NATIONAL BORDER SECURITY

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Introduction

Many of the world's nations have concerns about national border security and in particular, people entering their country either to live and work there, or smuggle in illegal goods. At official border crossings, substantial fences and formal security controls provide adequate protection, however in remote areas, the cost of providing and maintaining effective physical barriers is excessive.

A nation's borders are one of its primary defences against a range of threats, but they also have a number of vulnerabilities that can be exploited for criminal gain, illegal migration or terrorist activity.

The integrity of the physical border remains critical, particularly in areas with long land or sea borders. These vulnerable frontiers can be enhanced by using technological innovations such as infrared sensors, heat-sensing cameras, unmanned aerial vehicles, and radar and satellite surveillance. Countries are also co-operating along shared borders to increase the breadth of coverage.

Advancements in e-scanning radar capabilities mean that they are being used as the primary detection sensor for long-range remote surveillance systems where the ability to detect slow moving targets, even in complex mountainous terrain, makes them the ideal solution for the remote surveillance and detection of vehicles, people and even crawlers trying to cross borders illegally.

Figure 1: Typical national border security fence in the Middle East

Threat Environment

Nations faced with the challenges of maintaining the security of their borders against those wishing to take advantage of border vulnerabilities have to contend with a

wide array of evolving threats, ranging from terrorists and transnational criminals smuggling drugs or counterfeit goods, to unauthorised migrants.

Until recently, national border security was focussed on surveillance of ground level activities, looking for movements of people and threats on the ground such as smuggling, terrorism and migration. The requirement was to look at ground targets, and then augment it with the need for strategic long-range capability. Radar then started looking at long range targets such as aircraft hundreds of miles away. But drones appeared and these soon began to feature on the threat landscape for national border security broadening the requirement for skyward surveillance. The target for surveillance suddenly changed from a two-dimensional flat plane into a three-dimensional volume.

The threat landscape is now more complex as drones become ubiquitous, more accessible, have longer range, fly faster, higher and with greater payload capacity. And this complexity has increased as the commercial use of drones becomes more prevalent for cross-border activities, such as shopping, medical and agricultural uses. The threat landscape is evolving with the use of drone swarms, a mixture of different drones, large and small, fast and slow, able to carry different payloads. State actors, governments or the military could launch a coordinated attack with a whole range of different drones, each carrying different sensors and effectors. It is necessary to detect the bad drones, the drones that are being misused in the midst of those which are legitimate.

Capabilities for Effective National Border Security

Radar and long-range cameras with very sensitive low light performance, and thermal imaging capability to see the heat profile of people and vehicles, are most commonly used for national border security. Cell phones, walkie talkies, and radio frequency direction finding equipment, as well as unattended ground sensors are also used. And if there is a perimeter fence, then fence detection sensors and fibre-optic or coaxial cable that runs along it will detect movement and generate an alarm at that position, but this approach is often prone to false alarms.

Radars are becoming increasingly more capable and electronic scanning Doppler radars are now able to detect crawling persons on the ground. Blighter was the first electronic scanning ground surveillance radar able to detect ‘crawlers’, through the combination of static electronic scanning radar beams, micro-Doppler signal processing and Frequency Modulated Continuous Wave (FMCW) technology. Drones are now commonly used for surveillance as well for self-protection, particularly where there are long land borders or coastal borders. Long-range, long-endurance surveillance drones are also used for border protection. But the very obvious limitation is that they are not usable in poor weather such as high winds, and rain. Satellite surveillance is also possible with nano-satellites and earth observation satellites now being very capable of detecting changes on the ground.

Challenges for National Border Security Systems

The principal challenge for national border security systems is detecting small, low and slow moving targets in complex terrain, and adverse weather conditions.

Weather Conditions

Weather is the biggest challenge for intruder detection systems. Moving water in particular, where it is dynamically changing in position, size and appearance, without careful sensor design can hide or obscure the target from detection by radar and

cameras. Rain also serves to reduce the effectiveness of sensor systems. In the case of camera systems, rain simply blocks the visible image of the intruder, but for radar, unless it is carefully designed, the rain not only attenuates the radar signal but also creates false targets due to the reflectivity and motion of the pockets of rain. It is worth noting that many intruders, wise to sensor limitations in poor environmental conditions, choose to exploit bad weather to evade detection. The sensors therefore need to be able to operate at the very time when they are likely to be most compromised by the complexity of the environment.

Remote Infrastructure

A further challenge for many remote surveillance systems is finding a suitable location on which to site the surveillance platform. This typically consists of an equipment cabin, mast, sensors and a source of power and remote communications. The remoteness of many ideal surveillance sites makes the installation of traditional large and power-hungry systems near impossible. It is just not possible to build concrete bases for masts or to supply mains power. Compact, lightweight, low power systems have a light footprint for installation and are potentially tripod mounted and operated from solar or wind power. Satellite communications is an available option for almost all sites, but is expensive and has a number of major technical disadvantages including poor latency (communication delay) and marginal operation in heavy rains. Alternatively, sensor systems that require only low bandwidth communication can make use of lower cost and more effective direct radio links including microwave communications links.

Operational and Maintenance Resourcing

Customers and users want a national border security system that provides protection at minimal cost, and maximum efficacy; often that is a real challenge. Manning these complex electronic surveillance systems is the biggest burden. The costs of providing security officers, personnel to view the video screens 24 hours a day, with regular chains of shifts, creates a significant cost. There is also a training and maintenance burden, particularly relevant when operating equipment in extreme environments.

Radar Wave Band

Threats from vehicles, people, animals, big drones, large military grade aircraft, are all detectable by radars. There are various radar bands available, from the low frequency, long wavelength L-Band for long range aircraft tracking, for instance, where it can travel hundreds of miles but it has very poor resolution, up to X-Band, and Ku-Band. The practical upper limit is Ku-Band, but significantly, putting small commercial hobby drones into the mix with all of these national border security applications, forces the use of higher frequencies, specifically X-Band and Ku-Band. The older frequencies, L and S-Band, with wavelength measurements of 10 cm and 20 cm, are larger than all the component parts in a typical hobby drone. The radar beam, rather than bouncing off the drone and coming back to the radar, just diffracts through the drone as if it is almost invisible. For optimum effect the X-Band and Ku-Band radars are most suitable for drone detection.

National Border Security Solutions

The Blighter radar uses patented, state-of-the-art electronic-scanning (e-scan), FMCW and Doppler signal processing technology to provide a robust, ultra-reliable, zero moving parts remote sensor that will detect intruders and cross-border activities in all weather conditions and in most environments. The Blighter radar is ideally suited

to remote detection over large open-areas of land including rocky mountainous terrain.

Detection of Illegal Immigrants and Smugglers of Contraband Goods

The Blighter radar is used as the primary detection sensor for long-range remote surveillance platforms. Where persistent surveillance of borders is required then integrated fixed tower structures can be used to mount the Blighter radar and other sensors to provide optimal long-range surveillance.

In remote areas, it is common for intruders to follow natural routes across the land; valleys, mountain paths, desert animal tracks. In these instances, mobile or portable surveillance systems can provide a cost-effective way of monitoring key areas with limited resources. As the flow of intruders and cross-border activities is reduced through successful interception by the surveillance system then it can be moved to the next hot-spot. The Blighter radar is sufficiently compact and robust to be fitted to fixed integrated surveillance towers, or vehicle-based surveillance vehicles. Typically, these use extendable masts to elevate the Blighter radar and electro-optic system for optimal visibility and detection range.

In extreme environments, where it is not possible to drive vehicles, then the Blighter radar system can be backpacked and carried to the surveillance area. The Blighter radar is man-portable, and battery-powered which can be operated for extended periods from battery and solar-power sources if required.

Figure 2: US and Mexico national border security fences (San Diego Sector)

Prevention of Narco-terrorism

A key characteristic of narco-terrorism is the increasing capability and resources of the smugglers and terrorists. With organised and frequent illegal border-crossings, the narco-terrorists learn about the quality and effectiveness of surveillance systems and discover how to avoid or defeat them.

The Blighter radar's ability to detect crawler sized targets moving slowly allows it to detect intruders who are knowingly trying to defeat the sensor systems. The Blighter radar has a proven capability to detect a man belly-crawling or even rolling across an intensively monitored national border security zone.

High value payloads make flying an attractive option for narco-terrorists. The Blighter radar's ability to detect small targets coupled with its wide elevation beam width means that Blighter can surveil both the land and low air zones simultaneously. Using its Doppler processing technology, it can filter out and remove the ground clutter signal from the land and still see targets as small as parachutists, microlights, ultralights and UAVs flying over borders, unlike traditional air surveillance radars.

Monitoring of Border Incursions for National Border Security

The Blighter radar uses technology to electronically scan the border considerably faster than traditional ground surveillance radars. A suitably configured Blighter radar can scan 360° in one second with full Doppler processing. This provides rapid position updates to the operators. Also, the Blighter radar uses its Doppler signal processing and an integrated plot extractor to 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 intruder. This ensures that electro-optic systems point at the intruders and update frequently to follow the movements of the intruder.

Figure 3: Typical fixed integrated surveillance tower for long-range detection

Radar Capabilities for National Border Security

Integration as a primary detection sensor for remote surveillance. Almost every security 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 of intruders over long ranges and potentially thousands of square km, and classifies the target by assessing its key radar characteristics. Blighter radars are used as the primary detection sensor for long-

range remote surveillance platforms providing border protection against hostile threats.

Detects Low, Slow and Small (LSS) Targets in Complex Terrain and All Weather Conditions

The radar's ability to detect slow moving targets, including in complex mountainous terrain, is critical for the remote surveillance and detection of vehicles, people, crawlers and drones trying to cross borders illegally or defeat sensor systems. Blighter has always been good at 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 border surveillance applications, low, slow and small (LSS) 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 detection of targets close to the ground, and up into the sky, increasing the scanned volume. Blighter has traditionally led the national border security radar capability, and was the first to enter the market with 'crawler' detection.

State-of-the-art Electronic-scanning Technology

The Blighter ground surveillance 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 Ground Clutter

Doppler processing technology enables ground clutter signal to be filtered out and removed from the land picture and still allows the radar to see targets as small as parachutists, microlights, ultralights and micro-UAVs flying over a border. The key feature of Blighter radar's capabilities for national border security stems from its Doppler signal technology. On every radar scan all targets and background clutter are measured and characterised by their Doppler velocity. Valid targets can be discriminated and separated from the background environment leaving only targets of interest.

Installation on Fixed Integrated Surveillance Towers for Long-range Detection

Where persistent surveillance for border security is required, integrated surveillance towers can be used to mount the radar and other sensors to provide optimal long-range surveillance. The compact and robust design enables radar to be fitted to land surveillance vehicles to provide mobile, portable and cost-effective solutions for monitoring key areas with limited resources. Extendable masts are used to elevate the radar and electro-optic system for optimum visibility and detection range.

Rapid Time to First Detection, Maximising Target Range

The time to first detection and the update rates, are important features that enable targets to be detected at the very first opportunity when the target has appeared and at a longer range. 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 intruder, and provide the earliest warning of a threat. This ensures that electro-optic systems point at the intruders and provide frequent updates to follow the movements of intruders.

Figure 4: Blighter radar deployed on solar-powered trailer system

Low Power Operation from Renewable Energy Sources

Blighter radars' FMCW transmission technology, combined with sensitive Doppler target detection means that the radars have a small communications bandwidth requirement and needs only a fraction of the transmitter power used by traditional security radars systems and dramatically less than classic radar systems. Blighter transmits only 4 Watts of power, just a little more than a cell phone and equivalent to a modern LED light bulb, yet it is able to detect small targets at ranges up to 10 km away. This low power transmission requirement also means that the total power consumption is a fraction of other radars.

Robust, Reliable and Proven Technology Capable of Operating in All Environments

The Blighter radars have been installed in more than 35 countries and operate in extreme weather conditions from the hottest deserts to sub-zero temperature environments. The e-scan technology has no moving parts and uses a solid-state transmitter which provides high reliability, long life and requires only low levels of maintenance.

Creation of Alert Zones

Combined Doppler and FMCW technologies are used during radar scanning to detect potential targets and predict the position of the target through extrapolation of the target's heading and speed. When looking over land in national border security applications, there are typically areas where movement of objects is permitted and other more secure areas where traffic is unexpected or prohibited. The operator can create a large number of zone areas either to exclude and hide the radar detection or generate alerts. The alert zones can be prioritised and colour coded to create layers of

protection, allowing early detection at long ranges, initial warning of a possible intrusion at medium ranges and then full red alert with audible and visible alerts.

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 micro-Doppler characteristics and movements of objects, targets can be classified using existing templates for drones and other targets, enabling discrimination between people, vehicles and other objects. Importantly this will enable the classification of priority targets such as a people, animals, vehicles, and in so doing allow the categorisation of the remaining 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.

Case Study – Providing National Border Surveillance in the Korea DMZ

The Demilitarised Zone (DMZ) between North and South Korea was created by agreement between North Korea, China and the United Nations following the Armistice agreement in 1953 and it remains one of the most politically sensitive borders in the world. The DMZ is 250 km long, approximately 4 km wide and features many terrain types including forested areas, mountains and coastal regions and experiences environmental extremes of -30 °C in winter and a humid +40 °C in summer.

Large numbers of troops continue to be stationed along both sides of the border, and they remain on continuous alert against unlawful incursions into the DMZ area. In order to monitor the area from their side of the border, the Republic of Korea Army (ROKA) decided to add ground surveillance radar systems to their sensor inventory and in 2010 Blighter's B400 series Ground Surveillance Radars were selected to provide continuous surveillance, 24 hours a day, 365 days a year. The decision to use B400 series radars was made because of their suitability for use in harsh environments as well as their ability to remain operational without routine maintenance.

Blighter radars are particularly well suited to national border security applications with their long-range detection capability (from just 10 m up to 32 km), 20º wide elevation beam, which provides simultaneous hill-top and valley coverage, and their ability to detect very small and slow targets such as a crawling person up to 4 km away and a walking person up to 10 km, even in cluttered environments found in the DMZ. Blighter radars combine patented solid-state Passive Electronic Scanning Array (PESA) technology with advanced Frequency Modulated Continuous Wave (FMCW) and micro-Doppler processing to provide a robust and persistent surveillance capability in all weather conditions.

Figure 5: Blighter B400 series radar installed on Korean DMZ

Following a number of serious drone incursions from North Korea in 2014, the ROKA investigated the options for drone detection and after evaluating various international products, decided that the drone detection capability of their existing B400 series radars along the border would provide an effective solution. A number of the installed radars were fitted with a radar tilting system that enabled operators to angle the radars towards the sky during the day when the drone threat was the highest, and towards the ground for night time operation when the risk of unauthorised incursions by North Korean troops into the DMZ zone was the highest. The radars are generally used in conjunction with high performance thermal imaging cameras with each operational point having its own local control centre to allow instant response to incursions.

A number of Blighter radars are also installed on islands overlooking the coastal border towards North Korea. These radars offer the ability to monitor both the water and far land for early warning of possible incursion by individuals. Typically, the remotely installed radars are networked, together with cameras, to provide a hierarchical surveillance and command structure that allows coordinated regional response to incursions by water.

During the years of operation, the radars have proved to be highly reliable confirming their 65,000 hours mean time between failure (MTBF) status, and they have successfully detected various illegal crossings including drones, and swimmers in the coastal areas. Inevitably, over a period of 10 years a number of radars have required maintenance, upgrades and occasional repair, and for this reason Blighter has created a localisation support package, allowing a local partner to assemble, test and maintain installed radars. This local support ensures that all radars are operational and available to ROKA at all times.

Figure 6: Blighter radars installed on coastline for national border security

About the Author

Mark Radford is the technical Co-Founder and Chief Technology Officer (CTO) of Blighter Surveillance Systems Ltd.

Mark has worked in the radar industry since 1985, initially as a designer of high-performance signal processing solutions for naval radar systems and later as a system designer and development manager. Since moving to Cambridge, UK, in 2000, Mark has been involved in various radar development projects including the specification, design and development of the Blighter radar family, unique electronic-scanning FMCW Doppler surveillance radars.

Since his appointment as CEO of Blighter Surveillance Systems in 2013, Mark has overseen developments of the Blighter technology to enhance it for use in more complex environments such as the heavily cluttered operational areas of airports where buildings and airport traffic limit the effectiveness of traditional perimeter security radars. Further enhancements now see Blighter radars being used for coastal security and for air security, where Blighter's ability to detect very small and slow-moving targets in heavily cluttered environments is a key technological advantage. Mark first developed the AUDS (Anti-UAV Defence System) counter-drone system in 2014, which is now the principal Short-Range Air Defence (SHORAD) system used by US DoD in their warfighting efforts and is in operational use at leading UK Airports.

Mark headed the spin-out of Blighter Surveillance Systems Ltd. from its parent company in 2015 to enable rapid business growth and in March 2019 resumed his technology leadership position for Blighter by appointment to 'Co-Founder and CTO'.

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