SHORAD SYSTEMS

(SHORT RANGE AIR DEFENCE SYSTEMS)

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Introduction to SHORAD Systems

As modern warfare changes with the growth in stealthy, and agile threats, countries are investing increasingly in their national security and the development of air defence systems. These are used to take defensive measures to counter incoming hostile aerial threats such as ground attack fighter aircraft, missiles and uncrewed aircraft systems (UAS). Air defence systems act as counter-weapon systems for all air threats and are also used for operations such as airspace surveillance using radars and electro-optic sensors. With today's aerial threat environment continuing to evolve rapidly and with growing complexity, the need for Short Range Air Defence systems (SHORAD systems) have become increasingly relevant to military operations around the world. Missile threats have been addressed with very capable systems, but there is now a prevalence of smaller threats such as UAS and drones to exploit potential gaps in air defence.

SHORAD systems typically can be deployed quickly should the threat assessment change and can be put in places where radar coverage is degraded or non-existent. Equipping SHORAD systems requires component parts that can be manoeuvrable alongside vehicle formations and can maintain connectivity with other air defence assets for early warning and reporting.

SHORAD systems comprise a collection of sensors that typically includes multiple radar and RF sensors. But it can also incorporate electro-optical devices such as cameras or laser rangefinders. In addition, it includes either a C2 or C4I system to communicate between the various elements and the command-and-control system, and also effectors, kinetic weapons, missiles, or, more recently, directed energy weapons. A vehicle component enables SHORAD systems to be mobile (M-SHORAD) and provides a platform for mounting radars.

Radar sensors for threat detection and identification are at the heart of SHORAD systems. They are the principal all weather sensor and are often supported by electro-optic devices to provide precise angle measurements of aerial targets. Critical to the success of any SHORAD system is the ability for all the component parts of the system to be integrated together and in turn to be integrated within the battlefield communications system.

Figure 1: Containerised SHORAD Radar System

Threat Environment

The aerial threat environment for SHORAD has traditionally been aircraft, fixed and rotary wing, and missiles, but this is rapidly evolving to include drones and reversionary modes such as for weapon location. As the development of hypersonic missiles matures, these too will become a growing threat to air defence.

The most difficult threat for radar sensors currently is low, slow speed drones with a small radar cross section ('Low, Slow and Small – LSS'). These tend to operate in regions where there is ground clutter and precipitation clutter. Aircraft and missiles that are travelling at high speeds are well separated from this clutter in Doppler space, but slow small radar cross section drones are difficult to detect and identify among the clutter. Doppler filtering is needed to suppress the ground clutter and enable drone detection. Because drones are relatively slow and operate where clutter exists, it makes it far more difficult to filter out ground clutter and rain. Very fine Doppler resolution is needed to separate the very slow speed drones from clutter in order to detect them, and this calls for a combination of a relatively high Pulse Repetition Frequency (PRF) and a large number of pulses within a Coherent Processing Interval (CPI). This is difficult to achieve with medium to long range radars. These are key factors in managing the time-energy budget of radars used in SHORAD. Features on drones, especially rotary winged drones, can affect detection where for example the rotors create Doppler side bands that are well separated from the body echo, and these side bands may be used to detect targets rather than the body echo, even when the drone is hovering or flying tangentially to the radar.

The main purpose of SHORAD is to defend against attacks on expeditionary forces and airfields and airports, as well as command and control infrastructure targets.

Capabilities for SHORAD Systems

A key capability for SHORAD systems is to detect reliably and track stealthy targets travelling at a wide range of speeds from low to very high velocities. Detecting drones sporadically means it is very difficult to get a good track on that particular target, and without a good track it is not possible to get high accuracy positioning data. As a consequence, queuing an effector onto the target becomes difficult. Reliable detection of targets is essential.

The system components must be flexible enough to be developed organically to protect expeditionary forces, HQ and communications centres, and fixed assets such as ports and airfields. Critical requirements are sensors that can deliver a high probability of detection, and an overall system that has a high probability of successfully countering the threats. The ability to deal with threats at a distance, rather than waiting until they are close-up is important.

Cost is increasingly a constraint as nearly all militaries experience a reduction in real term expenditure and value for money is becoming an important selection requirement. Using lower cost equipment, and networking multiple sensors together rather than relying on a single high value asset which, if taken out of service means all capability has been lost, offers a viable alternative. In today's information age such mesh-networks, where a large number of smaller, lower cost sensors, are networked together, can serve to make the sum much greater than the parts.

Challenges for SHORAD Systems

The challenges for an effective SHORAD system are how to provide a high probability of detection and high probability of kill on targets, while benefiting from the advantages of reduced size, weight, power and cost (SWaP-C).

Overcoming the challenges of ever evolving threats requires incremental improvements in capability which can be achieved by making radars software defined. This allows the capability of radars to be upgraded in the future, as and when the threat changes and customers have more budget available.

It has been possible, theoretically, to operate SHORAD systems weapons-free for some decades. The Rules of Engagement employed by all militaries has meant this has never happened, and SHORAD systems have therefore operated weapons tight with a person in the loop to look at a camera image and provide positive identification that the target threat is hostile, prior to engagement.

Artificial Intelligence and Machine Learning can perform that positive identification and take the person out of the loop automatically. A human operator in the loop extends the detect-to-prosecution timeline, because computers can come up with answers far quicker than the human brain, and certainly far quicker than the human can actually initiate action. This will benefit SHORAD systems by reducing the engagement timeline, first detection to kill, and will most likely be essential to have any chance of combatting hypersonic missiles. Blighter is working on machine learning for target classification so that the targets being looked at by radar can be identified.

Affordability is also a key challenge for radar sensors used in SHORAD. Using multiple radars in a mesh-network creates an affordable system with radars geographically spread across different locations, each communicating either with themselves or with a central command post. In this way the same targets can be looked at multiple times by different radars, which helps tracking accuracy. If a drone is invisible to one

sensor, it is likely to be visible to some of the others. This creates more robust detection and tracking of targets at longer ranges, because it is being seen with multiple different radars of varying degrees and probability of detection by fusing together the information from these radars, this mesh-network of radars results in better performance than from an individual sensor.

Figure 2: Mast-deployed SHORAD radar at airport

Radar Capabilities for SHORAD Systems

Integration as a primary detection sensor. Almost every radar solution requires the interaction of an electro-optic camera system in order to observe the object initially detected by the radar. The Blighter radar is no exception and provides early warning over long ranges and potentially thousands of square kilometres and classifies the target by assessing its key radar characteristics.

Detection of small, low and slow-moving targets in complex terrain and all-weather conditions. The radar's ability to detect slow moving targets, including in complex terrain, is critical for the success of air defence and the detection of aerial targets including drones. Blighter's radars have a well-established capability in ground level detection, looking for targets moving slowly across it in a cluttered environment. This has now extended into the air domain with the capability to detect small drones whether they are moving slowly or fast. For SHORAD applications, low, slow and small moving objects near the ground or in the sky can be detected simultaneously with one radar system. With the development of 3D radars, there is the capability for the detection of short-range aerial targets and those close to the ground, by increasing the scanned volume.

State-of-the-art electronic-scanning technology. The Blighter drone detection radar uses state-of-the-art electronic-scanning, FMCW and Doppler signal processing technology to provide a robust, ultra-reliable, zero moving parts remote sensor that will detect intruders in all weather conditions and in most environments.

Filtering out and removal of background clutter. Doppler processing technology enables ground clutter signal to be filtered out and removed from the air-land picture and still allows the radar to see targets as small as drones and micro-UAVs. The key feature of Blighter radar's capabilities for air defence stems from its Doppler signal technology. The radar scans all targets and background clutter, and these are measured and characterised by their Doppler velocity. Valid targets can be discriminated and separated from the background environment leaving only targets of interest.

Rapid time to first detection, maximising target range. The time to first detection and the update rates, are important features that enable aerial targets to be detected at the very first opportunity after the target has been unmasked. Blighter radar can detect movement the instant it occurs, unlike traditional radars which need multiple scans before outputting a target. Moving target plots are output within a fraction of a scan to minimise the latency between detecting and responding to the threat and provide the earliest warning. This ensures that electro-optic systems point at the aerial threats and provide frequent updates to follow their movements.

Machine Learning. Machine learning technology is being introduced into future radar products to provide target classification capability. By mapping radar targets against reference signatures and looking at the Doppler characteristics and movements of objects, targets can be classified using existing templates for drones and other targets, enabling discrimination between aircraft and other objects. Importantly this enables the classification of priority targets such as a commercial aircraft and in so doing allows the categorisation of the remaining target objects as background clutter for removal. Previously this has taken significant skills to fine tune the radar settings for a particular installation and even for day-to-day operations, depending on the weather conditions.

Improving reliability of target detection. The key to success in detecting targets in such environments is to use fine Doppler resolution to separate targets from background clutter. Doppler resolution is the primary method of achieving this. Levels of protection against aerial threats can be increased by adding more sensors into the system positioned at a number of different locations and all linked together. Using a mesh-network in this way, each radar within the network will have a different view of the target, the terrain and the prevailing weather conditions and these will have different degrees of effect on each radar within the mesh-network. By fusing together the data provided by these radars, a much better picture is generated resulting in more reliable detection.

Detection of targets in both land and low altitude air domains. AESA radars allow the radar time-energy budget to be allocated according to the threats encountered and are able effectively to share their time between land and low altitude zones to maximum benefit. Detection of threats can be tailored to include those that are expected and most likely to occur, enabling the time energy budget to be managed.

Providing rapid position updates of targets. Unlike conventional radars with fixed scanning regimes, AESA radars, because of their flexibility, can schedule tracking tasks based on threat priority. This means high velocity targets that present a greater risk are updated more frequently than slower targets, resulting in the measured positional accuracy of targets being enhanced.

Synchronising radar sensors in mesh-networks. Every element of the system needs to share a common time frame. All of the elements of the SHORAD system need to synchronised to a single time slot. If some of the information passed between these sensors and effectors, or the control system is only a few seconds out, the effector will not be pointed accurately at the target. With multiple sensors inside the network, the times at which each one of the sensors detects a target will all be slightly different. This means that the command-and-control system or fusion engine has to make sense of that. To compensate for this, the entire system must be synchronised to a time source, theoretically using GPS. Knowing the precise location and orientation of the sensors is critical in order to achieve acceptable accuracies and avoid target bearings to be incorrect; even a few degrees can make a significant difference.

Figure 3: SHORAD radar system on GD Stryker vehicle

Future Trends for Radar and SHORAD Systems

The need for SHORAD is likely to increase over the over the coming years. The performance envelope of SHORAD systems ranges from relatively low capability to highly capable systems. Blighter is positioning itself in the high capability end of the spectrum whilst simultaneously ensuring value for money.

Innovation limited only by the laws of physics is the key to the next generation of radar technology development and will include AESA radar and working on artificial intelligence and machine learning.

Blighter will soon be introducing a new range of radars which can serve a number of roles, SHORAD being one. These advanced radars will have the capability to be fully networked into an almost unlimited mesh, and this combined with data fusion and Machine Learning will bring the performance of radar sensors to levels previously unseen. Critical to this are industry standard interfaces that allow that connectivity. Using networks of short to medium range smart radars enables improved performance, robustness and potentially greater value for money than sensor-centric SHORAD systems.

About the Author – Barry Wade

A mathematics graduate, Barry has accumulated over 30 years of experience in the radar industry, gained while working for Plessey Radar, GEC Marconi Radar and Defence Systems, BAE Systems, Kelvin Hughes, AMS Group and Blighter Surveillance Systems. Internationally recognised, he has held senior positions, in excess of ten years at director/vice president level, in the development of numerous air defence, fire control, weapon location and navigation radar systems.

While at Blighter Surveillance Systems Barry has applied his knowledge of Active Electronically Steered Array Radar, advanced signal processing and non-cooperative target recognition to the development of a new family of short range radars.

In 2011 he was presented with a prestigious Navigation Award by His Royal Highness the Duke of Edinburgh for Technical Achievement from the Council of the Royal Institute of Navigation (RIN) for his work in leading the design of the SharpEye™ radar. He has chaired sessions at international radar conferences and regularly reviews radar related papers for learned journals. His principal interest is in radar signal processing and has published several papers on this topic.

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