The Queen's Award for Voluntary Service
The MBE for volunteer groups

PART 15A

RADAR PRINCIPLES
&
SIMRAD RADAR/CHARTPLOTTER

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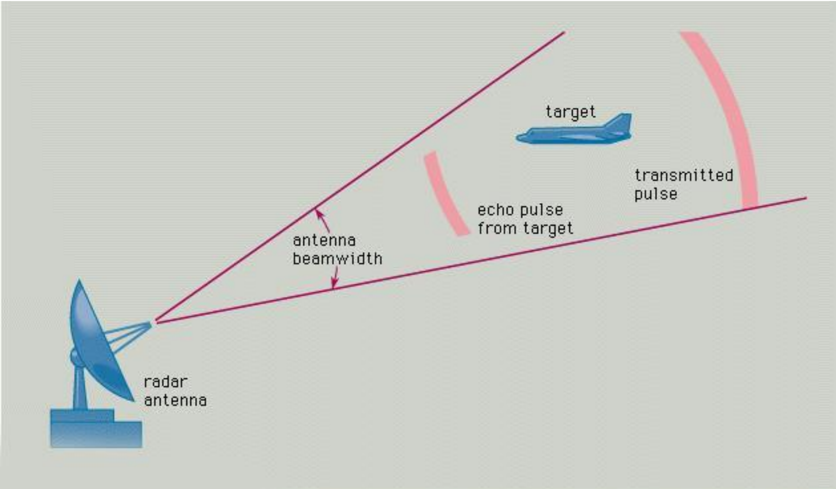
PRINCIPLES

Introduction

In simple terms a radar system works on the principle that a radio signal can be bounced off an object and returned to where it came from.



The term '**RADAR'** is derived from the basic operation of the system: i.e. ***Ra****dio* ***D****etection* ***A****nd* ***R****anging'.* While this basic principle had been discovered by Heinrich Hertz in 1886 it was not until 1935 that the first practical radar was engineered by Sir Robert Watson Watt. By 1939 England had a 'chain' of radar systems on the East and South coasts at the start of WW2.

Early Radar Systems

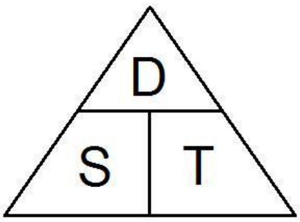
Early radar systems did exactly what the name implies; they provided a range from an object. Since Radio waves travel at the 'Speed of Light' it was a relatively simple problem to determine the distance of an object from the source of a radio signal. All that was required was a device which could measure the short time taken for a radio wave to travel to and from an object. Given that time and knowing the speed of light, the distance travelled may be worked out. As the time measured would be to and from the object the distance travelled had to be divided by 2 to obtain range.

Example Radar Range Calculation

The Speed of light is

3×10^{8} metres per second OR
186,000 miles per second OR
161,875 nautical miles per second. (This will be used for our example, since the majority of radars use the nautical mile notation).

Distance Speed Time Triangle



Distance = Speed xTime
Speed = Distance ÷ Time
Time = Distance ÷ Speed

Let's assume the Time taken for the radar beam/pulse to reach an object and return is 600 microseconds. ($\frac{600}{1,000,000}$ secs). Using the formula:

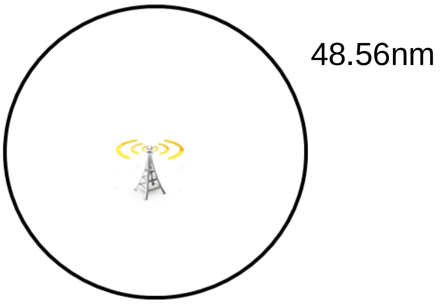
Distance = Speed (of light) x Time nautical miles
Distance = 161875 x $\frac{600}{1,000,000}$ nautical miles
Distance = 16.1875 x 6
Distance = 97.125 nautical miles

Remember this distance is there and back and so must be divided by 2:

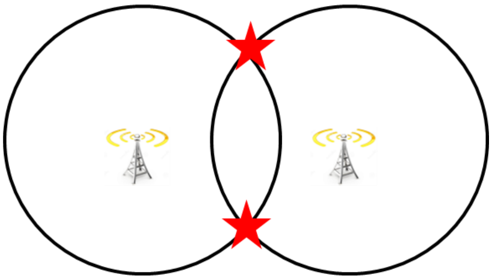
Actual Range to the target is 48.56 nautical miles

Determining Position

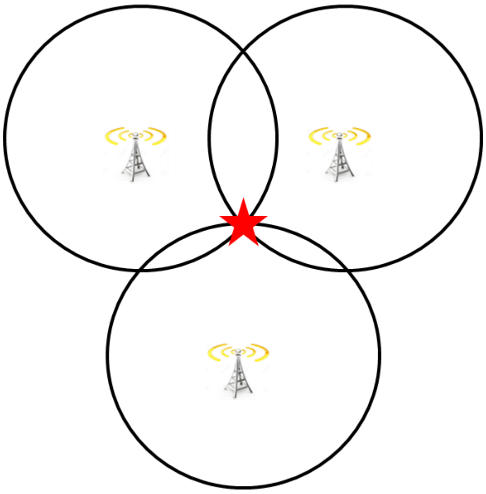
Whilst the range to the object is now known the actual position of the object is not. In our example we know that the object is somewhere on a circle at a range of 48.56 nm.



If a second system is employed the location is resolved to one of 2 positions where the range circles cross:



And finally to resolve the ambiguity a third system is added to refine the position to where all 3 range circles cross:



This early method of determining position was not very accurate and it also involved a lot of infrastructure. It also meant it was very difficult to make such a system both portable and accurate for an aircraft or small vessel. Another method had to be found.

Development of Accurate Radar Location

The method derived to resolve the location problem was to limit the omni directional wave radiated from the antenna to a section or beam that could be rotated. Such a system would provide both Range and Bearing from the rotational position of the antenna. In the early sets the position obtained would be relative to the scanner forward position. However, once synchronised to a compass system the systems provide compass bearing and range to contacts.

Rotating Scanner using a parabolic reflector to focus and form the radar 'Beam'.

Radar Evolution

The progression and evolution of radar since WWII has been rapid and to a large extent, mirrors that of the computer.

Once the preserve of the Military and Commercial Flight & Shipping, even sophisticated radar systems are now available to the general public for leisure pursuits: light aircraft, motor/sailing yachts etc. Pulse compression techniques are coming to the fore in civilian radar equipment and its use is becoming much cheaper due to the viability and mass production of devices such as Gallium Nitride amplifiers; these are being produced for mobile phones hence the low price.

Gone are the Cathode Ray Tubes and 'raw' radar displays of yesteryear. Modern radar sets use Multi-functional Displays (MFD) which may be selected to display many different equipment outputs. These displays present the outputs of any equipment by the use of a display processor. Radars may also use computer processed outputs which employ 'Computer Algorithms' to control many of the factors which can affect a radar system and its display. An algorithm is a step-by-step procedure used for calculations, data processing, and automated reasoning. For example, a radar algorithm could be as simple as the set has to see at least 3 radar returns (3 sweeps) from a contact before it puts it on the display. Any less and it is not displayed thus reducing the number of false returns shown to the operator.

The release of the Global Positioning System (GPS) satellite constellation in the mid 1980's revolutionised navigation at sea and in the air. The spin off also had a great impact on radar and electronic Chartplotter systems. Once these 3 systems were integrated along with a heading sensing system (Fluxgate compass in small boats) the scene was set for a step change in modern sea and air vehicle systems.

The MFD also allows for the integration of different systems to improve the 'Situational Awareness' of the operator. This means that all the information related to a particular contact is easily assimilated by the operator from one screen. What does that mean? An example would be to take the contacts from a radar screen and overlay them on to an electronic chart but all on the same screen. Workload is instantly reduced since the operator now doesn't have to manually transfer the information to see exactly where a contact is in relation to other contacts, land or depth features etc. Moreover, if the Automatic Identification System (AIS) is also overlaid on to the same screen it completes the 'Situational Awareness' picture providing:

Bearing and Range from own vessel
Latitude & Longitude of the subject vessel
AIS data Name, callsign, MMSI, course, speed, departure/destination and many other items as input by the subject vessel

Our own radar/Chartplotter system at NCI Fleetwood is a highly sophisticated device many times more effective and efficient than those in WW2. It employs Frequency Modulated Continuous Wave (FMCW) or broadband technology to achieve good performance at short range for a very low power output.

Types of Radar

Pulse Radars – the majority of radar systems employed this technique until relatively recently.

Continuous Wave/Doppler – CW radar used to pick up moving contacts and avoid returns from stationary contacts

Swept Pulse – Allows for more accuracy by employing a 'Chirp' pulse, the frequency in the pulse is swept.

Frequency Modulated Continuous Wave – FMCW also known as BROADBAND. Employs similar techniques as continuous wave but the frequency is swept allowing for greater accuracy and low transmitted output power.

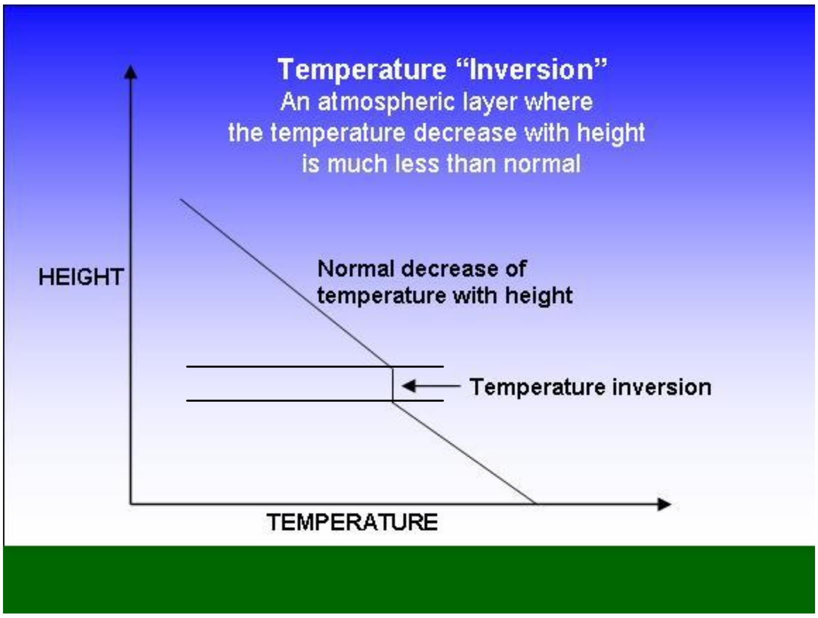
External Factors affecting Radar Performance

Contact size and Material – Radar Cross Section

The most important external factors to affect radar performance are the size and material that a contact is made from. Of these 2, material is by far the largest factor. For example, a large glass fibre yacht will only have a very small radar cross section area. Conversely a much smaller all metal boat will present a much larger cross sectional area

Weather – Rain, Mist, Storm cells

Radar transmissions start to decay as they leave the antenna. The inverse square law determines the amount by which an electromagnetic source decays and since a radar signal has to repeat the same journey back from the contact the signal decays at the same rate again. Hence the signal becomes quite weak very quickly. It follows that anything which is in the path of the signal further weakens the return that can be expected. Therefore the weather conditions can further weaken or even prevent a return signal to the source. A temperature inversion is a thin layer of the atmosphere where the normal decrease in temperature with height switches to the temperature increasing with height. An inversion may act like a ‘tube’ which can increase the range at which contacts may be seen. The same effect often occurs with radios.



Sea Clutter

The many variations of waves and water motion create many returns from a radar signal. In the early days of radar these could be seen as constantly fleeting contacts across the radar display. This could potentially mask a real contact from the operators’. However, the modern processed radar system uses computer algorithms to reduce/prevent these sea clutter or false returns.

Sea Swell and or Wave height

Both Sea swell and wave height can have a direct impact on the amount of sea clutter generated.

Land

Dependant on the type of radar in use land will be generally be displayed which sounds fine. However, the algorithms in processed radar can be altered from swamping as a result of the beam sweeping off land. This effect can prevent contacts just off a coast from being displayed unless some other method is employed. A similar effect can be observed around rig and turbine complexes. As the radar sweeps off the swamping objects it fails to pick up any smaller contacts for some distance. A simple fix is to reverse the direction of the scanner but there are also other electronic fixes for more sophisticated (expensive!) systems.

Electro-magnetic interference Man & Natural

Electromagnetic interference can cause many types of effects on a display from spoking to complete cover of a display. The man made interference now has some remedies in radar receivers to prevent noise, interference rejection is one such technique. The environmental interference may be mitigated by reverting to manual control of receiver gain and sea clutter vice automatic.

Manual Controls

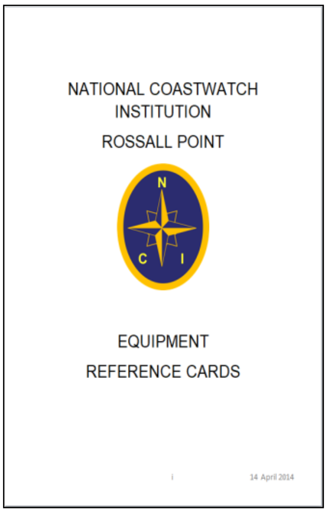
The majority of Radars' provide the operator with a range of manual control functions. The use of manual controls may on occasion be required due to external weather factors. However, great care must be taken to ensure that the settings made do not prevent the radar from 'seeing' contacts. Operators may find it useful to familiarise themselves with the manual controls when there are some contacts on display before trying to do it when it is actually required.

Any such use of manual controls must be put back to automatic at shutdown or handover to other operators.

NCI FLEETWOOD SIMRAD NSS 12- Radar/Chartplotter

The radar which is part of the SIMRAD NSS at NCI Fleetwood is an FMCW Broadband 3G system. It has a very low power output which is ideally suited to its use on small and medium maritime leisure craft. It has good target discrimination and can see larger contacts out to 24 nm. However, the design is optimised to provide a good reliable picture at short range to suit the leisure market users who primarily use it to avoid collisions at sea and for close range navigational purposes. Whilst the equipment may be used to display the outputs of many systems found on a vessel, in the tower it is only used to display radar, Chartplotter or radar overlaid on the Chartplotter. If the correct AIS system feed is available then this may also be displayed on both radar and Chartplotter.

Watch Keeper Reference Cards (WRC)



Ensure that the NSS is switched ON using the Watchkeeper Reference Cards (WRC). Located on the Ops Desk.
There are a number of controls which you will not see on general display that can affect the radar performance if they are not set correctly.
Always assume that the last operator has been 'investigating' radar functions and left the controls set incorrectly.

Can you read a bearing & range for a contact or chart symbol?
Can you read a lat/long for a contact or chart symbol?
Can you provide a bearing and range between 2 contacts?
Can you input a position from a Mayday for instance which is outside the station chart area.

ALL AVAILABLE IN THE WRC

Radar Capabilities

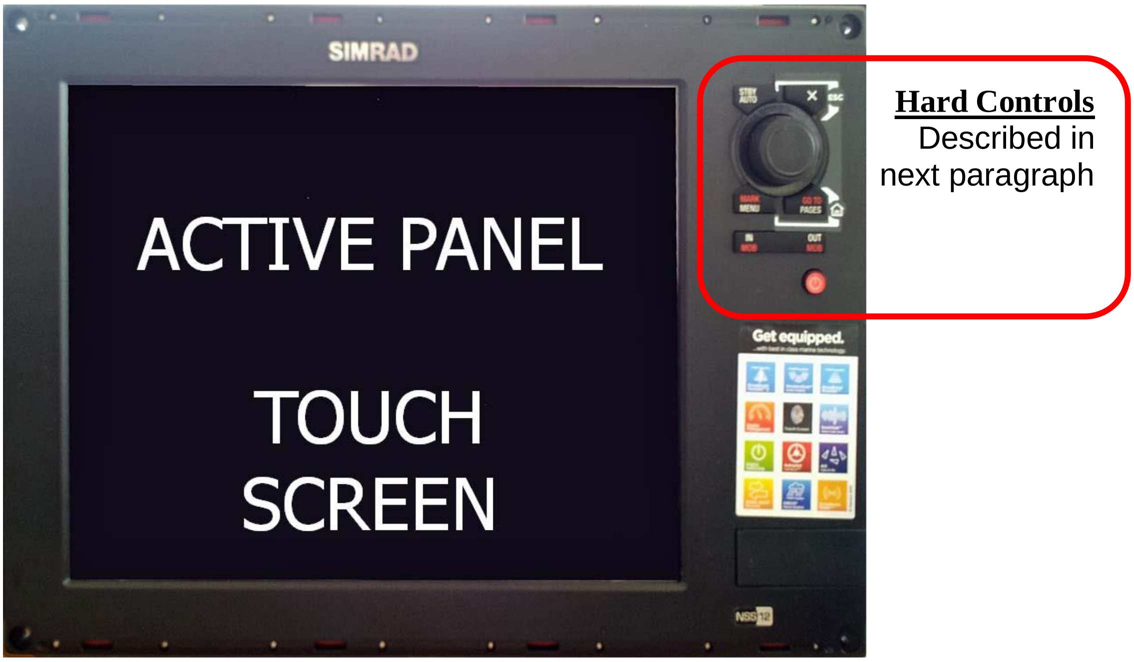
- Range 200 yards – 24nm or horizon
- Range rings distance between range dependent
- Bearing and range readout
  - Tower to contact
  - Contact to contact
- Receiver Gain Auto/Manual Control
- Sea clutter Offshore/Manual/Harbour Control
- Rain Clutter Manual Control
- Ability to track up to ten targets – MARPA (Mini Automatic Radar Plotting Aid)
- Closest Point of Approach(CPA) warnings
- Sector target warning areas.

Chartplotter Capabilities

- Range as required dependent on electronic map system loaded
- Range rings - distance between range dependent
- Display Radar overlay on Chartplotter – requires GPS and Compass feed
- Display AIS information if available
- Chart zoom in increases detail available
- Objects displayed have more information if selected on the chart
- Latitude & Longitude output from touch on screen
- Bearing and range readout
  - Tower to contact
  - Contact to contact
- Chart position control by touch screen
- Input of waypoint positions – useful for positions from radio e.g. Mayday

Controls

The controls on the set are a mix of 'hard' and 'soft' controls. Hard controls are those which have a physical control externally on the set whilst soft controls are those which are provided on screen by software driven menus.



Hard Controls

STBY AUTO key
Used for Autopilot operation

Rotary knob
Zoom chart and use menus
Press Rotary knob to select or step between gauges
Press and Hold to enter control change settings

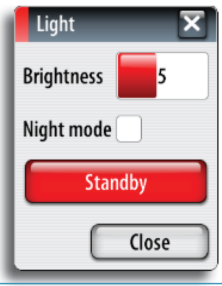
MARK / MENU key
Short press activates active panel's menu
Long press marks position

IN / OUT key
Zoom key for chart/radar panels
A simultaneous press on both key ends will position a MOB at vessel's position

X key - close menu/dialogs return to previous menu level
Remove the cursor from the screen on chart & radar panels

GOTO / PAGES key
A short press displays the Pages (Home) panel
Short presses toggle between Pages, Tools and Settings panels
Long press displays GOTO menu

POWER key - Used for turning the unit ON/OFF and for brightness adjustment

	• Press and hold:	Turn unit on/off	
	• Single press:	Display dialog for light adjustment, standby mode and radar standby/ transmit	
	• Repeated presses:	Toggle preset brightness levels (10 - 6 - 3- 1)	

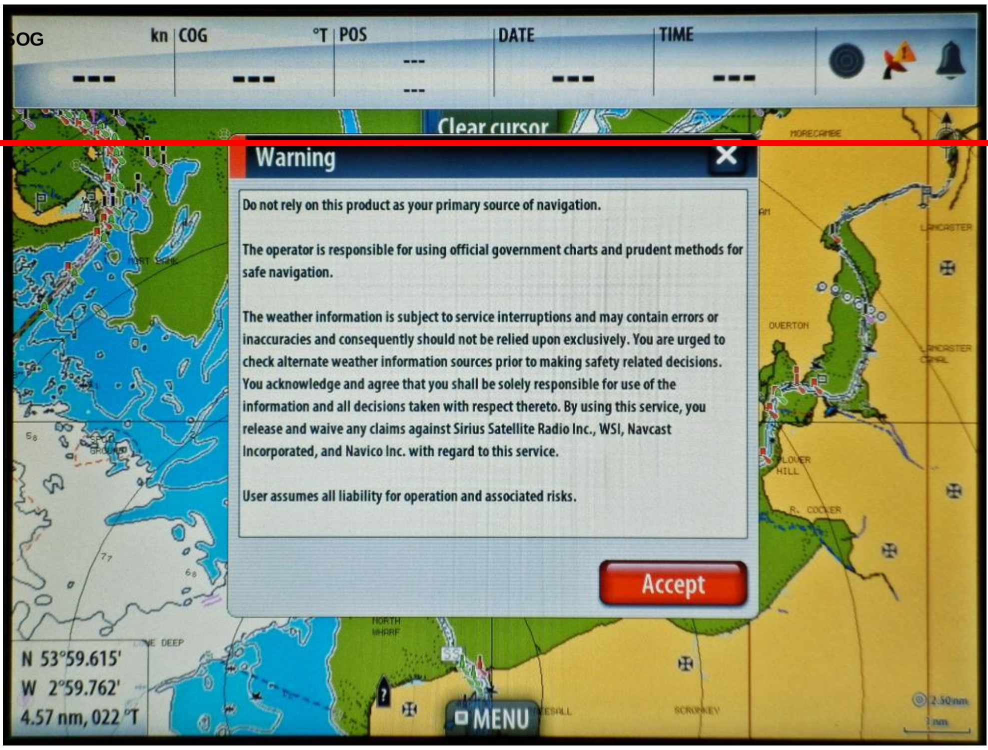
The Power ON/OFF Key

Notes: If the power key is released before shut-down is completed, the power off is cancelled.
A night mode which optimizes the colour palette for low light conditions is included. Details on the chart may be less visible when the Night mode is selected!

<u>Initial Power ON</u> – Press Power ON button

The equipment may take a minute to display anything – wait and follow the WRC.

<u>Status Bar</u>



The bar at the top of the display is the **STATUS BAR.** This displays the current status of the system. At the right of the display are 3 system indicators:

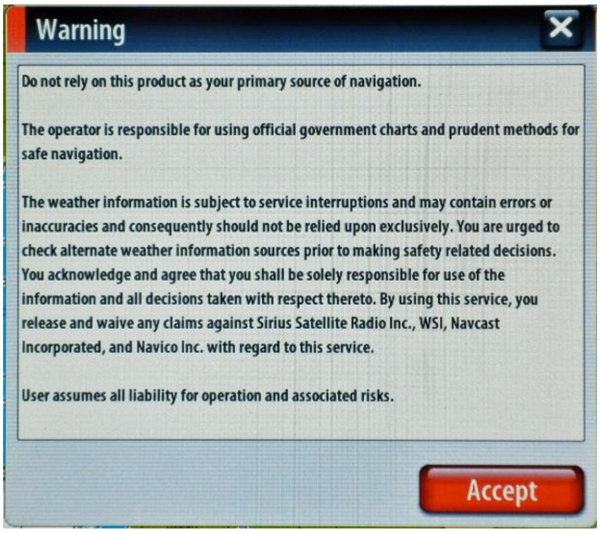
 Radar at Standby OR  Radar Transmitting

 GPS for the system has not located sufficient satellites. OR  Has located sufficient satellites to generate a Position and Time

 System has NO Faults OR  System Fault(s)

Once the GPS has located sufficient satellites to calculate a position the status bar is populated with a Position and Time as shown below.

The position and time is updated every second and is always slightly different due to the small errors generated. These small errors in turn allow the NSS to calculate a 'Speed over the Ground' (SOG) and a 'Course over the Ground' COG. Since we are a stationary platform, the greater the SOG the less accurate the position.



The 'Warning' that appears at initial switch ON is to inform the operator that this equipment is NOT to be used as the primary source of navigational reference.

Obviously this does not affect us since the station does not move!
When the Warning is cancelled the display will be what was selected when the set was turned OFF.
Provided this was done correctly in the tower the electronic chart will be displayed as shown.

Status Bar populated because GPS is active

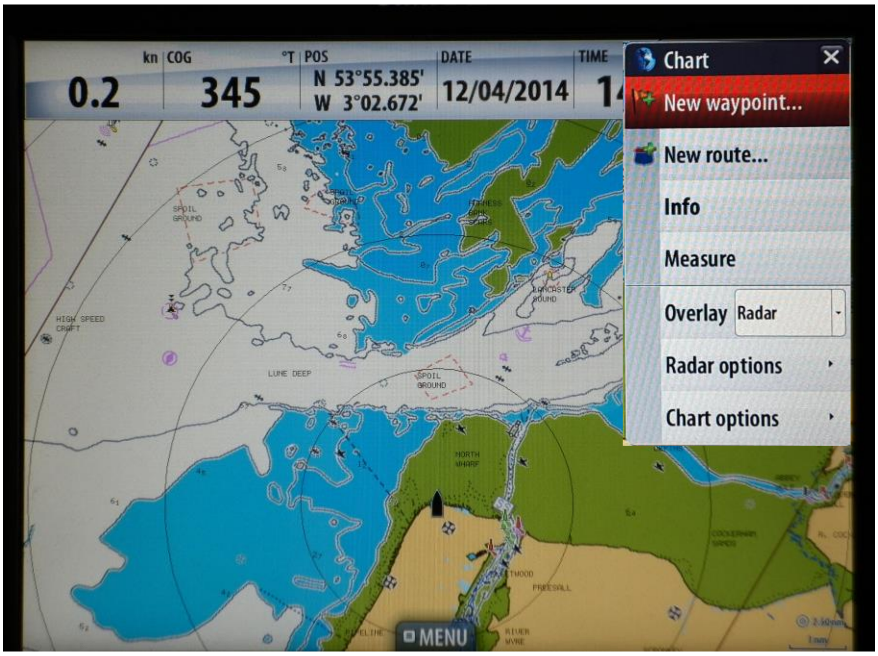
Radar at Standby

No Faults

'Ownship' tower

Chart displayed in 'Heading Up' mode: i.e. what you see on the screen matches what you see outside the window.

Continue with WRC to set up system: Select Menu from the display or the hard control; this will display the basic Chart menu as shown:



New Waypoint: Allows the input of a screen symbol in any position desired by the operator. This can be from the cursor or manually via Lat/Long.

Very useful for Mayday/Pan positions received via radio.

New Route: Not used in the Tower.

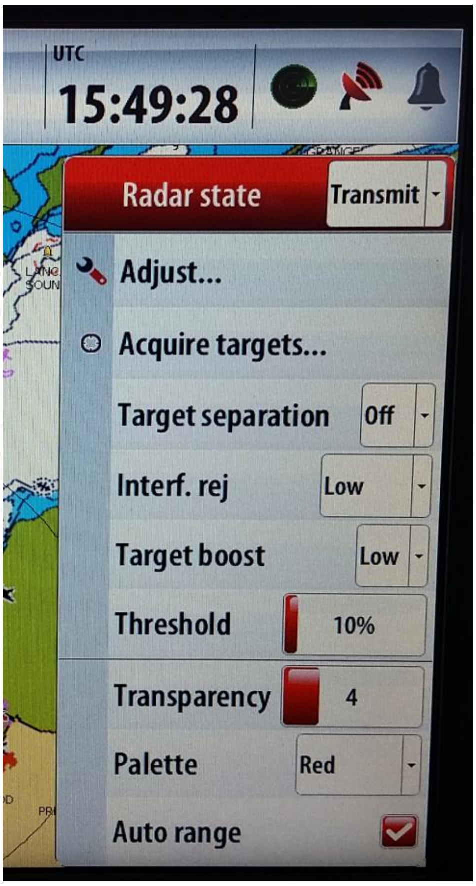
Info: If any object displayed on the chart is touched then any information associated with it can be displayed by selecting info.

Measure: Allows the operator to select 2 different points on the display and read out a bearing and range between the objects selected.

Overlay: Provides for selection of overlay sources. It is to be set to Radar for radar information to be displayed. If this is set to 'OFF' or 'GRIB' the radar contacts will not be displayed.

Radar Options:

To ensure the radar is operating correctly – Select 'Radar Options' from the menu. Radar Options displays a further sub menu: The sub menu displayed allows radar display controls to be set:



Radar State: Used to switch the radar from Standby to Transmit or OFF.

Adjust: Displays the radar 'gauges' for the control of the 'Gain', 'Clutter', 'Rain' and manual 'Range' settings. ***Note: these must be checked at every switch ON. Failure to do so will not detect changes made by previous operators which could degrade the radar performance.***

Acquire Targets: If selected the radar can track up to 10 contacts using a computer based process 'MARPA' (Mini Automatic Radar Plotting Aid). It requires each contact to be touched on the display.

Target Separation: If set can provide a warning Beep if contacts come closer than a range input by the operator on selection. *OFF in the tower*.

Interf rej: Allows the system to reject the interference caused by other radar systems using the same frequency band (9.24 GHz).
Note: If this is OFF the result is 'Spoking' on the display from other vessel radars.

Target Boost: A display function which enlarges the displayed contacts.

Threshold: Sets a level in the receiver to prevent fleeting/weak signals from being displayed. May be considered as 'Squelch' for radar – i.e. prevents noise being displayed.

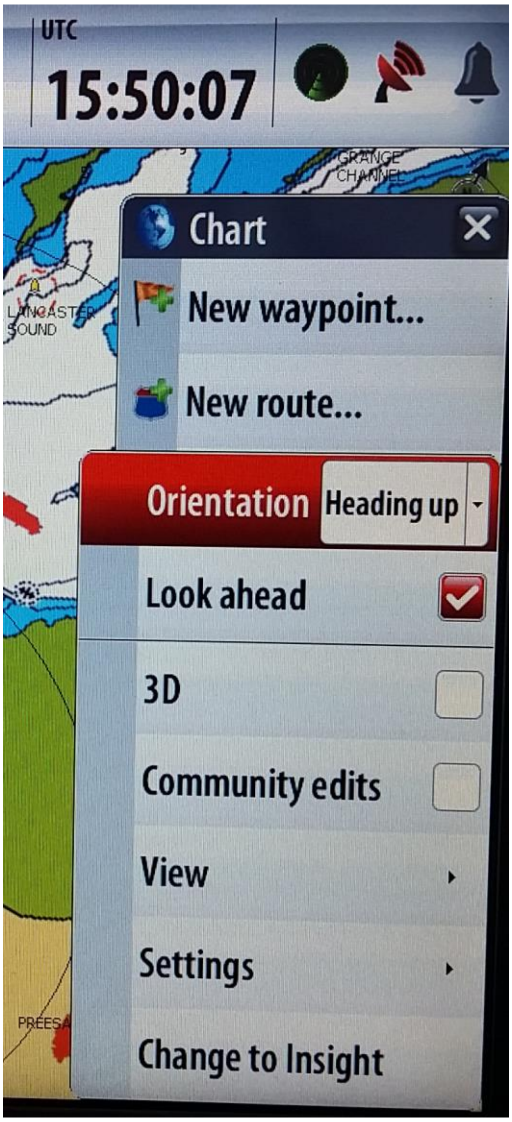
Transparency: Used to prevent Radar contacts from obscuring chart details: 4 is a good figure for our set.

Palette: Allows the colour to be changed for radar contacts. Red is a good compromise for daytime as it does not clash with chart colours.

Auto Range: When selected allows the radar 'Range' to be changed automatically to match the range selected on the chart display. *Note: Failure to do this may result in radar contacts not being displayed when the chart range is altered.*

Chart Options:

To ensure the chart is set up correctly – Select ‘Chart Options’ from the menu.



Orientation: Sets the display to either ‘North Up’ or ‘Heading Up’. Heading Up is preferred since it matches what you see out of the window

Look Ahead: Sets the display to ‘Centre’ or ‘Look Ahead’. Since most of the land is behind the tower ‘Look Ahead is the sensible option; this gives greater range ahead of the tower.

Community Edits: Allows the user community to add information to Navionics charts. Not used in the tower.

View: Allows display of other relevant information – not used in the tower.

Settings: Chart detail may be adjusted.

Change to Insight: The tower system has a ‘Navionics’ electronic chart installed which has very detailed information. The ‘Insight’ chart is much less detailed and uses a vector chart. *Do NOT switch to Insight – if this is done the menu item becomes ‘Switch to Navionics’ reselect this item to restore the optimum display.*