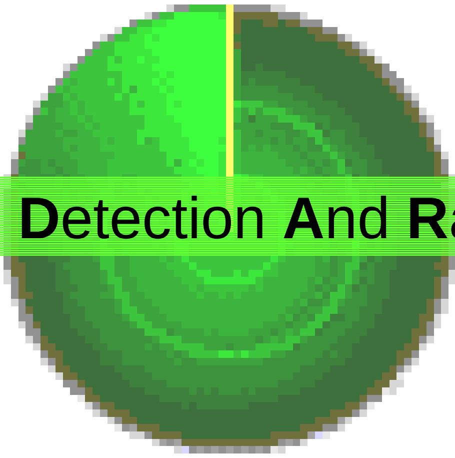
Training Centre

Skysail

Training

R A D A R

RYA 1 Day Course



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

Keith Bater

SKYSAIL TRAINING

www.skysailtraining.co.uk

Shorebased Courses

- RYA Radar
- Basic Navigation
- Day Skipper
- Yachtmaster

www.irpcs.com

SKYSAIL TRAINING

www.skysailtraining.co.uk

Skills Charts

- VHF Procedures
- Radar
- Day Skipper
- Chartwork
- Weather at Sea
- ColRegs Shapes and Lights
- Signals - Mayday, SOLAS, Flags, IPTS
- CEVNI Symbols and Lights

What do we need to know?

This course is not about the technology of Radar.

It is about how to:

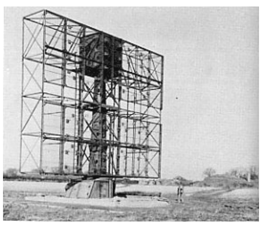
1. Get a Radar picture
2. Understand the picture
3. Use Radar information for better decisions
4. Be aware of the limitations of Radar

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 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

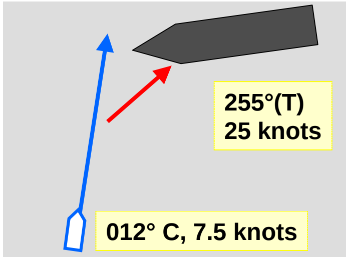
© K Bater 2008

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).

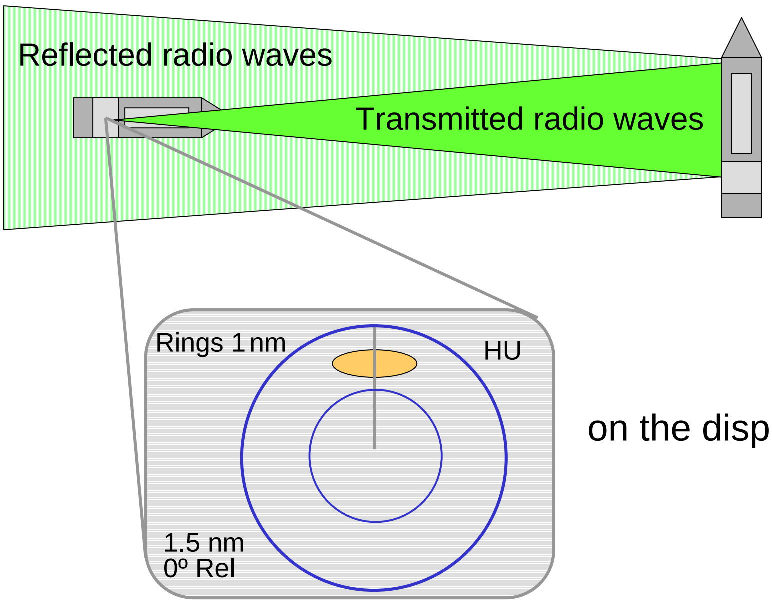
Factors contributing to the accident

- 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



on the display

Radar Facilities

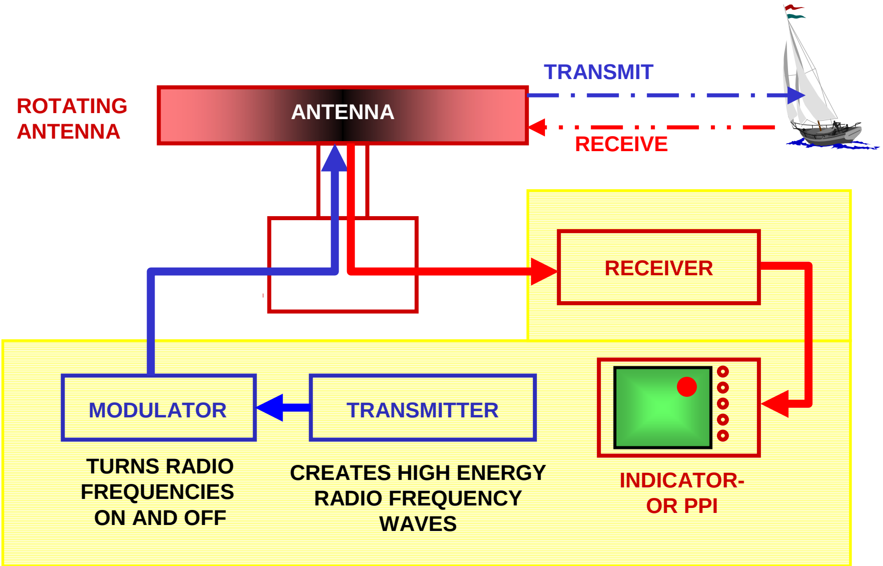
- **DETECT**
  - by transmitting microwave pulses and receiving reflections from contacts
- **RANGE**
  - Measure time for a pulse to hit contact and return to receiver.
    Distance = (Speed x Time) / 2
- **BEARING**

  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

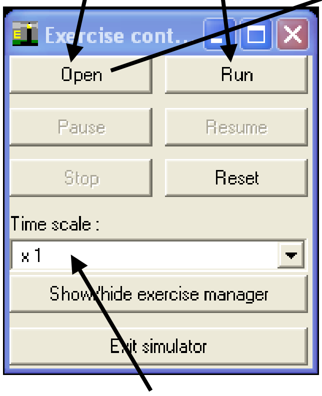
Warm up - 10 seconds

Tx = Transmit

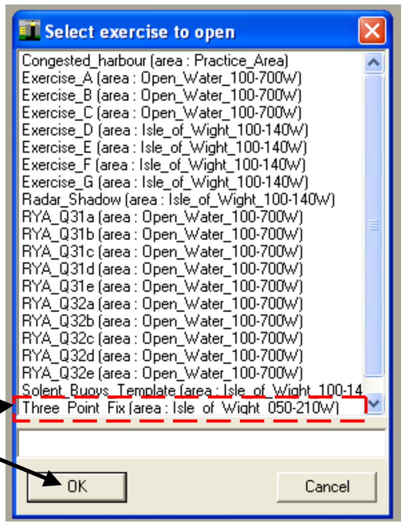
Radar Simulator
Selecting an exercise

Exercise Control

Open Run

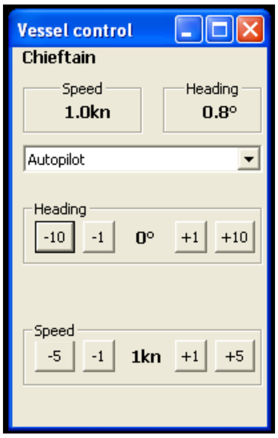


Speed up time

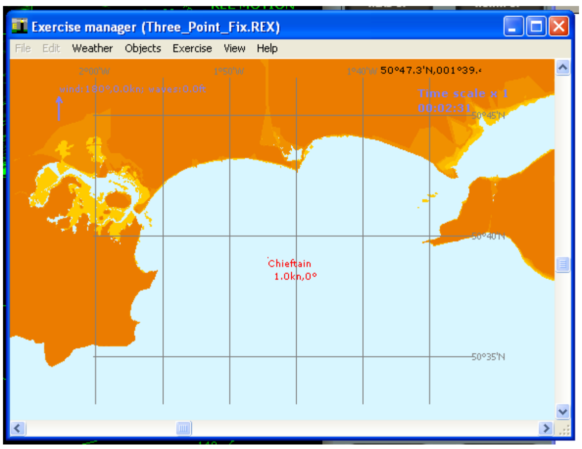


Radar Simulator

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, causes ‘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


Head-Up
Relative Motion
Rings
Heading
026
Speed
0.0
Tide Set
357
Tide Drift
0.0
Log
Trip
SEA
HBR
OSH
MAN
GAIN
AUTO
MAN
TUNE
AUTO
MAN
FTC
ON
OFF
RAIN
ON
OFF

Gain 3 - LCD Radar Display

When will you turn on the Radar?

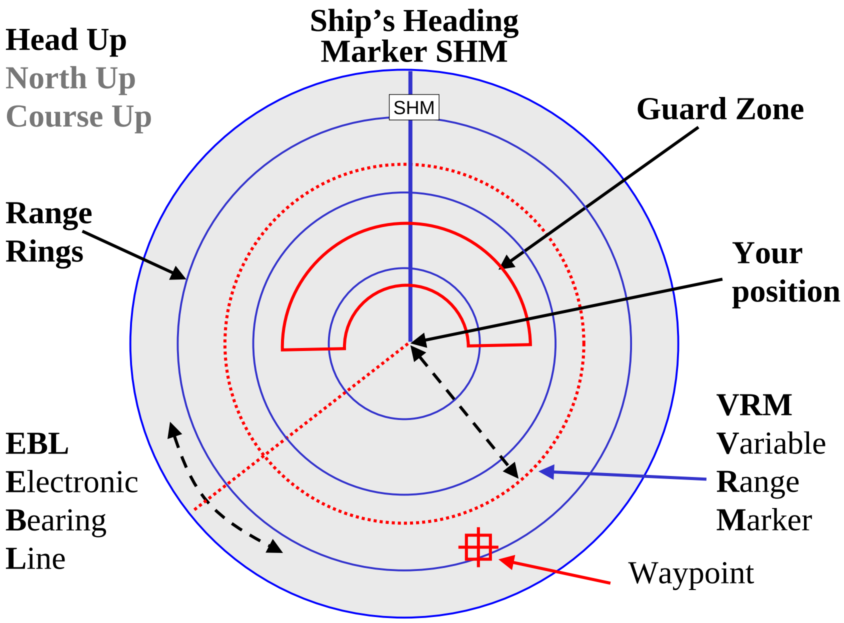
Rule 5 Lookout

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

- Interference Rejection - reduces mutual radar interference when two boats with radar are close. Normally switched on, but if switched off will show the presence of the other boats.
- 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.

Clutter

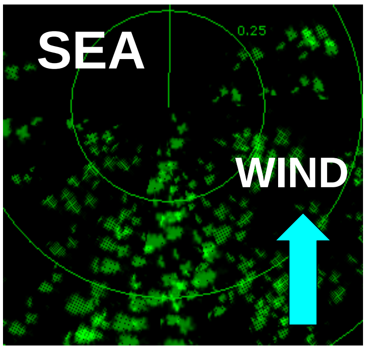
'Clutter' is real echoes returned by targets which are by definition uninteresting to the radar operator.

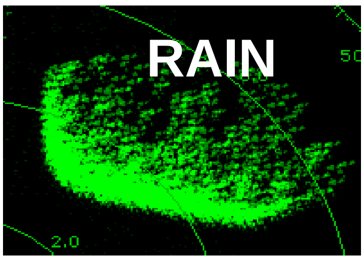
These include natural objects such as sea, rain, fog, and atmospheric turbulence.

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).

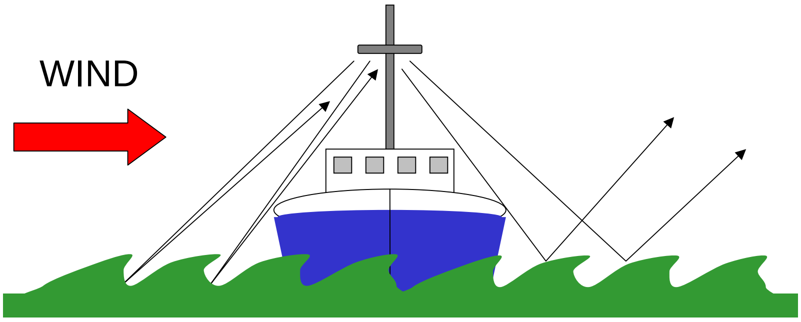
The clutter echoes can be reduced with clutter controls, but this may also eliminate real targets.





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

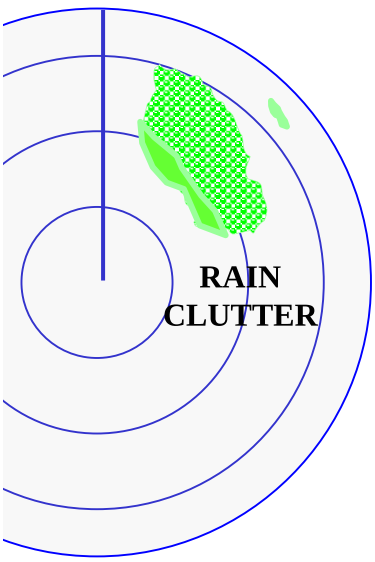


Rain Clutter

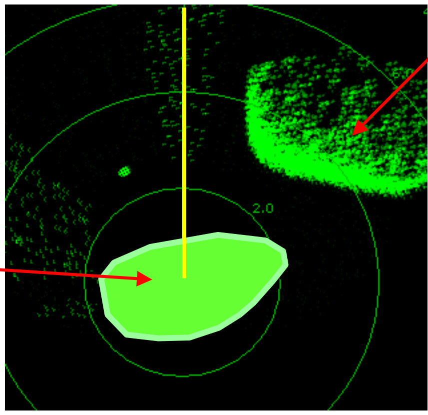
Heavy rain reduces range by 50%; fog by 30%

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

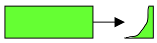
Rain Clutter

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



Wind

What affects Accuracy?

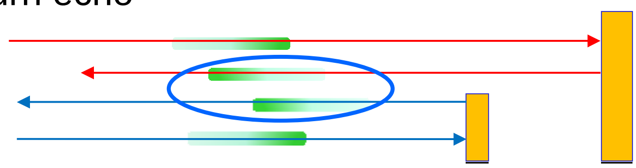
- **Power Output**
  - **Yacht 1 - 5 Kw, Ships 25 - 50 Kw**
- **Receiver Sensitivity**
- **Pulse Frequency**
  - **9.4 GHz 3cm 'X Band' (yachts)**
  - **3 GHz 10cm 'S Band' (ships)**
- **Horizontal Beam Width - Antenna size**
  - **120cm antenna - 2°; 30cm antenna - 8° (Vertical beam height 25 - 30°)**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

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

Accuracy of Range

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

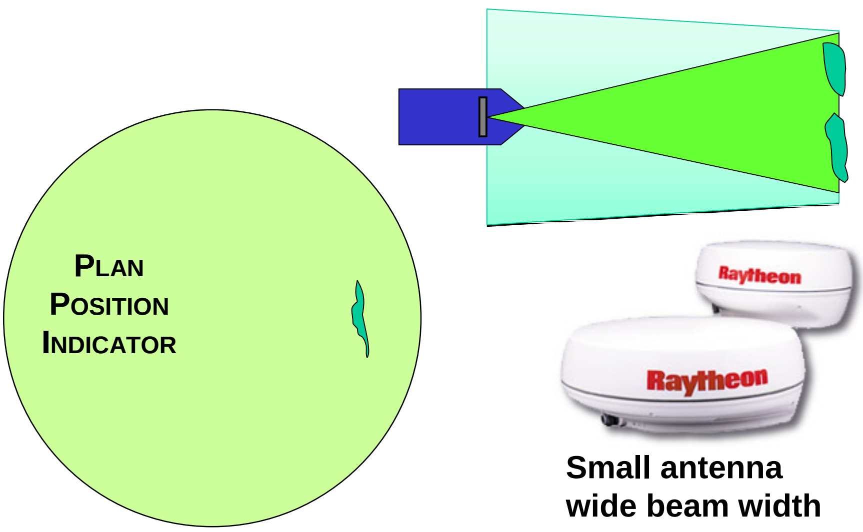


- Long range = Low Pulse Repetition Frequency; To increase range - longer pulse, longer PRF
- Range Control does this automatically

Resolution in range

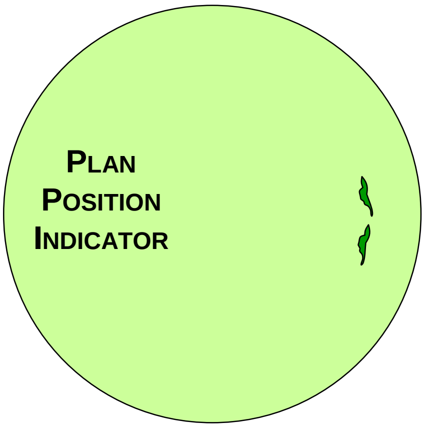
Range Nautical miles	Pulse length μs	PRI μs	PRF Hz	Resolution in range Metres
< 0.75	0.08	444	2250	24
0.75 - 6	0.25	667	1500	75
> 6	0.70 = 210 metres	1333	750	210

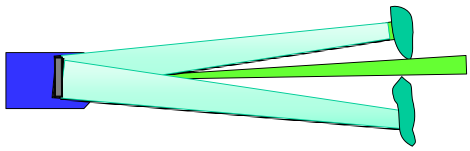
Beam width is more important than power



Small antenna
wide beam width

Beam width is more important than power





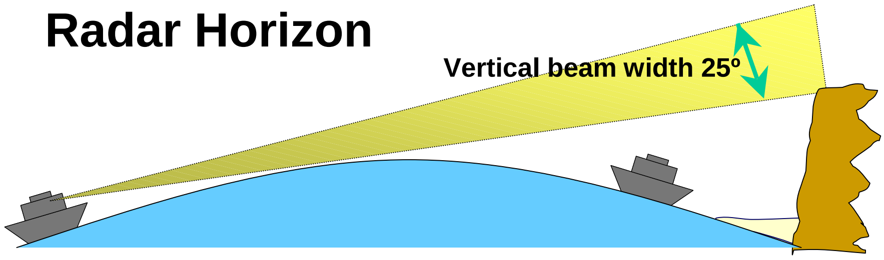
Large antenna
narrow beam width

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 =

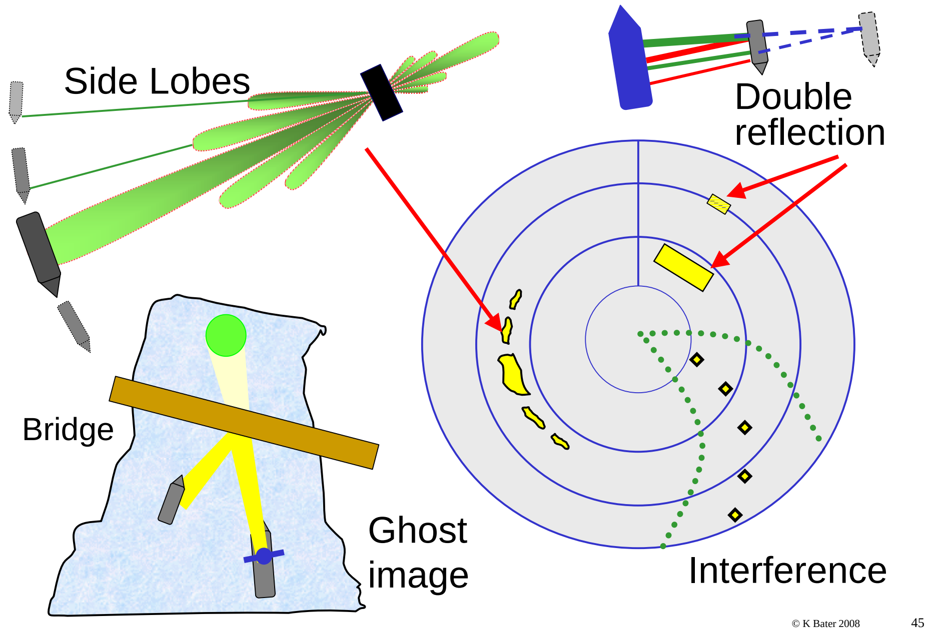
$2.21 \sqrt{\text{Antenna height m}} + 2.21 \sqrt{\text{Target height m}}$

- **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

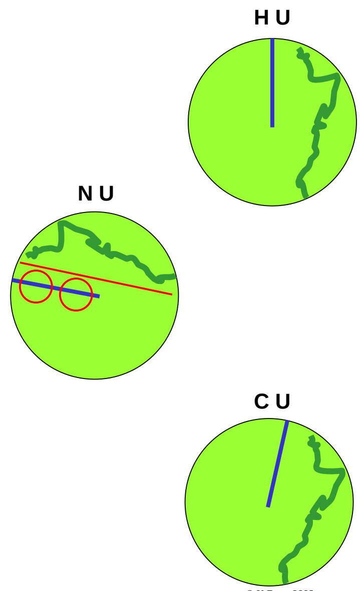
- Obstructions on your boat - blind arcs
- Radar cannot see round corners
- Shadow areas - small objects merge with large objects
- Side lobes produce echoes from good reflectors
- Double reflection produces second image at twice the range

False Images - reduce Gain



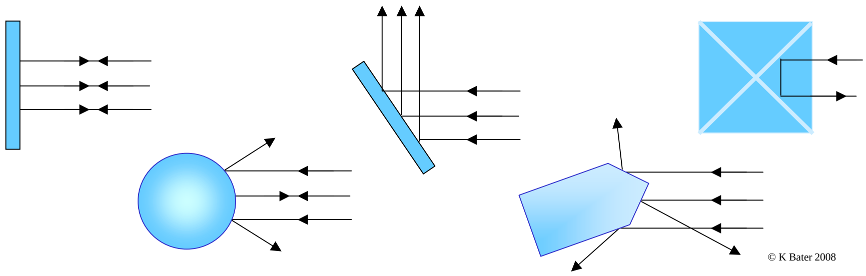
Head Up, North Up, Course Up

- 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



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

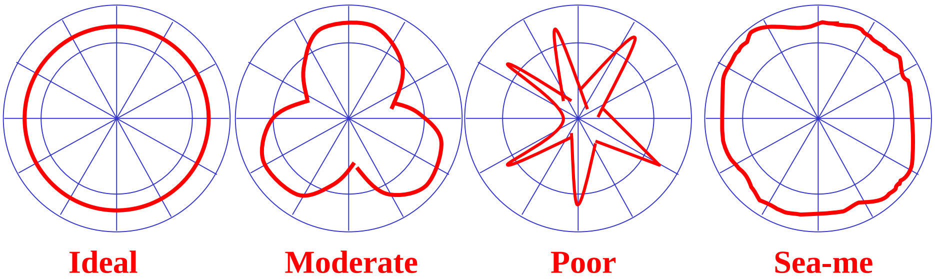


The Stealth Motor Yacht

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

- Octahedral - Rain catcher mode Peak RCS <10
- Lens - like a catseye – Tri Lens RCS < 5
- Stacked array
  Echomax Peak RCS 10 – 25, 6.5 at 15° heel
- Tubular - Mobri 2 - 4 in 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 type - detects your radar pulse and sends radar signal back to you

- Sea-me and Echomax Radar Target Enhancers: RCS = 63

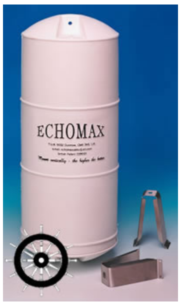
  Can also sound alarm when a radar pulse is received.

  X Band and S Band

- Racon RTE - Morse letter

- SART RTE - Search & Rescue Transponder

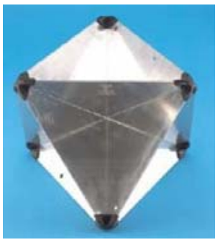
Reflectors



Echomax

Blipper

Mobri Tubular



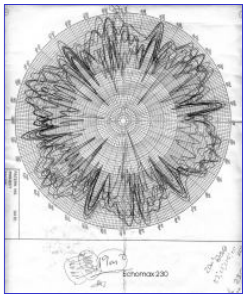
Octahedral

Sea me RTE

Tri Lens

Davis Octahedral

Echomax



Polar Diagram

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 2m²
- The Sea-Me is 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)**

Reflectors - Conclusions

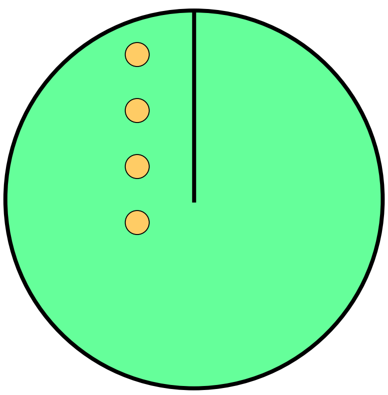
- The revised ISO standard will result from the new IMO requirement
- This new IMO resolution recognises that consistency of response is more effective in raising the probability of radar detection than single high peaks.
- This is defined as a Stated Performance Level (SPL) and is required to be maintained at up to 10 or 20 degrees of heel
  (two classes recognising the stability differences of power and sailing vessels)

Radar Display - Relative Motion

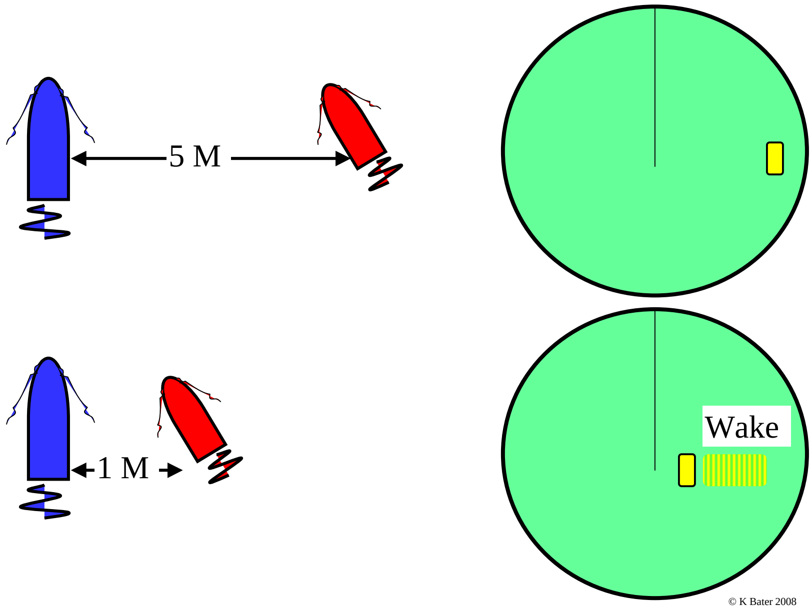
- Own boat position is fixed - usually at centre of screen
- All radar target echoes move with relative motion across the screen
- Relative motion = sum of own boat's true motion through the water and target's true motion through the water
- Used by 90% of mariners

Relative Motion

What is the trail of a fixed target?



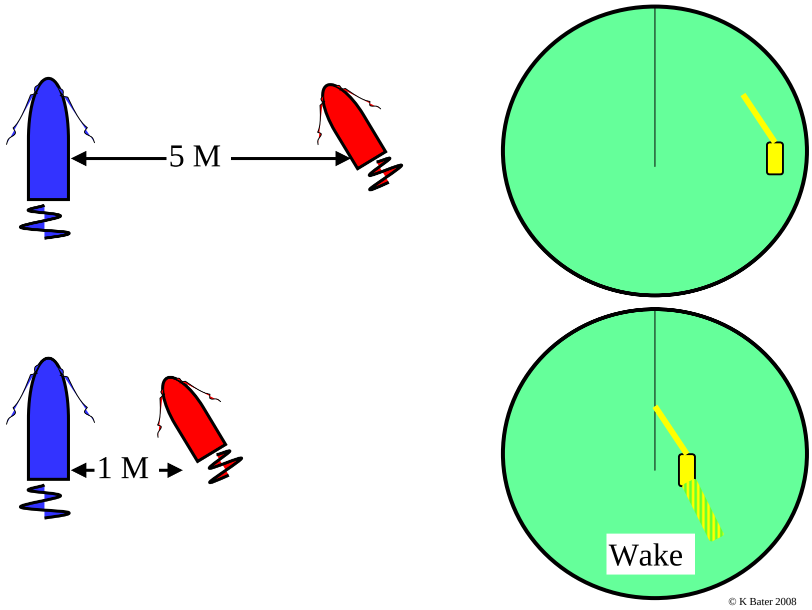
Relative Motion



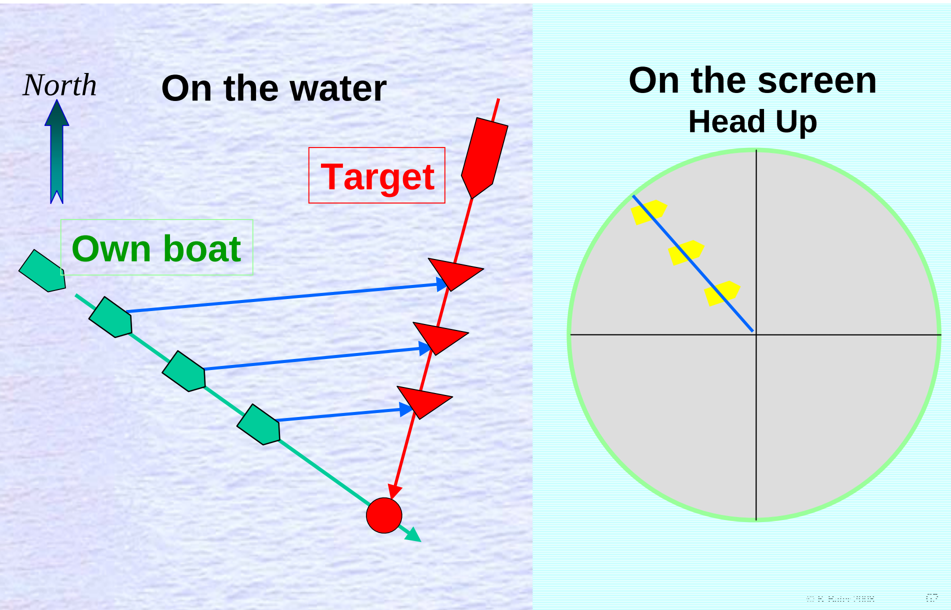
Radar Display True Motion

- 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



True vs Relative Motion



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?

Sea & Ground Stabilised

- To be "Sea stabilised" your radar must use inputs for heading from an onboard magnetic or gyro heading sensor source and speed from a speed through the water transducer/log instrument or Doppler sonar. Both need to be accurate (ie fast heading compass) to provide good collision avoidance data.
- Conversely a radar using GPS COG (course over the ground) and GPS SOG (speed over the ground) is "Ground stabilised" because the readings are in relation to the Earth.
- Collision avoidance should always use "Sea stabilisation" because boats/ships at sea (vessels) usually make way in a mass of water (the sea) which is itself moving over the ground for the majority of the time (i.e. tidal flow).
- Using "Ground Stabilised" radar, any CPA (closest approach) calculation done either manually, automatically by MARPA or by computer will only be correct if all the sea between you and the target vessel remains stationary relative to the ground for the whole period of the situation, i.e. no tidal flow, no river estuary flow influence and no wind created current.

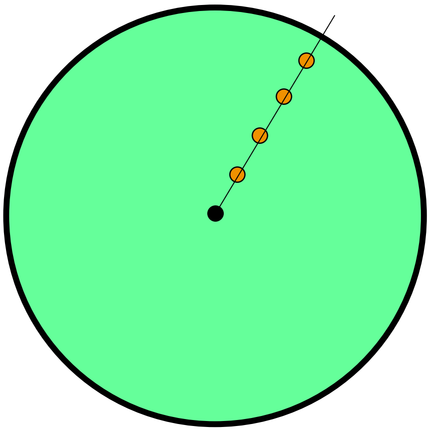
Do you have a sea-stabilised radar?

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

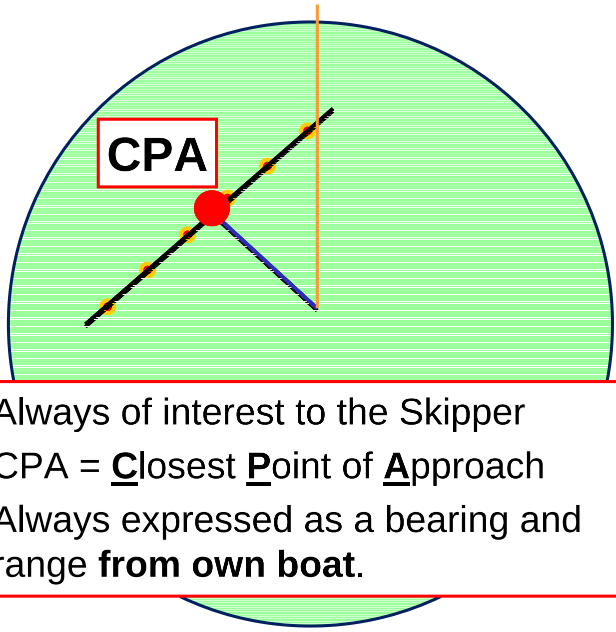
Collision Avoidance



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

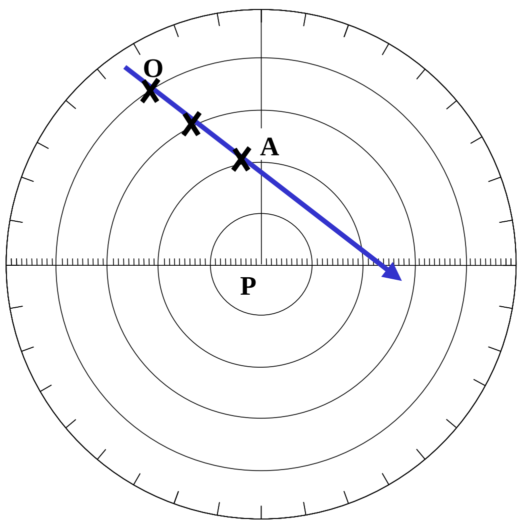
CBDR = Constant Bearing Decreasing Range

Closest Point of Approach - CPA



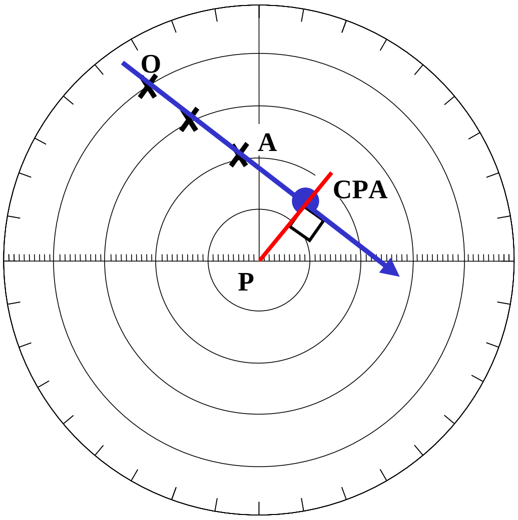
- Always of interest to the Skipper
- CPA = **C**losest **P**oint of **A**pproach
- Always expressed as a bearing and range **from own boat**.

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



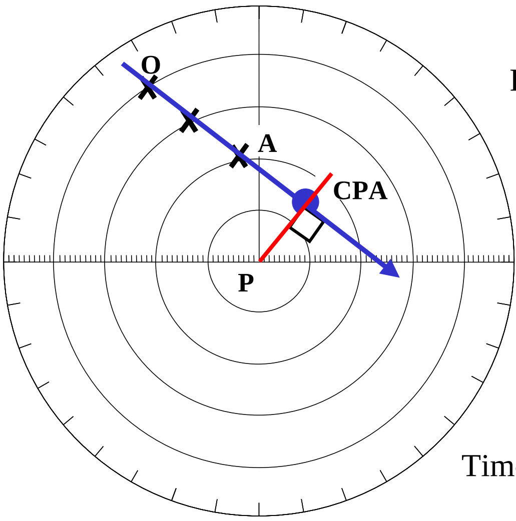
1. Plot target position X at 6 minute intervals (= 0.1 hour)
2. First plot = O (Original)
3. Last plot = A (Actual)
4. Draw O - A the blue line past P the centre of the plot (your position)

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* time from O to A

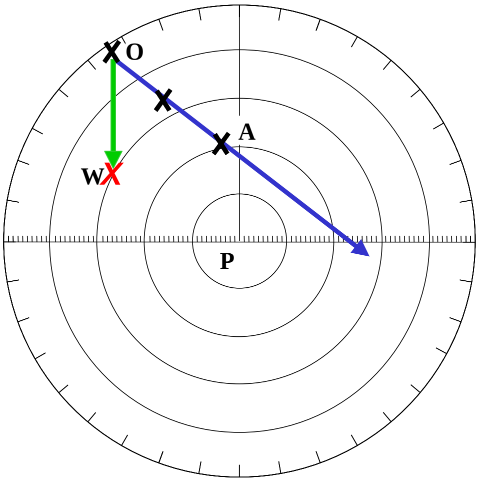
In this case time from O to A = 12 minutes = 0.2 hrs

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)

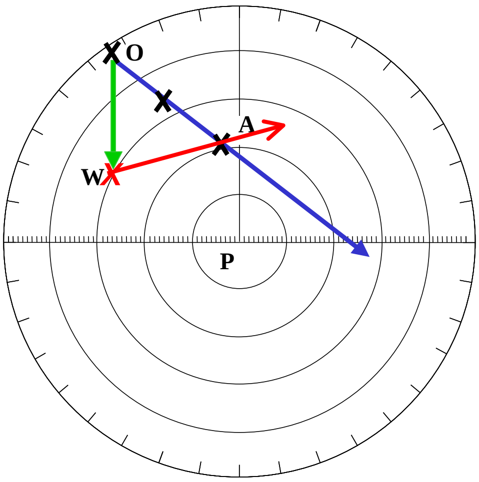
This gives the RELATIVE COURSE of the target

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.

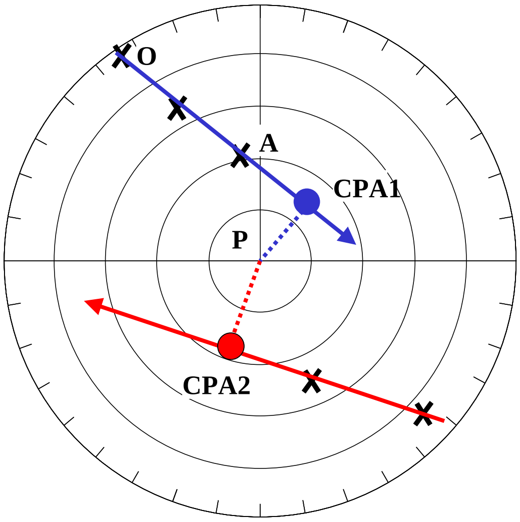
When the target reaches A the buoy will be at W, where A – W is our speed

The TRUE COURSE of the target is W to A

The TRUE SPEED of the target is

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

Combined Plot



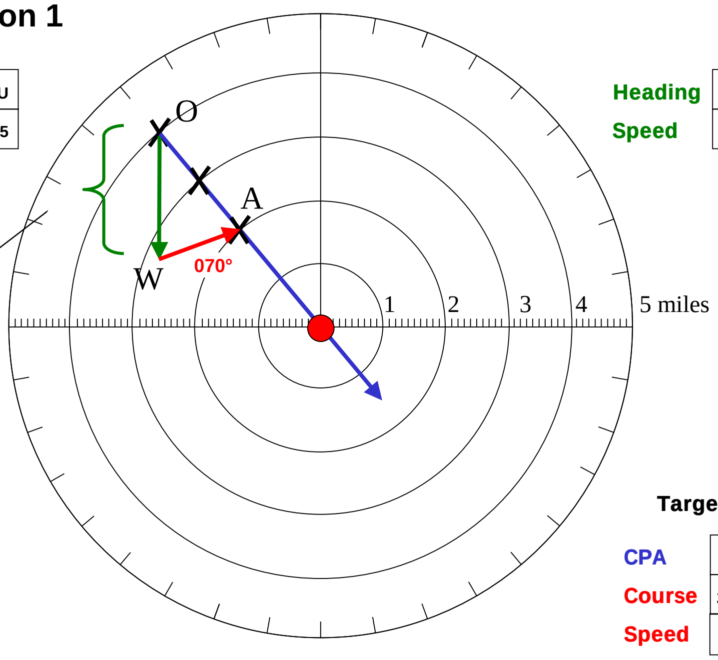
Target crossing ahead

Target crossing astern

Question 1

Mode	HU
Range	5

Heading	180°
Speed	10



Distance you travel in 12 minutes

= 10 x 1/5

= 2 miles

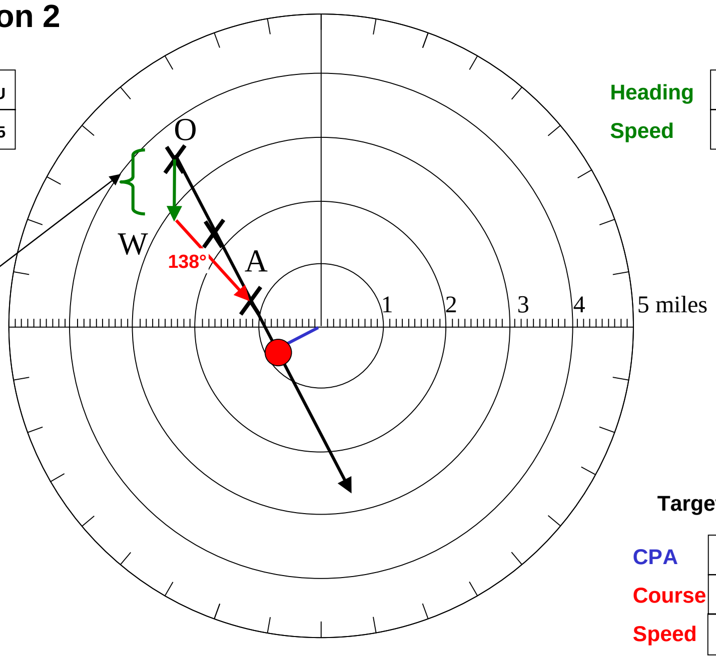
Target

CPA	0
Course	250°
Speed	7.0

Question 2

Mode	HU
Range	5

Heading	030°
Speed	5



Distance you travel in 12 minutes

= 5 x 1/5

= 1 mile

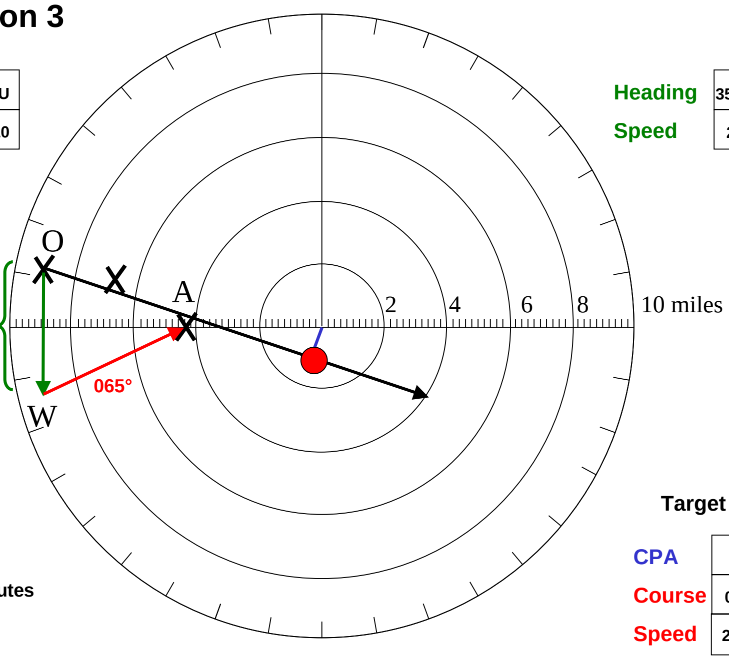
Target

CPA	0.7
Course	168°
Speed	9.0

Question 3

Mode	HU
Range	10

Heading	355°
Speed	20



Distance you travel in 12 minutes

= 20 x 1/5

= 4 miles

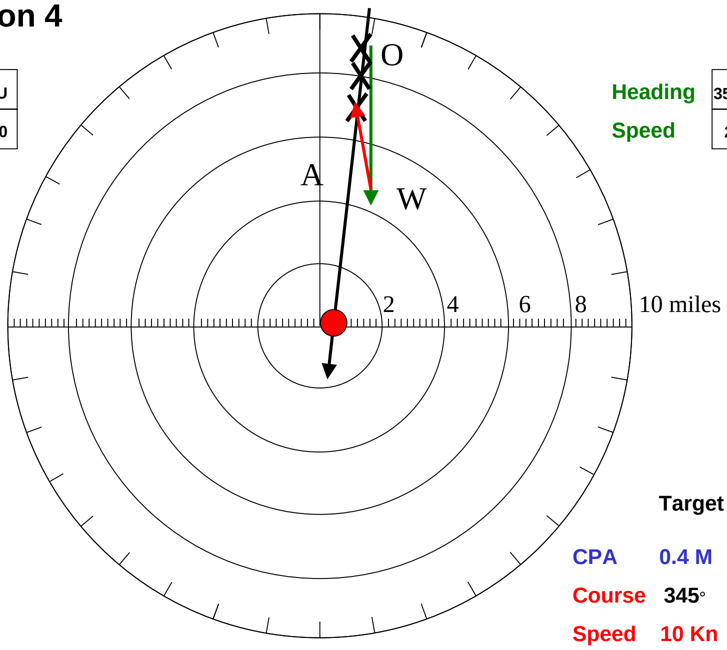
TCPA 10 minutes

Target

CPA	1.0
Course	060°
Speed	25.0

Question 4

Mode HU
Range 10



Heading 355°
Speed 20

Distance you travel in 12 minutes

= 20 x 1/5

= 4 miles

Target

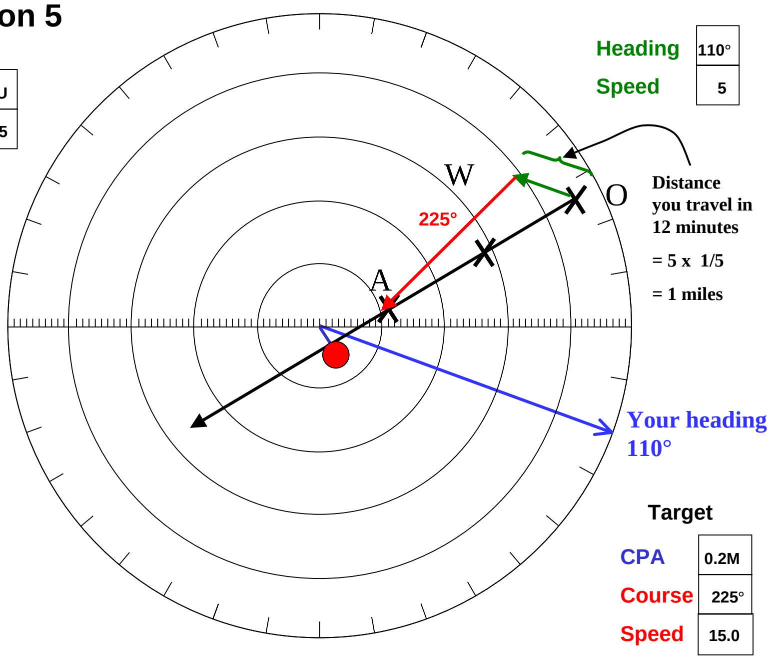
CPA 0.4 M

Course 345°

Speed 10 Kn

Question 5

Mode NU
Range 5



Heading 110°
Speed 5

Distance you travel in 12 minutes

= 5 x 1/5

= 1 miles

Target

CPA 0.2M

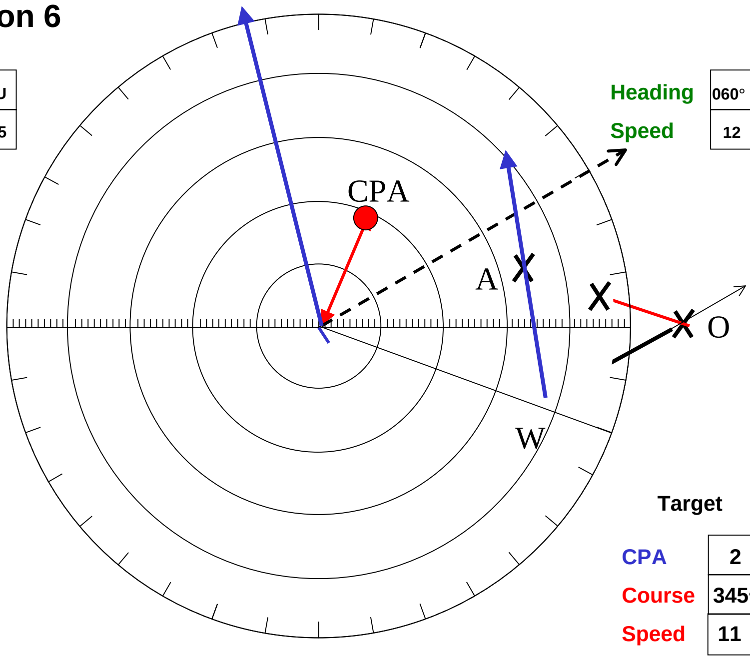
Course 225°

Speed 15.0

Question 6

Mode	NU
Range	5

Heading	060°
Speed	12



Target

CPA	2
Course	345° T
Speed	11

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.

© K Bater 2008

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;

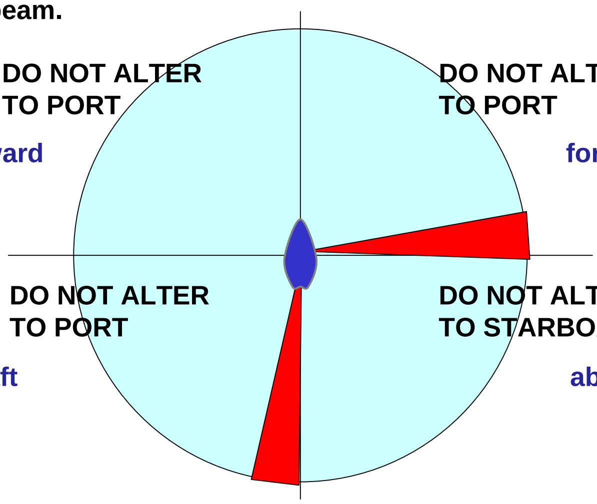
   ii. an alteration of course towards a vessel abeam or abaft the beam.

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.

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;

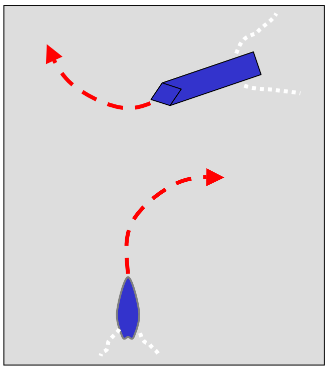
(ii) an alteration of course towards a vessel abeam or abaft the beam.

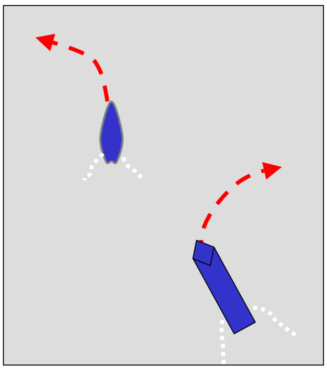


so far as possible the following shall be avoided:

(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.

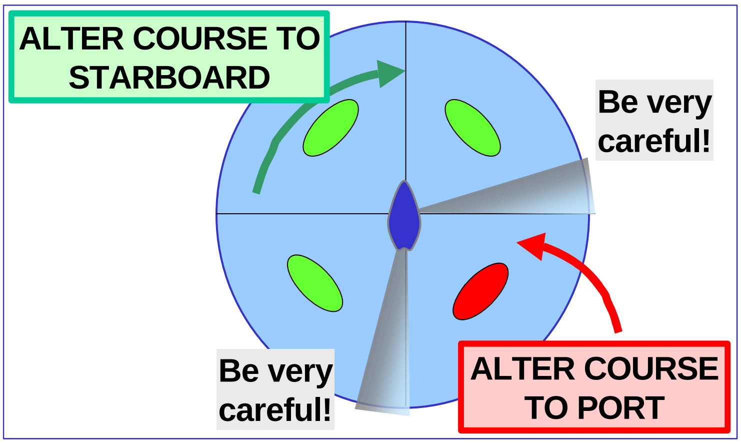




so far as possible the following shall be avoided:

(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.



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) 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.

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 suddenly producing 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
- 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 operational warnings for any selected target

- Target which closes to a specified range
- Target which enters a specified guard zone
- Target predicted to close to a specified minimum range and time
- A tracked target is lost

ARPA Display

1. Present range to the target
2. Present bearing of the target
3. Predicted target range at the closest point of approach (CPA)
4. Predicted time to CPA (TCPA)
5. Calculated true course of target
6. Calculated true speed of target

ARPA

ARPA - IMO standards for CPA

Condition	After 1 minute	After 3 Minutes
Bows-on	1.6 nm	0.5 nm
Crossing your track	1.8 nm	0.7 nm
You overtaking	2.0 nm	0.7 nm
Opening	-	0.8 nm

Provided the target is not subject to target swap, the ARPA shall continue to track an acquired target which is clearly distinguishable on the display for 5 out of 10 consecutive scans.

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.
- 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!
- 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 – Display

AIS - What is broadcast

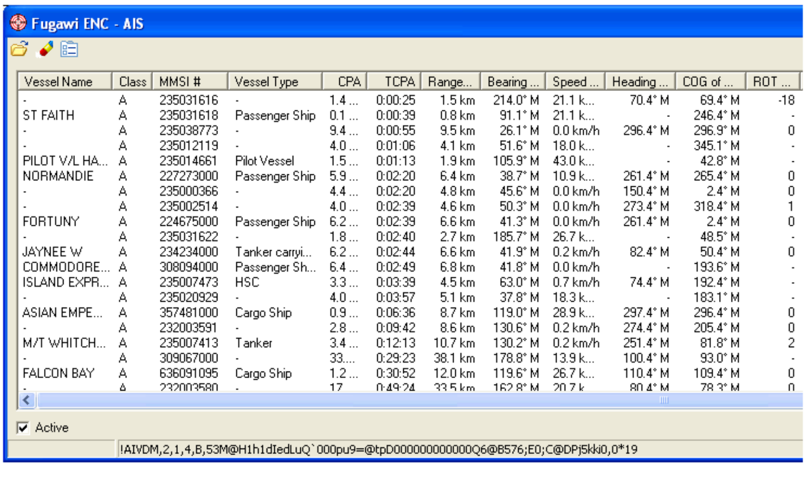
Class A AIS units broadcast the following information every 2 to 10 seconds while underway, and every 3 minutes while at anchor, at a power level of 12.5 watts.

- 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 Information Screen



Vessel Name	Class	MMSI #	Vessel Type	CPA	TCPA	Range...	Bearing ...	Speed ...	Heading ...	COG of ...	ROT ...
-	A	235031616	-	1.4 ...	0:00:25	1.5 km	214.0° M	21.1 k...	70.4° M	69.4° M	-18
ST FAITH	A	235031618	Passenger Ship	0.1 ...	0:00:39	0.8 km	91.1° M	21.1 k...	-	246.4° M	-
-	A	235038773	-	9.4 ...	0:00:55	9.5 km	26.1° M	0.0 km/h	296.4° M	296.9° M	0
-	A	235012119	-	4.0 ...	0:01:06	4.1 km	51.6° M	18.0 k...	-	345.1° M	-
PILOT V/L HA...	A	235014661	Pilot Vessel	1.5 ...	0:01:13	1.9 km	105.9° M	43.0 k...	-	42.8° M	-
NORMANDIE	A	227273000	Passenger Ship	5.9 ...	0:02:20	6.4 km	38.7° M	10.9 k...	261.4° M	265.4° M	0
-	A	235000366	-	4.4 ...	0:02:20	4.8 km	45.6° M	0.0 km/h	150.4° M	2.4° M	0
-	A	235002514	-	4.0 ...	0:02:39	4.6 km	50.3° M	0.0 km/h	273.4° M	318.4° M	1
FORTUNY	A	224675000	Passenger Ship	6.2 ...	0:02:39	6.6 km	41.3° M	0.0 km/h	261.4° M	2.4° M	0
-	A	235031622	-	1.8 ...	0:02:40	2.7 km	185.7° M	26.7 k...	-	48.5° M	-
JAYNEE W	A	234234000	Tanker carryi...	6.2 ...	0:02:44	6.6 km	41.9° M	0.2 km/h	82.4° M	50.4° M	0
COMMODORE...	A	308094000	Passenger Sh...	6.4 ...	0:02:49	6.8 km	41.8° M	0.0 km/h	-	193.6° M	-
ISLAND EXPR...	A	235007473	HSC	3.3 ...	0:03:39	4.5 km	63.0° M	0.7 km/h	74.4° M	192.4° M	-
-	A	235020929	-	4.0 ...	0:03:57	5.1 km	37.8° M	18.3 k...	-	183.1° M	-
ASIAN EMPE...	A	357481000	Cargo Ship	0.9 ...	0:06:36	8.7 km	119.0° M	28.9 k...	297.4° M	296.4° M	0
-	A	232003591	-	2.8 ...	0:09:42	8.6 km	130.6° M	0.2 km/h	274.4° M	205.4° M	0
M/T WHITCH...	A	235007413	Tanker	3.4 ...	0:12:13	10.7 km	130.2° M	0.2 km/h	251.4° M	81.8° M	2
-	A	309067000	-	33....	0:29:23	38.1 km	178.8° M	13.9 k...	100.4° M	93.0° M	-
FALCON BAY	A	636091095	Cargo Ship	1.2 ...	0:30:52	12.0 km	119.6° M	26.7 k...	110.4° M	109.4° M	0
-	A	232003580	-	17	0:49:24	33.5 km	162.8° M	20.7 k	80.4° M	78.3° M	0

!AIVDM,2,1,4,B,53M@H1h1dIedLuQ`000pu9=@tpD000000000000Q6@B576;E0;C@DPj5kki0,0*19

AIS B Transponder?

Small Craft Users
Link to GPS and VHF aerials

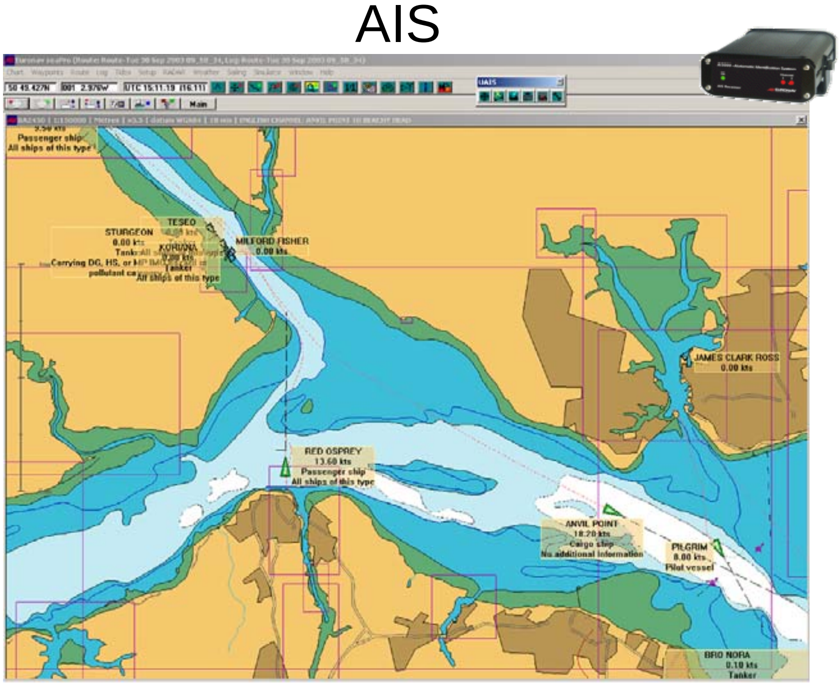
Information transmitted by the CSB200:
Name of vessel • Speed (SOG) • Heading • Call Sign • Position • Vessel dimensions • Type of vessel • Course (COG) • MMSI Number

AIS B or Sea-Me?

- 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 X-Band 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.
- Cross-Channel - AIS B, as many more ships will have AIS B signals activated in those areas and your AIS message should be seen.

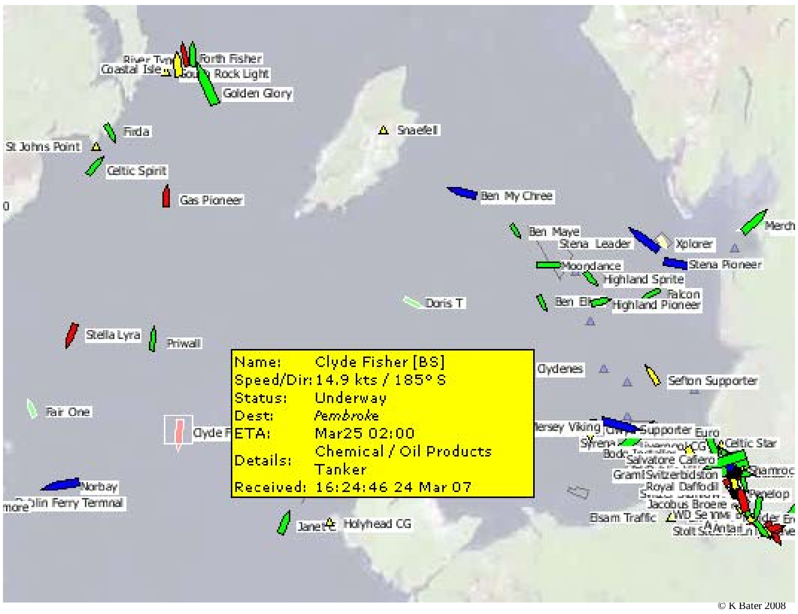
(Deputy HM, Southampton)

AIS



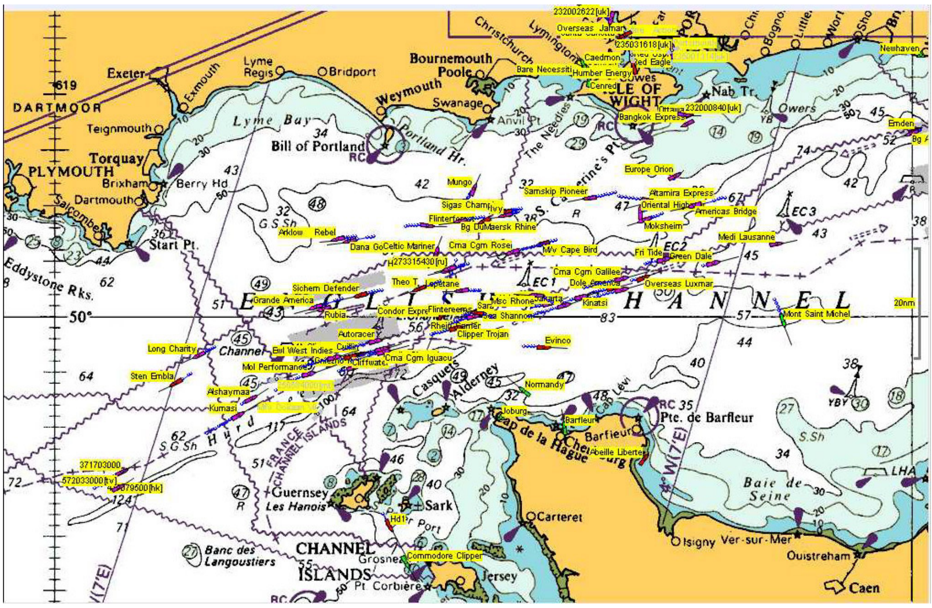
RED OSPREY
13.60 kts
Passenger ship
All ships of this type
ANVIL POINT
18.20 kts
Cargo ship
No additional information
PILGRIM
0.00 kts
Pilot vessel
JAMES CLARK ROSS
0.00 kts
MILFORD FISHER
0.00 kts
BRO NORA
0.10 kts
Tanker

AIS Live

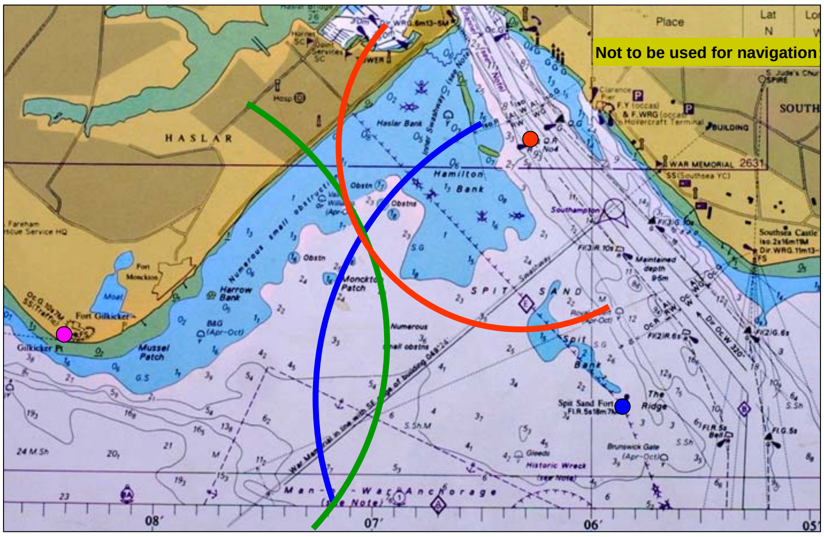


Name: Clyde Fisher [BS]
Speed/Dir: 14.9 kts / 185° S
Status: Underway
Dest: Pembroke
ETA: Mar25 02:00
Details: Chemical / Oil Products Tanker
Received: 16:24:46 24 Mar 07
Forth Fisher
Golden Glory
Snaefell
St Johns Point
Celtic Spirit
Gas Pioneer
Ben My Chree
Stena Leader
Xplorer
Stena Pioneer
Highland Sprite
Highland Pioneer
Doris T
Stella Lyra
Priwall
Fair One
Norbay
Holyhead CG
Sefton Supporter
Celtic Star

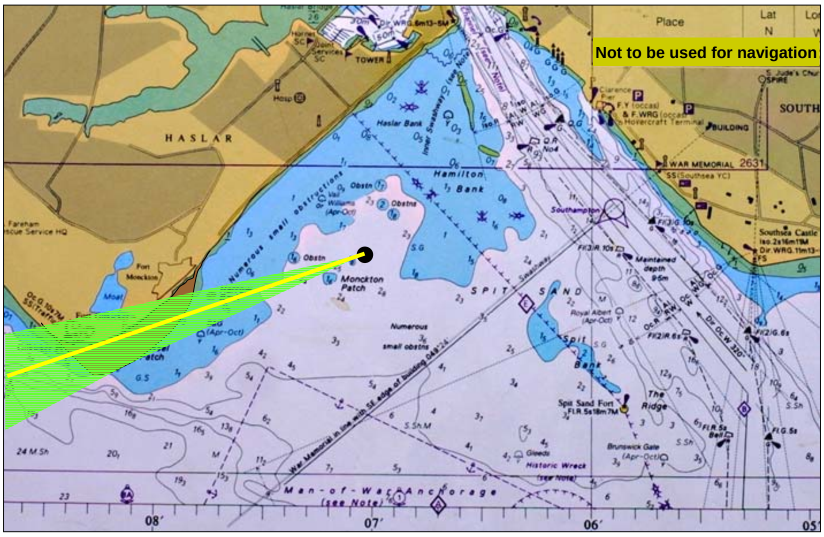
AIS Display



Position fixing by Range



Position fixing by Bearing



5. 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.

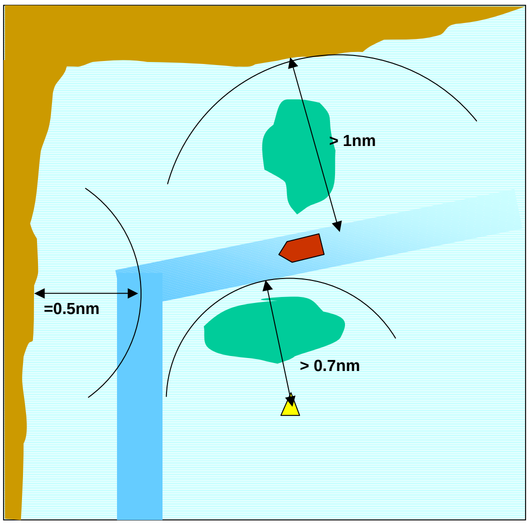
6. Pilotage

- **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**

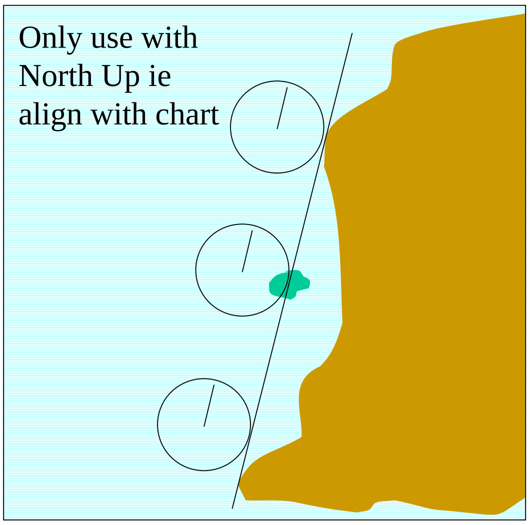
Pilotage

- '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

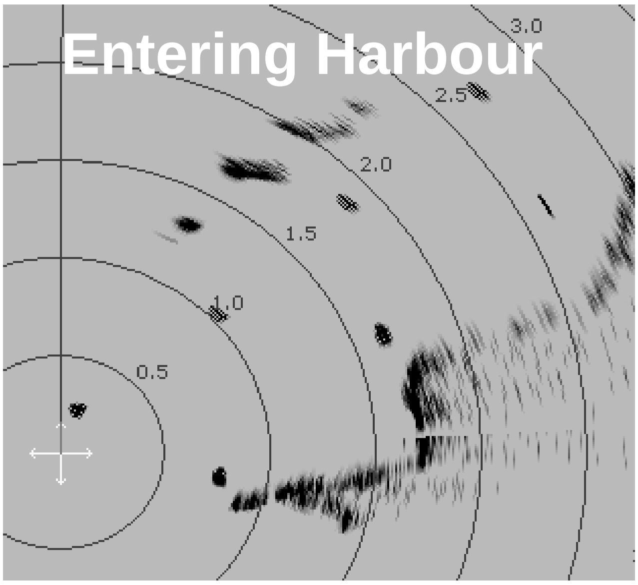
Clearing lines



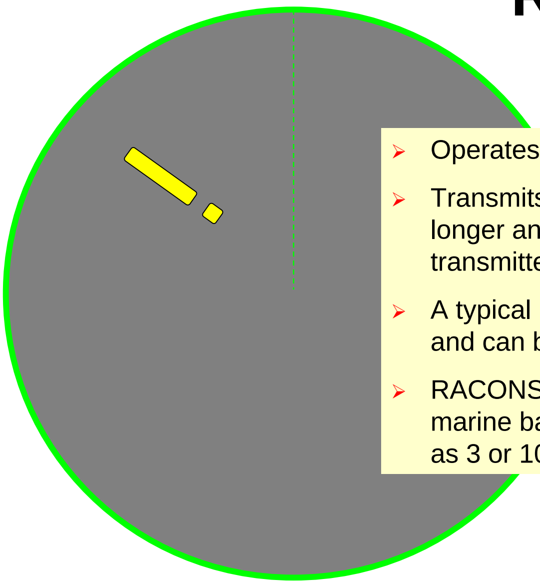
Parallel Indexing



Pilotage



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

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**

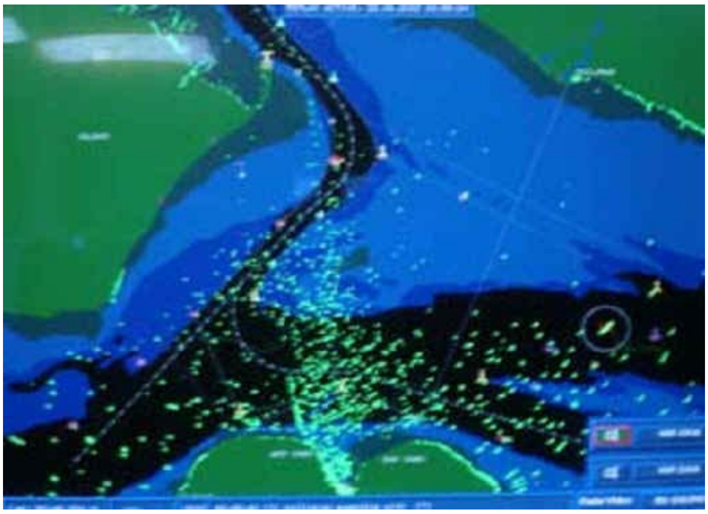
Advantages:

- **No minimum range - The much lower transmitted power means that the receiver can stay on and receive echoes continuously.**
- **Clearer picture (better discrimination) - each target will produce 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