Radar Usage and Plotting

www.bluewatermiles.com

Radar is an important tool on board in all conditions of visibility in **navigation and collision avoidance**. If radar is fitted on board, it must be operated at all times. When visibility is reduced, or at night when small crafts or objects (ice) are expected, a second radar should be operated if fitted. One of them dedicated to anti-collision (S-band) in sea stabilized mode and a second for navigation (X-band) in ground stabilized mode. Note that radar is designed for long operation so frequent switching on and off can damage their components.

Collisions have frequently occurred due to failures in making effective use of radar and radar plotting aids in both restricted visibility and good visibility. Common errors noted are, altering course based on insufficient information, and maintaining speed in excess of the safe speed that may be required, particularly when a close-quarters situation is developing. A good reference material on the subjects is MGN 379.

Radar Setup / Tuning

Use mnemonic to remember: **Big Randy Girls Take Cock**. After turning the set on, do the following:

1. Brilliance (B): set the brightness for your display. Dim it during the day.
2. Range (R): match to the desire area, usually middle range (e.g. 12NM).
3. Gain (G): turn up until you get white background speckles, usually around 70%.
4. Tuning (T): tune the receiver to get the best display (clearest and brightest), this is normally done automatic. It is similar to tuning frequencies on old radio.
5. Clutter (C): tune sea and rain clutter as required to reduce noise. If you use it too much, it's possible you won't be able to see small or even large contacts. Be careful.
    - Sea clutter: Suppresses reflection from waves near the ship (it reduces sensitivity of the receiver). The proper setting should be such that the clutter is suppressed and echoes become distinguishable. If the control is set too high, both sea clutter and echoes will disappear from the display. When there is no sea clutter visible on the display, turn the control fully counter clockwise.
    - Rain clutter: Suppresses reflected echoes from rain, hail and snow (does not display leading edge of the rain). When rain clutter masks the display, adjust the control so that the clutter just disappears; too much A/C rain action may shrink or erase the echoes from legitimate targets.
6. After around 10 minutes, re-check the gain control and re-tune. This is because as the radar warms up the transmitter frequency is likely to have changed slightly. Check gain, clutter controls and tuning again after every hour or so of operation as the set may gradually drift out of tune.

How to verify if the tuning was good?

- In sight of land, you would tune to the radar contact.
- Out of sight of land, you would tune to the sea clutter. When sea clutter is used for manual tuning adjustment, all anti-clutter controls should be either off or placed at their minimum. Also, one of the shorter-range scales should be used.
- If on a calm day and there is no sea clutter then tune to your own wake. Produce a by turning the vessel. Won't work on a small boat.

Radar setup for collision avoidance:

- North-up
- Relative motion: own ship remains stationary at the center and targets moving in relation to own ship, stationary objects appear to be moving, it is the same as what you can visually observe with your eyes
- Sea stabilized: using speed through water, showing correct aspect of targets, therefore, applicable to ColReg rules

Radar setup for navigation:

- North-up
- True motion: own ship moves across the radar screen, targets shows their actual movement relative to the ground, stationary objects remain fixed
- Ground stabilized: using speed over ground, showing true course and speed of targets over the ground, not showing the correct aspect of targets, therefore, not applicable to ColReg rules

Pre-departure Radar Checks

☐ Switch it on.

☐ Check performance by using Performance Monitor (before departure and every 4h whist the radar is being maintained). When radar is switched on it does self-test automatically. It checks the power output/transmitter (how well the magnetron is transmitting):

- Switch radar rings on to 12 NM.
- Press button performance monitor P.M.
- Plume comes in the front.
- Record every 4h how far the plume went, if the plume range reduces with time, it means the performance is deteriorating. It tells how well the magnetron is and if it needs replacement.

☐ Check VRM (Variable Range Marker) against radar rings.

☐ Check EBL (Electronic Bearing Line) against compass bearing of a known fixed object. Ensures navigational consistency between radar and compass systems.

☐ Check EBL against target that you can see visually. Confirms the radar display reflects real-world observations accurately.

☐ Check heading marker alignment:

- Check the heading marker is aligned with the true compass heading of the ship.
- Check the heading marker is aligned with the fore and-aft line of the ship by comparing the visual and radar relative bearings of a small but distinct target at the edge of the range scale in use.

☐ Check shadow sectors and blind spots:

- Shadow sectors are areas of reduced radar visibility (sensitivity) produced by obstructions (e.g. mast) presenting a narrow profile when viewed from the scanner. It is blocking the radar view but only in narrow profile. Targets which are in line with the scanner and the mast will be subjected to a weakened pulse due to absorption by the obstruction or reflection from it, and provide a weakened echo return over a very narrow sector (still can see but the sensitivity is reduced).

- Blind sectors will make it unable to see certain angles/segment. Rain or land masses can produce blind sectors.
- Information about shadow sectors and blind spots should be present in the radar manual. Best and easiest method is to check it in rough sea. Alternatively, you can drive a tender around the boat and mark down where you cannot see.

☐ Tune the radar (see previous section).

Radar Best Practices

- Review the operating manuals of your radar set on board and be familiar with their capabilities and limitations.
- Radar if fitted should be in continuous use at all times and all radars should be operated in high traffic areas, in restricted visibility and at night when small craft or ice may be encountered.
- Radars are designed for constant use. Frequently switching radar on and off can actually damage it.
- If two or more radars are running, they should be set on different range scales. S band (10 cm/3 GHz) for detecting vessels and landfalls due to their greater range and ability to penetrate precipitation, and X band (3 cm/9 GHz) for coastal navigation and pilotage due to their higher directivity and definition of targets.
- When two radars are in operation, it is recommended that the one fitted with ARPA is used for collision avoidance and the other is used for navigation.
- ARPA should be used with sea stabilized mode for collision avoidance as it would show the correct aspect of targets. For this ARPA has to have a feed from the speed log, not SOG.
- Ensure that the range scale in use is appropriate to the prevailing circumstances and conditions.
- Use long range scanning periodically to detect targets and landfalls, and when approaching high traffic areas.
- It may sometimes be appropriate to operate the radar off-centre for a better view ahead whilst maintaining the benefits provided by a smaller range scale.
- Re-tune radar regularly to ensure that it is optimized for the prevailing conditions.
- Ensure that the radar pulse length is optimized for the range scale in use. Shorter pulse lengths for lower ranges, longer pulse lengths for higher ranges. Remember that long pulse lengths have poor range discrimination (ability to make accurate detection) and may cause targets on the same bearing to merge if they are close to each other.
- Use the manual clutter controls and use the automatic clutter controls regularly to ensure that targets are not being masked by sea or rain clutter, or by the anti-clutter feature.
- Use the performance monitor to check the radar at regular intervals (every 4 hours).
- Check the alignment of the heading marker with the master gyro periodically, applying any gyro compass error to determine the true heading.
- Ensure that the heading marker is aligned with the vessel’s fore and aft line by comparing the visual and radar relative bearings of a small but distinct target.
- Check the accuracy of functions ELB and VRM at frequent intervals.

- Turn off the heading marker and range rings regularly to ensure that they are not obscuring small targets.
- Use Parallel Indexing (PI) whenever possible to continuously monitor the vessel's position relative to the pre-planned track in conjunction with other position fixing methods.
- Where possible set, verify and use electronic bearing clearing lines and range ring clearing distances to help monitor the vessel's progress along the pre-planned course.
- When fixing the vessel's position, remember that radar ranges are far more accurate than radar bearings.
- Bear in mind that beamwidth distortion may stretch the ends of headlands and similar features causing errors in radar bearings. The effect of beamwidth distortion may be reduced by turning down the gain temporarily.
- All radar targets must be positively identified prior to use for position fixing. Ideally buoys should not be used for this purpose as they can be off position and are bad reflectors. However, if unavoidable, their charted positions should be verified prior to use.
- Be aware of any radar blind or shadow sectors caused by masts or other obstructions. Post plans showing these sectors near the radar, updated following any structural changes.
- When taking over the watch, check settings of radars in use as they may have been changed in the meantime by previous watch.

Radar Modes and Displays

Radar modes (see video):

- Sea stabilized:
  - Used for collision avoidance.
  - Shows correct aspects of targets (true course and speed of targets over water) hence applicable to ColReg rules
  - Targets are displayed relative to the ship's heading, ignoring external forces like currents and wind
  - Use speed through water (STW) and gyro/heading feeds
- Ground stabilized:
  - Used for navigation and pilotage
  - Has no usage in ColRegs as aspect of targets is not shown correctly
  - Targets are displayed relative to the ground, factoring in external forces like currents and wind
  - Use speed over ground (SOG) and gyro/heading feeds

Display modes:

Mode	Display	Use	Advantages	Disadvantages
Head-up	• Heading point upward • Uses sea-stabilized mode • Unstabilized, no gyro/heading feed	Narrow passages and port approaches. But many still find it	• Easier to understand as the heading marker matches with	• Unstabilized display making it difficult to accurately determine the relative bearings

	• Bearings are relative to ships heading • Typically used with Relative motion (RM).	better to use North Up mode	what you see outside • Bearings are directly relative to the ship's heading, simplifying collision avoidance • Can function without a gyrocompass / heading feed	because the entire radar image will rotate due to the "yaw" or due to changing of the course • As the vessel turns, the display rotates, which can be disorienting • Difficult to correlate radar data with charts • Cannot be used for PI (Parallel Index) to check track against predetermined route
North-up	• Oriented with true north at the top of the screen • Uses ground stabilization mode. Stabilized, using gyro input • Bearings are true	Open waters	• Everything stays north up orientated so can be used to reference against charts • Can be used for PI • Easier to determine bearings	• Not as natural as the head-up one • Navigation in narrow passages and approaches could be more difficult
Course-up	• Current course (based on heading) points upward • Uses ground stabilization mode. Stabilized, using gyro input • Only moving heading marker • Bearings are true	Collision avoidance, better than head up because it's stabilized	• Similar to head up but stabilized • Ability to obtain a true bearings directly • Easier to compare radar data with the intended route • Targets are displayed relative to the current course	• The display may need frequent updates if the course changes • Relies on heading / gyro or course data to orient the display

Recommendations: North-up mode would be recommended to use in most situations. Course-up mode may be used for collision avoidance. Head-up mode should be avoided.

Type of Radars

Many ships are fitted with both X and S band radars and good bridge management should ensure that the differences, as well as the pros and cons of each type of radar are known.

The choice of range scale is important on any radar set, and periodic scanning at a longer-range scale will allow advance warning of hazards.

X-Band Radar	S-Band Radar
Better for navigation	Better for collision avoidance
More power and better resolution / discrimination (ability to detect small targets), can take bearings more accurately	Better in rain and longer range, worse definition / discrimination of targets but can detect targets at greater range
3 cm, 9 GHz	10 cm, 3 GHz
Ability to detect a 9GHz SART	Improved target detection in heavy weather (works better in heavy rain)
Improved small target detection	Improved longer range detection (6 NM and more)
Higher resolution image due to high frequency, improving coastline identification during navigation	Improved sea clutter response

What makes a good radar conspicuous object

Mnemonic: **MAST**

- Material (M): materials that conduct electricity provide good reflection, e.g. steel. Fiberglass and wood are poor reflectors, stone and concrete provide moderate echos
- Aspect (A): flat surface is a good reflector only when it is at exactly the right angle to the radar beam. A ship that is broadsided-on for instance, is likely to be a
- better reflector than one which is at an angle or bow to.
- Size (S): the larger the object /ship the more likely for it to return good echo. Height is often more important than width.
- Texture (T): rough surfaces are good reflectors. It makes a weaker but much more reliable echo than a smooth surface

Note that buoyage and longhouses are bad reflectors as they are round and small. Also beach / sand is not the best reflector so make allowance for that when navigating close to the shore.

Radar Limitations

- Heading marker must be correctly aligned otherwise you can get misleading interpretations.
- Small vessels and objects (ice, floating logs or containers) may not be detected by the radar.
- Video processing techniques (e.g. rain clutter) should be used with care.

- Echoes may be obscured by sea or rain clutter.
- Mast or other structural features may cause shadow sectors on the display.
- Radar cannot penetrate solid obstacles like landmasses, cliffs, or large ships, leaving blind sectors.
- Targets may not be detected at long-range especially on X-band radar. Radar signals weaken as they travel farther, reducing detection capability for distant targets.
- Bearing resolution: Radar may struggle to distinguish between two targets that are close together on the same bearing.
- Range Resolution: Targets close together at slightly different distances might appear as one, depending on the radar's pulse length.
- Beam Width: A wide horizontal beam may cause small or closely spaced targets to blend together or not be detected.
- Target Aspect and Speed: Targets oriented bow-on or stern-on present a smaller radar cross-section and may be harder to detect.
- Nearby radars operating on the same or similar frequencies can cause radio interference, resulting in false or unclear signals.
- Skilled interpretation is required to identify targets correctly and avoid mistaking side echoes, clutter, or false returns as real targets.
- Incorrect tuning of gain, range, or clutter suppression settings can reduce radar's effectiveness.
- Multipath reflections, side-lobe interference, or environmental conditions can create ghost targets or false echoes.

Radar Errors

- Misalignment of heading marker
- Shadow sectors and blind sectors caused by masts or other obstructions.
- Inaccuracy of EBL and VRM: check the accuracy of the Electronic Bearing Line (EBL), Variable Range Marker (VRM) and the bearing cursor at frequent intervals.
- Side lobe effects: small lobs can be produced by radar in all directions, sidelobes may pick up interfering signals, and increase the noise level in the receiver.
- Spurious echoes and Effects: false or misleading radar signals that do not correspond to actual physical objects
- Radar Interference: Interference from other radars in vicinity. They can interfere constructively, destructively, or produce a resultant of zero.
- Indirect echoes: false radar signals caused by reflections from secondary surfaces like ship structures or nearby objects.
- Multiple echoes: radar signal reflects back and forth between the radar carrying ship and a nearby target multiple times before returning to the radar receiver. This phenomenon creates false targets on the radar display.
- Radar horizon: maximum detection range limited by the Earth's curvature and the height of the radar antenna.

Detecting SART by Radar

If you want to increase the chance of detecting SART on your Radar X-band:

- Set sea clutter to min
- Set rain clutter to match conditions
- Detune the radar
- Set radar range scale to 6 or 12 M

The SART should have sufficient battery capacity to operate in the stand-by condition for 96 h and, in addition, following the stand-by period, to provide transponder transmissions for 8 h when being continuously interrogated with a pulse repetition frequency of 1 kHz.

If SART is detected:

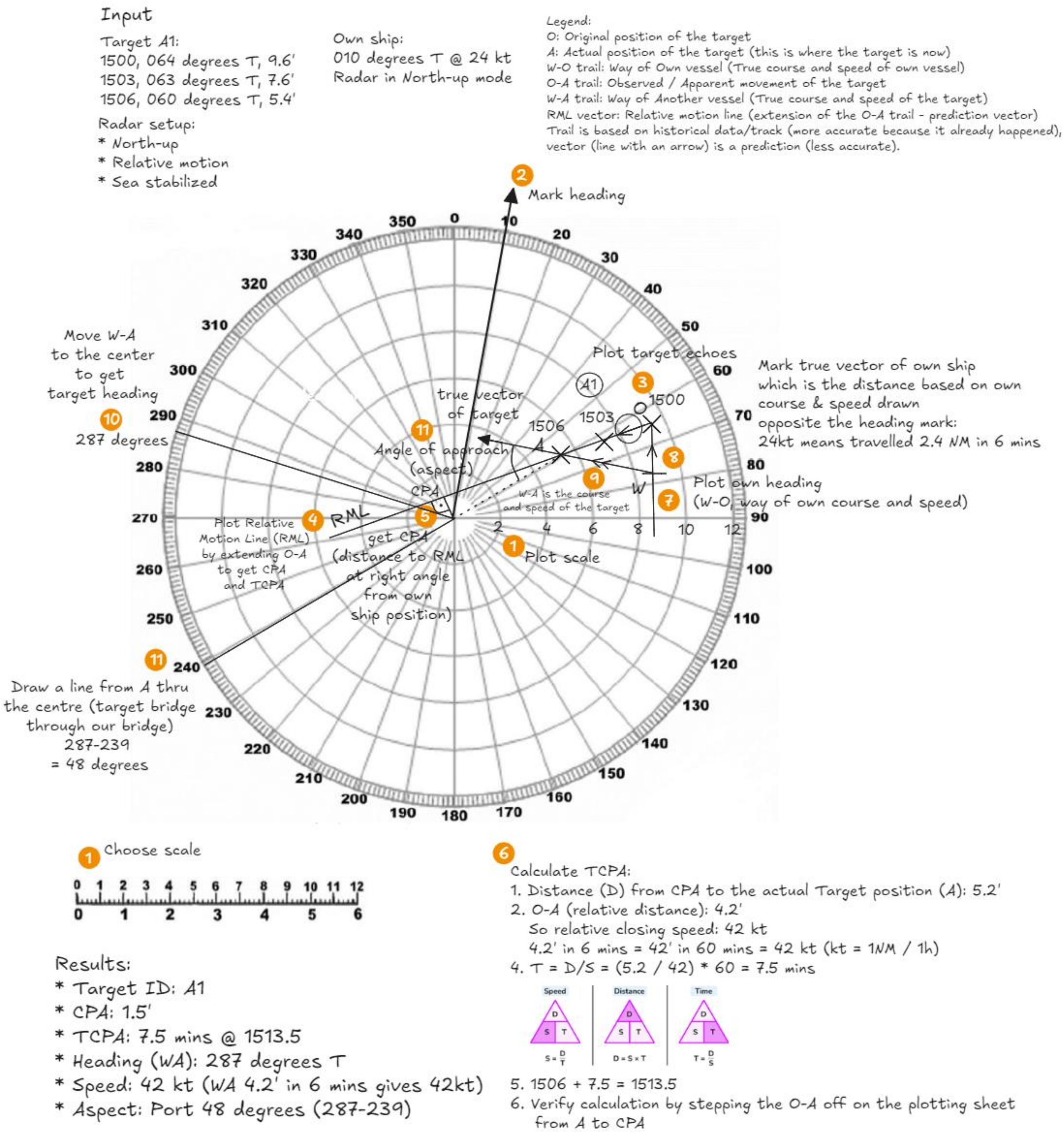
- It appears on the radar screen as a series of twelve dots with a gap of 0.6 miles between them, with the first dot representing the SART's position and the others extending in a straight line toward the edge of the screen.
- As you approach the SART's location, the dots on the radar display transform into short arcs, which increase in size as the vessel gets closer.
- Once you get in close proximity, the side lobes of the radar antenna activate the SART permanently, and the twelve dots will appear as complete circles on the radar screen, indicating that you reached the SART's location.

Radar Plotting

We use radar plotting to find out if risk of collision is deemed to exist. Modern radars are equipped with plotting aids like Automatic Radar Plotting Aid (ARPA). However, it is still important to understand the mechanics behind it. You will still need to do it if your radar set does not have these functions.

Using the radar plotting we can work out if the risk of collision exists, we can calculate CPA (Closest Point of Approach) and TCPA (Time to Closest Point of Approach). For determining these we need at least 3 plots of a target to get a trend. We take the echoes in intervals of 3 minutes so total 6 minutes (10th of an hour) to ease the plotting, e.g. if a ship is doing 10 kt, it will make 10 NM in 1 h, 1 NM in 6 minutes.

Examples:



Actions to take:

- If you can see the other ship then under Rule 15 (Crossing situation)), you are the "keep out of the way" vessel and you shall sound one short blast on the whistle of about one second duration, make a bold alteration of course to starboard of about 40 to 60 degrees. You will then monitor the situation until its past and clear and then return to original course.
- If in restricted visibility then under Rule 19 (Conduct of vessels in restricted visibility):
    - You shall avoid alteration of course to port for a vessel forward of the beam, other than for a vessel being overtaken. Therefore, you could slow down or make a bold alteration of course to starboard and continue using fog signals.

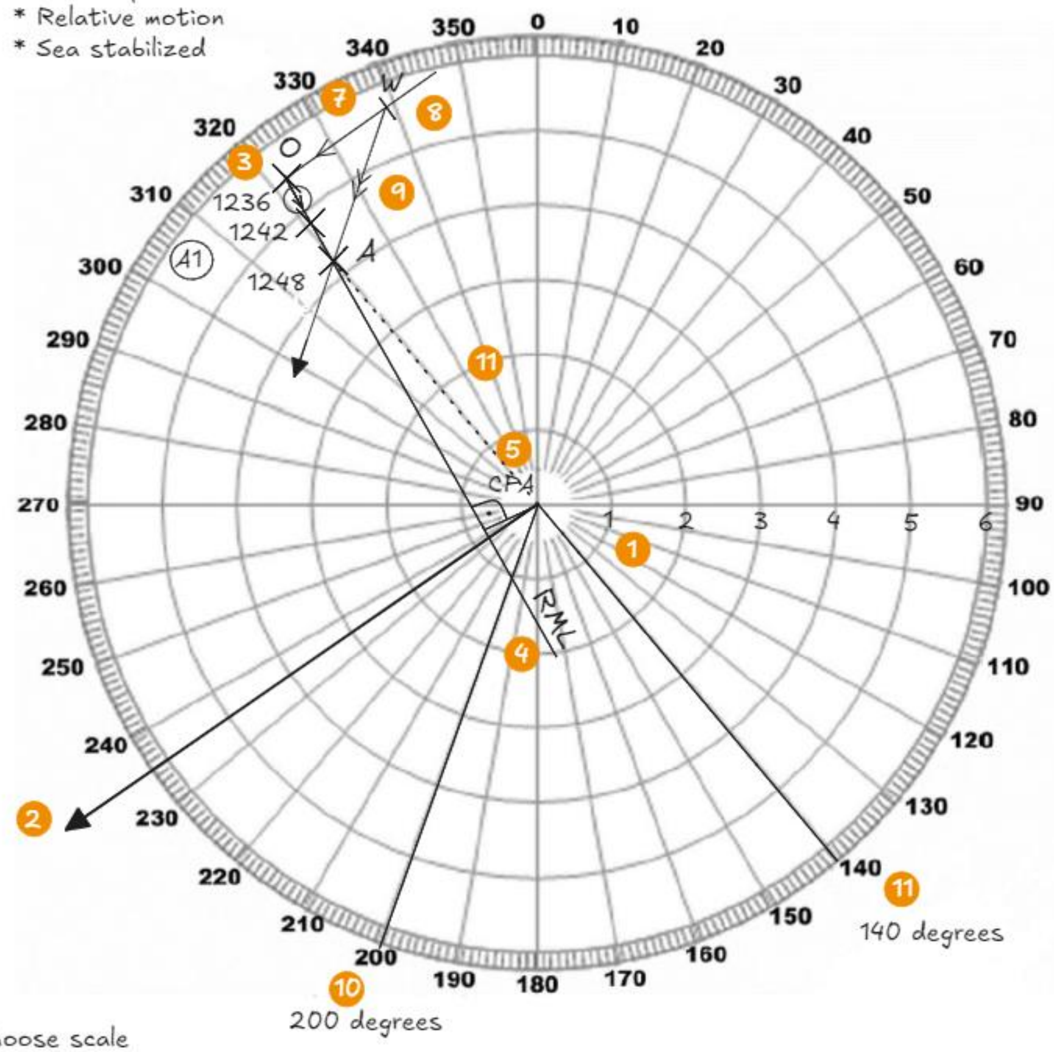
- In situations where the other vessel was at the beam or abaft the beam, you shall avoid an alteration of course towards the vessel. Therefore, you must turn to starboard if the vessel is coming from port quarter, and turn to port if coming from the starboard quarter.
- In situations where you overtake the other vessel, you could turn to port or starboard.
- In situations where you have 2 targets, one forward of the beam on the port side, and the other one abaft the beam on the starboard side, you could only slow down. You cannot turn to port for a vessel forward of the beam and you cannot turn to starboard because you have a vessel abaft the beam on the starboard quarter.

Input

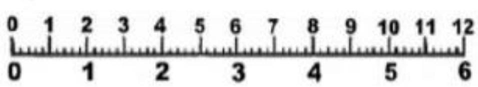
Target A1:
1236, 322 degrees T, 5.4'
1242, 321 degrees T, 4.8'
1248, 320 degrees T, 4.2'

Own ship:
235 degrees T @ 8 kt
Radar in North-up mode

Radar setup:
* North-up
* Relative motion
* Sea stabilized



1 Choose scale



6 Calculate TCPA:
D (from centre to A) = 4.2
S = 1.2 (O-A) in 12 min = 0.6 in 6 min = 6 kt
T = D/S * 60 = 4.2/6 * 60 = 42 min

Results:
* Target ID: A1
* CPA: 0.6'
* TCPA: 42 mins @ 1330
* Heading (WA): 200 degrees T
* Speed: 10 kt (WA 2' in 12 mins so 1 in 6 mins)
* Aspect: Port 60 degrees (200-140)