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## Use of Electronic Aids to Navigation

Notice to Owners, Masters, Skippers, Officers and Crews of Merchant Ships and Fishing Vessels

*This Guidance Note supersedes Merchant Shipping Notice No. 1158*

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### *Summary*

This note emphasises the need for correct use of navigational equipment by watchkeepers.

#### Key Points:-

- Be aware that each item of equipment is an aid to navigation
- Be aware of the dangers of over-reliance on the output from and accuracy of a single navigational aid
- Recognise the importance of the correct use of navigational aids and knowledge of their limitations
- Appreciate the need to cross check position fixing information using other methods
- Be aware of the factors which affect the accuracy of position fixing systems

### 1. NAVIGATIONAL EQUIPMENT

#### Provision of Navigational Equipment on Ships

1.1 The Merchant Shipping (Navigational Equipment) Regulations 1993 (SI 1993 No 69) require certain ships to be provided with a magnetic compass installation and other specified ships to be fitted additionally with a direction finder, an echo sounder, a gyro compass, radar and ARPA installations, a speed and distance measuring installation and a rate of turn indicator.

1.2 Provision is also made in the Regulations in respect of siting and serviceability of the installations and, in the case of radar and ARPA installations, the qualifications of the radar observers.

1.3 A number of recent accidents have been caused by over-reliance on a single electronic navigational aid. Watchkeepers must always ensure that positional information is regularly cross-checked using other equipment, as well as visual aids to navigation.

1.4 Some radars are equipped with Auto-Tracking Aids (ATA) which enable targets to be acquired manually and automatically plotted. Such systems do not provide all the functions of ARPA. Radars for smaller vessels may be provided with Electronic Plotting Aids (EPA) which require the operator to plot each target manually. EPA provides the target calculations for each manual plot. Operators should be aware of the functional limitations of ATA and EPA.

## **2. THE USE OF RADAR AND PLOTTING AIDS**

### **General**

2.1 Collisions have been caused far too frequently by failure to make proper use of radar and ARPA in both restricted visibility and in clear weather. A common error has been altering course on insufficient information and by maintaining too high a speed, particularly when a close quarters situation is developing or is likely to develop. Information provided by radar and ARPA/ATA in clear weather conditions can assist the watchkeeper in maintaining a proper lookout in areas of high traffic density. It cannot be emphasised too strongly that navigation in restricted visibility is difficult and great care is needed even with all the information available from the radar and ARPA/ATA. Where continuous radar watchkeeping and plotting cannot be maintained even greater caution must be exercised. A "safe speed" should at all times reflect the prevailing circumstances.

### **Interpretation**

2.2 It is essential for the observer to be aware of the current quality of performance of the radar (which can most easily be ascertained by the Performance Monitor) and to take account of the possibility that small vessels, small icebergs and other floating objects such as containers may not be detected. When video processing techniques are employed, caution should be exercised.

2.3 Echoes may be obscured by sea or rain clutter. Correct setting of clutter controls will help but will not completely remove this possibility. When plotting larger targets on a medium range scale, the display should be periodically switched to a shorter range, and the clutter controls adjusted, to check for less distinct targets.

2.4 The observer must be aware of the arcs of blind and shadow sectors on the display caused by masts and other on-board obstructions. They must be plotted on a diagram placed near the radar display which must be updated following any changes which affect the sectors.

### **Plotting**

2.5 To estimate the degree of risk of collision with another vessel it is necessary to forecast the closest point of approach. Choice of appropriate avoiding action is facilitated by the knowledge of the other vessel's track. This can be obtained by manual plotting methods or using EPA, or automatically, using ATA or ARPA. The accuracy of the plot, however obtained, depends upon

accurate measurement of own ship's track during the plotting interval. Observers should be aware that an inaccurate compass heading or speed input will greatly reduce the accuracy of true vectors when using ARPA or ATA, and should therefore treat the apparent precision of the digital display with caution. This is particularly important with targets on near-opposite courses where a slight error of own-ship's data can make the difference between a target apparently crossing ahead or passing clear.

### **Choice of range scale**

2.6 Although the choice of range scales for observation and plotting is dependent upon several factors such as traffic density, speed of own ship and the frequency of observation, it is not generally advisable to commence plotting on a short range scale. Advance warning of the approach of other vessels, changes in traffic density, or proximity of the coastline, should be obtained by occasional use of longer range scales. This applies particularly when approaching areas of expected high traffic density when information obtained from the use of longer range scales may be an important factor in determining a safe speed.

### **Appreciation**

2.7 A single observation of the range and bearing of an echo will give no indication of track of a vessel in relation to own ship. To estimate this, a succession of observations must be made over a known time interval. The longer the period of observation, the more accurate the result. This also applies to ARPA/ATA which requires adequate time to produce accurate information suitable for assessing collision risk and determining appropriate manoeuvres.

2.8 Estimation of the target's true track is only valid up to the time of the last observation and the situation must be kept constantly under review. The other vessel, which may not be keeping a radar watch or plotting, may alter its course and/or speed. This will take time to become apparent to the observer on own ship. Neither ARPA nor ATA will detect any alteration immediately and therefore should also be monitored constantly.

2.9 It should not be assumed that because the relative bearing of a target is changing, there is no risk of collision. Alteration of course and/or speed by own ship may alter the relative bearing. A changing compass bearing is more reliable. However, account should be taken of the target's range because, at close quarters, risk of collision can exist even with a changing compass bearing.

2.10 Radar should be used to complement visual observations in clear weather to assist assessment of whether risk of collision exists or is likely to develop. It also provides accurate determination of range to enable appropriate action to be taken in sufficient time to avoid collision, taking into account the manoeuvring capabilities of own ship.

#### **Clear weather practice**

2.11 It is important that all using radar and ARPA/ATA should obtain and maintain experience in its operation by practice at sea in clear weather. This allows radar observations and ARPA/ATA vectors to be checked visually. Thus misinterpretation of the radar display or false appreciation of the situation, which in restricted visibility could be potentially dangerous, is highlighted. By keeping themselves familiar with the process of systematic radar observation, and the relationship between radar and electronically plotted information and the actual situation, watchkeepers will be able to deal rapidly and competently with the problems which will confront them in restricted visibility.

#### **Operation**

2.12 The radar display should be kept on at all times when weather conditions indicate that visibility may deteriorate, and at night wherever fog banks, small craft or unlit obstructions such as icebergs are likely to be encountered. This is particularly important when there is a likelihood of occasional fog banks so that vessels can be detected before entering the fog. The life of components, and hence the reliability of the radar, will be far less affected by continuous running, than by frequent switching on and off.

#### **Radar watchkeeping**

2.13 In restricted visibility the radar display should be permanently on and observed. The frequency of observation will depend on the prevailing circumstances, such as own ship's speed and the type of craft or other floating objects likely to be encountered.

#### **Parallel index techniques**

2.14 Investigation of casualties where radar was being used as an aid to navigation prior to the vessel grounding have indicated that inadequate monitoring of the ship's position contributed to many of the accidents. Parallel index techniques provide valuable assistance to position monitoring in relation to a pre-determined

passage plan, and would have helped to avoid these groundings. Parallel indexing should be practised in clear weather during straightforward passages, so that watchkeepers become thoroughly familiar with the technique before attempting it in confined difficult passages, or at night, or in restricted visibility.

2.15 The principles of parallel index plotting can be applied, using electronic index lines, to both relative and true motion displays. These index lines can be stored and called up when required on all modes of display. Electronic index lines also enable the operator to switch ranges. With such a facility, care must be taken during passage planning to ensure that the correct parallel index lines for the intended voyage are available for retrieval.

2.16 On a relative motion display, the echo of a fixed object will move across the display in a direction and at a speed which is the exact reciprocal of own ship's ground track. Parallel indexing uses this principle of relative motion, and reference is first made to the chart and the planned ground track. The index line is drawn parallel to the planned ground track with a perpendicular distance (cross index range or offset) equal to the planned passing distance off the object. Observation of the fixed object's echo moving along the index line will provide a continuous indication of whether the ship is maintaining the planned track. Any displacement of the echo from the index line will immediately indicate that own ship is not maintaining the desired ground track, enabling corrective action to be taken.

2.17 Electronic parallel index lines are drawn and used in the same way on true motion displays in both sea-stabilised and ground-stabilised mode. Parallel index lines are fixed relative to the trace origin (ie to own ship), and will consequently move across the display at the same rate and in the same direction as own ship. Being drawn parallel to the planned charted track, and offset at the required passing distance off the selected fixed mark, the echo of the mark will move along the index line as long as the ship remains on track. Any displacement of the fixed mark's echo from the index line will indicate that the ship is off track enabling corrective action to be taken.

2.18 Parallel indexing is an aid to safe navigation and does not replace the requirement for position fixing at regular intervals using all appropriate methods available including visual checks.

2.19 When using radar for position fixing and monitoring, check:

- (a) the radar's overall performance,
- (b) the identity of fixed objects,
- (c) the gyro error and accuracy of the heading marker alignment,
- (d) the accuracy of the variable range marker, bearing cursor and fixed range rings,
- (e) that parallel index lines are correctly positioned on a suitable display.

2.20 Some older radars may still have reflection plotters. It is important to remember that parallel index lines drawn on reflection plotters apply to only one range scale. In addition to all other precautions necessary for the safe use of radar information, particular care must therefore be taken when changing range scales.

### **Regular operational checks**

2.21 Frequent checks of the radar performance must be made to ensure that the quality of the display has not deteriorated.

2.22 The performance of the radar should be checked before sailing and at least every four hours whilst a radar watch is being maintained. This should be done using the performance monitor.

2.23 Mis-alignment of the heading marker, even if only slight, can lead to dangerously misleading interpretation of potential collision situations, particularly in restricted visibility when targets are approaching from ahead or fine on own ship's bow. It is therefore important that checks of the heading marker should be made periodically to ensure that correct alignment is maintained. If misalignment exists it should be corrected at the earliest opportunity. The following procedures are recommended:

- (a) Check that the heading marker is aligned with the compass heading of the ship.
- (b) Ensure that the heading marker line on the display is aligned with the fore-and-aft line of the ship. This is done by selecting a conspicuous but small object with a small and distinct echo which is clearly identifiable and lies as near as possible at the edge of the range scale in use. Measure simultaneously the relative visual bearing of this object and the relative bearing on the display. Any misalignment must be removed in accordance with the instructions in the equipment manual.

2.24 To avoid introducing serious bearing errors, adjustment of the heading marker should not be carried out by using the alignment of the berth on a ship which is alongside in harbour; nor should it be carried out using bearings of targets which are not distinct, close to the vessel or have not been identified with certainty both by radar and visually.

### **Electronic radar plotting aids (ARPA and ATA)**

2.25 In addition to the advice given above and the instructions contained in the Operating Manual, users of ARPA /ATA should ensure that:

- (a) the test programmes are used to check the validity of the ARPA/ATA data,
- (b) the performance of the radar is at its optimum,
- (c) the heading and speed inputs to the ARPA/ATA are satisfactory. Correct speed input, where provided by manual setting of the appropriate ARPA/ATA controls or by an external input, is vital for correct processing of ARPA/ATA data. Serious errors of output data can arise if heading and speed inputs to the ARPA/ATA are incorrect. Users should be aware of possible hazards of using ground stabilised mode with ARPA/ATA when assessing risk of collision with approaching vessels, particularly in areas where significant tidal streams and/or currents exist. When course and speed inputs are derived from electronic position fixing systems (eg LORAN, GPS and DGPS) the display is ground-stabilised. The output data of tracked targets will relate to their ground track and, although accurate, may be highly misleading when assessing target aspect and determining collision-avoidance manoeuvres. In cases of gyro failure when heading data is provided from a transmitting magnetic compass, watchkeepers should remember to determine and apply the errors of the magnetic compass.

2.26 The use of audible operational warnings and alarms to denote that a target has closed on a range, transits a user-selected zone or breaks a pre-set CPA or TCPA limit does not relieve the user from the duty to maintain a proper lookout by all available means. Such warnings and alarms, when the ARPA is in automatic acquisition mode, should be used with caution especially in the vicinity of small radar-inconspicuous targets. Users should familiarise themselves with the effects of error sources on the automatic tracking of targets by reference to the ARPA Operating Manual.

2.27 Information on detection and use of Search and Rescue Transponders (SARTs) is provided in Chapter 4 of Volume 5 of the Admiralty List of Radio Signals.

### **3. TERRESTRIAL HYPERBOLIC POSITIONING SYSTEMS**

#### **General**

3.1 With world-wide coverage by satellite navigation systems, the use of hyperbolic positioning systems at sea is declining. The Omega system has ceased operation, and under present plans the Decca Navigator System will cease to operate in Europe around the year 2000. LORAN C, however, is to be retained for the time being in certain areas. It will be available to maritime users as the terrestrial electronic position fixing service to back-up global satellite systems.

3.2 The use of lattice charts with hyperbolic positioning systems has declined, because most receivers convert the readings to latitude and longitude. These receivers display positions referred to a particular horizontal datum (eg WGS 84). This may not be the datum of the chart in use. The user must still remember that hyperbolic systems have inherent errors, and that the apparent accuracy of the displayed positions should be treated with caution.

3.3 Some equipment processes data from several electronic positioning systems (eg Decca, LORAN and GPS) and computes the best possible position, so providing a valuable check of one system against another. The use of such equipment does not remove the responsibility of the navigator to check the position periodically using other means, including visual aids.

3.4 Users should be vigilant when receivers are capable of reverting to dead reckoning (DR) mode. Serious accidents have occurred when faults in sensors and antennae connections have caused the receiver to switch to DR mode undetected by the watchkeepers.

3.5 Some terrestrial hyperbolic navigation receivers give a numerical indication of positional accuracy in the form of values of Horizontal and Positional Dilution of Precision (HDOP and PDOP). Users should refer to the equipment manual, as the receiver will not necessarily allow for fixed or variable errors in the system.

3.6 Further information on hyperbolic position fixing systems as well as up to date details of their operational status and coverage can be found in the *Admiralty List of Radio Signals, Volume 2*.

#### **The Decca Navigator System**

3.7 Decca Marine Data Sheets give the fixed errors for geographical areas where these are known. Where no errors are given, it should not be assumed that no error exists. In areas where no fixed errors are given, Decca positions should be treated with caution, especially when near the coast and in restricted waters. Receivers which convert positional data to latitude and longitude may not take fixed errors into account.

3.8 Decca is also subject to variable errors which depend on the time of day, season and distance from the transmitters. The error in a given location is not constant, and the Decca Marine Data Sheets give diagrams and tables which can be used to predict an approximate error based on a 68% probability level, (ie they are not likely to be exceeded on more than one in three occasions).

#### **Lane Slip**

3.9 Particularly at night, there is a possibility of slipping lanes due to interference such as excessive Decca skywave signals, external radio interference and electric storms. The possibility of this happening is small at short range, but increases towards the edge of Decca coverage. Fouling of the Decca antenna and disruptions to the power supply can also cause lane slip. It can best be detected by plotting the ship's position at regular intervals and comparing with fixes obtained by other means.

#### **The LORAN C system**

3.10 LORAN C has a greater range than Decca and is based on the measurement of time difference between the reception of transmitted pulses. The ground-wave coverage is typically between 800 and 1200 miles, although the accuracy of positional information will depend upon the relative position of the transmitters.

3.11 When entering the coverage, or when passing close to transmitters on the coast, the receiver may have difficulty in identifying the correct ground-wave cycle to track. Care should be taken to ensure that it is tracking on the correct cycle.

3.12 The fixed errors of the LORAN C system are caused by variations in the velocity at which the pulses travel. Additional Secondary Factor (ASF) corrections are provided to allow for these errors. Account should be taken of ASF corrections which may be very significant in some areas. Some receivers automatically allow for calculated ASF values and display a corrected position.

#### 4. GLOBAL POSITIONING SYSTEM (GPS)

4.1 The NAVSTAR GPS Standard Positioning Service (SPS) now provides a global positioning capability giving a 95% accuracy in the order of 100 metres. The system is capable of much greater accuracy, but the commercial service is deliberately degraded by Selective Availability (SA). Differential GPS (DGPS) is also becoming more widely available. DGPS receivers apply instantaneous corrections to raw GPS signals determined and transmitted by terrestrial monitoring stations. Positional accuracy of better than 5 metres may be possible.

4.2 The GLONASS system is fully operational and available to commercial users. The system is similar to GPS and also provides global positioning for 24 hours a day. Some receivers use both GPS and GLONASS signals to compute a more precise position. The repeatable accuracy of GLONASS is higher than GPS as there is no degrading of signals by SA. When navigating in confined waters, navigators must bear in mind that the displayed position from any satellite positioning system is that of the antenna.

4.3 Serious accidents have occurred because of over-reliance upon global satellite positioning equipment. In one case a passenger vessel grounded in clear weather because the watchkeepers had relied totally upon the GPS output which had switched to DR mode because of a detached antenna. The switch to DR mode was not detected by the watchkeepers. Checking the position using other means, including visual observations, would have prevented the accident.

##### Datums and Chart Accuracy

4.4 GPS positions are referenced to the global datum WGS 84. This may not be the same as the horizontal datum of the chart in use, meaning that the position when plotted may be in error. The receiver may convert the position to other datums. In this case the observers must ensure that they are aware of the datum of the displayed position. Where the difference in datums is known, a note on the chart provides the offset to apply to positions referenced to WGS 84, but where this is not given the accuracy of the displayed position should be treated with caution. DGPS positions are normally referenced to WGS 84 though local datums may be used (eg NAD 83 in the USA). Also, when using DGPS, it is possible that the positioning of charted data may not be as accurate as the DGPS position. Mariners should therefore always allow a sensible safety margin to account for any such discrepancies.

4.5 From April 1998, a new Volume 8 of *The Admiralty List of Radio Signals*, entitled *Satellite Navigation Systems* will contain full descriptions of all satellite systems, including GPS and DGPS, as well as notes on their correct use and limitations. Also included will be descriptions and examples of over-reliance on GPS, together with the advantages and disadvantages of using DGPS, and a full account of the problems caused by differing horizontal datums. Mariners using satellite navigation systems are strongly advised to study the information and follow the advice contained in this publication.

#### 5. ELECTRONIC CHARTS

5.1 A number of vessels now use electronic charts. Mariners should be aware that the only type of electronic chart system with performance standards adopted by IMO is the Electronic Chart Display and Information System (ECDIS). One requirement of an ECDIS is that it must only use official vector data produced by a national hydrographic office. At present, this Electronic Navigational Chart (ENC) data is not widely available and the use of ECDIS is limited. An ECDIS using official ENC data satisfies the SOLAS Chapter V requirement for vessels to carry up to date charts.

##### Vector charts

5.2 The ENC is a database of individual items of digitised chart data which can be displayed as a seamless chart. ENCs of appropriate detail are provided for different navigational purposes such as coastal navigation, harbour approach and berthing. The amount of detail displayed is automatically reduced when the scale of a particular ENC is reduced, in order to lessen clutter. Individual items of data can be selected and all relevant information will be displayed (for instance, all the available information relevant to a light or navigation mark.) ECDIS is therefore very much more than an electronic version of the paper chart. With vector charts the data is "layered", enabling the user to de-select certain categories of data, such as a range of soundings, which are not required at the time. This facility, as well as reducing chart clutter, enables the user to select a depth contour so providing an electronic safety contour which may automatically warn the watchkeeper when approaching shallow water. Mariners should use the facility to de-select data with extreme caution as it is possible accidentally to remove data essential for the safe navigation of the vessel.

5.3 Unless using an ECDIS meeting the relevant international performance standards in an area where ENC data is available, navigation must be carried out on an up-to-date paper chart. A number of vector chart systems are available which use commercially produced data for which the manufacturers accept no liability. These systems vary in capability and are termed Electronic Chart Systems (ECS). Such systems have no IMO adopted standards. If an ECS is carried on board, the continuous use of paper charts is essential.

#### **Raster charts**

5.4 Another type of electronic chart system is the Raster Chart Display System (RCDS). This uses Raster Nautical Charts (RNCs), which are exact facsimiles of hydrographic office paper charts, for which hydrographic offices take the same liability as for their paper products. There are at present no IMO performance standards for RCDS and they too must only be used in conjunction with paper charts.

#### **General**

5.5 Electronic chart systems are integrated with an electronic position-fixing system (LORAN, GPS or DGPS) enabling the vessel's position to be continuously displayed. Problems may arise caused by the possible differences in horizontal datums referred to above. Electronic charts may also be integrated with the radar and electronically plotted data from ARPA, ATA or EPA, with part or all of the radar display overlaid or under-laid on the chart display. There is a danger that the combined display may become over-cluttered with data. The combining of target data on an electronic chart does not reduce the need for the targets to be observed on the radar display. Mariners should also exercise caution where target vectors based on the vessel's water-track are overlaid on an electronic chart which displays the vessel's ground track.

5.6 Electronic charts will become an essential part of the navigation system of the modern bridge and contribute greatly to navigational safety. However such systems must be used prudently bearing in mind the proliferation of approved and unapproved equipment and the current scarcity of official vector data.

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