Figure 1. Leading-edge customers like the Australian Border Force require the assured communications that the EM Solutions Cobra terminal helps to provide

Assured military communications while on-the-move

Ensuring continuous military communications in remote and mobile environments has become a top priority for military and defence forces around the world. While we've seen a lot of innovations in this field in recent years, there remains a lot of room for technology advancement, particularly when it comes to ensuring redundancy. Dr. Rowan Gilmore, CEO of EM Solutions, discusses how availability can be increased with new products, and outlines how the company has met the needs of the Australian Border Force and the Australian Navy.

Broadband communications anywhere, anytime, anyplace can only be provided by satellite communications. But when communications are mission-critical, how can it be made more assured, resilient, and resistant to hostile or environmental interference?

Sophisticated defence forces around the world are demanding higher quality mobile communications (Figure 1). Assured communications requires multiples steps to provide resilience: Taking defensive measures to protect against hostile threats; bringing new assets on line to replenish lost functionality; and deploying network equipment designed to have higher probability of mission success. The latter can be achieved through careful system design, for example by distributing functionality, building in protective capability, and providing inherent redundancy.

For example, well-designed satellite communications terminals should mitigate against the effects of weather, satellite congestion, frequency jamming, and motion itself to help achieve assured connectivity.

This article describes how these features have been considered in the design of a highly assured and robust satellite communications terminal, with almost no increase in the total cost of ownership compared to lower cost platforms.

Increasing availability of the satellite communications channel

Channel availability is one measure of how an assured communications link performs. Time on satellite is increased by reducing the time for an on-the-move terminal to acquire or reacquire the satellite, and by maintaining the link even under violent motion conditions. Good tracking performance is essential.

Secondly, a larger fade margin also results in increased availability. Good design maximises the fade margin by using the highest power transmitters possible, the most sensitive receivers, steered antennas to maintain maximum antenna gain, and ensuring highest pointing accuracy to minimise pointing loss.

For on-the-move applications, complex engineering is required to steer the antenna's transmit beam directly to the satellite to minimise pointing loss during vehicle motion. Electrically steered antennas (flat panel antennas and phased arrays) lose gain off-axis, reducing the fade margin. While mechanically steered antennas are able to maintain constant gain at any pointing angle, only 'monopulse' pointing technology is able to maintain lock on the satellite without deliberately introducing an intentional miss-pointing error off boresight to search for the beam maximum.

Monopulse technology is a closed-loop system that measures the relative level in a higher order mode generated inside the antenna feed, typically the TE21 mode from the satellite signal. A monopulse terminal uses that mode's sharp null along boresight to derive a very accurate corrective pointing vector to force the antenna back in line, without the need to introduce any deliberate pointing loss to determine whether the antenna is aligned for maximum receiver power, as happens with conical or step scan systems. Furthermore, the monopulse system and motion algorithms used to acquire the link and re-establish it after blockage result in tracking performance that has been reported by customers to be the best in the industry. All these features, together with a steered parabolic antenna that always gives maximum gain irrespective of pointing direction, ensure the link equation is optimally tuned for maximum uplink time, availability and link capacity.

Implementing redundancy

However, there is even more that can be done to assure satellite communications. Redundancy in hardware, frequency and satellite selection are three additional ways to introduce resilience into the link. The choice of satellites and use of multiple bands mitigate against weather effects, jammers, interferers, congestion, and even loss of a satellite.

Redundancy can be improved in satellite communications by the use of multiple transmitters since block up converters (BUCs) are usually the most failure prone component in the link; by the use of dual terminals to avoid blocking by obstructions; and by using multiple satellite systems. In addition, by switching the RF frequency band, further redundancy is introduced. Changing to a lower frequency band can protect against weather effects that can cause loss of the satellite link at the higher Ka-band frequencies.

EM Solutions has engineered a satellite terminal with all these options. Its new Cobra terminal can electronically switch between any of three different satellite bands on different satellites, even while on-the-move. Although maritime terminals already exist with either commercial or military Ka-band capability, or with dual X-band and military Ka-band capability, none offer universal on-the-move capability (on land or sea) in a convenient size package, simultaneously operating in both X and Ka-bands, and with fall back to commercial Ka-band on demand. This requires the use of separate BUCs for X-band

and Ka-band, but this is beneficial since the pair then adds increased hardware redundancy on top of the improved link redundancy. Such a combination brings the benefits of assured communications whenever a satellite is visible without manual changeover of hardware.

By also adopting highly accurate monopulse pointing technology to ensure the link budget is always maximised, the new Cobra terminal class achieves maximum system availability. Compared with older terminals, the benefits of a terminal like this include:

- Network survivability with assured communications in a contested environment;
- Rapid and automatic self-healing in the event of rain fade or other link outage by switching satellites or frequency band;
- Fully transportable and operational on-the-move capability with unparalleled satellite tracking capability in three bands across all ranges and types of motion (land or sea);
- Support for broadband communications (data rates up to several Mbps) without using excessive satellite transponder resources that would be consumed by a very small terminal;
- Fall-back to a fully integrated commercial capacity in the event of failure or congestion of the military network;
- Configurability for a range of platforms to suit either a small or medium vehicle or vessel, with simplified field repair and cost optimisation; and
- Universal stabilisation to the most severe motion conditions i.e. the terminal can be used either on land or at sea.

Providing assured communications

To meet the demanding requirements of the Australian Border Force and the Australian Navy, EM Solutions cooperated with several collaboration partners. These included the Australian Defence Science and Technology Group (DST), Inmarsat Global Government, who provided support during the type approval process, and Intellian, who modified their iDirect GX modem and below deck unit to pass signal control information between the Inmarsat Operations Centre and the EM Solutions transmitter equipment and stabilised platform.

The Cobra terminal design was based on EM Solutions latest generation military Ka-band Taipan-class COTM (Communications on the Move) terminal, in which pointing using monopulse beacon tracking was first perfected. However, that system was land-based and with its squat profile did not give the negative elevation angles required from a maritime terminal

Figure 2: The first of the Cobra Ka-multiband terminals on board an Australian Border Force vessel

Figure 3: Under the cover – the Cobra multiband X/Ka terminal in test at the EM Solutions factory

to compensate for ship roll below the horizon. Using the same powerful direct-drive brushless motors, balanced three-axis gimbal design, and a new pedestal offering greater elevation range, the new system provided minimum mechanical play and thus maximum position accuracy in a very robust and strong platform. The monopulse pointing system and tracking algorithms were ported and tuned to the new pedestal and proved to be extremely fast and accurate, equally capable of maintaining the link in rough sea profiles as they had off-road.

Now type approved by Inmarsat GX and operational on Cape Class ships defending Australia's coastline (Figure 2), the Cobra-class terminals are providing for the first time broadband services to the crew, capable of utilising either the military or commercial bands – the choice depending on satellite availability and network congestion. Simultaneous operation on both X- and Ka-bands has also been tested on the military payload of the Optus C1 satellite, with WGS certification testing now underway.

The greatest innovation in the Cobra X/Ka-multiband terminal is its antenna feed system. Optimised for its electromagnetics, the system generates antenna pointing vectors from both the X-and Ka-band beacons of the WGS satellite for steering, while supporting simultaneous communications on the satellite's Ka-band and X-band transponders, whenever required to protect against rain fade or to provide added capacity. In addition, the system can fall back to tracking and operating on the alternative Inmarsat GX satellite system in the case of congestion or for operational reasons.

Using a 1m diameter parabolic reflector, the terminal has a footprint of only 0.75m, and can be deployed on a range of vessels, from small patrol boats to large ships. At the same time, re-engineering effort has been applied to reduce cost, top weight, and overall terminal volume consistent with the other operating constraints. The newly developed terminal shown in Figure 3 meets both WGS and Inmarsat specifications.

A roadmap for connectivity

No longer a pipe dream, high availability satellite communications is now available in a single terminal whose total cost of ownership is no greater than conventional single-band non-redundant terminals. EM Solutions' roadmap includes extending the system to Ku-band and to airborne platforms for even more versatility – stay tuned! **GMC**