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Iceberg Detection Performance Simulations to Support the Installation of New S6 Processor with the Reef Island Radar

Report
R-14-030-1016

Prepared for:
Prince William Sound RCAC

Revision 1.0
July, 2014

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Prepared by:
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Project Team

Desmond Power

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1 INTRODUCTION

In 2002, under contract from the Prince William Sound Regional Citizens' Advisory Council (PWS-RCAC), C-CORE assisted with the installation of an ice detection radar on Reef Island in PWS (Figure 1). The primary function of the ice detection radar is to provide a means to locate icebergs as they calve from Columbia Glacier and drift across the Sound towards the shipping lanes. This provides a means for deciding whether it is safe for tankers and other vessels to transect the Sound through the region of highest iceberg density; this region is generally located in front of the Columbia Glacier and in the general vicinity of Point Freemantle and Glacier Island. The installation of the ice radar on Reef Island was a joint initiative, led by RCAC, and involved C-CORE, the US Coast Guard (USCG) and Ship Escort/Response Vessel System (SERVS).

The PWS ice detection radar, in its original form, consisted of a USCG surplus Vessel Traffic System (VTS) surveillance radar and a SeaScan processor from Sigma Engineering Limited. The SeaScan processor is past end of life and is presently non-operational (as of March 2014). This report provides some guidance and rationale behind the installation of a modern S6 Ice Navigator from Rutter Inc.

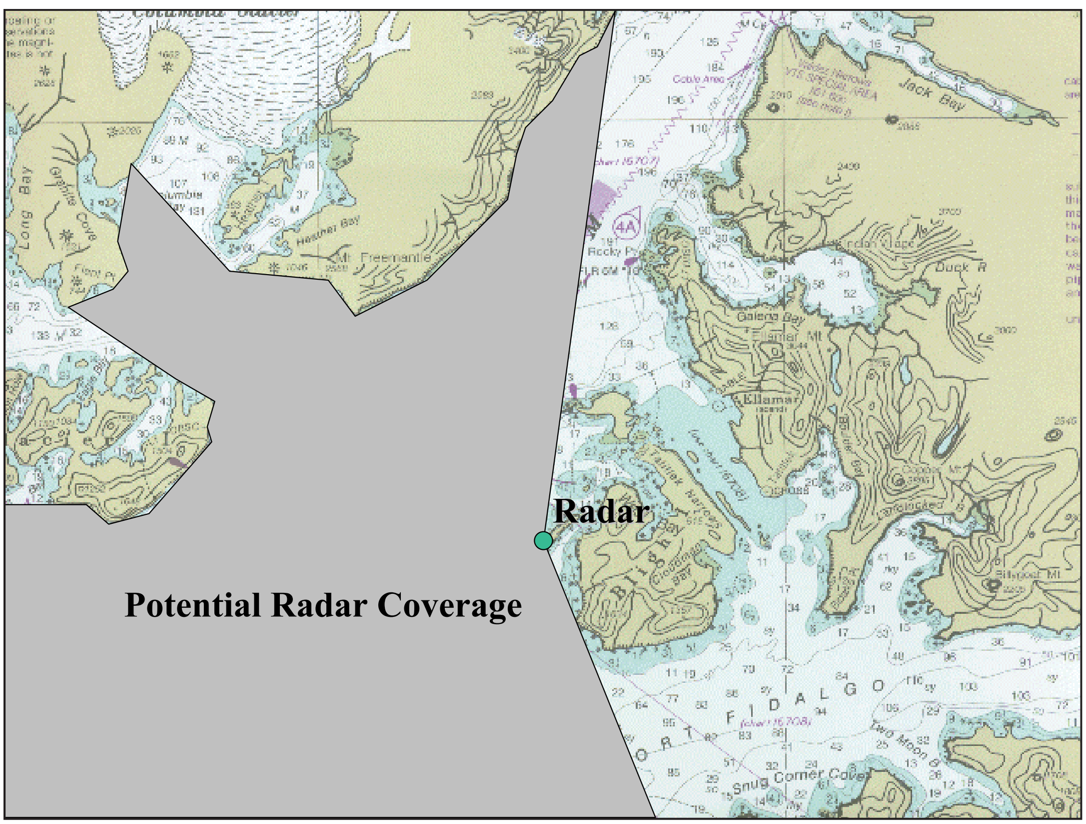

Figure 1. Radar coverage from Reef Island radar installation

2 PWS ICE DETECTION RADAR

The Reef Island ice detection system consisted of a surplus VTS radar and a SeaScan processor. In 2007, the surplus VTS radar was replaced with a modern and more capable VTS radar from Terma. The Terma radar included a model 2001 transceiver (25 kW peak power) with a 21 foot circularly polarized antenna. The SeaScan processor is presently obsolete and was not upgraded since its installation in 2002. However, it was modified to accommodate the new Terma radar. Initially, the output from the Terma transceiver was incompatible with the SeaScan processor, and modifications were necessary to make the SeaScan functional once again. These modifications were not performed until C-CORE submitted a report to RCAC in 2007 (C-CORE, 2007) demonstrating the additional iceberg detection benefits that the Terma would have in combination with the SeaScan processor.

The SeaScan processor product has since been modernized by Rutter Inc., the new owners of Sigma Engineering Limited. It is now called the Sigma S6 Processor and it comes in a version for ice navigation (Sigma S6 Ice Navigator) and for slick detection (Sigma S6 Oil Spill Response).

3 BENEFITS OF SCAN AVERAGE PROCESSING

The Terma radar, like any traditional VTS surveillance radar, is designed for vessel surveillance. However, the SeaScan processor and its modern equivalent (Sigma S6) are designed specifically for ice and icebergs. It includes what is known as scan average processing, which allows it to significantly improve marine and VTS radars for iceberg detection. This improvement is so significant that they have become standard equipment on vessels and offshore facilities that exist in the Canadian Arctic, Greenland, the Barents Sea and other locations. Table 1 contains a small subset of the total number of S6 installations that exist today.

Table 1. Sample Installations of Sigma S6 Processor (source: Rutter Inc.)

Oil Companies	**Seismic Operators**
Exxon Mobil	Western Geco
Husky Energy	Fugro NV
Suncor Energy	**Research Institutes**
BP	Arctic and Antarctic Research Institute (Russia)
Rig Operators	Alfred Wegner Institute (Germany)
TransOcean	**Tanker Operators**
Stena Drilling	Ocean Tankers
OceanRig	Primorsk Shipping
Supply Vessel Operators	Canship Ugland
Edison Chouest	**VTS Centres**
Harvey Gulf	St. Laurence Seaway Management
Transatlantic	PT Multi Integra (Indonesia)
Maersk	Australian Maritime Systems

At the time that the SeaScan was installed at Reef Island in 2002, it was the only product of its type on the market. However, with an increasing number of oil and gas (O&G) and transportation companies venturing in ice frequented waters, the market for 'enhanced ice processors' has increased. Today, there are several competitors to the Sigma S6 Ice Processor, including models from Kelvin Hughes and Sea-Hawk.[1] Sea-Hawk and Rutter also offer multi-polarized radar scanners, which are useful for improved sea-ice mapping. Polarimetric radars also offer increased performance for oil spill delineation over traditional radars.

Icebergs are generally slow moving targets with a low radar cross section, and as such, scan averaging (stacking of many radar scans into one picture) is highly effective at enhancing their target signatures in the presence of sea clutter. The overall effect of stacking many scans is to smooth and reduce sea clutter and noise while enhancing slow moving or stationary targets. An

[1] C-CORE has not tested the performance of these new models for iceberg detection, but would do so if requested by either the manufacturers or a potential end user of the product.

example of this effect is shown in Figure 2; in this figure, the navigational markers are entirely masked by clutter, however, the markers are clearly visible in the S6 enhanced display.

The target enhancement is limited by several factors including the relative motion of the target of interest to the radar and the limit to which clutter is reduced by incoherent averaging. To achieve maximum effect on a moving platform such as pilot boat or tanker, motion compensation by means of an inertial navigation unit may be necessary. Note that for slow moving targets such as icebergs, enhancement is reliant on the fact that target returns overlay one another and are *additive*. In the case of a moving vessel, the radar signature on a scan-averaged display would manifest itself as a streak across the display. Icebergs tend to be very slow moving and are *more or less* stationary over the integration time of the scan-average processing. Thus, these targets are enhanced through successive radar scans.

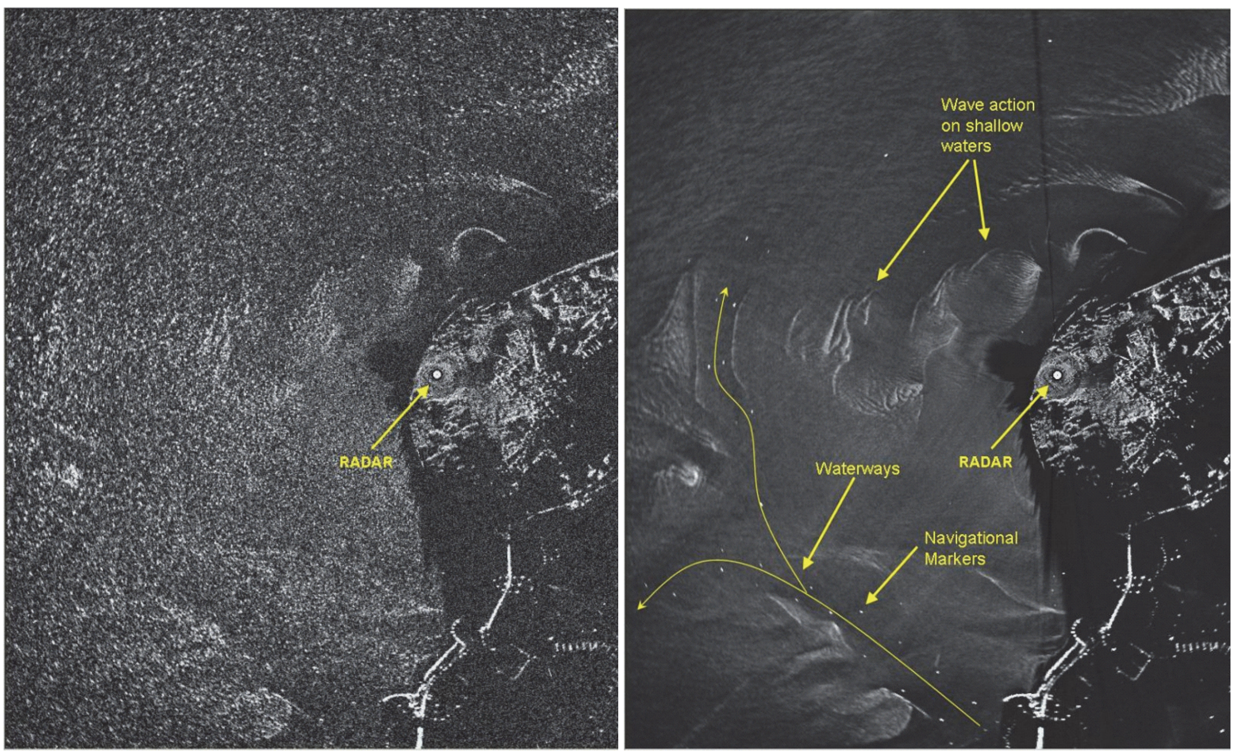

Figure 2. Example of Sigma S6 processing – (left) normal radar return, (right) reduced clutter through scan-to-scan processor (images supplied by Rutter Inc.)

4 ICEBERG DETECTION PERFORMANCE OF TERMA RADAR AND SIGMA S6

C-CORE and Sigma Engineering Limited performed extensive testing on the SeaScan processor for iceberg detection in 1999 and 2001 using a Raytheon Pathfinder X-Band marine radar with a 25 kW transmitter and a 7 foot antenna. This allowed for the validation of a radar model that could simulate the performance of the SeaScan (and the Sigma S6) in combination with any radar. In particular, the simulations can show when the S6 enhancement of Terma radar works the best. This is typically for very small icebergs and for icebergs in adverse weather conditions (high sea states and wind speeds).

4.1 RADAR CONFIGURATIONS

For the radar simulations, two radar scenarios were considered. The first is the Terma VTS radar on Reef Island and the second is traditional marine radar that might be mounted on an escort vessel or pilot boat in PWS. Since detection performance is a function of the radar type and height, RCAC was consulted to determine typical mounting configurations of radars on PWS vessels. A radar height of 14.3 m was used here. In comparison, the radar height of the Terma radar was estimated to be approximately 57 m, using information from topographical maps and knowledge of the radar tower height. For the Terma radar, a 21 foot antenna was used; for the pilot vessel, a standard 8 foot antenna was used.

The radar simulations also used two iceberg examples: 2.5 and 5 m waterline length. These icebergs are designated as growlers by the International Ice Patrol (IIP) and are the most difficult bergs to detect via radar.

And finally, the radar simulations used a variety of different sea state, winds conditions and rainfall rates. High winds, waves and intense rainfall adversely affect target detection via radar. Two different wind/wave conditions were considered: sea state 6 (4 to 6 m waves with 30 knot winds) and (sea state 4 – 1.25 to 2.5 m waves with 18 knot winds). Rainfall rates of 5mm (moderate rain) are also included. A summary of the simulation scenarios is provided below in Table 2.

Table 2. Iceberg Detection Simulation Scenarios

Radar Configuration	Terma Radar (Reef Island), X-Band, 21’ antenna, 25 kW transceiver
	Sperry Bridgemaster E, X-Band, 8’ antenna, 25 kW transceiver
Sea State and Winds	Sea state 4 (1.25 to 2.5 m waves) in combination with 18 knot winds
	Sea state 6 (4 to 6 m waves) in combination with 20 knot winds
Rainfall	No rainfall 0 mm/hr
	Moderate rainfall 5mm/hr

4.2 TERMA VERSUS PILOT VESSEL COMPARISON

As a first comparison, consider detection capabilities of the pilot vessel radar versus the Terma. The Terma, having the larger antenna and the higher elevation, will have better iceberg detection capabilities than the pilot vessel radar. Examples of this are provided in Figure 3 for no rain, and sea state 4 with a 2.4 m iceberg (left) and a 5 m iceberg (right). For the 5 m iceberg in these conditions, the radar appears to have 100% probability of detection (POD) out to the radar horizon. However, for the 2.5 m berg, detection is a little less reliable. The Terma radar still has detection almost out to the horizon, but the vessel radar starts to become less than 100% almost immediately in front of the vessel and detection is completely lost after a range of 8 km.

Detection becomes more problematic when considering sea state 6 for these two icebergs (Figure 4). Both plots in the figure show zero POD for the vessel; the Terma radar is reliable detection of the 5 m iceberg, but detection is degraded for the 2.5 m iceberg through much of its range.

When rainfall is added, detection becomes even more problematic for the Terma. Figure 5 shows POD for the 2.5 metre iceberg for moderate rain and sea state 4 and 6. As expected, the vessel radar has zero POD for both sea states. However, both sea states also show increasing unreliability of the Terma at sea state. For sea state 4, the Terma has zero POD from 6 km to 21 km in range and has virtually zero POD at sea state 6.

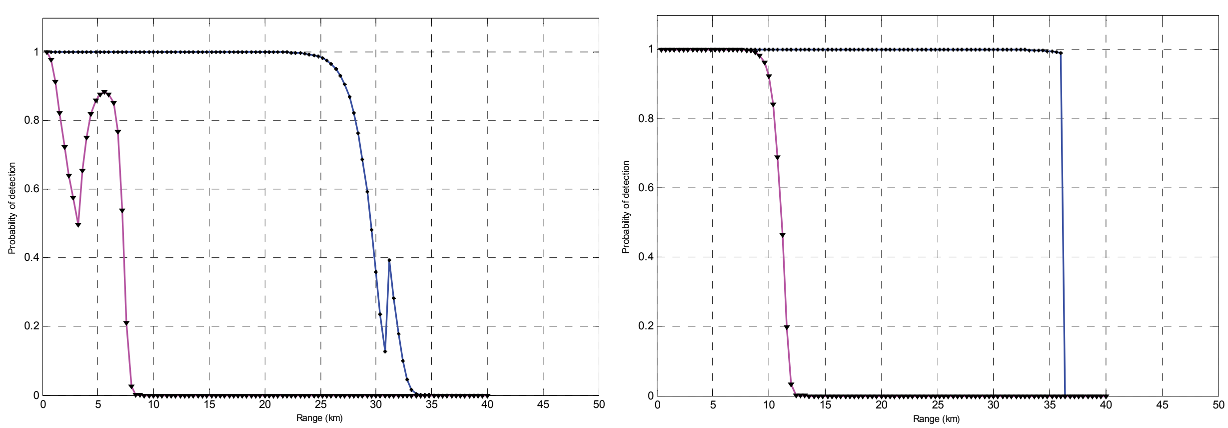

Figure 3. Iceberg POD versus range for Reef Island (blue line) versus pilot vessel (red line/ triangle markers) for a 5 m iceberg (right) and a 2.5 m iceberg (left) at sea state 4.

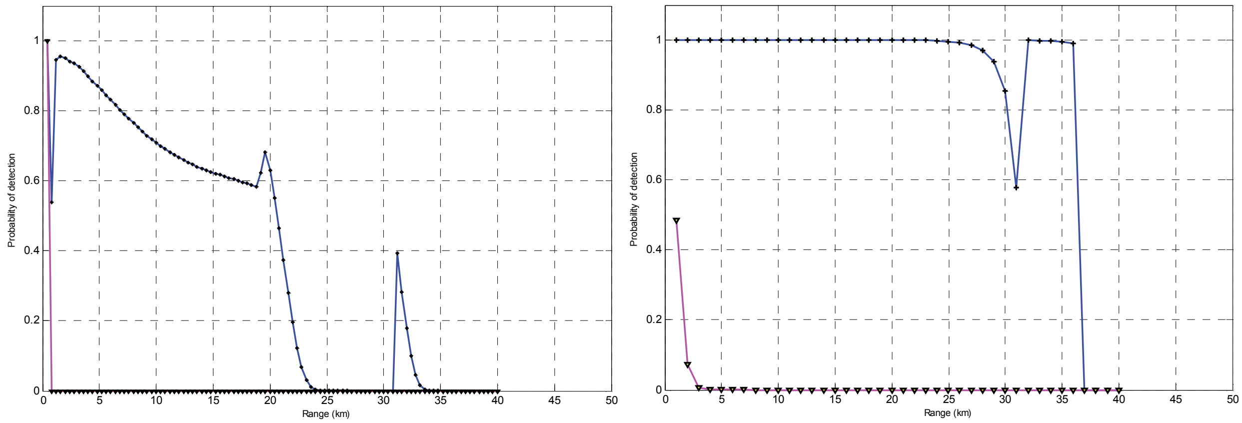

Figure 4. Iceberg POD versus range for Reef Island (blue line) versus pilot vessel (red line/ triangle markers) for a 5 m iceberg (right) and a 2.5 m iceberg (left) at sea state 6.

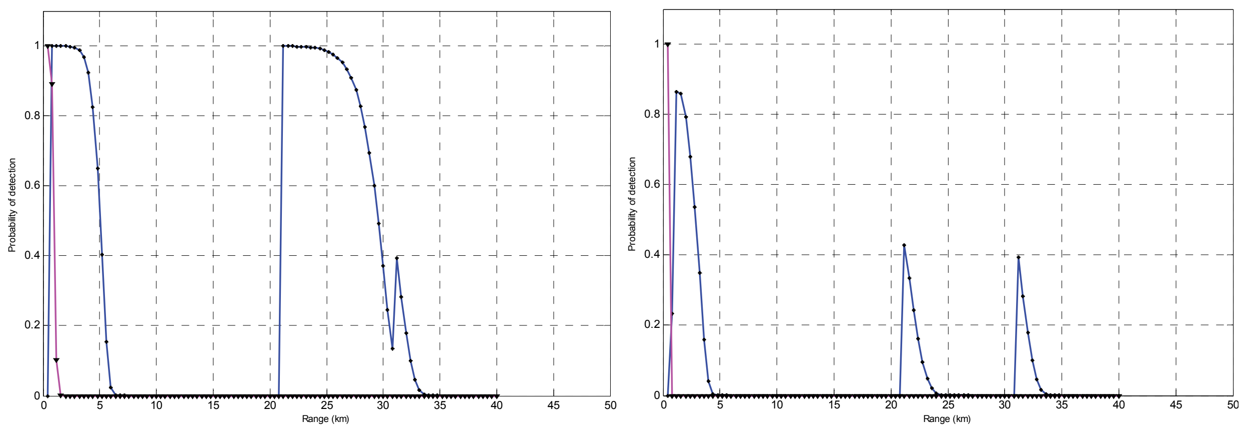

Figure 5. Iceberg POD versus range for Reef Island (blue line) versus pilot vessel (red line/ triangle markers) for a 2.5 m iceberg for moderate rain (5mm/hr) for sea state 4 (right) and 6 (left).

4.3 Pilot Vessel with S6 Processor

For the pilot vessel, the examples provide in Section 4.2 are repeated here with S6 processing included. Plots are included for those cases where detection improvement is desirable.

Previously it was shown that the improved detection is desirable for the 2.5 m iceberg in both sea state 4 and 6. Simulations shown in Figure 6 provide these examples with scan averaging enabled (green) and disabled (red), thus simulating the effect of including a Sigma S6 processor onboard. For added conservatism, the plots only simulate scan averaging of 16 scans, whereas the S6 is capable of averaging up to 128 scans. The plots show consistent improvement in POD throughout the range of the radar. For sea state 4, detection is improved to 100% out to the horizon, and for sea state 6, detection is increased by a few kilometers in range, although not to 100%. In the latter case, improvements of up to 100% are expected if the simulations considered 128 rather than 16 scans.

In the case of the 5 m iceberg, including Sigma S6 processing shows substantial improvement for sea state 6 (Figure 7). Detection PODs of 100% are increased from a few kilometers to 7.5 km in range, and detection is possible out to approximately 17 km. The simulation is likely to show increased improvement if scan averaging is increased to 128 scans.

When precipitation is considered, the Sigma S6 also shows improvement of the vessel's radar. In Figure 8, moderate rainfall (5mm/hr) is considered for the 2.5 m iceberg for sea state 4 and 6. For sea state 4, the 100% detection limit is almost doubled by the Sigma S6 over a standard radar to about 2.5 km. For sea state 6, improvements are also seen, but not to the same extent as sea state 4. In this latter case, detection is improved by a little under a kilometer.

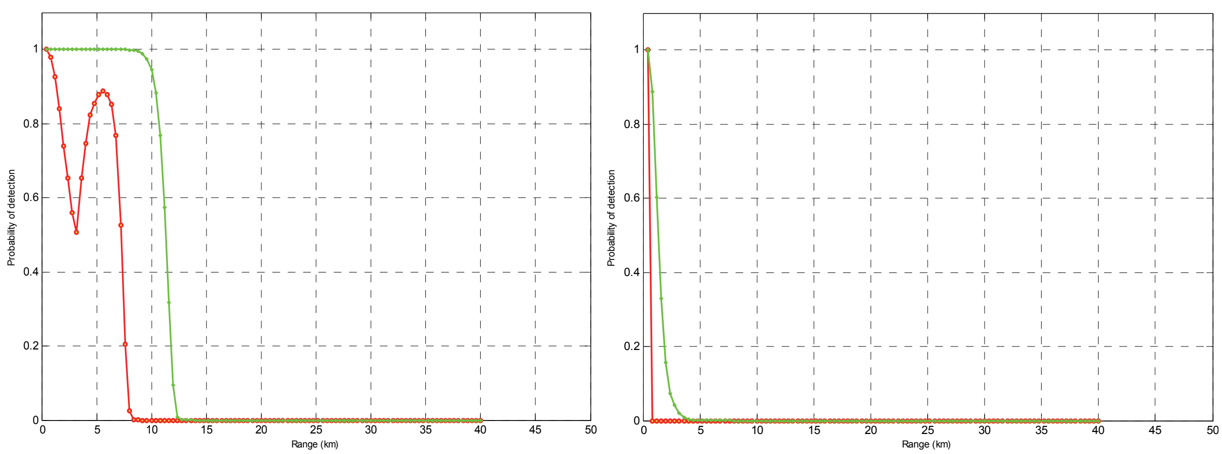

Figure 6. Iceberg POD versus range for the pilot vessel radar for a 2.5 m iceberg for sea state 4 (left) and sea state 6 (right). The plot compares scan averaging (green) versus no scan averaging (red).

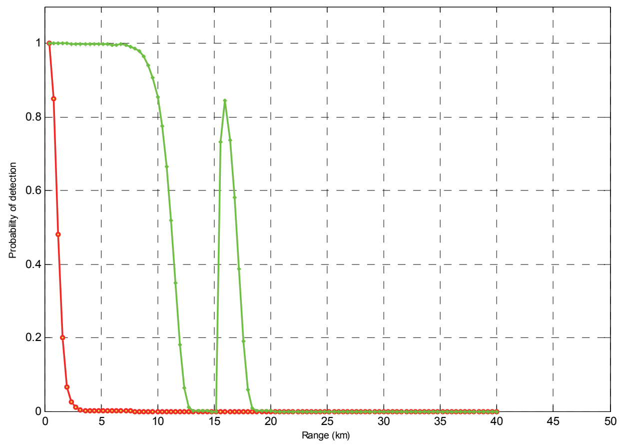

Figure 7. Iceberg POD versus range for the pilot vessel radar for a 5 m iceberg for sea state 6. The plot compares scan averaging (green) versus no scan averaging (red).

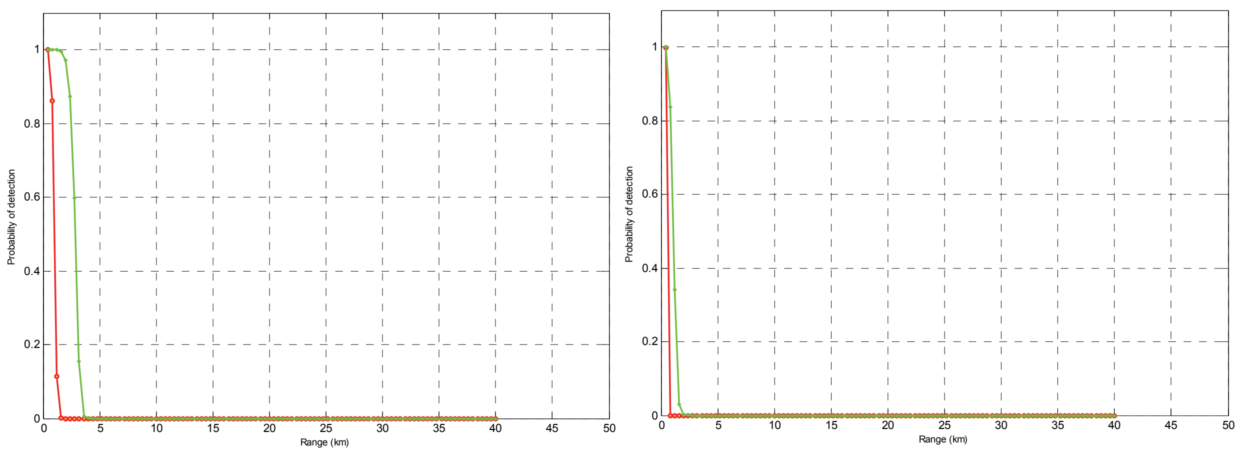

Figure 8. Iceberg POD versus range for the pilot vessel radar for a 2.5 m iceberg for sea state 4 (left) and sea state 6 (right) and 5mm/hr rain. The plot compares scan averaging (green) versus no scan averaging (red).

4.4 Reef Island Radar with S6 Processor

For the Reef Island Terma radar, the examples provide in Section 4.2 are repeated here with S6 processing included. Plots are included for those cases where detection improvement is desirable.

For the 2.5 metre iceberg in sea state 6, Figure 9 shows that detection is improved to 100% for almost all of the usable radar range.

When moderate rain is considered, detection improvements are also significant. In Figure 10, the plots show significant range improvements for sea state 4, whereby detection is increased from 3 to 7.5km and from 25 to 35 km; note that there is still a blind spot in the radar where clutter is significant and detection improvements do not manifest themselves for 16 scans from the 13-21 kilometre range. The same 'blind spot' is evident for sea state 6, however it can be seen that the standard Terma radar does very poorly at iceberg detection throughout the entire range. When scan averaging is enabled, performance is significantly improved with near 100% detection up to 6km and from 21 to 35 km.

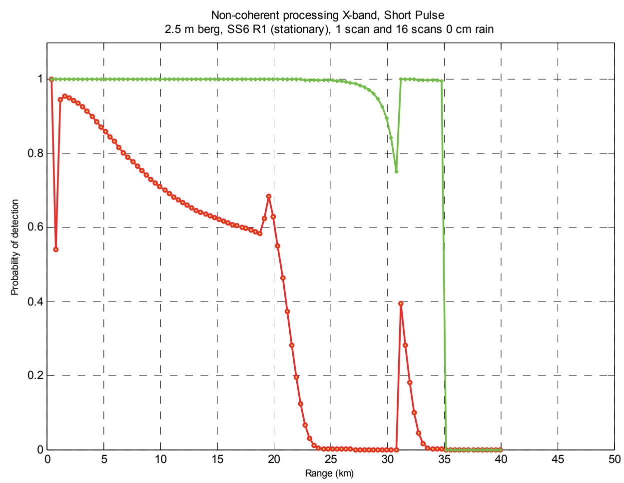

Figure 9. Iceberg POD versus range for Reef Island Radar for a 2.5 m iceberg for sea state 6. The plot compares scan averaging (green) versus no scan averaging (red).

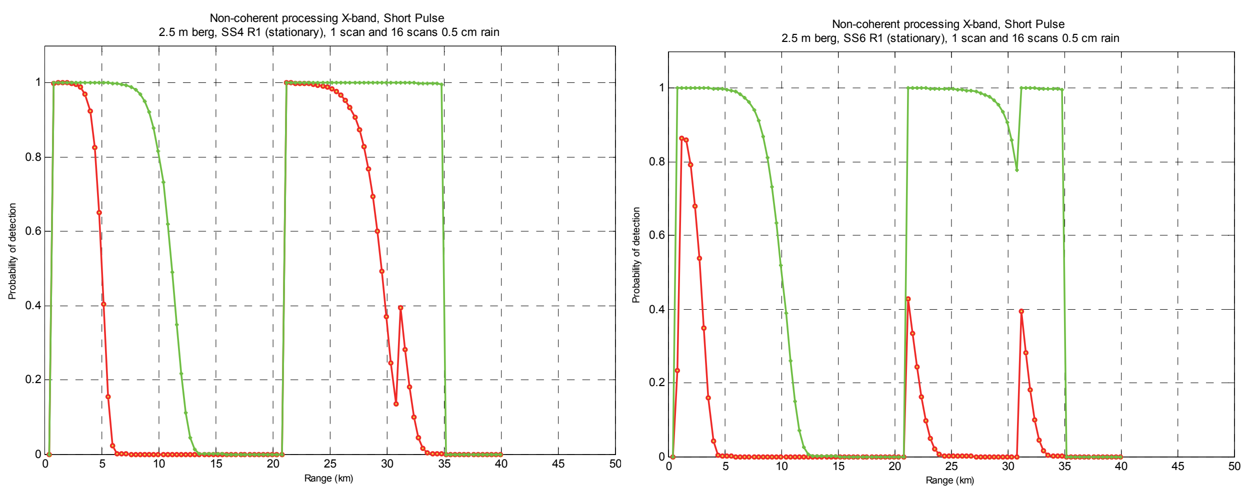

Figure 10. Iceberg POD versus range for the Reef Island Radar for a 2.5 m iceberg for sea state 4 (left) and sea state 6 (right) and 5mm/hr rain. The plot compares scan averaging (green) versus no scan averaging (red).

5 CONCLUSIONS

The Terma radar is one of the most advanced vessel surveillance radars in the world and the unit has innovative features for enhanced detection of vessels. However, this radar is not optimal for iceberg detection because it was not designed for this type of target. Simulations using a validated radar model show that the Terma radar has difficulty detecting growlers in situations with high winds, sea states and with moderate rainfall. The simulations were not all encompassing of all sea and rainfall conditions primarily to focus in on a few case studies that demonstrate where improvements can be made. In all situations, the addition of an enhanced ice processor using scan-to-scan averaging (such as the Sigma S6) improved iceberg detection; in many cases, these improvements are very significant. Simulations using a pilot/escort vessel radar were also performed. These simulations showed significant weakness in the vessel's ability to detect growlers, even at close range, when conditions are at sea state 4 or higher. Moderate rainfall worsened the detection rates. The Sigma S6 processor was able to provide significant improvement to the vessel radar detection performance; nonetheless this performance is still inferior to the Reef Island Terma radar in combination with the Sigma S6 processor.

Minimally, these simulations point to the improved performance that the ice detection radar will have with the addition of an enhanced ice processor. The simulations also point to a benefit of having enhanced ice processors on board the pilot and escort vessels. The enhanced performance of ice radar processors mean that risk to offshore structures is significantly reduced when they are used in operations. As a consequence, C-CORE has included a recommendation for the use of these ice processors for virtually every ice/iceberg risk assessment that it had performed. Since 2005 and without exception, every single offshore O&G related operational program that C-CORE has been involved with has included enhanced ice processors on the drilling, exploration or production platforms; often times it also includes enhanced processors on support vessels as well.

In addition to the benefits that can be had from an iceberg detection viewpoint, there are additional benefits to the ice of an enhanced radar processor for oil spill delineation. Scan-to-scan averaging has been employed to enhance slick delineation and mapping to support oil spill response. Both Rutter and Sea-Hawk offer slick-mapping products. For the Sigma S6, the oil spill mapping module is a simple software upgrade. Considering the investment that would be made to improve iceberg detection, should the Sigma S6 processor be purchased, the inclusion of the oil spill model is expected to be a small incremental cost. The benefits of this additional tool are enhanced oil spill mapping to provide a real-time synoptic view of oil slicks in the Sound.

6 REFERENCES

C-CORE (2007). *Ice Radar Processor for Prince William Sound – Summary of Configuration and Benefits*, C-CORE Report R-07-044-546 v5.0, January 2013.

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