ROYAL CANADIAN MARINE
SEARCH & RESCUE
Saving Lives on the Water

Radar Tests on Falkins Class Vessels

Station 1 - March 2014

Introduction

Ever since Station 1 received its Falkins class vessel 2 years ago, the performance of the standard Raymarine 4kW 24” closed radome radar has been a topic of concern. Anecdotal evidence pointed to less accurate detection and limited range when compared to the Raymarine 4kW 48” open array installed on our older SAR-1B vessel. After a few months we reconfigured the radome to tilt it 7° forward to compensate for the typical vessel angle when on plane. This improved matters marginally but the team was still not convinced. This last winter was foggier than usual and for the first time we were repeatedly operating in extremely restricted visibility, both for training and for taskings. A number of close calls prompted us to question the efficiency of the radar, and a technician of CMC, our authorised Raymarine agent, was tasked with tuning the unit. He found the unit to be close to perfectly tuned, and could not improve its performance in a meaningful way. This prompted us to initiate a test with a 12kW 48” open array. At the request of the Region, the test was extended to document as accurately as possible the operation of the Raymarine units typically found on RCM-SAR vessels.

Tested Configurations

The following configurations were tested (see section 8 for more details):

1) 24” closed radome, 4kW, tuned, tilted forward 7°, mounted on SAR-1.

2) 48” open array, 4KW, factory tuned, mounted on SAR-1B.

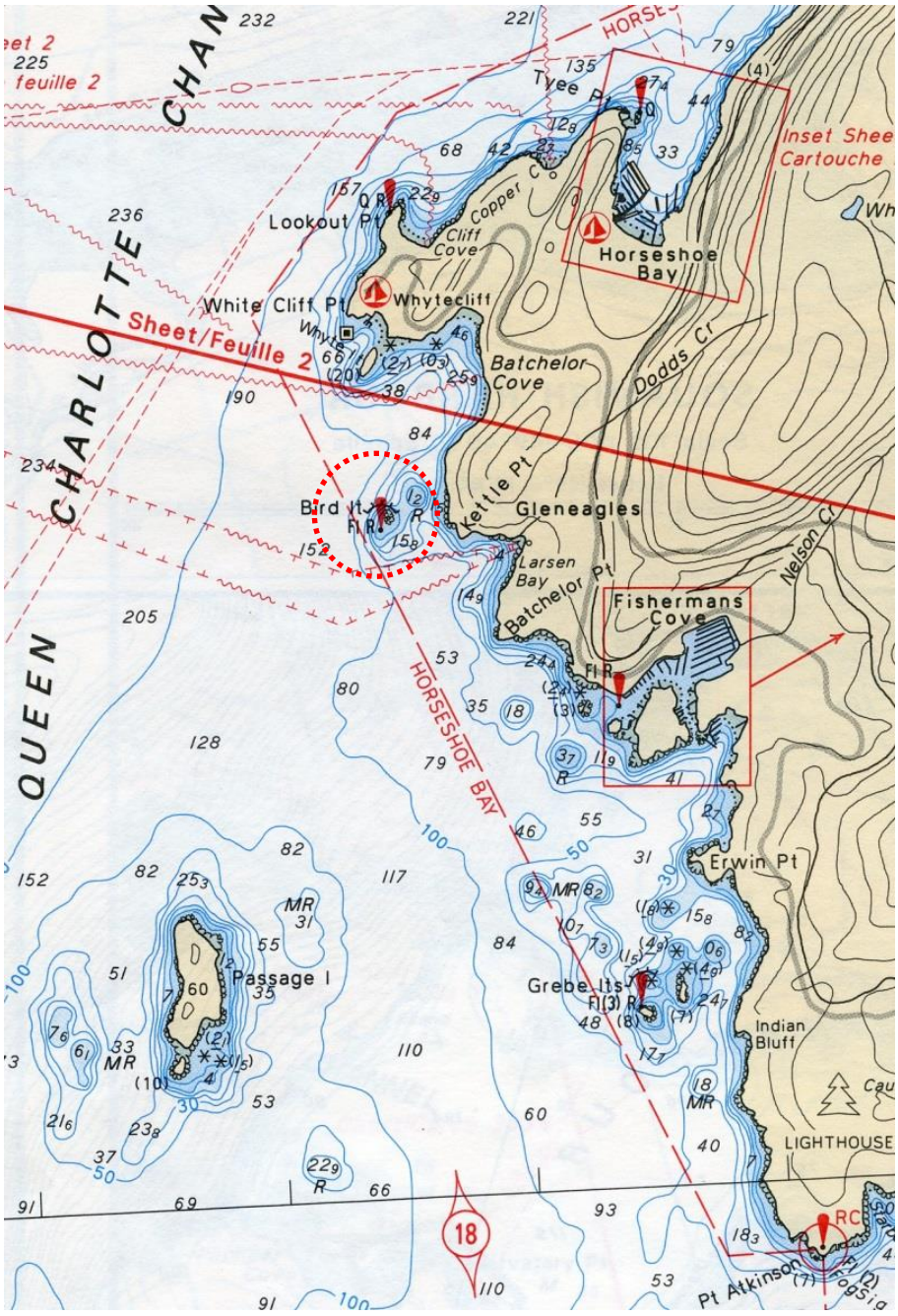
3) 24” closed radome, 4kW, factory tuned, mounted on SAR-2. Special thanks to Station 2 for participating in these tests.

4) 48” open array, 12kW, factory tuned, tilted forward 7°, mounted on SAR-1.

Test Environment

The moving target was a Coast Guard type 733 RHIB with no radar, radar deflector or other large metallic objects on board. Special thanks to Mike Cupit for providing us with this vessel for the tests.

The fixed target was a standard navigational aid with an effective echoing area of roughly 10m^2. The tests used Bird Islet's red beacon, which is situated approximately 60 meters off Bird Islet and 320 meters or 0.18 nm off the mainland (see the red dotted circle on the chart).



Weather for the four test runs was generally quite similar, with light winds, a light 1ft chop, and good to perfect visibility. Three of the four tests happened with a very light intermittent drizzle, as noted in section 8.

Radar Setup

All tests were conducted with the radar set to Harbour mode, automatic gain, automatic sea state, rain filter off (unless stated otherwise in the test results). Enhanced Echo mode was turned off on all units.

Test Protocol and Results

Both stationary (fixed) and moving targets were detected, at various vessel speeds. Additionally, the discrimination resolution of the radars was tested by verifying their ability to distinguish two close-by targets.

The goal of the tests was to emulate situations that are most common and critical for coastal SAR vessels. We therefore focussed on the detection of small vessels (the 733 RHIB) and small land features, both at slow and high speeds, at distances under 3nm. The various tests and results are listed below.

In some cases there was a significant difference between the intermittent detection of a target (target detected every 2nd or 3rd scan) and continuous detection (target detected every scan). In such cases both measurements are listed, with an “i” for the intermittent detection and a “c” for the continuous detection. If there was little difference between the two measurements, a single data point is listed.

At closer ranges, targets were sometimes immediately detectable (i.e. at the outer edge of the screen). In such case the measurement is printed in *italics*.

If a target was not detectable at a defined range, the cell is marked with a “-“.

All tests were performed with a primary tester in seat #3 (radar station) on the vessel, with a secondary tester in seat #4 confirming the readings of the primary tester.

In the following tables the four configuration columns correspond to:

1) 24” closed radome, 4kW, tuned, tilted forward 7°, mounted on SAR-1
2) 48” open array, 4KW, factory tuned, mounted on SAR-1B
3) 24” closed radome, 4kW, factory tuned, mounted on SAR-2
4) 48” open array, 12kW, factory tuned, tilted forward 7°, mounted on SAR-1

1. Slow/stationary detection

Starting at 3 nm from the fixed target the SAR vessel is driven at slow speed (5 kn) towards the fixed target (light by Bird Islet). The table shows the distance at which the combined light+islet target detaches from the mainland, and then the distance at which the light detaches from the islet. Finally, the SAR vessel drives away from the target on an opposing course and the distance at which the light merges with the islet is shown.

Speed (kn)	Range (nm)	Target separates from mainland at (nm) forward				Target separates from islet at (nm) forward				Target joins islet at (nm) aft			
Configuration		1	2	3	4	1	2	3	4	1	2	3	4
5	6.0	-	2.0	-	2.7	-	-	-	-	-	-	1.25	-
5	3.0	1.8	i 2.3 c 2.0	1.6	*3.0*	-	-	-	-	1.8	i 2.2 c 1.7	1.55	-
5	1.5	*1.5*	*1.5*	*1.5*	*1.5*	1.0	i 0.7 c 0.5	i 0.85	i 0.85 c 0.5	1.1	i 0.9 c 0.4	0.35	0.5
5	0.75	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	0.65	i 0.75 c 0.6	0.65	0.65
5	0.5	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*
Rain filter set at		0	36	14	0								

2. Detection at high speed

Starting at 3.5 nm from the fixed target the SAR vessel is driven at high speed (35 kn) towards the fixed target (light by Bird Islet). The table shows the distance at which the combined light+islet target detaches from the mainland, and then the distance at which the light detaches from the islet. Finally, the SAR vessel drives away from the target on an opposing course and the distance at which the light merges with the islet is shown.

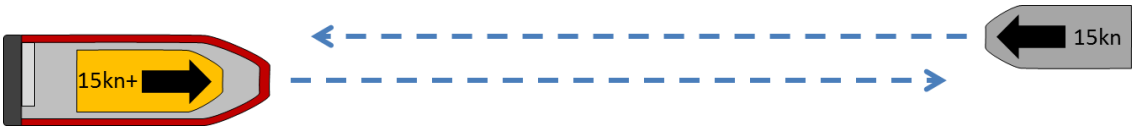
Speed (kn)	Range (nm)	Target separates from mainland at (nm) forward				Target separates from islet at (nm) forward				Target separates from islet at (nm) aft			
Configuration		1	2	3	4	1	2	3	4	1	2	3	4
35	6.0	-	-	1.4	3.3	-	-	-	-	-	-	-	-
35	3.0	1.6	i 2.5 c 2.3	1.4	*3.0*	-	-	-	-	1.7	i 2.5 c 2.0	-	-
35	1.5	*1.5*	*1.5*	*1.5*	*1.5*	1.1	i 1.4 c 0.4	i 1.0	0.75	0.9	1.0	0.8	0.5
35	0.75	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*	0.65
35	0.5	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	0.4	*0.5*
Rain filter set at		0	36	14	0								

3. Moving target detection

Starting at 2 nm from the target the SAR vessel is driven at slow speed (5 kn) towards the moving target (733 RHIB) on a perpendicular course. The table shows the distance at which the target is detected. The SAR vessel then drives away from the target on an opposing course and the distance at which target disappears is shown.

Speed (kn)	Range (nm)	Target detected at (nm) forward				Target disappears at (nm) aft			
Configuration		1	2	3	4	1	2	3	4
5	6.0	-	-	-	-	-	-	-	-
5	3.0	-	i 0.7 c 0.6	-	1.3	-	0.6	-	1.0
5	1.5	0.4	i 0.7 c 0.6	i 0.7 c 0.5	1.4	0.3	0.7	0.5	*1.5*
5	0.75	0.5	i 0.5 c 0.4	i 0.7 c 0.6	*0.75*	0.5	0.5	0.5	*0.75*
5	0. 5	*0.5*	i 0.5 c 0.35	*0.5*	*0.5*	*0.5*	*0.5*	0.4	*0.5*
Rain filter set at		0	36	0	0				

4. Moving target detection at speed



Starting 2 nm apart the target vessel and the SAR vessel drive towards each other. The target vessel proceeds straight toward the SAR vessel at a fixed 15 kn speed then continues past the SAR vessel holding course. The SAR vessel drives at various speeds as defined below. The table shows the distances at which the target is first detected, and the distance at which the target disappears after the vessels have past each other and continued on their respective courses.

Speed (kn)	Range (nm)	Target detected at (nm)				Target disappears at (nm)			
Configuration		1	2	3	4	1	2	3	4
15	6.0	-	-	-	-	-	-	-	-
15	3.0	-	0.6	-	1.3	-	-	-	1.4
15	1.5	-	0.6	0.5	*1.5*	-	0.7	0.7	1.3
15	0.75	0.4	0.6	0.6	*0.75*	0.3	0.5	0.3	*0.75*
15	0.5	0.4	-	*0.5*	*0.5*	0.3	-	0.4	*0.5*
25	6.0	-	-	-	-	-	-	-	-
25	3.0	-	0.8	-	1.5	-	0.6	-	1.5
25	1.5	-	0.8	-	*1.5*	-	0.6	-	*1.5*
25	0.75	0.5	0.4	-	*0.75*	0.6	0.3	0.4	*0.75*
25	0.5	*0.5*	0.4	-	*0.5*	*0.5*	0.3	0.3	*0.5*
35	6.0	-	-	-	-	-	-	-	-
35	3.0	-	0.8	-	1.3	-	0.8	-	1.5
35	1.5	0.7	0.8	-	1.3	-	0.6	-	*1.5*
35	0.75	0.7	0.5	0.4	*0.75*	0.4	0.5	0.6	*0.75*
35	0.5	*0.5*	*0.5*	0.3	*0.5*	0.4	*0.5*	*0.5*	*0.5*
Rain filter set at		0	36	0	0				

5. Target resolution – side by side

The target vessel is positioned 35 meters to the side of the fixed target. The SAR vessel starts 1.5 nm from the target and drives at 5 kn towards the fixed target. The table shows the distances at which the target vessel first detached from the light, the distances at which the separation becomes constant, and the same measurements with the SAR vessel driving away from the targets on an opposing course.

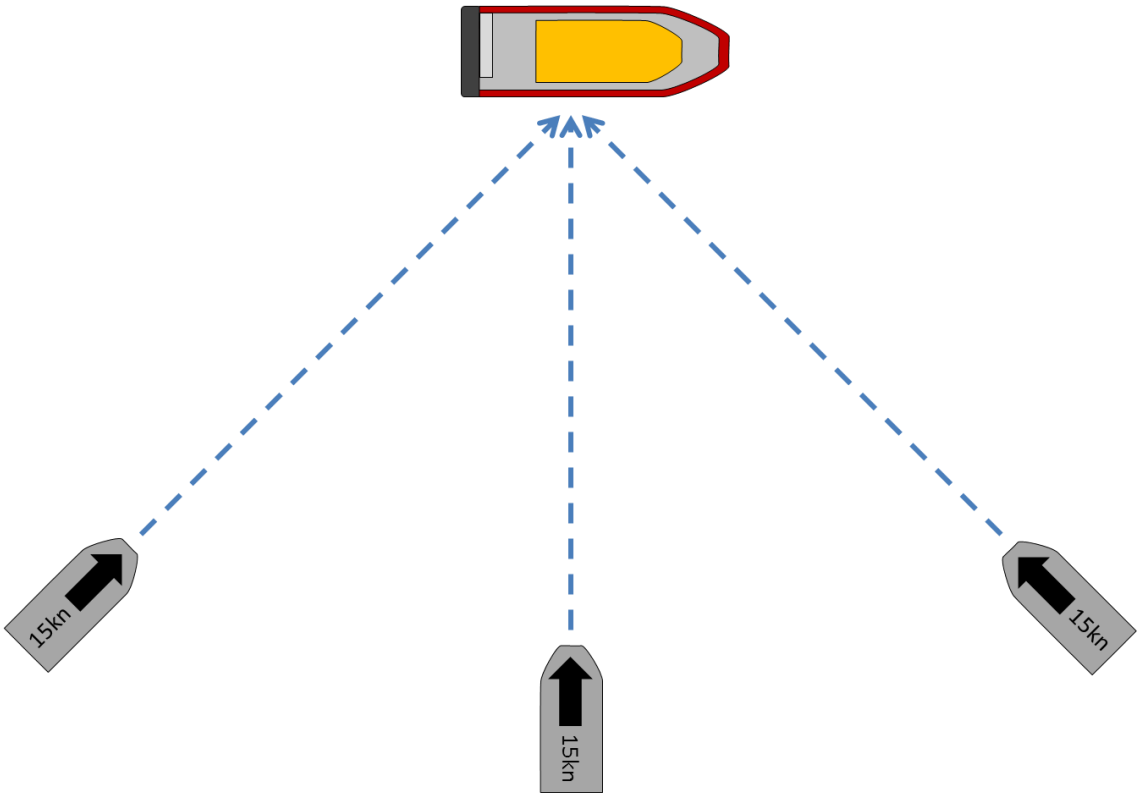
Speed (kn)	Range (nm)	Target intermittently separated (nm) forward				Target constantly separated (nm) forward				Target constantly separated until (nm) aft				Target intermittently separated until (nm) aft			
Configuration		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
5	6.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	1.5	-	0.4	-	1.0	-	-	-	0.5	-	0.4	-	0.4	-	0.5	-	0.7
5	0.75	0.5	0.4	0.5	0.65	0.35	0.4	0.4	0.5	0.45	0.4	0.35	0.5	0.5	0.4	0.4	0.7
5	0.5	*0.5*	*0.5*	*0.5*	*0.5*	0.4	0.4	*0.5*	*0.5*	0.4	0.25	*0.5*	*0.5*	0.45	0.3	*0.5*	*0.5*
Rain filter set at		0	36	0	0												

6. Target resolution – in front of each other

The target vessel is positioned 50 meters I front of the fixed target. The SAR vessel starts 2 nm from the target and drives at 5 kn towards the fixed target. The table shows the distances at which the target vessel first detached from the light, the distances at which the separation becomes constant, and the same measurements with the SAR vessel driving away from the targets on an opposing course.

Speed (kn)	Range (nm)	Target intermittently separated (nm) forward				Target constantly separated (nm) forward				Target constantly separated until (nm) aft				Target intermittently separated until (nm) aft			
Configuration		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
5	6.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	1.5	-	0.6	0.6	*1.5*	-	0.5	0.4	*1.5*	-	0.4	0.7	0.7	-	0.5	0.75	0.8
5	0.75	0.6	0.6	0.6	*0.75*	0.5	0.5	0.5	*0.75*	0.4	0.4	0.4	*0.75*	0.5	0.45	0.6	*0.75*
5	0.5	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	0.35	*0.5*	*0.5*	*0.5*	0.25	0.3	*0.5*	*0.5*	0.25	0.3	*0.5*
5	0.25	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	-	*0.25*
Rain filter set at		0	36	0	0												

7. Target detection – side angles



The SAR vessel is stationary in open water. The target vessel drives at 15 kn at 45°, 90° and 135° towards the stationary SAR vessel, starting 2 nm away. The table shows the distances at which the target is first detected, and then the distance at which the signal becomes constant.

7.1 – at 45° from the bow

Speed (kn)	Range (nm)	Target detected intermittently at (nm)				Target detected constantly at (nm)			
Configuration		1	2	3	4	1	2	3	4
15	6.0	-	-	-	-	-	-	-	-
15	3.0	-	-	-	1.5	-	-	-	1.2
15	1.5	0.7	0.7	-	*1.5*	0.5	0.6	-	1.2
15	0.75	0.7	0.5	0.6	*0.75*	0.5	0.4	0.5	*0.75*
15	0.5	*0.5*	0.45	*0.5*	*0.5*	*0.5*	0.3	0.3	*0.5*
Rain filter set at		0	36	0	0				

7.2 – at 90° abeam

Speed (kn)	Range (nm)	Target detected intermittently at (nm)				Target detected constantly at (nm)			
Configuration		1	2	3	4	1	2	3	4
15	6.0	-	-	-	-	-	-	-	-
15	3.0	-	0.6	-	1.4	-	0.5	-	1.3
15	1.5	0.6	0.6	0.6	*1.5*	0.5	0.5	0.5	1.3
15	0.75	0.6	0.5	0.5	*0.75*	0.5	0.25	0.5	*0.75*
15	0.5	*0.5*	0.4	*0.5*	*0.5*	*0.5*	0.2	*0.5*	*0.5*
Rain filter set at		0	36	0	0				

7.3 – at 135° from the bow (or 45° from the stern)

Speed (kn)	Range (nm)	Target detected intermittently at (nm)				Target detected constantly at (nm)			
Configuration		1	2	3	4	1	2	3	4
15	6.0	-	-	-	-	-	-	-	-
15	3.0	-	0.7	-	1.4	-	0.6	-	0.9
15	1.5	0.7	0.7	0.4	1.3	0.5	0.6	0.25	1.2
15	0.75	0.7	0.5	0.7	*0.75*	0.5	0.4	0.35	*0.75*
15	0.5	*0.5*	0.3	*0.5*	*0.5*	*0.5*	0.25	0.4	*0.5*
Rain filter set at		0	36	0	0				

8. Test details

8.1 – SAR-1 with 4kW Radome

Date of test	15-mar-2014
Start time	11:30
End time	13:00
Vessel	SAR-1
Height of radar above WL (m)	3.40
Radar type	Raymarine 4kW Radome E92143 s/n 0210117
Radar speed & tune level	24 rpm; tune 78
Display type	Raymarine E90W D699 E62220 s/n 0503074
Display software level	App 2.65; Boot 1.10; Baseboard 3.20
Coxswain	B. Falkins
Tester	B. Neijens
Sea state	1ft chop
Wind speed	10
Visibility	10
Rain	Intermittent light drizzle

This unit was tuned by CMC in February 2014, resulting in a small adjustment to the factory settings. It is mounted at a 7° forward angle to compensate for the vessel angle when on plane.

8.2 – SAR-1B with 4kW Open Array

Date of test	22-mar-2014
Start time	9:30
End time	12:30
Vessel	SAR-1B
Height of radar above WL (m)	2.70
Radar type	Raymarine 4kW Open Array
Radar speed & tune level	24 rpm; tune 90
Display type	Raymarine E120 D598 E02013 s/n 1250441
Display software level	App 5.69; Boot 1.03
Coxswain	B. Falkins
Tester	B. Neijens
Sea state (ft)	1 ft chop
Wind speed (kn)	5
Visibility (nm)	10
Rain	Light drizzle

This unit uses the older Raymarine E120 display, which is larger and higher resolution than the E90W.

8.3 – SAR-2 with 4kW Radome

Date of test	22-mar-2014
Start time	12:30
End time	15:30
Vessel	SAR-2
Height of radar above WL (m)	3.40
Radar type	Raymarine 4kW Radome E92143 s/n 0210030
Radar speed & tune level	24 rpm; tune 154
Display type	Raymarine E90W D699 E62220 s/n 1203131
Display software level	App 2.49; Boot 1.10; Baseboard 3.20
Coxswain	D. Wright
Tester	B. Neijens
Sea state (ft)	1ft chop
Wind speed (kn)	5
Visibility (nm)	10
Rain	Light drizzle

This unit has not been tuned since installation. It is mounted flat (no forward tilt).

8.4 – SAR-1 with 12kW Open Array

Date of test	23-mar-2014
Start time	13:30
End time	16:00
Vessel	SAR-1
Height of radar above WL (m)	3.60
Radar type	Raymarine 12kW Open Array E52082 s/n 0130056
Radar rpm & tune	24 rpm; tune 73
Display type	Raymarine E90W D699 E62220 s/n 0503074
Display software level	App 2.65; Boot 1.10; Baseboard 3.20
Coxswain	D. Purdie
Tester	B. Neijens
Sea state (ft)	1ft chop
Wind speed (kn)	5
Visibility (nm)	20
Rain	None

This unit was installed and immediately tested “as is”, without further tuning. It is mounted at a 7° forward angle to compensate for the vessel angle when on plane.

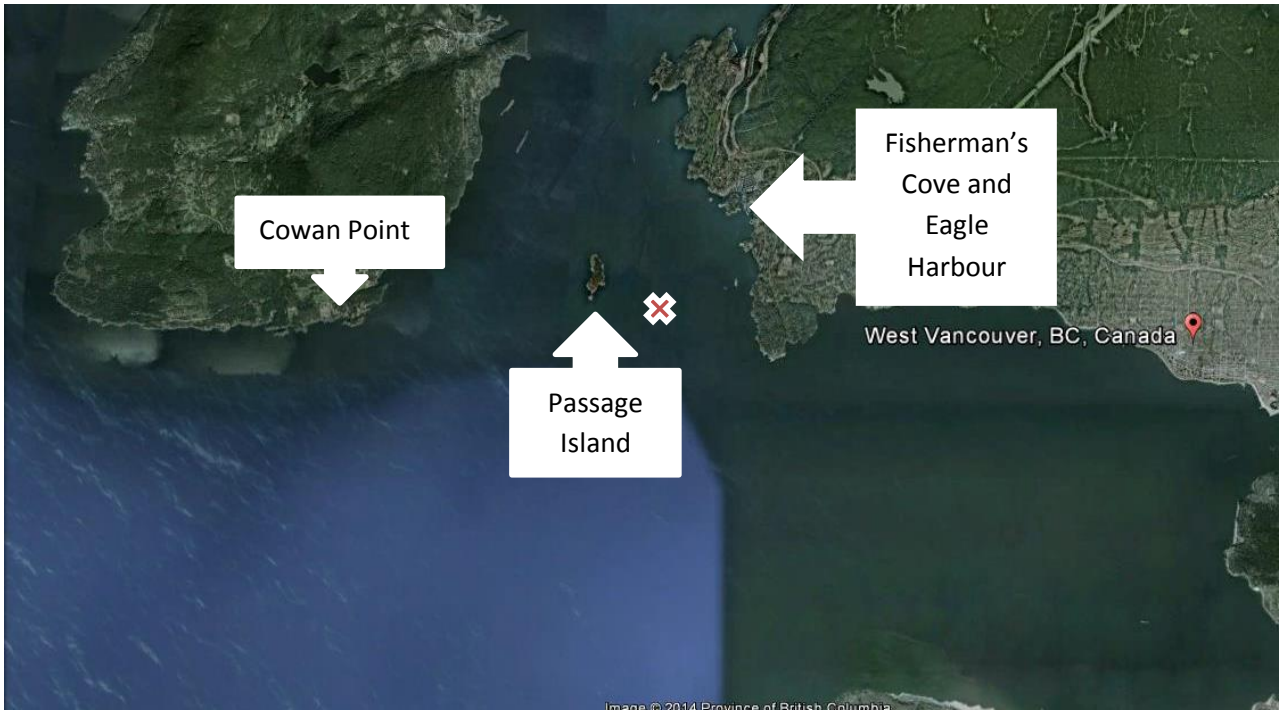
Observations

Signal filtering: On both radome units we observed a significant signal strength reduction for the moving target at distances between 0.25 nm and 0.1 nm, to the point that the target would often disappear for a few radar sweeps. This was observed in all radome unit tests and seems to point to excessive automatic filtering applied when the target signal becomes too large/close on screen**.** The open array units did not present the same issue.

Missed targets: The radome on SAR-2 failed to detect the moving target on an opposing course (test 4) at 25 kn despite three repeat runs. At 35 kn it barely picked up the signal.

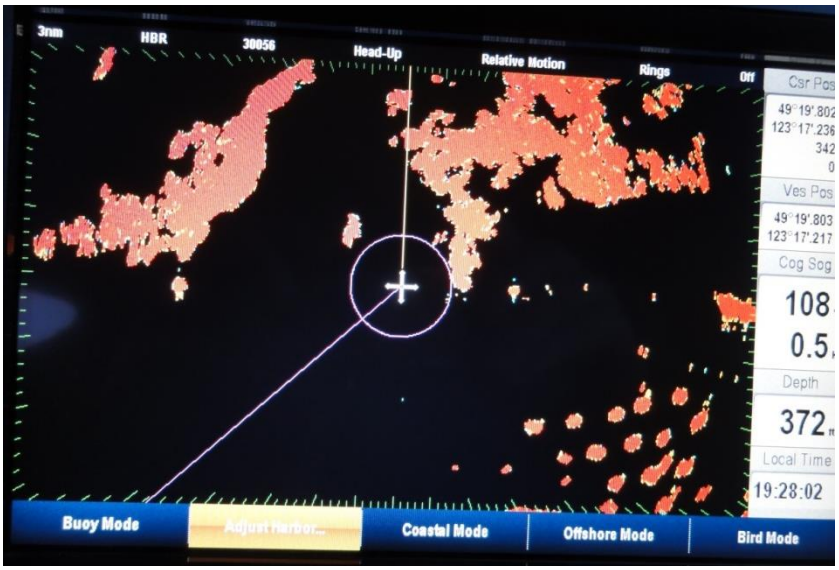
Image resolution and accuracy: the open arrays presented a much clearer picture of far-away targets and shoreline features. Both open arrays picked up the QA and QB racon beacons at distances of 3 to 5 nm, whereas the radomes did not. Detecting racons was not formally part of the test, but from past experience SAR-1 with a 4kW radome typically only picks up the QB racon signal at 0.5 nm, if at all.

Photography was extremely difficult due to vessel movement, lighting conditions and screen reflections. Nevertheless, the three images below are representative of the differences witnessed between radome and open array image quality. The first image was taken on SAR-1 with the 4kW radome. The second image was taken on SAR-1B with the 4kW open array, the third on SAR-1 with the 12kW open array. In all cases the range is 3nm, the pictures were taken between Point Atkinson and Passage Island.



SAR-1 with 4kW radome. Note the poor clarity of the freighters anchored in English Bay (lower right hand corner) and the significant side-lobe smear all over the image.

SAR-1B with 4kW open array. Note the sharper and more accurate shoreline contours of West Vancouver and Bowen Island (left).



SAR-1 with 12kW open array. Note the QB racon signal on the far right, the ferry off Cowan Point on the south of Bowen, the entrance to Eagle Harbour and Fisherman's Cove clearly visible.

Ranges: With the exception of detecting prominent shoreline features and large vessels, the 6 nm range is of little use on SAR vessels. The 6 nm range proved useless in most tests, except in tests 1 and 2 where the 12kW open array unit presented much better resolution and could separate Bird Islet from the mainland at distances beyond the 3 nm range.

Configuration: the Raymarine open array units are roughly 7" taller than the radome units. The open array partially obscures the all-round white navigation light on Falkins class vessels. We therefore raised the navigation light by 12" as shown below. The raised light shines onto the bow deck at certain radar array angles, creating a flashing effect on deck. This can be avoided with a deflector mounted by the light.

The radar array interferes with the Taiyo RDF if the latter is mounted using the original Titan folding mount on the port side of the cabin roof. In the raised position the lower part of the RDF antennas are in the path of the array. This can be fixed by inverting the RDF mount (i.e. raising the RDF mast towards the front of the vessel) or by mounting the RDF above the all-white navigation light.

Test Interpretation

Tests 1 & 2: The detection distance and discrimination of fixed targets is largely independent of speed. Open arrays detect fixed targets much further away and can discriminate at twice the distance of a radome, but the difference is not significant at ranges of 1.5 nm and lower. All units were able to discriminate the islet from the mainland at least 1.5 nm away, which gives the navigator 2.5 minutes to process the information at 35 kn.

Tests 3 & 4 are most crucial, as they show open array radars detect small moving targets two to three times earlier than radomes. The ability to detect such small targets is critical at high speeds. At 50 knots combined speed SAR-2 only detected the moving target at 0.4 nm, or a mere 29 seconds from collision time. SAR-1 with a tilted radome did slightly better at 0.7 nm, which equates to 50 seconds. SAR-1 with an open array detected the target at 1.3 nm, or 94 seconds before collision. The tests were performed at a combined speed of 50 kn, and the table below extrapolates this to 70 kn – simulating two vessels on a collision course at 35 kn each. At a radar scan speed of 24 rpm, 21 seconds represent only 8 radar sweeps. Such a short time and scarce data would require a very experienced and confident radar operator to detect and confirm a target within 2-3 sweeps, and issue timely instructions to avoid a collision.

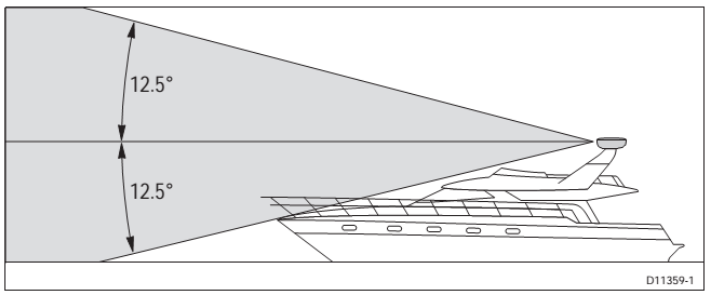
Combined speed (kn)	Detection at (nm)	Time to collision (sec)
50	0.4	29
50	0.7	50
50	1.3	94
70	0.4	21
70	0.7	36
70	1.3	67

More importantly, SAR-2 never detected the moving target at 25 kn, despite three repeat runs of the test. This is simply unacceptable.

Tests 5 & 6: All units are better at detecting small targets in front of a fixed target than targets side by side. Open arrays can detect side by side targets at higher ranges but not much further out in distance. At lower ranges radomes and open arrays are roughly equal in side by side discrimination. Open arrays are 50% to 100% better at front to back discrimination.

Test 7: Each unit was relatively consistent at different detection angles. Once again SAR-2 performed worse, and was at times only detecting targets at 0.4 nm. The 12kW open array was significantly better at detecting small moving targets under all angles, picking up targets at twice the distance from all other units.

Tilted units: the detection differences between SAR-1 and SAR-2 equipped with the same radome tend to indicate that tilting the radar forward 7° does help improve detection. Raymarine radars (both



radomes and open arrays) have a 25° vertical beam opening, which means a vessel on a plane at 7° to 10° comes dangerously close to the bottom of the beam. This could explain the poor performance of SAR-2 at 25 kn and 35 kn in test 4.

Conclusions

We started these tests with an open mind and with the feeling that a 12kW open array could well be overkill for the anecdotal issues we were encountering. However, the campaign of systematic tests quickly highlighted that the problems were not only real, but also more severe than we expected. The Raymarine 4kW radome units presented a number of highly concerning characteristics:

- Poor image resolution and discrimination. This makes it hard for the navigator to cross-reference the radar image with the chart plotter or paper charts.
- Dropped signals for close-by targets. This can lead to dangerous close quarter situations.
- Unacceptable performance identifying small moving targets on a collision course. This can lead to extremely dangerous situations, especially at higher combined speeds.

The Raymarine open array units typically performed 2 to 3 times better than the radome units when it mattered most. In addition, the 12kW unit consistently outperformed all other units tested confirming that there is some merit to upgrading to a higher power unit even for relatively short detection distances.

The tilted radome unit generally performed better than the non-tilted radome, indicating that tilting the units is likely a cheap way to improve performance of any radar unit on our fast vessels.

The tests confirmed the importance of systematically switching ranges on any radar unit as some targets are too small to appear on higher ranges (e.g. kayaks). The tests showed that with 4kW radomes the reaction times required from the crew are often extremely short. This highlights the importance of appointing experienced radar operators with the ability to rapidly interpret at times intermittent data. Our concern is that most volunteer RCM-SAR crew have relatively limited radar experience, which therefore calls for radar units with reliable and longer distance detection ability to allow the crew more reaction time.

Recommendations

Based on the tests and observations, we conclude that the Raymarine 4kW radome units are unacceptable for FRVs operating in restricted visibility at speed. We recommend all Type II vessels be equipped with open array units as soon as possible.

We also recommend the Region develops minimum radar detection standards for FRVs. Such standards would make it much easier to determine which radar configurations offer acceptable operation and safety conditions on RCM-SAR vessels.

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