostats and airships, the limitations and issues of elevated sensor platforms need to be considered. While typical aerostats, like the Tethered Aerostat Radar System (TARS), which can lift about one ton of sensor equipment to a height of 3,500m, provide persistent surveillance out to over 350km and stay aloft for months, they are vulnerable to enemy ground fire and severe

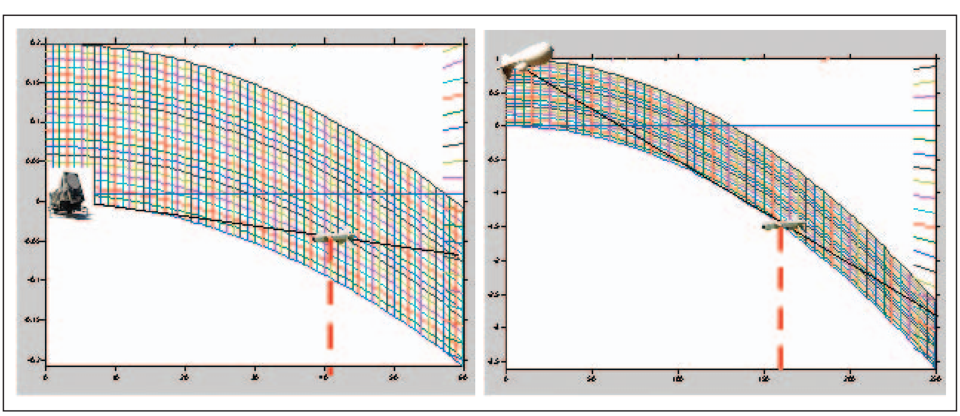

Figure 5. LOS range of cruise missile from ground-based and elevated sensors

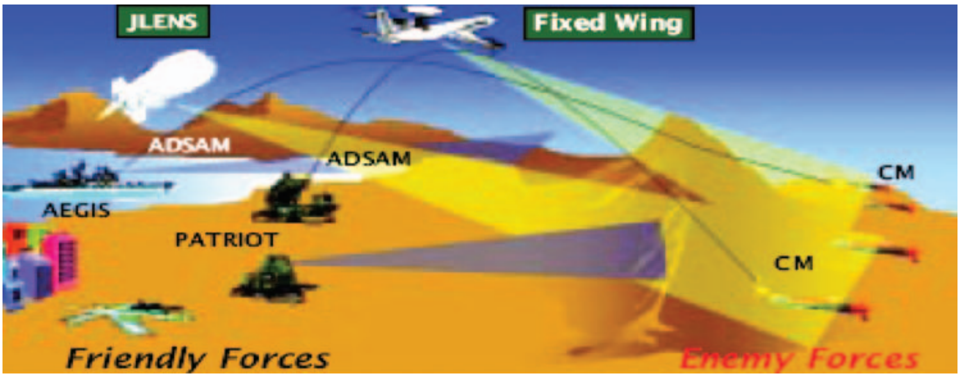

Figure 6. Elevated sensor air defence to detect low altitude targets[3]

wind conditions. Moreover, aerostats are tethered to the ground by a cable that also provides power and data links, imposing flight restrictions in the surrounding airspace. Airships, on the other hand, can move to change sensor coverage and also operate at higher altitudes (up to 21,000m, as in the case of High Altitude Airship) to avoid enemy ground fire. However, its higher maintenance cost and significantly reduced endurance (for example, limited power supply) compared to aerostats need to be taken into consideration.

2. Passive Surveillance

Another emerging concept in the detection of low altitude and NLOS targets is the development of passive radar systems. By exploiting signals from "illuminators of opportunity" such as commercial TV and FM radio transmitters and cellular base stations to illuminate targets (Figure 7), passive radar can detect and track targets in real-time without an intrinsic active transmitter (Griffiths, 2003).

The basic principle of passive radar is to perform cross-correlation of the received signals with a copy of the direct LOS signal (which is usually received on a separate, dedicated receiver channel). As the target is moving, it is necessary to cross-correlate the signals with several hundred frequency-shifted replicas of the reference signal, in order to take into account every potential Doppler shift and subsequently cancel out unwanted direct signals to prevent the masking of small reflected signals. Having detected targets in the Range-Doppler space by cross-correlation, sophisticated tracking algorithms are then used for plot-to-target association and to estimate the target location, heading and speed from the measurements.

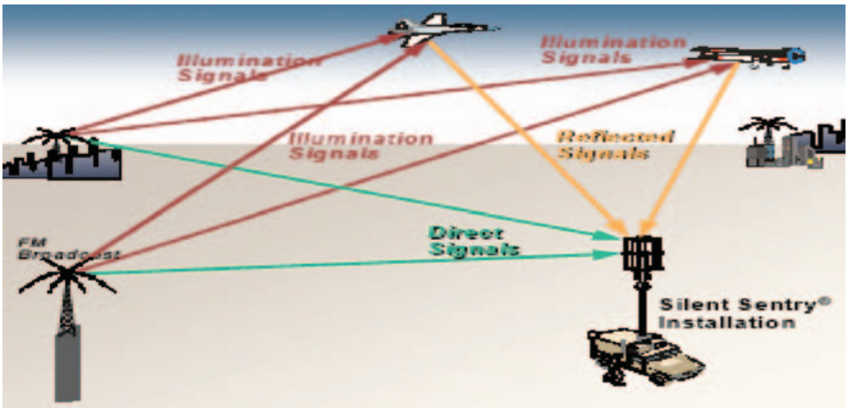

Figure 7. Passive radar concept of operation using FM broadcast (Griffiths, 2003)

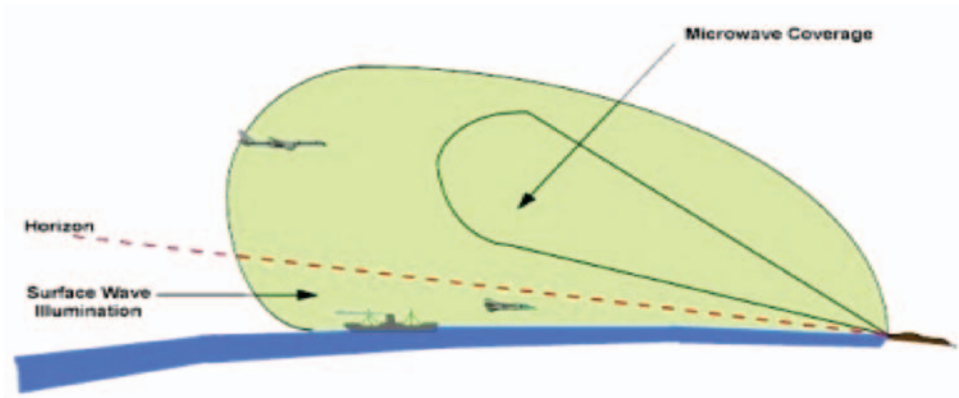

Figure 8. Coverage comparison between microwave and HFSW radars (Daronmont Technologies)

The range performance of passive radar is closely associated with the type of illuminator used. Systems exploiting GSM mobile cellular transmitters may only have a range of 20km, while FM radio stations are able to cover around 100km to 150km. High power television broadcast stations can achieve a range that is several times higher.

Passive radar and its concept of operation offer many distinct advantages over conventional active radar system. They are highlighted below[4]:

a. Passive radar is inherently survivable and ideal for covert operation since it has no RF "signature" that might give away its position during operation.

b. Passive radar reuses commercial broadcast signals from existing transmitters without requiring dedicated frequency allocation. It allows the deployment of surveillance systems in areas where a conventional UHF/VHF radar would have to compete with interference from an already dense electromagnetic environment.

c. Most importantly, passive radar has excellent low altitude coverage, allowing it to detect and track low altitude and NLOS targets that are masked by terrain. This is because TV, FM and mobile cellular broadcast stations are designed to focus their RF energy toward the Earth's surface, thereby providing the necessary illumination of low flying targets for detection and tracking. Besides that, the geometric diversity of these commercial transmitters results in simultaneous and multi-directional illumination of a target, offering additional information about the target from different viewing aspects.

d. The use of broadcast signals in the UHF and VHF frequencies also enables the detection of NLOS targets in the shadow region behind tree tops and low ridges through the phenomenon of knife-edge diffraction, which is more pronounced for longer wavelengths. This knife-edge effect is explained by the Huygens' principle, which states that a well-defined obstruction to an electromagnetic wave acts as a secondary source, and creates a new wave front. This new wave front then propagates into the geometric shadow area of the obstacle, enabling NLOS detection.

e. Passive radar is also a relatively low cost solution compared to conventional radar. It is, in general, a phased array system with no rotary mechanical parts. Besides, it has no transmission components. These attributes greatly reduce power requirements, mechanical upkeep and cost.

While the concept of passive surveillance seems promising, there are also drawbacks that need to be taken into consideration. In addition to the complex geometry and multi-path issues that are inherent in bi-static/multi-static configurations, passive radar is reliant on third-party transmitters, giving the operator little control over the availability of the illuminators. Moreover, there may be significant challenges in simultaneously fulfilling the LOS requirements between the transmitter and the target, the target and the receiver, and the receiver and the transmitter .

3. High Frequency Surface Wave Radar

Advances in ship launched cruise missile technologies have rendered air defence systems vulnerable to long-range attacks, as the detection range of most ship-borne air defence sensors (operating in microwave frequencies) are limited by their LOS range. HF surface wave radar (HFSWR), which operates between 3MHz and 30MHz, is designed to detect low-flying targets beyond the horizon as shown in Figure 8. The typical detection range of HFSWR is 10 times that of the microwave radar (Anderson, Bates, Tyler, 1999). It is also a cost-effective solution for maritime surveillance compared to other candidates, as illustrated in Table 2.

In surface wave mode operation, the HF wave travels along the ocean surface, which serves as the conducting surface for propagation. By following the curvature of the Earth, HFSWR can provide coverage in the order of several hundred kilometres. Rain or fog does not affect HF signals, making it an ideal all-weather surveillance system. An example is the Marconi S123 coast-based early warning system, which has a range of 250km (low altitude) to 500km (high altitude) with 1km track accuracy.

An operational HFSWR must be able to operate in the presence of sea clutter, ionospheric interference, and other external interference sources that include co-channel interference, man-made noise and impulsive noise (Dizaji, Ponsford, Mckerracher, 2003). In addition, it operates within the congested HF band, placing many challenges on its signal processor. Another consideration is the ability to deploy a HF radar system rapidly. Due to its long wavelength, HFSWR tends to be physically large and it has only been installed at fixed locations along the coast. A system that can be remotely sited, unmanned, and autonomous in operation will offer a much more flexible military capability.

Non-Cooperative Target Recognition Techniques

The target identification technique used in today's air defence systems is based on the "question and answer" interrogation loop of

Asset	Typical Operating Cost (USD)	Annual Cost (USD)	Notes
King Air Aircraft	$500 per hour	$2.5M	Typical annual subcontract
Challenger Jet	$2,500 per hour	$1.0M	One 8-hr flight per week
P3 Patrol Aircraft	$10,000 per hour	$2.0M	One 8-hr flight every 2 weeks
Coast Guard Cutter	$4,000 per hour	$8.0M	Seven days at sea per month
HF Radar	$10,000 per month	$120k	

Table 2. Cost comparison for surveillance of a 200-nautical-mile Exclusive Economic Zone[5]

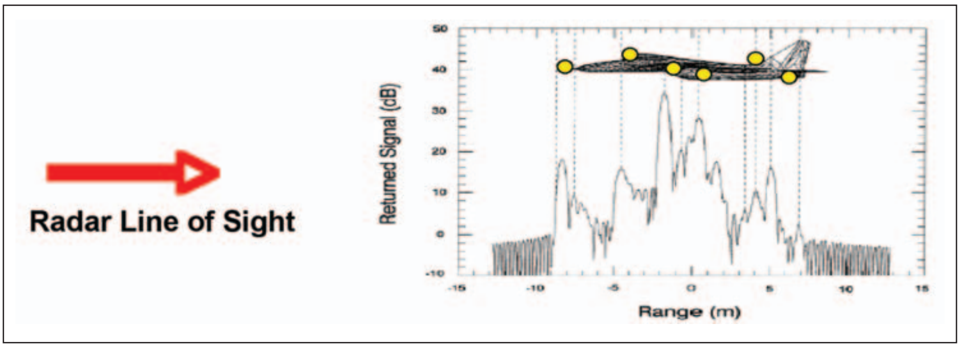

Figure 9. HRR range profile of a fighter aircraft (Defence Research Development Canada, 2005)

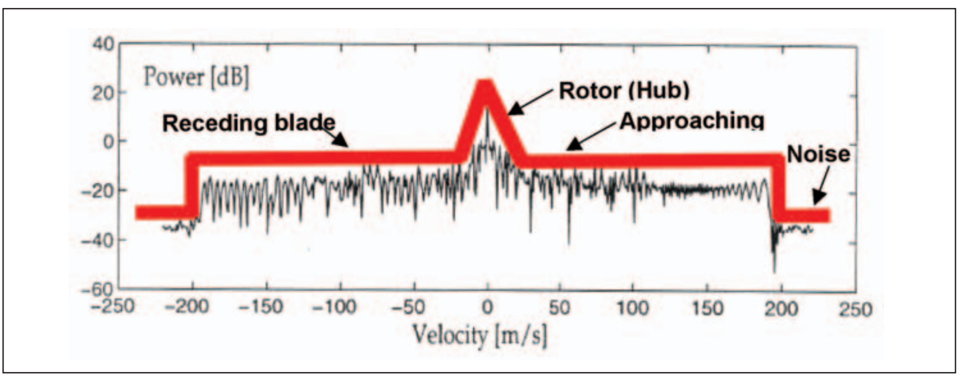

Figure 10. HERM spectrum of a hovering helicopter (Bullard, 1991)

unidentified aircraft. Although friendly aircraft can be identified by this technique, positive identification and classification of hostile and neutral aircraft poses significant challenges. The goal of Non-Cooperative Target Recognition (NCTR) radar techniques is to identify such targets without their active participation. The basic idea is that the geometry of an aircraft and its moving parts imposes unique features on the reflected radar signal. These features can be matched against a reference database that contains signatures of different target types for classification and identification.

The radar range profile method is one of the main NCTR techniques. It classifies an aircraft based on its high-resolution radar (HRR) images. The scatterers, which are the parts on the aircraft that give strong radar reflection, are projected onto the LOS to form the HRR range profile. Figure 9 shows a range profile of an aircraft viewed from the left, where responses from the scatterers (denoted by dots) along the radar LOS are projected. The radar range profile contains information on the geometry and heuristic features of the target, such as its nose to wing-tip distance, single or double tail airframe. By matching these characteristics against a reference database, it is possible to classify targets into broad categories of civilian airliners, fighters, missiles or helicopters, or even identify the specific platform types.

Another class of NCTR techniques focuses on the radar radiation reflected off the rotating parts of an aircraft. It includes Jet Engine Modulation (JEM), Propeller Rotor Modulation (PROM) and Helicopter Rotor Modulation (HERM) methods, which characterise a target based on the compressor blades in a jet engine, the propellers of a propeller-aircraft, or rotors on a helicopter, respectively. The radar spectra of JEM, PROM and HERM can be analysed to obtain information pertaining to the type of engine, propeller or rotor, the number of blades, the frequency of rotation and other information. An example of a HERM spectrum of a hovering helicopter is shown in Figure 10. Since each type of aircraft has a unique engine, propeller or rotor, these characteristic parameters can be matched against a reference database for classification and identification.

CONCLUSION

We have seen how the surveillance systems' operational environment has evolved to be far more complex over the past decade. Legacy systems, which are designed to thwart conventional attacks originating outside domestic airspace, are in many ways inadequate in dealing with adversaries that are stealthy, low altitude, and NLOS. The novel radar system concepts highlighted in this paper offer some insights into how the evolving threats might be dealt with in future air surveillance systems, but they are by no means complete. New solutions that are more capable and cost-effective are constantly being sought after. We must remember that the contest between surveillance and detection avoidance technologies is never ending as the adversary is always searching for loopholes in the current system, requiring even more advanced technologies to be developed to stay ahead of the game.

REFERENCES

Buderi, R. (1996). Invention that Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution.

Bullard, B. (1991). Pulse Doppler Signature of a Rotary-Wing Aircraft. Atlanta: Georgia Tech Research Institute, Georgia Institute of Technology.

Daronmont Technologies, SECAR HF Radar Theory. Retrieved on May 2007 from http://www.daronmont.com.au/products_secar_radartheory.htm

Defence Research and Development Canada. (2005). Retrieved on May 2007 from http://www.ottawa.drdc-rddc.gc.ca/html/RAST-309-nctr_e.html

Dranidis, Dimitris V. (2003). Airborne Stealth in a Nutshell: Countering Stealth – Technologies & Tactics, WayPoint Magazine Issue No 6.

Griffiths, H. D. (2003). From a Different Perspective Principles, Practice and Potential of Bistatic Radar. Radar Conference, Proceedings of the International, pp 1-7.

Headquarters, Department of the Army. (2000). US Army Air and Missile Defense Operations.

Miasnikov, Eugene. (2005). Threat of Terrorism Using Unmanned Aerial Vehicles: Technical Aspects, Center for Arms Control, Energy and Environmental Studies, Moscow Institute of Physics and Technology.

Naval Research Advisory Committee. (2005). Light-Than-Air Systems for Future Naval Missions.

Neale, B. T. (1985). CH - The first operational Radar, The GEC Journal of Research, vol. 3, No.2 1985 pp 73-83.

R, Dizaji, A. M. Ponsford, and R. Mckerracher. (2003). Signal Processing Challenges in High Frequency Surface Wave Radar. Proceeding of Signal and Image Processing 2003.

Sinnott, D.H. (1988). The Development of Over-the-Horizon Radar in Australia.

Stuar J. Anderson, Bevan D. Bates and Mark A. Tyler. (1999). HF Surface-Wave Radar and its Role in Littoral Warfare, Journal of Battlefield Technology, Vol 2, No 3.

ENDNOTES

1. Courtesy of American Institute of Aeronautics and Astronautics. Scanned copy obtained from http://www.f22totalairwar.de/F-22_Total_Air_War_Stealth_Radar_Cross_Section_RCS.htm

2. Taken from http://www.tscm.com/rcs.pdf, which credited Dr. Allen E. Fus.

3. Taken from U.S. Army Space and Missile Defense Command, Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System.

4. Defence Systems Institute - MDTS2005 (Group 1), DTS5709: Sensor Technology and Systems Report, Novel Sensor Systems Solution for Future Air Defence

5. Courtesy of Raytheon Systems Canada Ltd.

BIOGRAPHY

Yeo Siew Yam is Assistant Director (Surveillance). As Assistant Director, Siew Yam manages the R&T portfolio in surveillance (including radar, Electro-Optics / Infrared and exploitation tools) in Directorate of R&D (DRD). His other responsibilities include fostering R&T in Temasek Laboratories at Nanyang Technological University (NTU) as well as in the Supélec, ONERA, National University of Singapore, DSTA research alliance (SONDRA). He graduated with a Bachelor of Electrical Engineering from Nanyang Technological University (NTU) in 1989 and a Master of Science in Electrical Engineering from Naval Postgraduate School in 1998 under the DSO Postgraduate Scholarship. Siew Yam won the DTP team Award in 1992 and 2004.

Yeo Jiunn Wah is Principal Engineer and Technology Manager (DRD). As Technology Manager, Jiunn Wah manages R&T initiatives and radar portfolio in the Surveillance Office. He also contributes to the plotting of the technology roadmap for Advanced Surveillance Radar and prospecting of leading technologies. He graduated with a Bachelor of Electrical Engineering from the NTU in 1997. He also attained a Master of Science in Defence Technology and Systems from Temasek Defence System Institute in 2007 and a Master of Science in Combat Systems Science and Technology from Naval Postgraduate School in 2007 under the DSTA Postgraduate Scholarship. Jiunn Wah has won the DSTA Team Excellence Award in 2002, DSTA Innovation Excellence Award in 2003, Defence Technology Prize (Engineering Team) in 2003 and Defence Technology Prize (R&D Team) in 2005.

Henry Yip is Engineer (DRD). He is currently assisting in the management of R&T projects in the area of surveillance. He graduated with a Bachelor of Science in Electrical and Computer Engineering from Cornell University in 2006 and a Master of Engineering in Electrical and Computer Engineering from Cornell University in 2007 under the DSTA Overseas Scholarship.