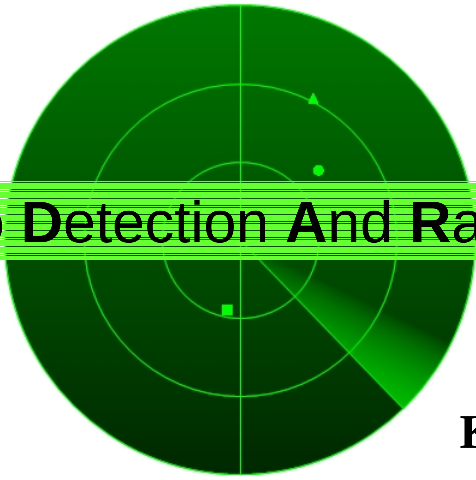
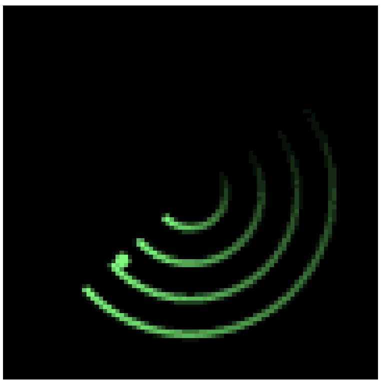
R A D A R

RYA 1 Day Course



RAdio **D**etection **A**nd **R**anging

Keith Bater



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What do we need to know?

This course is not about the technology of Radar.

It is about how to:

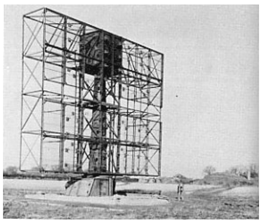
1. Get a Radar picture
2. Understand the picture
3. Use Radar information for better decisions
4. Be aware of the limitations of Radar

Plan for Today

0915	Introductions	
0925	History	
0930	Why are we here? - MAIB Reports: Wahkuna & Ouzo Case Studies	
0940	Principles	
0950	The Radar simulator	Exercise
1010	Switching on and setting up the radar set	Exercise; Q&A
1045	Understanding and improving the radar picture	Exercise
1115	Reflection and Radar Reflectors	
1200	Relative Motion, collision avoidance	
1230	LUNCH	
1315	Collision avoidance with radar, plotting, MARPA	Exercise
1430	Fixing Position and Pilotage by radar	
1500	More collision exercises	Exercise
1610	Uninstall simulator from program list	
1615	Wrap up, feedback	Discussion
1630 ish	END	

1. HISTORY

- **1861** **Maxwell's wave theory**
- **1886** **Hertz generated radio waves**
- **1904** **Hülsmeyer's 1st patent - anti collision**
- **1922** **Marconi tested for ships**
- **1935** **Watson-Watt implementation, closely followed by German scientists. Initially ground stations, then ships and aircraft**
- **1940** **Cavity Magnetron - big breakthrough in size and accuracy**
- **1990s** **Small craft installations**



MAIB Accident Report
Yacht Wahkuna and MV Vespucci May 2003

SY Wahkuna and MV Vespucci

MV Vespucci
66,000 tons
900 feet

Moody 47 Wahkuna
15 tons
47 feet

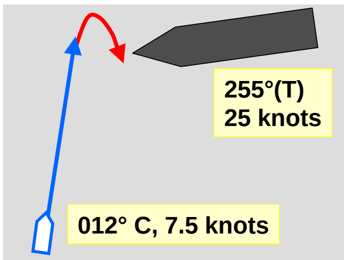
© K Bater 2008

Vespucci - Wahkuna, 8 May 2003

English Channel, visibility down to 50 metres at times.

Each vessel detected the other by radar at a range of about 6 miles.

The yacht skipper wrongly estimated by eye from his radar that *Vespucci* was passing 1.5 miles ahead of *Wahkuna*, and put his engine in neutral to slow down. There was a large alteration in the yacht's heading, and put the two vessels on a collision course.



The actions of the yacht, the CPA of which now appeared as 2 cables to port on ARPA, concerned the master of *Vespucci*, but he was reluctant to take any action because he was uncertain of what the yacht would do next.

The vessels collided and the bow of *Vespucci* struck the bow of *Wahkuna*, demolishing the first 3m of her hull and dismasting her.

The master of the Vespucci was not aware of a collision, and continued on passage.

The yacht crew abandoned to the liferaft, and were rescued 5 hours later. (NB their EPIRB failed).

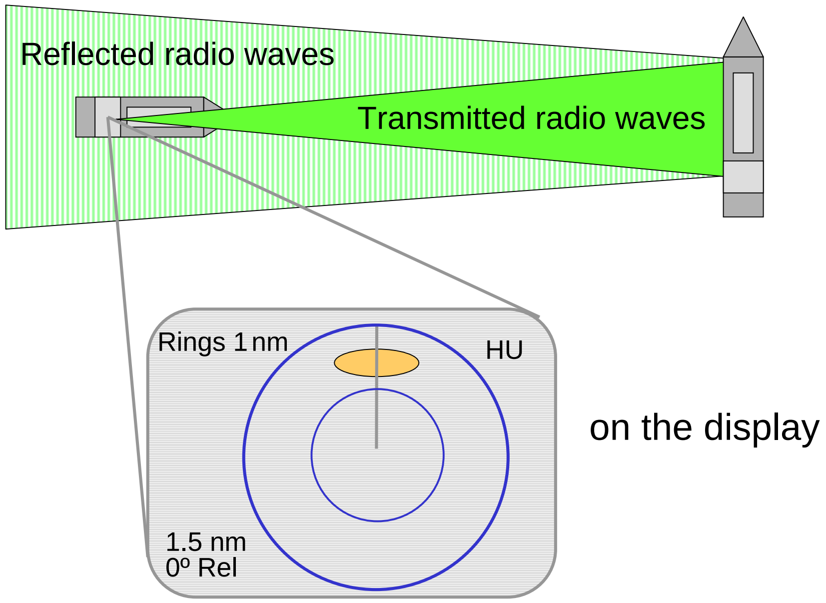
Factors contributing to the accident

- Misunderstanding by *Wahkuna*'s skipper of the Collision Regulations applicable in fog
- Over-confidence in the accuracy of ARPA by the master of the *Vespucci.*
- The GPS speed input to radar (SOG) was not suitable.
- Acceptance by the master of the container ship of a small passing distance
- The inability of the yacht skipper to use radar effectively
- Both vessels failed to keep an effective radar lookout
- The high speed of the container vessel
- Poor bridge resource management.

Ouzo - MAIB Report

- Wind SW F 5-6, waves 2 to 3 metres high
- The 25 ft yacht *Ouzo* was not detected by the radars on board *Pride of Bilbao* due to:
  - The small radar cross section area of the yacht
  - The poor performance of the yacht's radar reflector
  - The sea conditions
  - The use of auto sea clutter suppression
  - No use of periodic manual adjustment of the radar clutter controls to search for small targets
- There were also problems with the lookout's night vision

RADAR - How it works



Radar Facilities

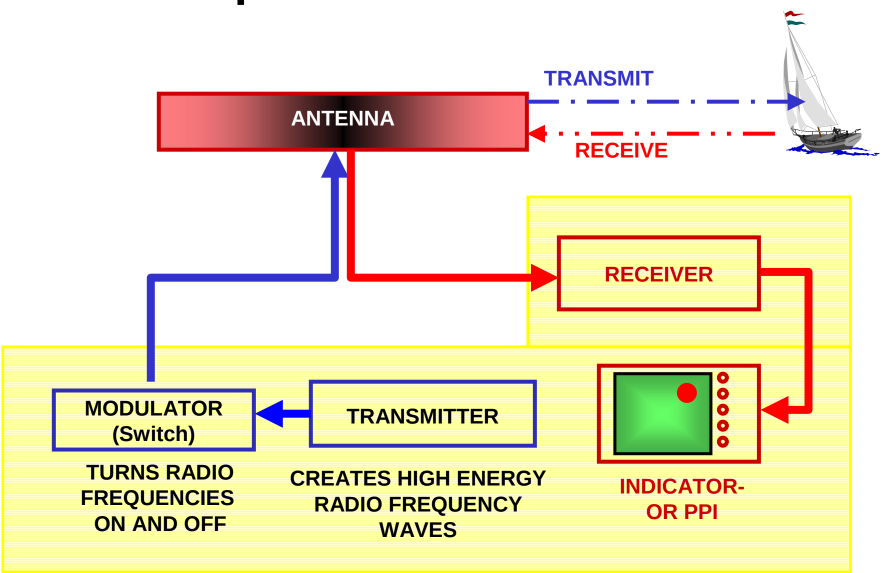
- **DETECT**
  - by transmitting microwave pulses and receiving reflections from contacts
- **RANGE**
  - Measure time for a pulse to hit contact and return to receiver.
    Distance = (Speed x Time) / 2
- **BEARING**

  The angle of the rotating scanner (24 rpm)

Radar Facts

- Target size depends on pulse length (duration of echo) and beamwidth
- Radar may not show everything you can see
- Radar may show you things you cannot see
- The movement of echoes and tracks on the screen may show up differently to the movement of ships on the water

Components of a Radar set



Operation

- Pulse is very high energy
- Return echo is very low energy
- Receiver must be very sensitive, so it must be switched off when a pulse is sent
  - Objects at very close range not detected
  - Approx 30m short range,   250m long range
- Radar listens for 99.9% of the time
- All the echoes from one pulse must be returned before another pulse is sent

Definitions

- **Pulse** - burst of transmitted microwave energy
- **Echo** - burst of reflected energy
- **Target** - any object which returns an echo
- **Contact / blob** - a target on the screen

- **Millisecond** - 1 msec = 1/1000 of a second
- **Microsecond** - 1 μsec = 1 millionth of a second
- **Speed** of pulse - 162,000 nautical miles per second = 300 metres per μsec.

Abbreviations

ARPA	Automatic Radar Plotting Aid
CPA	Closest Point of Approach
Contact	Target on a radar screen (blob)
EBL	Electronic Bearing Line
Echo	Return from a target
FTC	Fast Time Constant (Rain Clutter control)
MARPA	Mini Automatic Radar Plotting Aid
PRF	Pulse Repetition Frequency
Racon	Radar Beacon
RCS	Radar Cross Section
RTE	Radar Target Enhancer
S Band	3 GHz 10cm band - Ship radar
SART	Search and Rescue Transponder
STC	Sensitivity Time Control
Target	Object which returns an echo
TCPA	Time to Closest Point of Approach
VRM	Variable Range Marker
X Band	9.4GHz 3cm band - Yacht radar

Radar Simulator

- *Start*
- *Agree*
- *Standalone*
- *CRT*

Simulator
Radar Controls
Screen
Radar Set
Reality

Power on

Warm up - 10 seconds

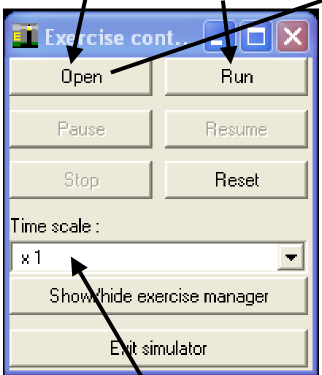
Tx = Transmit

Radar Simulator

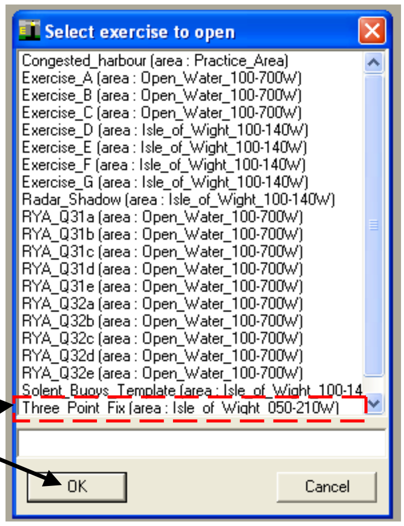
Selecting an exercise

Exercise Control

Open Run

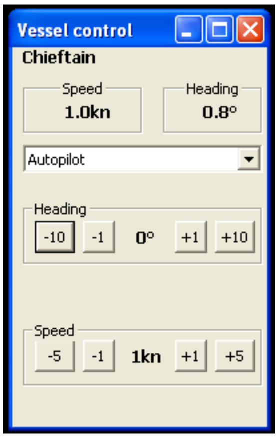


Speed up time

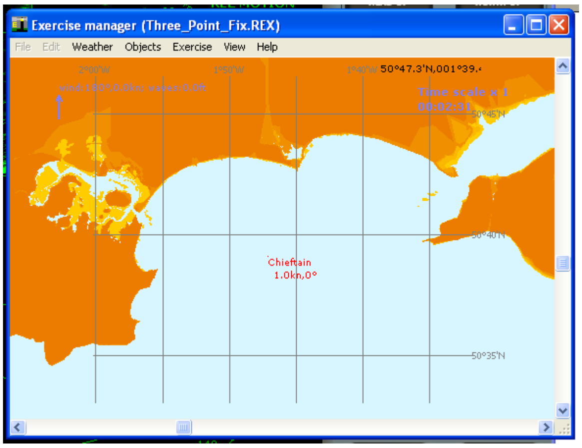


Radar Simulator

Vessel control Heading / speed



Exercise Manager



Simulator Exercises

Exercise		Targets	
A	Open water	1 ship, 1 buoy	Collision? Stop exercise. Set up Wind, Sea Clutter & Rain control
B	Open water	3	
C	Open water	1 ship, 4 buoys	
D	West Solent	1 ship dead ahead	CPA 0.1M
E	Portsmouth approaches	1 ship, forts	
F	Solent off Ryde harbour	2 ships, 4 buoys	
G	Needles - Calshot	2 ships. 2 buoys	
	Radar Shadow		
	RAIN and SEA CLUTTER	Racon + Ship in rain	Rain and Sea Clutter
31a	Open water	1 @ 16kn	CPA 1M ahead
31b	Open water	1	Collision
31c	Open water	1 Stbd beam 20kn	Crossing ahead
31d	Open water	1	Stationary
31e	Open water	1 14kn	CPA 0.3M long way ahead
	Christchurch 3 point fix	None	
	Congested harbour		

1. Switching on and setting up

Power / transmit

- Power - warm up time (2 minutes for magnetron)
- Standby (also Watch mode)
- Transmit - Tx

Main controls - B G R T

- Brightness of image
- Gain - amplifies the weak return signal, shows 'speckle'.
- (Contrast - if present)
- Range - alters range rings and varies pulse length and interval.
    - Long range = long pulse at long intervals.
- Tuning - matches frequency of sent and received pulses. Need a target to tune on - use sea clutter

Gain 1

Gain 2

Gain 3 - LCD Radar Display

When will you turn on the Radar?

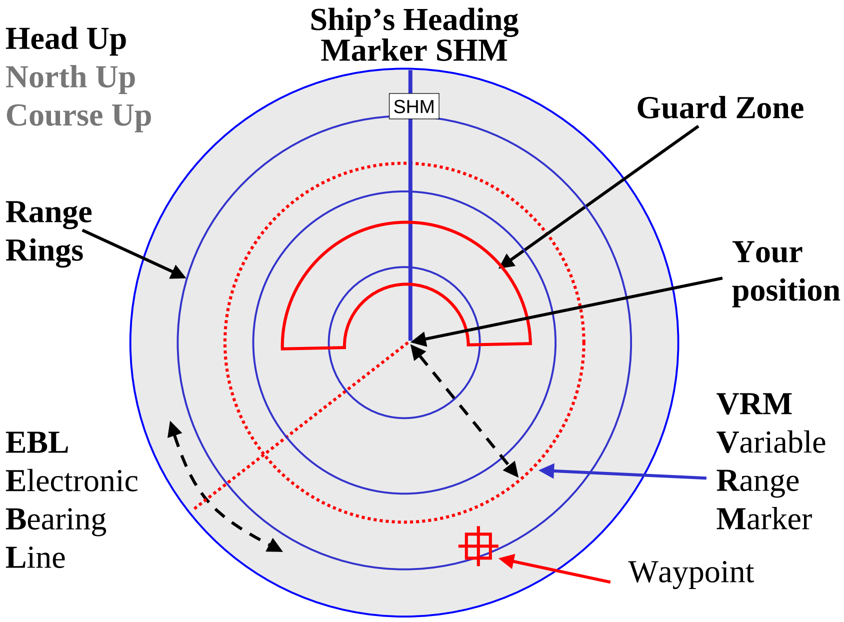
Rule 5 Lookout

a) Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist.

b) Proper use shall be made of radar equipment if fitted and operational, including long-range scanning to obtain early warning of risk of collision and radar plotting or equivalent systematic observation of detected signals.

c) Assumptions shall not be made on the basis of scanty information, especially scanty radar information.

2. Understanding The Radar Picture



2. Understanding The Radar Picture

Targets on screen

- may be large, small, bright or faint depending on size, orientation, material, surface and range.
- Small boats and buoys may vary in return and disappear for a time.

Raymarine radar

- Strong targets in yellow, weak returns in blue

2. Understanding The Radar Picture

Target controls

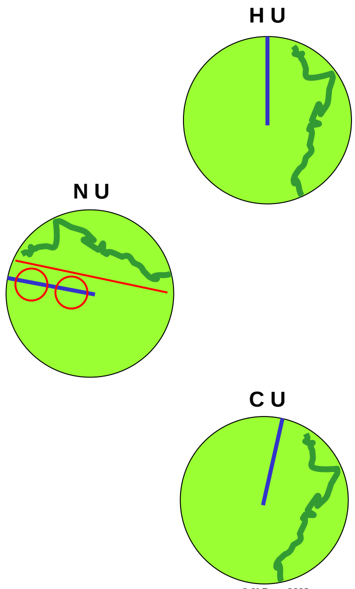
- Expansion or Echo Stretch - expands target returns; easier to see target but reduces range accuracy.
- Wakes - shows approx direction and speed of a moving target. Duration of wakes may be varied. Note this is NOT the true wake of the target, but movement relative to you
- Interference Rejection - reduces mutual radar interference when two boats with radar are close. Normally switched on, but if switched off may show the presence of the other boats.

Range Controls

- Always start with sufficiently high range
- Adjust range periodically
- Short range - short pulses, high repetition frequency - higher definition
- Long range - long pulses, low repetition frequency - lower definition

Head Up, North Up, Course Up

- Head up
  - Heading marker is boat's heading
  - Best for collision avoidance
  - Picture moves as boat yaws
- North Up
  - True North upwards
  - True Motion
  - Stabilised
  - Like a chart
  - Best for navigation
  - Parallel indexing
- Course Up
  - Stabilised
  - More stable than Head Up
  - Picture takes time to settle



Clutter

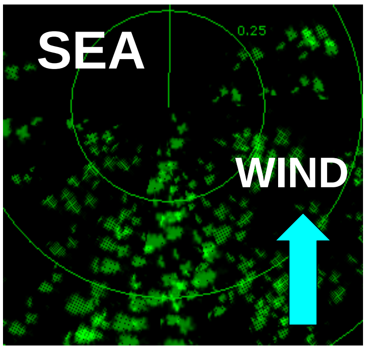
'Clutter' is real echoes returned by targets which are by definition uninteresting to the radar operator.

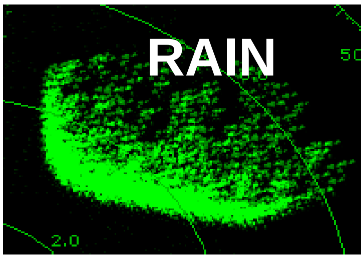
These include natural objects such as sea, rain, fog, and atmospheric turbulence.

Sea clutter from close waves has multiple small echoes at short range which are not consistent in position, and may form a solid disc in rough sea states.

Rain clutter form large hazy areas. More pronounced on X Band radar (yachts).

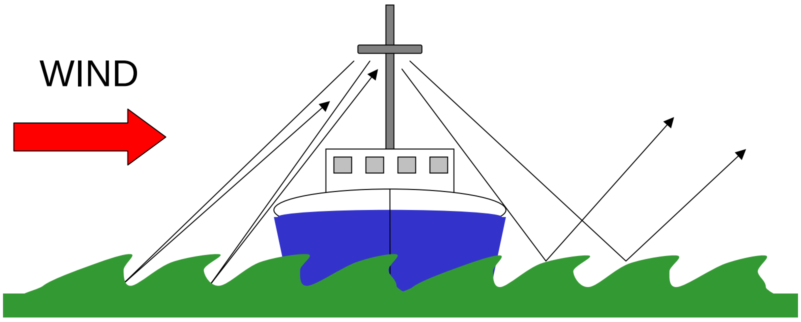
The clutter echoes can be reduced with clutter controls, but this may also eliminate real targets.





Sea Clutter

- Sea Clutter - reflections from close waves form an irregular blob at centre of picture
- Clutter increases with wave height and scanner height
- More to windward than leeward
- 3 cm radar – more clutter than 10 cm
- Long pulse length – increases number of echoes displayed

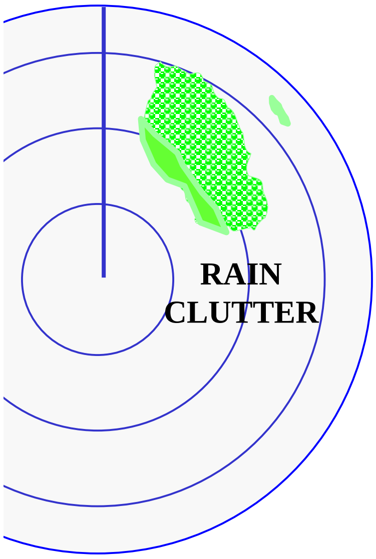


Rain Clutter

Heavy rain reduces range by 50%; fog by 30%

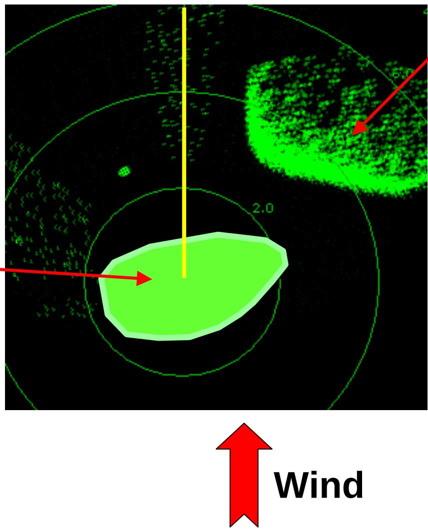
Suppression

- Difficult with X band, as water is very absorbent to microwaves at this frequency
- Reduce pulse length (range) to reduce rain echoes
- Use long pulse (range) to search for targets beyond the rain
- STC can work in near areas
- FTC for targets in showers – not effective in heavy rain.



Sea and Rain Clutter Suppression

Sea clutter
Reduce with
STC
Sensitivity Time Control reduces gain for strong signals from close targets like waves - and also real targets

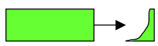


Rain Clutter
Reduce with
Rain Clutter Control and FTC

Fast Time Constant

Clips to the leading edge of all targets- use to find targets in rain.

Separates close targets

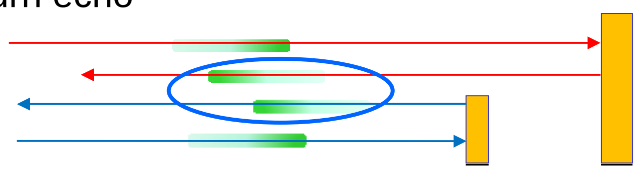


What affects Accuracy?

- Power Output
  - Yacht 1 - 5 Kw, Ships 25 - 50 Kw
- Receiver Sensitivity
- Pulse Frequency
  - 9.4 GHz 3cm 'X Band' (yachts)
  - 3 GHz 10cm 'S Band' (ships)
- Horizontal Beam Width - Antenna size
  - 120cm antenna - 2°;   30cm antenna - 8° (Vertical beam height 25 - 30°)
- Display size and resolution

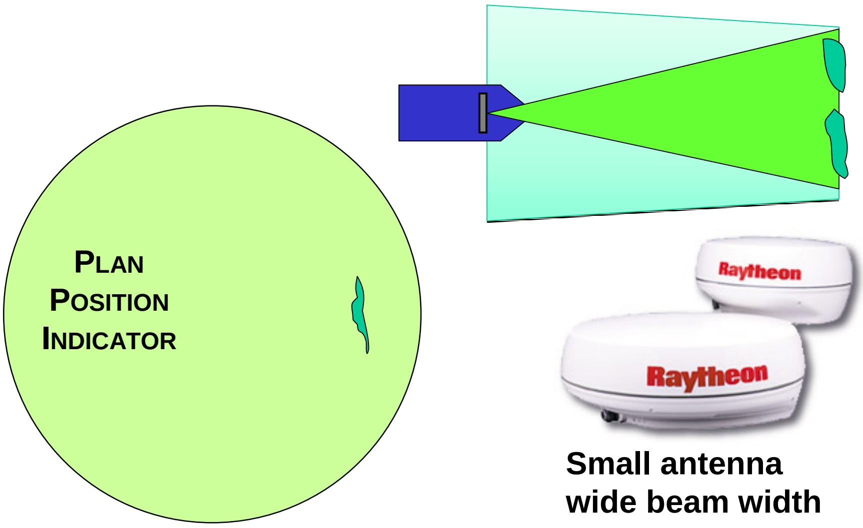
Accuracy of Range

- Short pulses measure range with more accuracy
- Long pulses travel further, but they can merge in the return echo



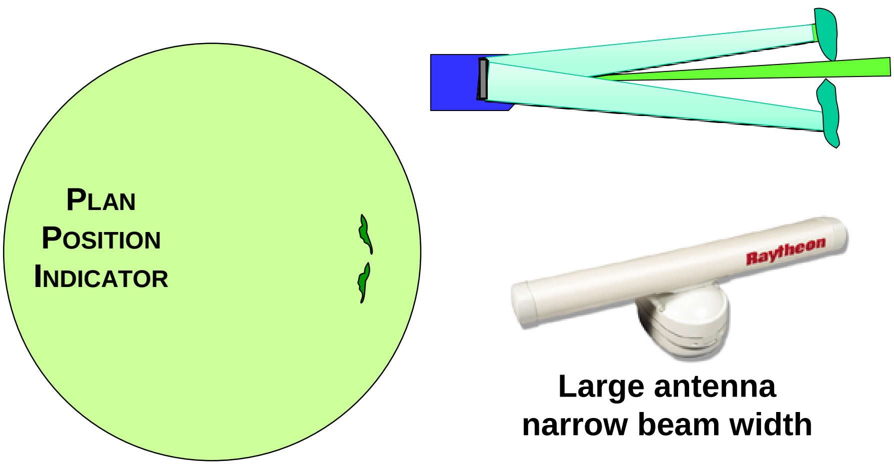
- Long range = Low Pulse Repetition Frequency; To increase range - longer pulse, longer PRF
- Range Control does this automatically

Beam width is more important than power



Small antenna
wide beam width

Beam width is more important than power



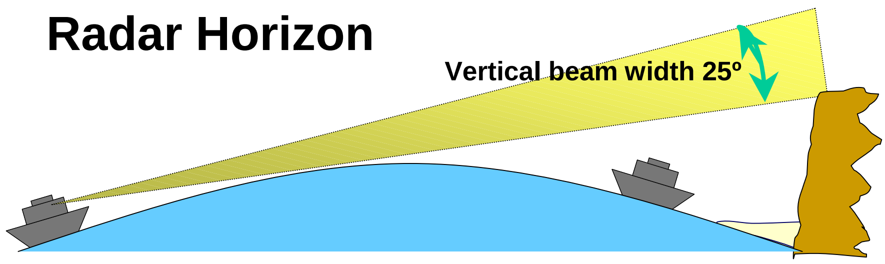
Large antenna
narrow beam width

S Band and X Band Radar

(these bands were chosen because the atmosphere is more transparent to microwaves at these frequencies)

	'S' band 3 GHz Wavelength 10cm	**'X' Band** 9.4 GHz Wavelength 3.2cm
Used on	**Ships (only)**	**Yachts** **Ships (Inshore, harbour)**
Range	**Long**	**Short**
Resolution of small targets	**Moderate**	**High**
Sensitivity	**Moderate**	**Good**
Interference Rejection(Clutter)	**Good – 10% of X Band**	**Poor**
Visibility of your Reflector	**Poor (10% of X Band)**	**Good**

Radar Horizon



Distance in Nautical Miles =

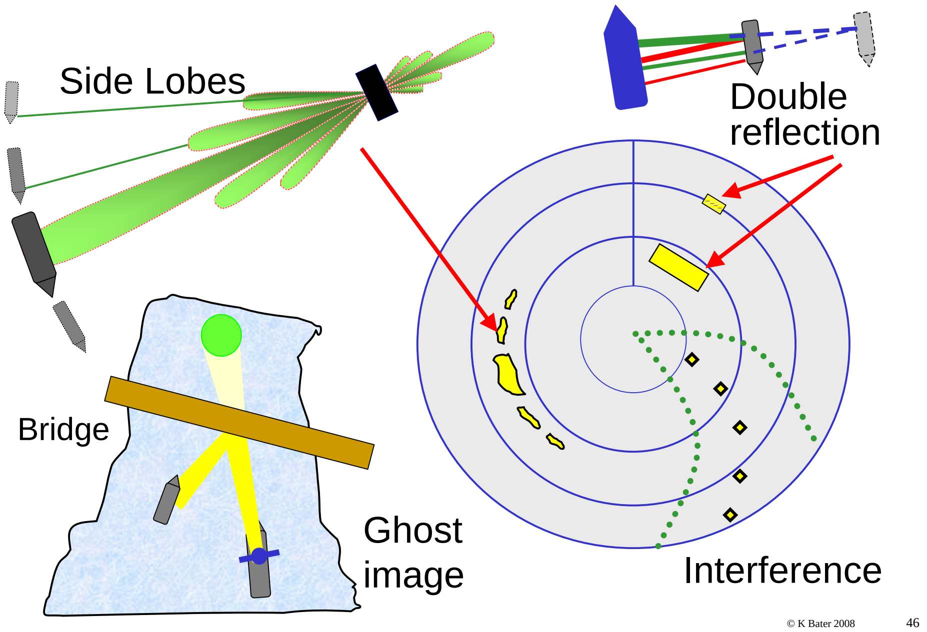
$$2.21\sqrt{\text{Antenna height m}} + 2.21\sqrt{\text{Target height m}}$$

- **4m antenna - 4.4 miles + 100m cliff @ 22 miles = 26.4 M**
- **About 10% more than visible horizon**
- **Atmospheric conditions and Refraction may change the distance**
- **'Ducting' can allow very long ranges**

False Radar Images

- Obstructions on your boat - blind arcs
- Radar cannot see round corners
- Shadow areas - small objects merge with large objects
- Side lobes produce echoes from good reflectors
- Double reflection produces second image at twice the range

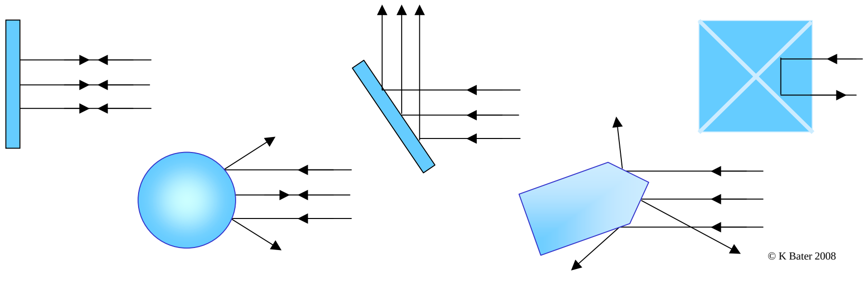
False Images - reduce Gain



Questions in Exercise Book

4. Radar Reflectors

	GOOD	POOR (= Yacht!)
Material	**Conductor** **Metal, Water**	**Non conductor** **Wood, GRP**
Aspect	Facing the pulse	Oblique
Size	Large	Small
Shape	Flat	Curved
Texture	Rough	Smooth

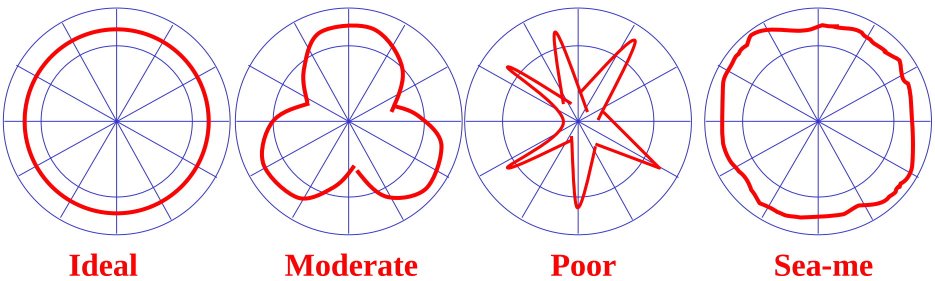


The Stealth Motor Yacht

Radar Reflectors - Requirements

- High Radar Cross Section of an equivalent steel sphere in square metres
- Reflects 360° all round as seen on a polar diagram
- Equally effective when heeled

Polar Diagrams



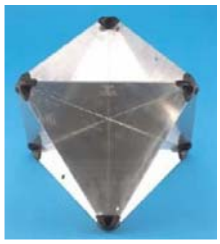
Radar Reflectors - Requirements

- Remember – the closer you are to a ship the less likely you are to be seen

Reflectors

Blipper

Mobri Tubular



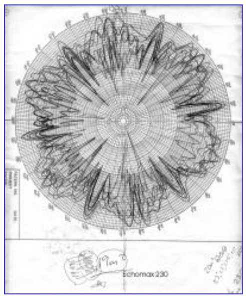
Octahedral

RTE - Sea me Echomax

Tri Lens

Davis Octahedral

Echomax



Polar Diagram

Radar Reflectors - Passive

- Octahedral - Rain catcher mode Peak RCS <10
- Lens - like a catseye - Tri Lens RCS < 5
- Stacked array
  eg Echomax Peak RCS 10 - 25, 6.5 at 15° heel
- Tubular - Mobri 2 - 4in - very poor

- *NB RCS is for X band radar with reflector vertical, peak values. There will be null areas with no reflection.*
- *Heeling can reduce RCS by 75%.*
- *with S Band, RCS is only 25% of above values.*

Radar Reflectors – Active

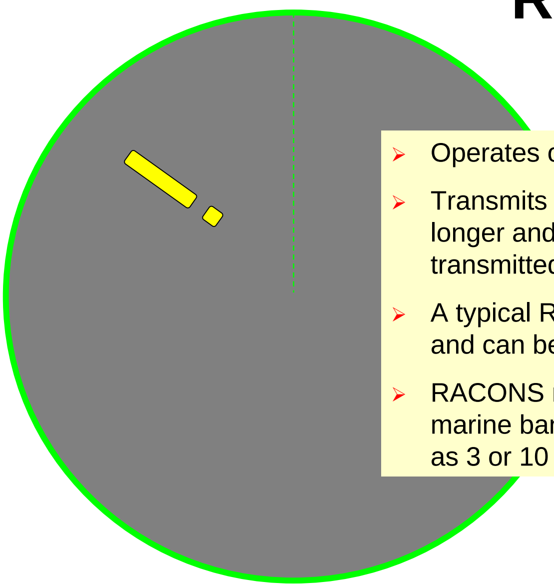
- Detects a radar pulse and returns a strong radar echo from your boat.
- Sea-me Radar Target Enhancer:

  RCS = 63

  Can sound alarm when a radar pulse is received.
- Echomax RTE XS Dual band

  RCS = 118 (X Band)   RCS = 6 (S band)
- Racon RTE - Morse letter
- SART RTE - Search & Rescue Transponder

RACON



- Operates on trigger from a radar pulse
- Transmits its own pulse which is longer and more powerful than the transmitted radar pulse
- A typical RACON flash is elongated and can be coded ie as a Morse letter
- RACONS must activate on the entire marine bandwidth and can be defined as 3 or 10 cm or both

Ouzo - Qinetiq Report Recommendations

- Yachtsmen should fit a radar reflector with the largest RCS practicable for their vessel
- The radar reflector should have a minimum **consistent** RCS of $2m^2$
- The Sea-Me and Echomax RTE are recommended if power is available
- If no power is available the passive Large Tri-Lens reflector is recommended
- The 4” tube reflector is not suitable due to its poor performance.

Reflectors - Conclusions

- **There is no substitute for size when it comes to radar reflectors. Devices with smaller size and lower windage simply don’t work as well.**
- **Passive reflectors are no more than marginally useful offshore if only S-band is used, except perhaps in calm sea conditions.**
- **Angle of heel is critical.**
- **OUZO – (octahedral?) at best a 50% probability that the ship would detect Ouzo on the radar at close range, even on X-Band**
- **Look for ISO 8729 in manufacturers’ specifications (Echomax)**

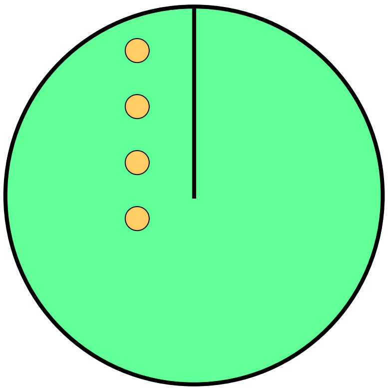
Questions in Exercise Book

Radar Display - Relative Motion

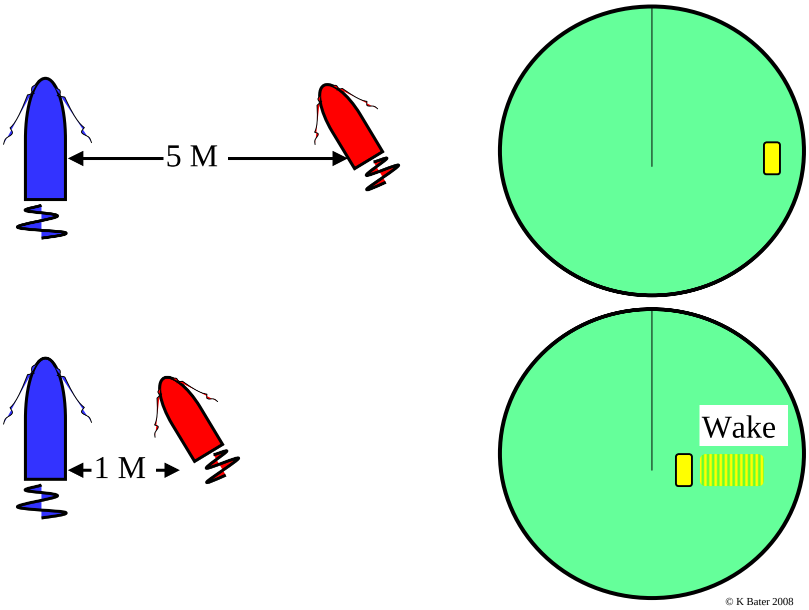
- Your boat position is fixed - usually at the centre of the screen
- The same view as standing in your cockpit
- All target echoes move with relative motion across the screen
- Relative motion = result of your boat's true motion through the water and the target's true motion through the water
- Used by 90% of mariners

Relative Motion

What is the trail of a fixed target?



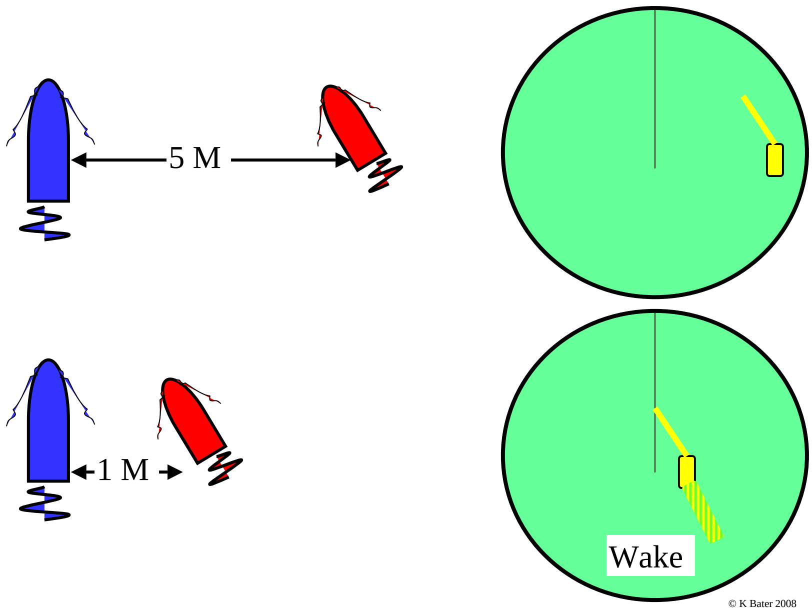
Relative Motion



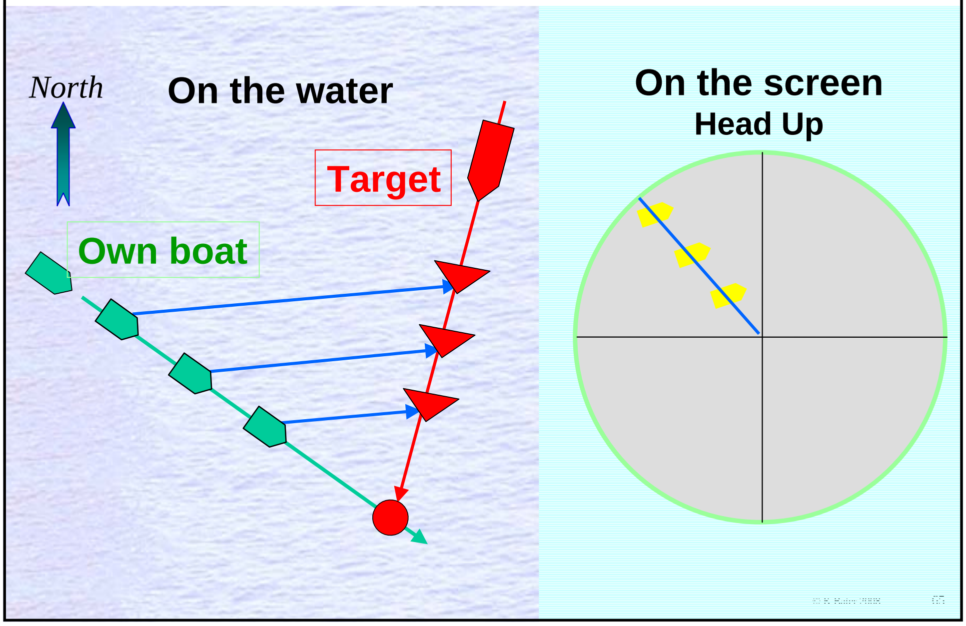
Radar Display True Motion

- Own boat's position moves across the screen with own course and speed
- Own boat's position resets when you near of screen edge – like a plotter
- Radar target echoes move across the screen with own true motion through the water.
- Track of the target will indicate target's true course and speed through the water

True Motion - Moving



How it looks

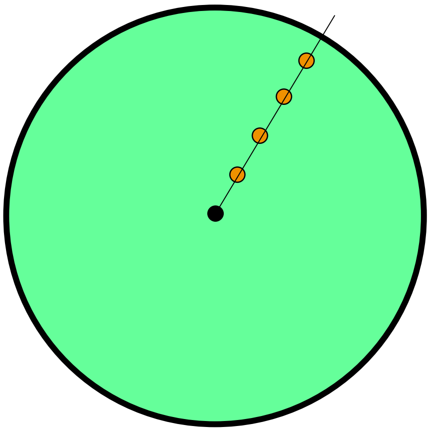


7. Collision Avoidance

- For collision avoidance the Radar should display ***Relative Motion, Head Up***
  - Your boat appears stationary and other objects appear to move - including buoys.
  - Must be ***Sea Stabilised*** - information is provided by boat's log and compass, NOT the GPS.
  - Errors in heading, speed and bearings can all be present.

IRPCS Steering and Sailing Rules – what do they say?

Collision Avoidance



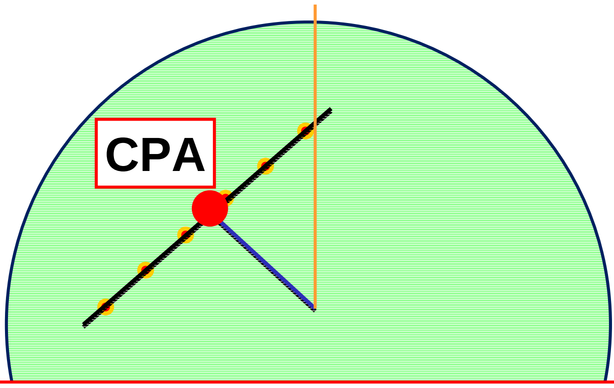
A target whose range is decreasing and relative bearing is not changing is on a collision course

CBDR = Constant Bearing Decreasing Range

Collision Detection

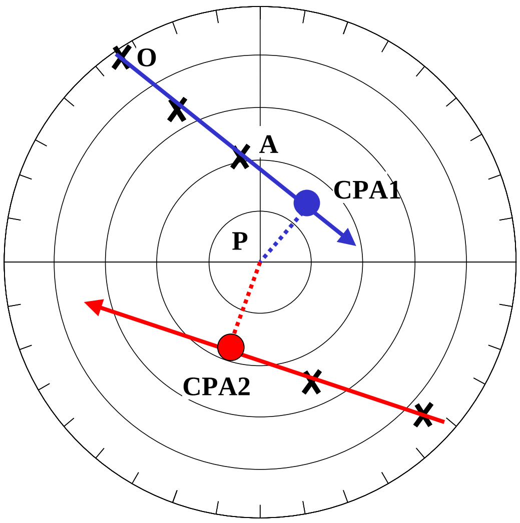
- Wakes
  - Very simple and quick, easy to use, crude indication only – for multiple targets
- EBL
  - Very simple and quick, easy to use
  - Hard to track multiple targets
- MARPA
  - Easy to use
  - Tracks multiple targets
  - Can lose targets
- AIS
  - Easy to use. Not used by every target

Closest Point of Approach - CPA



- Always of interest to the Skipper
- CPA = **C**losest **P**oint of **A**pproach
- Always expressed as a bearing and range **from own boat**.

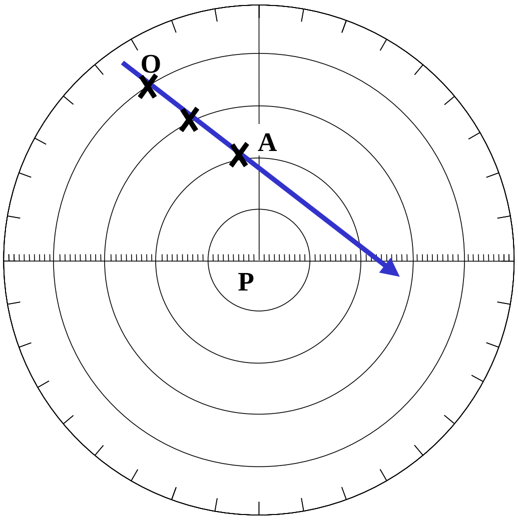
Combined Plot



Target crossing ahead

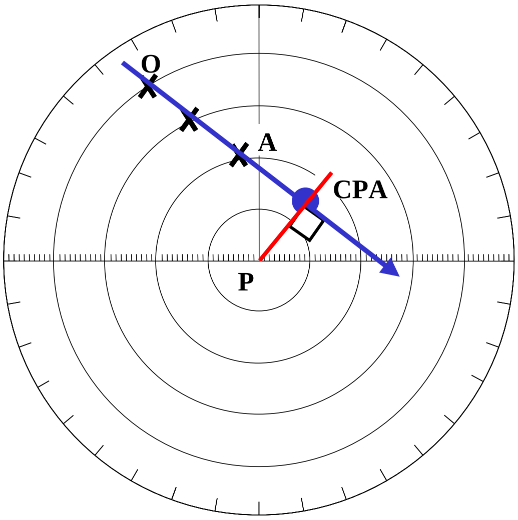
Target crossing astern

Finding the Closest Point of Approach - CPA of a Target 1



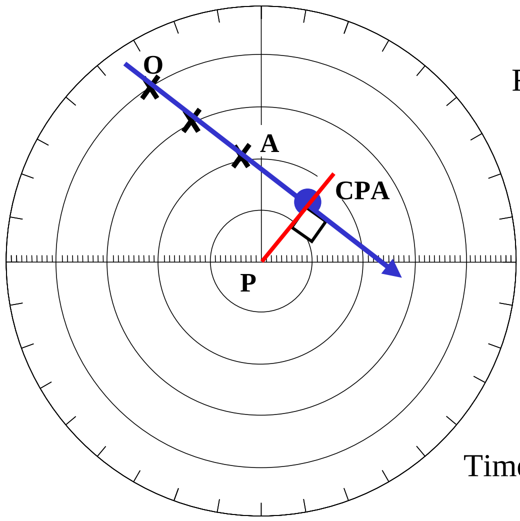
1. Plot target position X at 6 minute intervals (= 0.1 hour)
2. First plot = O (Original)
3. Last plot = A (Actual)
4. Draw O - A the blue line past P the centre of the plot (your position)

Finding the Closest Point of Approach - CPA of a Target 2



1. Plot target position X at 6 minute intervals (= 0.1 hour)
2. First plot = O (Original)
3. Last plot = A (Actual)
4. Draw O - A the blue line past P the centre of the plot (your position)
5. Draw a line from P (in red) to meet the blue line at right angles.
6. This is the CPA
7. Find the Time to CPA = (A-C / O-A) *x* Time for OA

Finding the Time to Closest Point of Approach



Find the Time to CPA =

$$\frac{A - C}{O - A} \; x \text{ time from O to A}$$

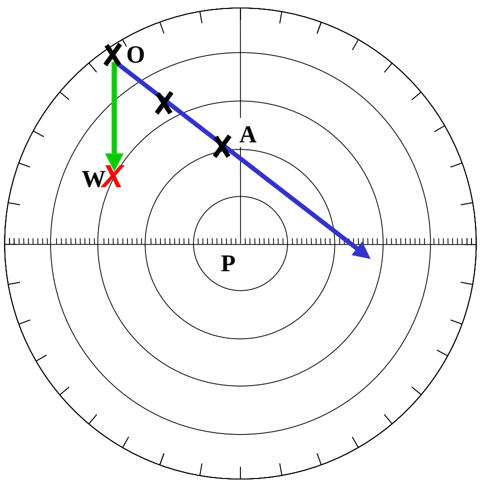
In this case time from O to A = 12 minutes = 0.2 hrs

So if OA = 3 miles

AC = 1.3 miles

Time to CPA = 0.2 x (1.3/3)
= .087 hours
= 5.2 minutes

Finding the TRUE course and speed of the target 1



1.Plot target position X at 6 minute intervals (= 0.1 hour)

2.First plot =O (Original)

3.Last plot = A (Actual)

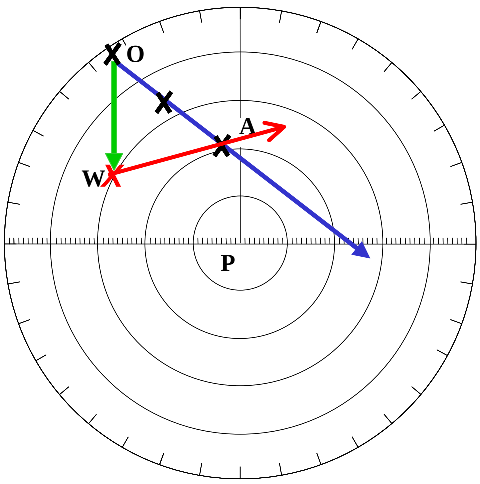
This gives the RELATIVE COURSE of the target

Our boat is travelling up the screen, so we need to take away our speed from the target.

Draw O – W: the distance we travel in 12 minutes

O - W = the WAY of our boat

Finding the TRUE course and speed of the target 2



We must adjust the target Relative course by allowing for our speed – up the screen.

Imagine the target dropped a buoy at O.

When the target reaches A the buoy will be at W, where A – W is our speed

The TRUE COURSE of the target is W to A

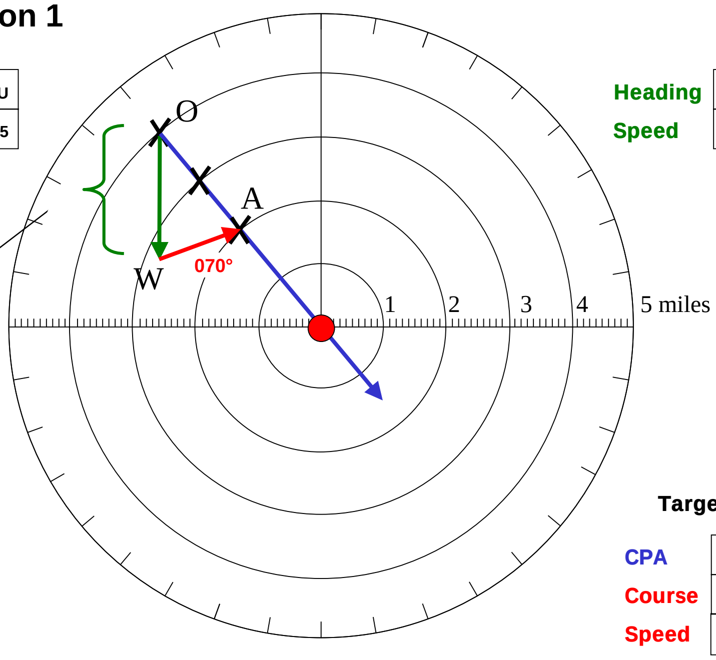
The TRUE SPEED of the target is

$$\frac{W - A}{\text{Time } O - A}$$

Question 1

Mode	HU
Range	5

Heading	180°
Speed	10



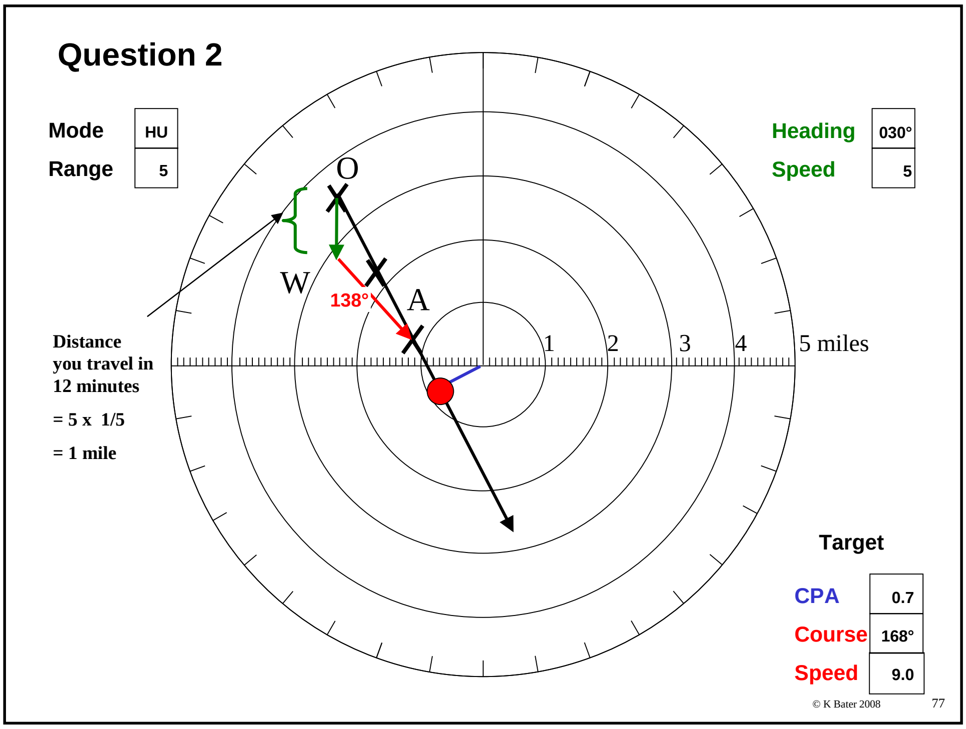
Distance you travel in 12 minutes

= 10 x 1/5

= 2 miles

Target

CPA	0
Course	250°
Speed	7.0


Question 2
Mode
HU
Range
5
Heading
030°
Speed
5
O
W
A
138°
1
2
3
4
5 miles
Distance
you travel in
12 minutes
= 5 x 1/5
= 1 mile
Target
CPA
0.7
Course
168°
Speed
9.0
© K Bater 2008
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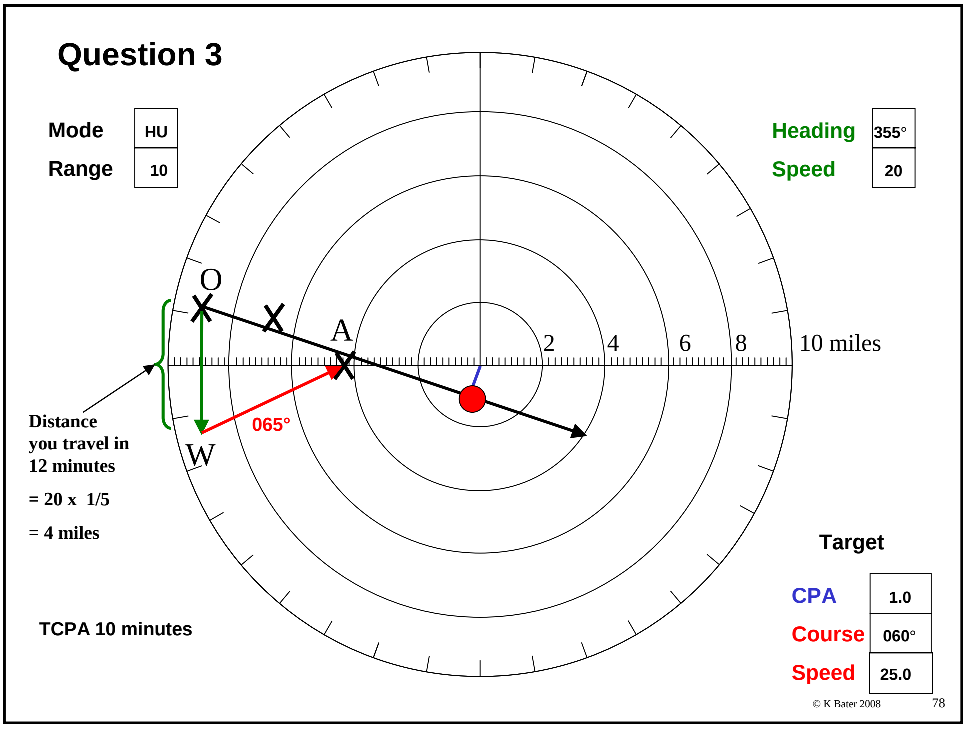
Question 3
Mode
HU
Range
10
Heading
355°
Speed
20
O
A
W
065°
2
4
6
8
10 miles
Distance
you travel in
12 minutes
= 20 x 1/5
= 4 miles
TCPA 10 minutes
Target
CPA
1.0
Course
060°
Speed
25.0
© K Bater 2008
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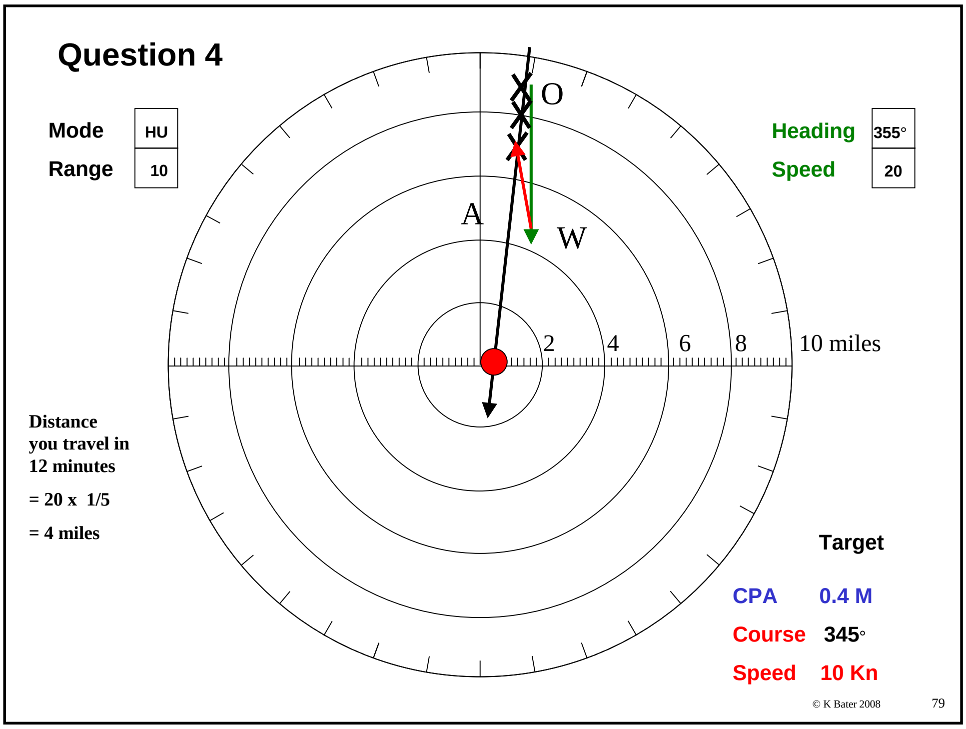
Question 4
Mode
HU
Range
10
Heading
355°
Speed
20
O
A
W
2
4
6
8
10 miles
Distance
you travel in
12 minutes
= 20 x 1/5
= 4 miles
Target
CPA
0.4 M
Course
345°
Speed
10 Kn
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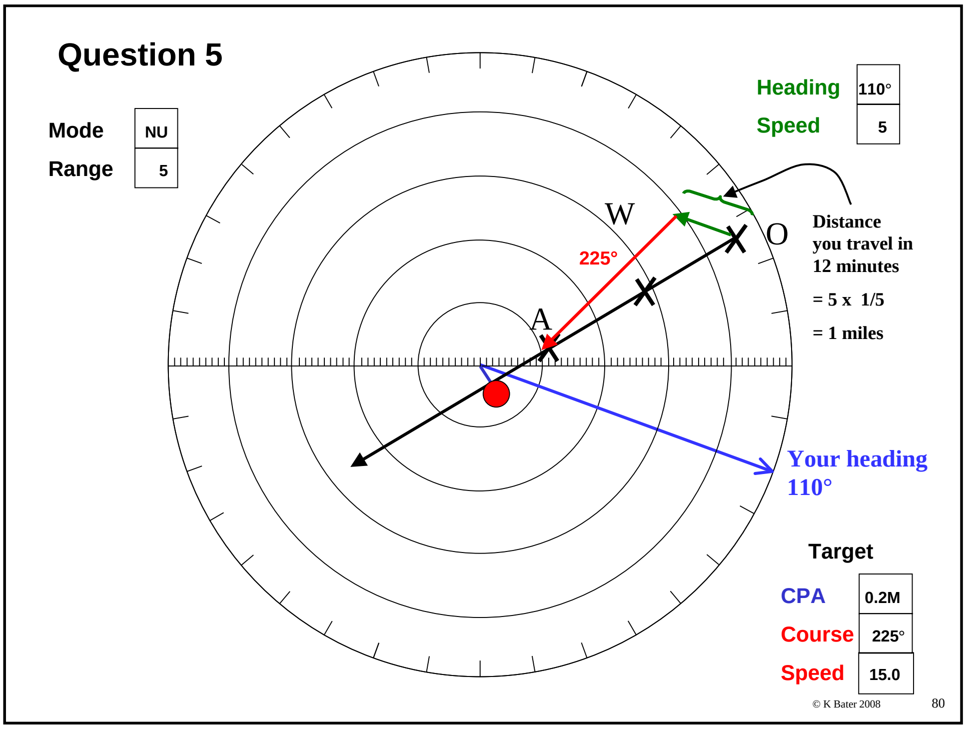
79


Question 5
Mode
NU
Range
5
Heading
110°
Speed
5
W
O
225°
A
Distance
you travel in
12 minutes
= 5 x 1/5
= 1 miles
Your heading
110°
Target
CPA
0.2M
Course
225°
Speed
15.0
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80

Sea me Plotter

IRPCS Steering and Sailing Rules

Rule 5 Lookout

a) **Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist.**

b) **Proper use shall be made of radar equipment if fitted and operational, including long-range scanning to obtain early warning of risk of collision and radar plotting or equivalent systematic observation of detected signals.**

c) **Assumptions shall not be made on the basis of scanty information, especially scanty radar information.**

RULE 6 Safe Speed

Every vessel shall at all times proceed at a safe speed

In determining a safe speed the following factors shall be among those taken into account ….depth, traffic, hazards, sea state etc.

Additionally, by vessels with operational radar:

- i. the characteristics, efficiency and limitations of the radar equipment;
- ii. any constraints imposed by the radar range scale in use;
- iii. the effect on radar detection of the sea state, weather and other sources of interference;
- iv. the possibility that small vessels, ice and other floating objects may not be detected by radar at an adequate range;
- v. the number, location and movement of vessels detected by radar;
- vi. the more exact assessment of the visibility that may be possible when radar is used to determine the range of vessels or other objects in the vicinity

Rule 7 Risk of Collision

a. Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist.

b. Proper use shall be made of radar equipment if fitted and operational, including long-range scanning to obtain early warning of risk of collision and radar plotting or equivalent systematic observation of detected objects.

c. Assumptions shall not be made on the basis of scanty information, especially scanty radar information.

d. In determining if risk of collision exists the following considerations shall be among those taken into account:

- i. such risk shall be deemed to exist if the compass bearing of an approaching vessel does not appreciably change;
- ii. such risk may sometimes exist even when an appreciable bearing change is evident, particularly when approaching a very large vessel or a tow or when approaching a vessel at close range.

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Rule 19 Conduct of vessels in restricted visibility

a) This Rule applies to vessels not in sight of one another when navigating in or near an area of restricted visibility.

b) Every vessel shall proceed at a safe speed adapted to the prevailing circumstances and conditions of restricted visibility. A power-driven vessel shall have her engines ready for immediate manoeuvre.

c) Every vessel shall have due regard to the prevailing circumstances and conditions of restricted visibility when complying with the Rules of Section I of this Part.

d) A vessel which detects by radar alone the presence of another vessel shall determine if a close quarters situation is developing and/or risk of collision exists. If so, she shall take avoiding action in ample time, provided that when such action consists of an alteration of course, so far as possible the following shall be avoided:

   i. an alteration of course to port for a vessel forward of the beam, other than for a vessel being overtaken;

   ii. an alteration of course towards a vessel abeam or abaft the beam.

e) Except where it has been determined that a risk of collision does not exist, every vessel which hears apparently forward of her beam the fog signal of another vessel, or which cannot avoid a close-quarters situation with another vessel forward of her beam, shall reduce her speed to the minimum at which she can be kept on her course. She shall if necessary take all her way off and in any event navigate with extreme caution until danger of collision is over.

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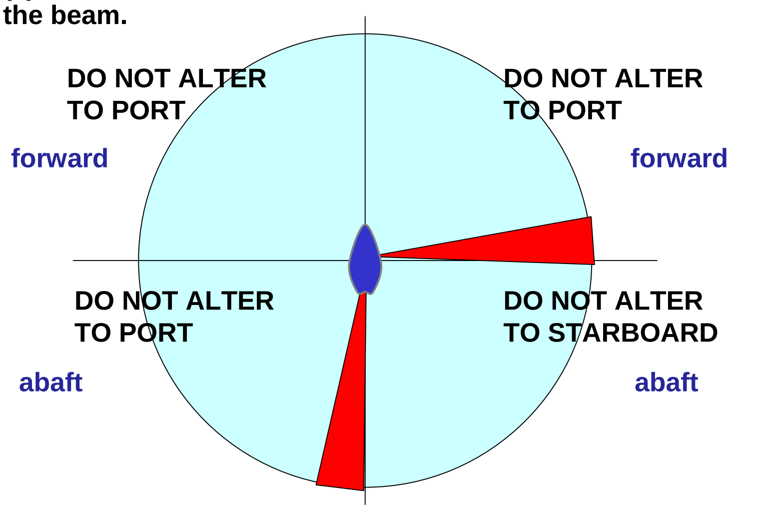

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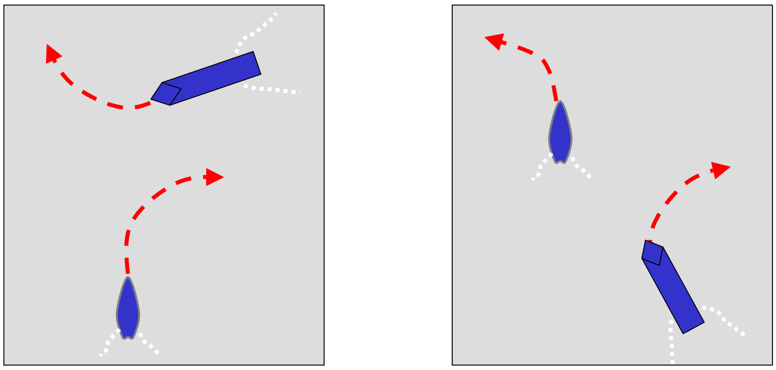

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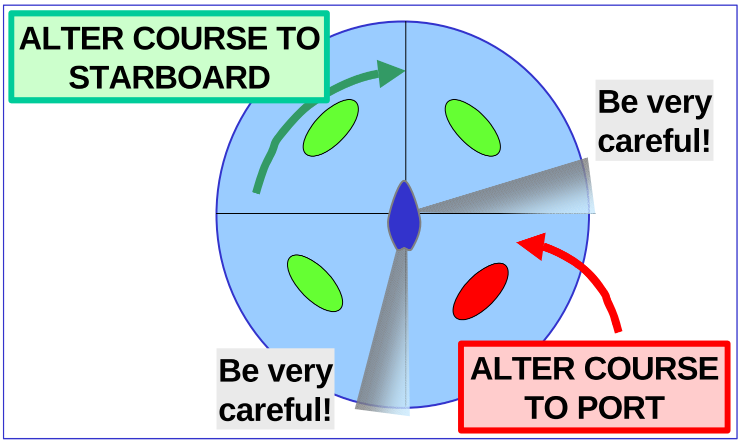

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NOTE there is no mention of overtaking.

even if you are being overtaken it is still your responsibility to take avoiding action

Make a RADICAL

Course Change

in order for it

TO BE OBVIOUS

on Radar

ARPA - Automatic Radar Plotting Aid for Ships

- Calculates and displays Target's Bearing, Range, True Course and Speed, CPA, TCPA.
- ARPA is excellent at tracking all visible targets but ONLY if they are visible on about 50 -75% of antenna rotations.
- It is no use to produce a strong echo only to be missing the next time the antenna goes around.
- If not carrying a good radar reflector, most yachts cannot be tracked on ARPA.
- *As always ARPA will depend on reliable inputs.*

(Mini) ARPA - for Yachts

- 10 targets possible in a list
- Select target on screen with cursor
- Takes a minute to acquire information
- Displays dangerous targets and sounds alarm
- You can set alarm limits for CPA and TCPA
- Needs fast heading compass
- *Don't depend on it!*
- *Inputs can be in error*
- *Not accurate to 0.5 M*

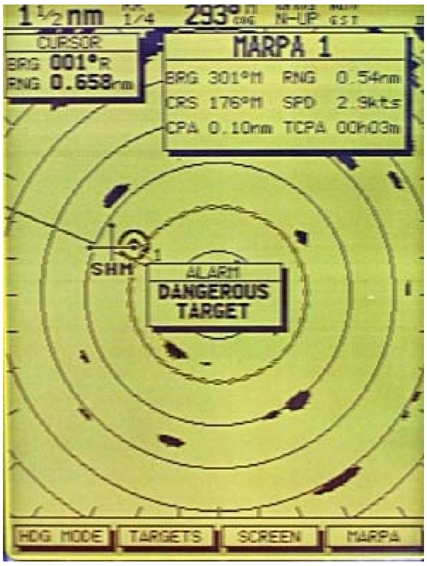
MARPA - Limitations

MARPA is historic
it shows what the target WAS doing
Echoes must be consistent

Acquiring targets may be difficult for:

- Weak echoes, and targets close to land, buoys, or to other large targets
- Rapid manoeuvres by your boat or the target
- Rough seas with sea clutter may bury the target
- Poor heading data
  MARPA relies on accurate heading information.

ARPA



AIS – Automatic Identification System

- AIS is a system for ships to communicate their positions as part of the global maritime safety system (GMDSS).
- Ships over 300 tons carry an AIS system which broadcasts information about the ship
- AIS uses bursts of high speed data on two VHF channels in the marine band. 161.975 (Ch 87) and 162.025 (Ch 88) MHz.
- Using an AIS receiver and a display, you see a radar-like real-time chart of all the large ships manoeuvring in your area.
- Required for VTS systems in ports
- Security was a major motivator in USA post 9/11.
- http://www.nautinst.org/ais/PDF/AIS_Human_Factors.pdf

AIS and Collision Regs

- Ships broadcast their identity, type, MMSI number, position, course, speed and destination so that other ships can take account of their movements.
- Other data is draught, length, cargo, no of passengers…
- Do not rely on this data for collision avoidance!
- AIS does not appear in any part of the Collision Regulations

AIS – Display

AIS - What is broadcast

Class A AIS units broadcast the following information every 2 to 10 seconds while underway, and every 3 minutes while at anchor, at a power level of 12.5 watts.

- MMSI number - unique identification
- Navigation status - "at anchor", "under way using engine", "not under command".
- Rate of turn - right or left, 0 to 720 degrees per minute
- Speed over ground - 1/10 knot resolution from 0 to 100 knots.
- Position accuracy
- Longitude and Latitude
- Course over Ground - relative to true north to 1/10th degree
- True Heading - 0 to 359 degrees derived from gyro input
- Time stamp - The universal time that this information was generated

Class A AIS unit also broadcasts the following information every 6 minutes:

- MMSI number - same unique identification as above.
- IMO number - unique identification (related to ship's construction)
- Radio call sign - Name of ship, 20 characters
- Type of ship/cargo
- Dimensions of ship
- Location on ship where reference point for position reports is located
- Type of position fixing device – GPS options
- Draught of ship - 0.1 metre to 25.5 metres
- Destination
- Estimated Time of Arrival at destination

AIS B Transponder?

Small Craft Users can transmit AIS
Link to GPS and VHF aerials

Information transmitted:
Name of vessel • Position • Speed (SOG) • Heading • Course (COG) • MMSI Number • Call Sign • Vessel dimensions • Type of vessel

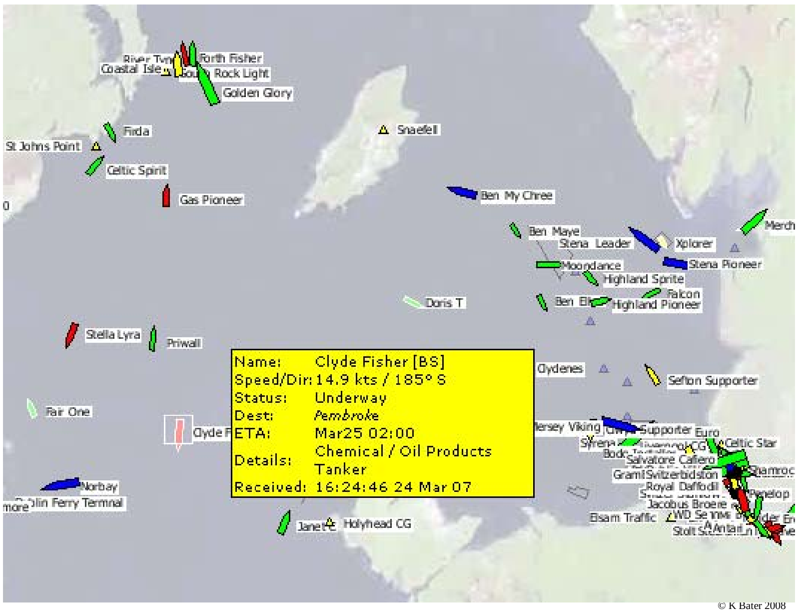
Do not rely on a watchkeeper seeing this on a radar screen

AIS B or Active Reflector?

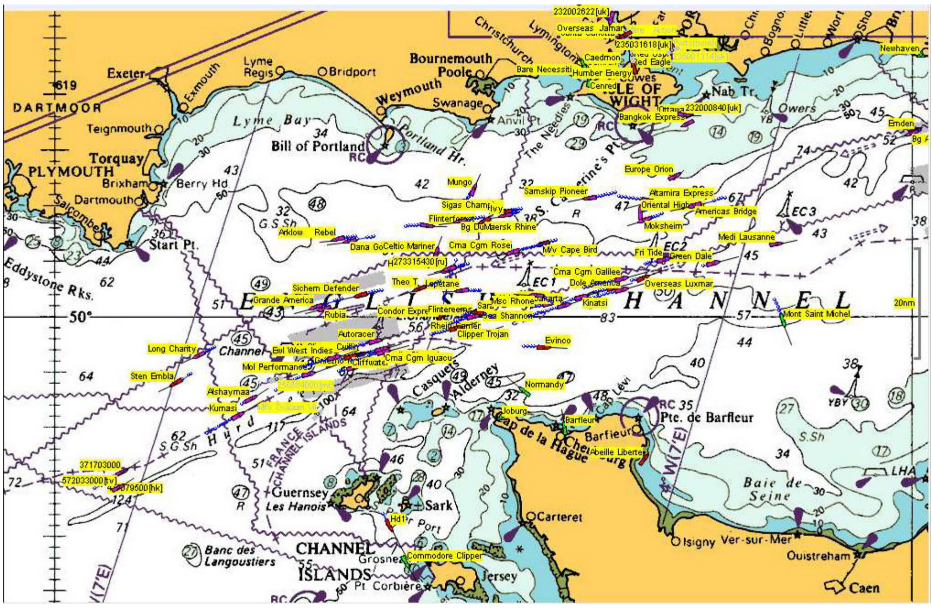
- In busy coastal waters, such as The Solent, the 'active radar reflector' is likely to be a better choice. It enhances your radar echo and improves your chance of being seen by commercial vessels - particularly at night. Also, your enhanced echo will be seen on any radar, cannot be filtered out, and does not need any additional equipment or watch from the bridge watchkeeper.
- Many AIS sets are stand alone and not integrated into navigation suites - so they may not be monitored in busy shipping situations.
- AIS B in busy areas - The Solent, for example - it seems that many vessels filter AIS B out of their AIS picture. They will have it activated for offshore and ocean waters but, on closing the coast, will switch off AIS B responses.
- AIS B is becoming cheaper and more popular, but Southampton VTS often filters it out, or the central Solent picture becomes very cluttered.
- The advantage AIS B has over the reflector, is that you get to see other vessels' information but, remember, if the equipment is not integrated into your navigation suite it is providing CPAs etc using only GPS and 'simple' mathematics.
- Inshore – Sea-me or Echomax
- Cross-Channel - AIS B, as many more ships will have AIS B signals activated in those areas and your AIS message should be seen.

(Deputy HM, Southampton)

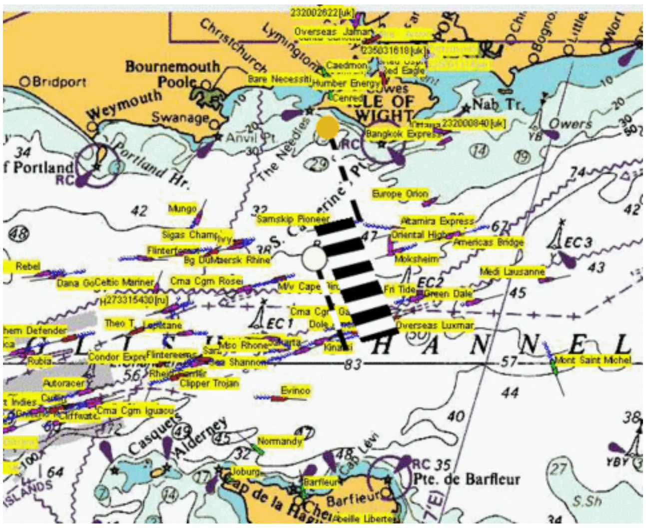
AIS Live



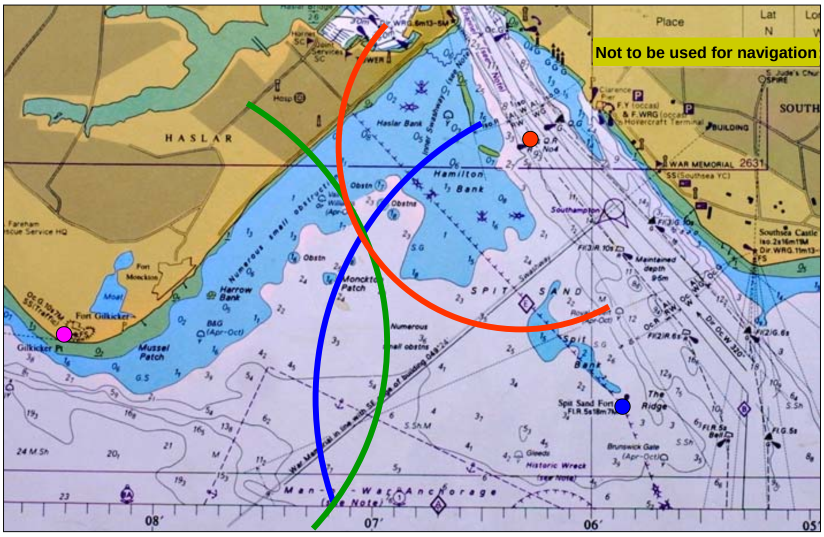
AIS Display



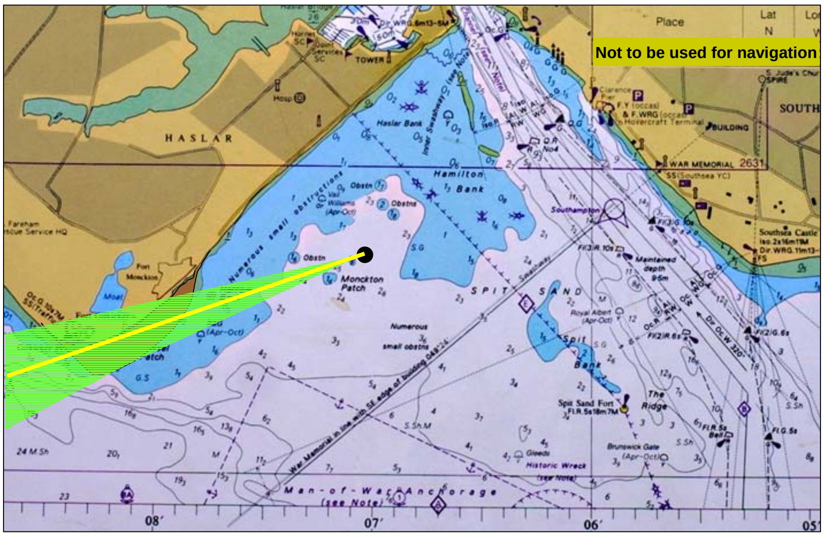
AIS Display



Position fixing by Range



Position fixing by Bearing



Fixing Position with Radar

Order of preference for accuracy to determine position:

1. Visual observation (Hand bearing compass) of object's relative bearing and distance determined by radar
2. Radar range to two or more objects
3. Radar range and radar relative bearing on the same object
4. Radar relative bearings to two different objects
5. To convert relative to true:

Bearing	**265**	**Relative**
Heading	**317**	**Compass**
Add	**582**	
Subtract	**360**	**Compass**
	222	**Compass**

Apply Variation and Deviation to find True Bearing

Fixing Position

Similar guidelines apply as with visual fixes:

1. Identify the mark accurately on the screen and the chart
2. Measure range as accurately as possible – shortest range scale
3. Measure as quickly as possible
4. Use marks that are well spread out
5. Use closer marks
6. Measure ranges that change quickly last

- The strongest echo is not necessarily the highest mountain.
- The first echo is not necessarily the highest object above the radar horizon.

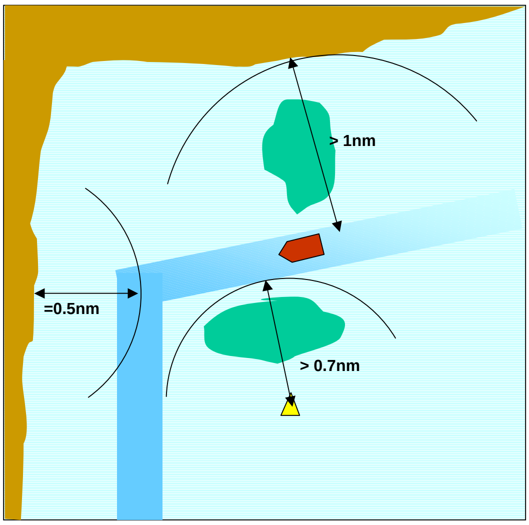
Pilotage

- Radar –
  is not electronic Navigation
- Radar cannot tell you where you are
- It can display the location of certain fixed and moving objects in relation to your vessel
- Radar –
  is electronic Pilotage

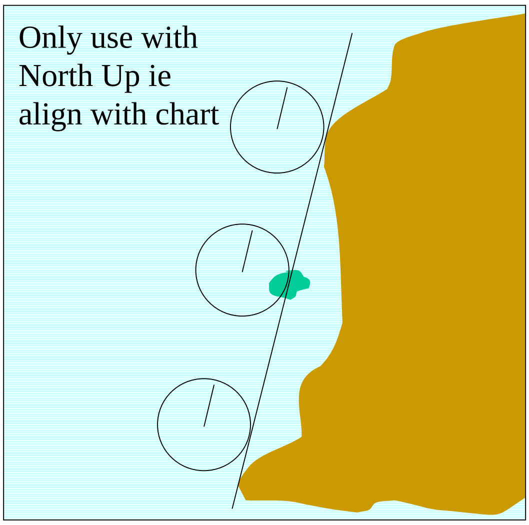
Pilotage

- ‘Eyeball’ Pilotage
  - Stay in a channel
  - Buoy hopping – track each buoy
  - Shallow water does not show!
  - Watch the current
- Clearing Ranges (like clearing bearings)
  - Use the VRM to stay 1.0 mile off the coast
- Parallel Indexing

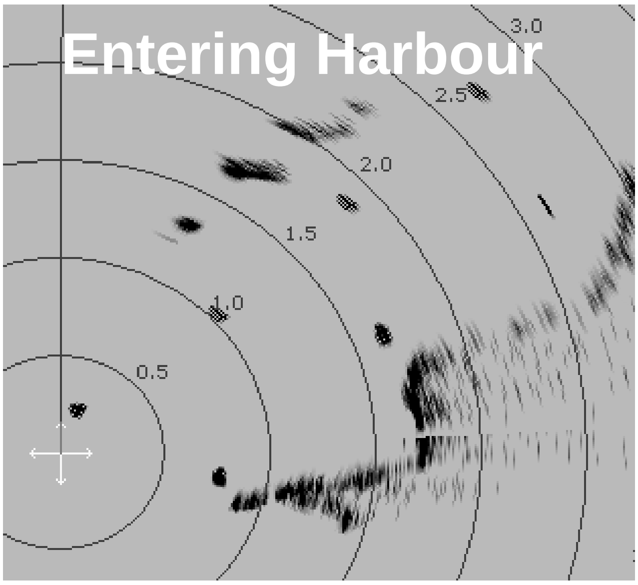
Clearing lines



Parallel Indexing



Pilotage



Raymarine Radar Set

- Most controls are 'soft keys', one or two levels down.
- All the usual functions are available

FMCW RADAR - How it works

(Frequency Modulated Continuous Wave)

- **Conventional radar 'bounces' pulses off a target.**
- **FMCW radar broadcasts continuously, but modulates the frequency of transmissions.**
- **Range is measured by the difference in frequency between transmission and reception - the bigger the difference the longer the range**

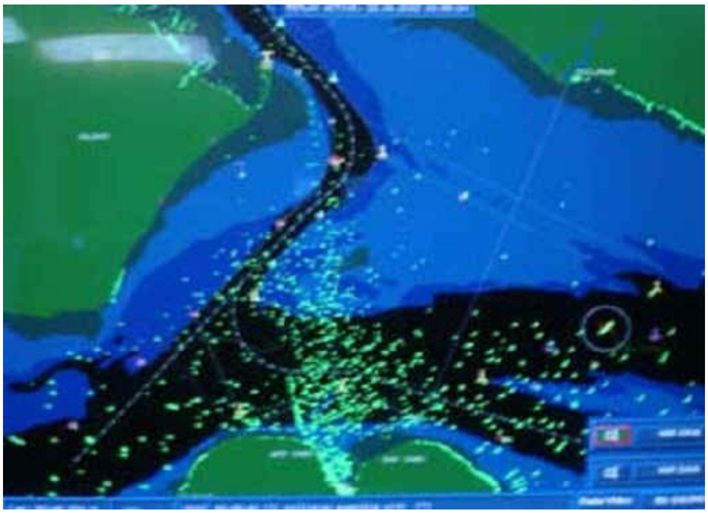
Advantages:

- **No minimum range - The much lower transmitted power means that the receiver can stay on and receive echoes continuously.**
- **Clearer picture (discrimination) - each target produces an echo**
- **Clearer picture (less clutter) - virtually immune to rain clutter and less susceptible to sea clutter**
- **Instantly available - no warm-up time**
- **User friendly - simpler controls**
- **Lower power consumption, Lower radiation.**

Finale

1610	Uninstall simulator software	
	Certificates	
1615	Wrap up, feedback forms	Discussion
1630 ish	END	

What is this?



Books

- Adlard Coles Book of Electronic Navigation (Paperback) by Tim Bartlett
- Superyacht Master by Robert Avis

Question 1 Head Up, Range 5M, Heading 180º, speed 10 Kn

Time	Range	Bearing
1010	4.0 M	320°
1016	3.0 M	320°
1022	2.0 M	320°

Is there a likelihood of collision?	Yes
What is the other vessel's true course?	250º
What is the other vessel's speed?	7.0 Kn

Question 2 Head Up, Range 5M, Heading 030º, speed 5 Kn

Time	Range	Bearing
1301	3.6 M	320°
1307	2.3 M	312°
1313	1.2 M	292°

Is there a likelihood of collision?	No
What is the other vessel's true course?	168º
What is the other vessel's speed?	9.0 Kn

Question 3 Head Up, Range 10 M, Heading 355º, Speed 20 Kn

Time	Range	Bearing
2050	9.2 M	282°
2056	6.8 M	283°
2102	4.4 M	270°

Is there a likelihood of collision?	No
What is the CPA?	1.0 M
What is the TCPA?	10 mins
What is the other vessel's true course?	060º

Question 4 Head Up, Range 10 M, Heading 355º, Speed 20 Kn

Time	Range	Bearing
1110	9.0M	008°
1116	8.0 M	009°
1122	7.0 M	009°

What is the CPA?	0.4M
What is the other vessel's speed?	10 Kn
Is there a likelihood of collision?	??
What light will you see?	White

Question 5 North Up, Range 5M, Heading 110º, Speed 5 Kn

Time	Range	Bearing
1440	4.6 nm	064°
1446	2.9 nm	066°
1452	1.2 nm	077°

Is there a likelihood of collision?	??
What is the CPA?	0.8 M
What is the other vessel's true course?	225º
What is the other vessel's speed?	15.0 Kn

Question 6 North Up, Range 5M, Heading 110º, Speed 5 Kn

Time	Range	Bearing
0212	5.0 nm	002°
0218	3.9 nm	359°
0224	2.7 nm	354°
0230	1.8 nm	334°

Is there a likelihood of collision?	No
What is the CPA?	0.9 M
What is the other vessel's true course?	210º
What is the other vessel's speed?	15.0 Kn
What is the CPA if we turn 45° to Port?	1.2 M

***My radar course notes are here* (PDF 5Mb)**

Loss of the Ouzo - MAIB and MCGA documents

Ouzo_synopsis.pdf

Ouzo MAIB full reports

Ouzo Flyer to Leisure industry.pdf
Moody 47 Wahkuna and MV Vespucci report
RSYC Radar Discussion
CHIRP Feed Reports and forms *CHIRP is a confidential incident reporting system - you can use it to report safety incidents.*
Radar plotting sheet.pdf
Qinetiq report on effectiveness of radar reflectors
Pat Manley on reflectors
Click here for live AIS feeds:
http://www.shipais.com/currentmap.php?map=default *and* *http://www.marinetraffic.com/ais/*
FMCW Radar: *http://www.timbartlett.co.uk/briefing.html#fmcw_radar*

Conclusions

- The Sea-Me is a good example of an active reflector (RTE) exceeding the requirements of the current and future ISO 8729 at heel/elevation angles of up to 15˚, it is also very small and light. Drawbacks are that it requires power to operate (which on a yacht is at a premium), it will only operate at X-Band and will offer no performance at S-Band.
- The POLARef shows excellence is possible but at a price, technically it just fails meet current ISO8729 [1] or its replacement [2]. The main drawbacks are it is very costly at £2000 and its quite heavy at around 5kg. It is currently used as a radar measurement standard although it could possibly be re-engineered for commercial production which could reduce the price.
- The Large Tri-Lens performs well especially at larger angles of heel and elevation, it just falls short of ISO8729 [1] having a peak RCS of 8.5m2 but otherwise performs well. It is the heaviest reflector supplied for test at 5.5kg and costs around £300.
- The Echomax 230 narrowly failed to meet ISO8729 during this testing, but showed good peak and average RCS performance. The reflector is reasonably priced at £130 and weighs 2.4kg; the main drawback was a RCS drop-off above an elevation angle of 10˚.
- The Firdell Blipper 210-7 narrowly failed to meet ISO8729 during this testing, but showed good peak and average RCS performance. The Blipper is priced at £130 and weighs 1.8kg; the main drawback was a RCS drop-off above an elevation angle of 10˚.
- The Standard Tri Lens does not meet ISO8729 as the peak RCS was too low at 4m2. However its consistent RCS response outperformed most of the other reflectors when heeled over beyond 10˚; it is reasonably priced at £130 and weighs 2.5kg.
- The Plastimo 16" octahedral is inexpensive at £16 and lightweight at 0.65kg but failed to meet ISO8729 in either tested position. It had reasonable peak and average performance averaging around 2m2 but had wide nulls which kept its stated performance level down. Other drawbacks are that its mounting arrangement is by suspension only (often in an unfavourable position) and could be subject to damage.
- The Davis Echomaster failed to get close to ISO8729 during this testing. Its peak RCS is too low at 7.5m2 and its average performance is only 1.75m2. This reflector is priced at £60 and is lightweight; it can be mounted on a rod as well as by suspension (in the correct catch-rain position).
- The 4" tube reflector performed very poorly.
- It is concluded that either the active Sea-Me, POLARef and the Standard or Large Tri-Lens radar reflectors are the best reflectors at heel and elevation

Reflectors – SOLAS Ch 5 Reg 19

- Regardless of your vessel's size, if by any practical means you can carry a radar reflector then you must carry one:
- if over 15m you must carry an IMO-compliant one;
- if below 15m, you must carry the best you can.
- In either case, it is your responsibility to have reason to believe that it works.
- Make no mistake: be in a collision with a larger vessel whilst not carrying a correctly installed reflector and, whether or not you survive the experience, the subsequent Enquiry will place much of the blame on you.

Reflectors for Small Craft

SOLAS Chapter V Regulation 19

Regulation 19 para.2.1.7 requires radar reflectors to be carried, where practicable, by ships under 150 GT. For UK-flagged this includes pleasure vessels.

The following notes gives further guidance on the choice of a radar reflector for small vessels:

2.) An important parameter of a radar reflector is echoing area, or equivalent radar cross-section, as this determines the amount of the radar energy which is reflected back. Reflectors to the above standards have a maximum echoing area of at least 10 m^2 with a minimum echoing area of at least 2.5 m^2 over 240° of azimuth.

4.) Owners and operators of craft vessels of less than 15m in length should fit reflectors with the greatest echoing area practical. In all cases, the reflector should be mounted as high as possible for maximum detection range, following the manufacturer's instructions.

5.) It should be noted by Master of all vessels that even the 10 m^2 reflectors referred to above will be difficult to detect in sea clutter on radar displays. Masters of all vessels are reminded that this should be taken in to account when setting lookouts and determining safe speed as required by Rules 5 and 6 of the IRPCS

6.) Radar target enhancers can be considered as “other means” in the Regulation. These have a larger equivalent radar cross-section for a physically smaller size than radar reflectors and produce a response on a radar display, which is stronger and more consistent, but does not increase the apparent size of the target. Some navigation buoys are being fitted with electronic radar enhancers and seafarers should be aware this improves their detection range. Mariners should note that radar enhancers currently available do not operate in the radar “S” band.

Do you have a sea-stabilised radar?

On a day when there is no wind:

1. Choose somewhere where the tide is running.
2. Target a fixed object, such as a buoy.
3. Stop the boat and drift with the water.
4. Locate the buoy on the radar, and choose a range scale to fit. Acquire MARPA target, and wait.

- If MARPA shows the buoy is stationary (or virtually stationary given instrumentation errors), and the radar shows an apparent speed for your vessel, the radar is ground stabilised.
- If MARPA shows that the buoy appears to be moving at the speed of the tide, but in the opposite direction to the tide, then you are sea stabilised, which is the correct setting to run MARPA for collision avoidance. The MARPA data box should detail this info as well

Plan for Today - Details

Know about
Understand
Can do

1. Switching on and setting up

- How a radar set measures distance
- How a radar set measures bearing
- The main components of a radar set
- *The limitations of small-craft radar*
- **Switch on a small-craft radar set and adjust its brilliance, contrast, gain, range and tuning**

2. Understanding the radar picture

- How antenna size and frequency affect beam width
- How range, pulse length and PRF are varied
- What reflects best
- Fog and rain effects
- *The effect of beam width on discrimination*
- *The effect of pulse length on discrimination*
- *The effect of side lobes, blind arcs, shadow sectors, ghost images and radar horizon*

3. Refining the picture

- The cause and cure for sea clutter
- The cause and cure for rain clutter
- The cause and cure for interference
- Echo stretch / expansion
- The dangers associated with clutter clearance tools
- *Head Up, Course Up, and North Up modes*
- **Adjust the sea clutter and rain clutter controls to suit prevailing conditions**

4. Radar Reflectors

- Desirable characteristics
- Radar cross section and how it is measured
- Passive reflector types
- Active reflector in common use (RTE, Racon, SART)
- *The limitations of passive radar reflectors*

5. Collision avoidance

- The principles of relative motion
- Automatic radar plotting aids - MARPA
- *The implications of IRPCS Rules 5, 6, 7, and 19 (lookout, safe speed, risk of collision, restricted visibility)*
- *The practical limitations of small craft radar*
- *Avoidance strategies*
- **Assess the risk of collision with another vessel**
- **Assess the closest point of approach of another vessel, and determine whether it will pass ahead or astern**
- **Assess the course and speed of another vessel**
- AIS - Automatic Identification System

6. Fixing Position by radar

- The principles of a three point fix
- Selecting good landmarks for a three point fix
- *How to take and plot a position fix using the EBL*
- *Limitations of the EBL for position fixing*
- **Plot the vessel's position on a chart by using the VRM**

7. Pilotage by radar

- "Eyeball" pilotage by radar
- The limitations of "eyeball" pilotage
- *The principle of parallel indexing*
- **Simple pilotage plans using clearing ranges**