9.1.3 Galileo

GPS and GLONASS are controlled by the governments of two 'super powers'. The systems can be switched off fully or selectively without warning to users, leading to dependency concerns. The European Union programme, known as Galileo, is designed to overcome many of these concerns and it is part of the second phase of the evolution of global navigation satellite systems, as part of GNSS-2.

Galileo is planned to be independent from, but fully compatible with, GPS and GLONASS. The accuracy of each is compared in Table 9.1. Commercial service is claimed to offer accuracy of 1m for global use and better than 10cm for local use, using locally augmented signals similar to DGPS.

Galileo is forecast to be fully operational in 2008. Five positioning services are planned:

Open The basic level for mass market applications (Free)
Commercial Available for commercial and professional applications
Public Regulated For government applications with high continuity characteristics
Safety of Life Restricted access, certified service for safety critical applications, e.g. for passenger safety – air, rail, other transport, etc.
Search and Rescue Global service to pinpoint the location of distress messages (evolution of COSPAS/SARSAT) (Free)

9.1.3.1 Galileo System Architecture

The core system comprises :

- A navigation control and constellation management centre
- A constellation of medium earth orbit satellites.
- An up-link service network
- An integrity monitoring service network
- Communication links to services

The system will be linked to local and regional user components, operational services systems, the COSPAS-SARSAT ground segment, navigational users, communication links and other external complementary systems. Galileo is open to international partnerships outside of the European Union. The system is also being considered for navigation related communications and may eventually replace COSPAS-SARSAT.

9.1.4 Satellite System Comparison

Table 9.1 - Satellite Navigation System Comparison

	GPS	GLONASS	GALILEO
Coverage	Global	Global	Global
Availability	Continuous	Continuous	Guaranteed 99.8% of the time
Satellites	24 + 3	24 + 3	27 + 3
Orbit inclination	55°	64.8°	56°
Altitude km	20,200	19,100	23,222
Orbit time	11h 58m	11h 15m	13h
Orbital planes	6, with 4 satellites each	3, with 8 satellites each	3, with 9 satellites each
Preferred use	Low to middle latitudes	High latitudes	Up to 75° Latitude
Accuracy Single Fq	22m	8 to 33 m	15 m
Accuracy Dual Fq	5 to 10 m	5 to 10 m	4 m
Control	Defence	Defence	Civil
Service	User's risk	User's risk	Guaranteed

9.1.5 Differential GPS

Satellite navigation systems changed navigational practices and has a lot of reliance placed on them. In certain areas, such as harbours and approaches, the accuracy available was not adequate. To achieve a high level of accuracy, differential GPS was introduced.

A number of land based stations, equipped with a GPS receiver, have been set up at critical locations. As these reference stations are at fixed positions, the errors or differences in the received signals can be calculated. There are a number of ways in which the differences are recorded, but the preferred method is the pseudo-range differential as it can be worked out separately for each of the satellites in view.

The pseudo-range differential is transmitted to receivers in the locality on MF (285 – 325 kHz) in RCTM SC104 format. This is an industry standard for encoding DGPS corrections. Users wishing to receive the DGPS service need to have equipment for receiving the MF transmission from the local beacon, as well as the GPS receiver capable of incorporating encoded DGPS corrections. Some of these stations are commercial and require the receiver to have a special encryption decoding receiver unit. The general range of DGPS service is 200′, although some beacons are operating at longer ranges of up to 300′. DGPS systems covering a large area using geostationary satellites are also available. The standard of accuracy is that of the PPS. After discontinuity of selective availability (SA), accuracy figures of 2 to 5m are being claimed. After SA there is a question mark on the number of users requiring DGPS service, although the system is still very attractive to users requiring high precision, e.g., DP, survey, dredging, etc. One advantage of DGPS is that it provides independent monitoring of the satellites.

9.1.6 Combined System – GNSS 1 (Global Navigation Satellite System)

GPS and GLONASS constellations have features that, if combined, can make up for the limitations of one another. A unit capable of receiving signals from both systems can make use of increased numbers of satellites, and can offer a number of added advantages:

- In higher latitudes, enough satellites at a good elevation would be available. This is not possible using GPS alone
- Faster acquisition time can be achieved as more satellites are visible at any given time and location
- A decrease in PDOP parameter
- As GLONASS P code is not yet encrypted, civilian users can enjoy accuracy equivalent to GPS Y code.

When Galileo becomes operational, plans are that it will integrate with GPS and GLONASS, while working independently of both systems, to form GNSS 2.

9.1.7 Augmentation Systems

These improve the use of the GPS and GLONASS through:

- improved accuracy resulting in reliability
- integrity
- availability and continuity

Regional arrangements, in the form of overlay systems are in place. The overlay stations provide a network of ground stations that detect and relay interpolative corrections through geostationary satellites (INMARSAT).

Presently, 3 satellite based augmentation systems (SBAS) are in use:

WAAS American Wide Area Augmentation System
EGNOS European Geostationary Navigation Overlay System
MSAS Japanese Multi-functional transport satellite (MTSAT) – based Augmentation System

9.1.7.1 SBAS Functioning

The signals from GPS or GPS/GLONASS satellites are received at many widely-spaced reference stations. The reference station locations are precisely surveyed so that any errors in the received signals can be detected.

The GPS/GLONASS information collected by the reference stations is forwarded to the Master stations, via a terrestrial communications network, where the augmentation messages are generated. The messages contain information that allows GPS and GLONASS receivers to remove errors in the direct signals, significantly increasing location accuracy and reliability. The augmentation messages

are sent from the Master station(s), via uplink stations, to be transmitted to geostationary communications satellites.

The geostationary satellites broadcast the augmentation messages on a GPS/GLONASS-like signal. The receiver processes the augmentation message as part of the exercise to estimate position by applying corrections directly to the signal received.

9.1.7.2 WAAS

The Wide Area Augmentation System (WAAS) is a GPS-based navigation system that provides precision guidance capability for the USA and some parts of neighbouring countries. WAAS specified accuracy is 7.6m, but provides accuracy of up to 2-3m for horizontal use. Further improvements are being made to achieve accuracy of 1m. WAAS can notify receivers within 6 seconds of any potential problems with the GPS system. WAAS was designed for aviation use and is not optimised for surface use. It may be used, with caution, in the maritime environment but it should not be relied upon for safety-critical maritime navigation.

9.1.7.3 EGNOS

This is a GPS and GLONASS based system covering Europe and will provide accuracy of 5m or less. In addition to basic ranging corrections, EGNOS will provide wide area differential corrections and an integrity monitoring service. EGNOS is also intended to work with Galileo when it becomes operational. Like WAAS, it targets the aviation field. In the maritime field it improves available accuracy where DGPS is not available.

9.1.7.4 MSAS

This system covers most of the Asia-Pacific region with an accuracy of within 5m or less since 2005.

9.1.8 Comparison Of DGPS And SBAS

The SBAS signals are transmitted on an L-band radio frequency which travels in line of sight only. The SBAS signal can be blocked behind obstructions. DGPS transmits on MF (285 – 325 kHz), the ground wave of which can wrap around objects and arrive at the receiver position within the coverage area.

DGPS only covers a small region of about 200′ radius (some beacons up to 300′), whereas SBAS can cover a large area.

DGPS is designed for marine safety-critical navigation applications.

9.1.9 Factors Affecting Satellite Derived Positions

9.1.9.1 Satellite Clock Bias Error

Very small discrepancies in the accuracy within the atomic clocks of the satellite can result in travel time measurement errors, causing a degradation of about 1.5m in the final calculated position. For radio waves, a time difference of 1µs (microsecond) equals 300m in terms of distance.

9.1.9.2 Relativity Error

Time is compressed the closer one is to the earth's centre of mass. The satellite time is therefore different to a user who is closer to the earth's centre.

9.1.9.3 Positional Error

Monitoring of satellites takes place at specific periods. Between these periods, small errors in position of the satellite can lead to range error of about 2.5m.

9.1.9.4 GDOP (Geometric Dilution of Precision)

GDOP is an indicator of reliability of the position, rather than the accuracy. It depends upon the geometry of the satellites relative to the receiver and measures the spread of satellites around the receiver. The best combination would be to have one in a position overhead of the receiver and three spread at 120° on the horizon.

Satellites at low elevation produce a poor vertical position and can affect the determination of altitude. The VDOP (vertical) describes the effect of satellite geometry on altitude calculations. Satellites that are widely spaced cause different intersecting positions crossing at almost right angles and the HDOP (horizontal) describes the effect of this on position errors (latitude and longitude). A HDOP < 3 is a good working figure. VDOP and HDOP combine to determine PDOP (position). PDOP combined with TDOP (time) results in GDOP. Good quality receivers have a built-in ability to determine the combination of the satellites in view that will provide the best possible calculated result, although user override is permitted.

9.1.9.5 Selective Availability

The intentional degradation of GPS satellite constellation was controlled by the US Department of Defence to limit the accuracy for non-US military users. This is so that hostile interests cannot use accurate positional data for ill intentions. The degradation was introduced by adding random noise into the clock data of the satellite. This practice has now been discontinued by the US and instead a selective denial of GPS signals on a regional basis is employed.

9.1.9.6 Atmosphere and Ionosphere

Ionosphere is the part of the atmosphere that contains a high density of ions and exists at 70 to 80 km above the Earth's surface. An error, in the form of a delay, may occur when the signal path from the satellite to the receiver passes through it. These

delays are predictable. The delays are worked out using complex mathematical models, but the model used often sets one GPS receiver apart from another. It may cause range errors up to 5m.

Troposphere is the lower part of the atmosphere that lies between the ground and 9-16 km above it. This layer contains the greatest mass of air, as well as all the water vapour. Within this region, weather systems cause complex and substantial pressure, temperature, humidity and density changes to occur. As these conditions are variable, the delays cannot be predicted with any degree of accuracy. These conditions usually account for range error of up to 1 m. The error can be minimised by calculating the relative speeds of two different signals from the same satellite.

9.1.9.7 Solar Activity

Large scale eruptions on the sun can lead to adverse effect on the transmission of the GPS signal, which may be anything from a negligible amount to total loss. The changes in the Sun's magnetic field blow out a large part of sun's outer atmosphere. The earth is generally well protected to deflect such magnetic material. However, some may penetrate the atmosphere and can induce enhanced currents and particle streams which may cause tracking failure for satellites as well as power failures in general.

9.1.9.8 Multi-Path

It is likely that the receiver will pick up signals reflected from surfaces in its vicinity. Such signals will not have followed a straight line path and will have bounced from one or more surfaces. These signals may cause confusion in calculations at the receiver because of delayed reception compared to the direct signal. It is difficult to detect the effect using ordinary receivers but good quality receivers using signal rejection techniques can minimise the error.

The resultant combination of some of the above errors can limit the accuracy of the calculated horizontal position for the signal frequency GPS receivers to about 22m for 95% of the time which is the equivalent of 2drms (two-distance root mean squared).

9.1.10 Precautions for Navigation

- All operators must be fully conversant with the manufacturer's instructions regarding set up and use of the receiver unit
- All operators must be properly familiarised with, and trained on, use of equipment before working with it
- System limitations must be known and it must be understood that the displayed position is not necessarily the ship's actual position. If there are no errors, the position is that of the receiver antenna. If errors exist, the position is not of the antenna, but is within a circle of probability and contains the antenna within this circle

- Errors are generally applied automatically, but if not the operator should make allowances accordingly and decide on the level of reliance to be placed on output data
- Warnings received about any problems with the systems in use must be taken into consideration and brought to the attention of the bridge team
- Set up should be appropriate for the passage plan in use, setting the safety margins for the relevant stages of the passage plan. Where required, the antenna height must be entered correctly, and adjusted for any changes on passage
- GDOP should be checked regularly. Most receivers select satellites automatically, but override is possible and where better satellites are available, the same should be tracked for position purposes
- Differences between the chart datum and WGS 84 must be applied, as per the notes on the chart
- Position monitoring must include the use of primary and secondary systems
- Where charts in use are based on older survey data, the charted positions may be significantly out from actual positions, with no reference to the corrections to be applied between satellite derived positions and charted positions. In such cases, effort should be made to obtain the range and bearing of charted objects and they should be applied on the chart for position fixing. A log should be maintained of satellite positions
- Transferring positions between charts should not simply be by latitude and longitude, but also by range and bearing from a common charted mark
- A good check should be kept on the receiver and all alarms should be followed-up
- Regular cross check with other systems and thorough celestial observations must be carried out. The operator must know the limitations of the systems that are being used for cross checking purposes
- If a receiver shifts to DR mode, the attention of all watchkeeping officers must be drawn to the fact and positions plotted from other sources
- Plot positions at the agreed fix frequency and check distances run and course made good
- Keep a separate check on DR and estimated position after every fix, based upon courses and speed, taking into account the expected set and drift
- Cross track error and arrival alarms should be checked regularly, especially when approaching waypoints
- Track adjustments should not be made too frequently unless in congested waters
- Where other integrated bridge equipment requires satellite navigation data, ensure that the reliance and accuracy required from the other equipment is not greater than the base data that is provided.

9.1.11 Satellite System Vulnerabilities

The use of satellite systems are likely to be affected by a number of external influences.

9.1.11.1 Human Factors

Over-reliance on any system is poor practice. Any system output is only as accurate as the data put in and the interpretation of the results.

9.1.11.2 Intentional Interference

Intentional interference is likely to be meant for longer periods. The most obvious is the selective or complete denial by an administration. External influences may attempt to jam the system or spoof it through counterfeit signals.
Physical damage may be caused to the satellites or the ground segment, which will leave the system crippled for longer periods.

9.1.11.3 Unintentional Interference

Unintentional interference would generally be of short term duration. Some radio frequencies are likely to interfere with the satellite signals, making them useless for as long as the influence of the external frequency remains. In the recent past an active television antenna had the capability to transmit on GPS frequency. The high powered military radar fitted on warships has been known to severely affect the commercial GPS set on a merchant vessel. Satellite system testing may leave the signals unusable during the test period. It is also likely that the system will be affected by the frequency spectrum being congested. Solar magnetic particles may cause problems with the signals and ground segment control.

9.2 Hyperbolic Systems

A number of hyperbolic systems based on signals coming from terrestrial stations on land were in use in the recent past. Presently LORAN-C (and a similar Russian system CHAYKA with limited coverage) is still available for marine navigation and others like DECCA, LORAN A, and OMEGA have been phased out.

9.2.1 LORAN-C (Long Range Navigation system)

LORAN C is a hyperbolic position fixing system. It uses a low frequency of 100 kHz and transmits pulses. The system has a ground wave range of 800′ to 1200′ However, high accuracy useful range is only 300′ or so from the transmitting stations in the vicinity of the base line.

9.2.1.1 Principle

A Hyperbola is a line or a curve joining all points that are an equal difference of distance between two fixed points. LORAN C uses the speed of a radio signal to calculate the difference of distance from the transmitting station. At the time of the development of such systems, the absolute accuracy of the clocks that could be economically made available on ships (and other moving vehicles) was inadequate. The hyperbolic system uses two stations for each position line, which makes it possible to measure accurately the time difference between the receipt of the two separate signals.

Figure 9.3 shows two stations that simultaneously send a radio pulse. The pulse would arrive at the Line of Position (LOP) with a time difference of 2000 µs (microseconds). All the points with a 2000 µs form a position line, known as a hyperbolic line.

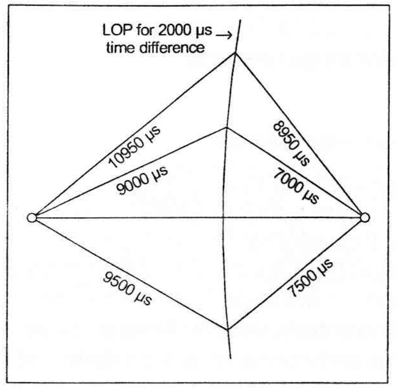


Figure 9.3 - Hyperbolic LOP

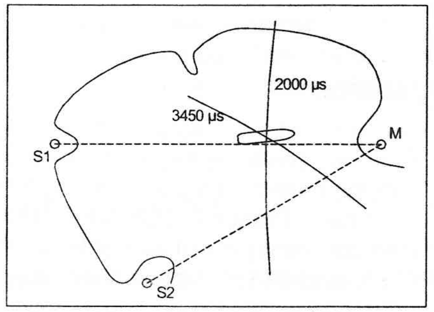


Figure 9.4 - Two LOPs for a fix

Two LOPs are required for a fix. If another hyperbolic line from measurements of two more stations (or more likely one new station and one existing station) crosses this LOP, a position can be generated.

Figure 9.4 shows the use of 3 stations for fix, with 2 LOP's generated by measurements of time difference between stations M to S1 and M to S2.

9.2.1.2 Transmission Timing

The full hyperbolic pattern, or lattice, for time differences can be understood by considering the transmissions from two stations.

As the speed of radio waves is the same, the signals will travel equal distance in equal time. If the stations transmitted at the same time, the hyperbolic lines can be generated between two stations, which are 12000 µs apart, as follows.

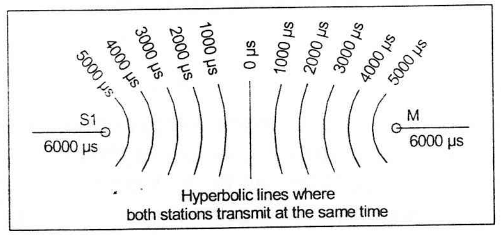


Figure 9.5 - Hyperbolic Lines

The lattice at Figure 9.5 has a number of problems. The most significant is that if the receiver is close to the region of lattice line 0, at say around 1000µs, then it is not possible to ascertain which of the pulses arrived first. Because the receiver would not know which of the 1000µs it is currently on, there is ambiguity. This problem is overcome by incorporating a known delay to the transmission from the second station (S1).

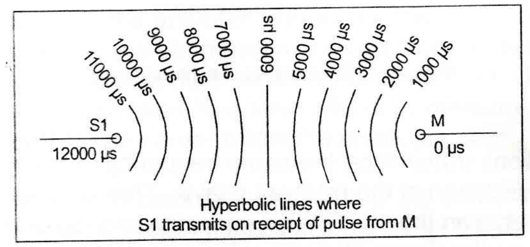


Figure 9.6 - Hyperbolic Lines (2)

The second station S1 should not transmit until the signal from M actually reaches S1, and this time would be 12000µs. The hyperbolic lines in Figure 9.6 are the same as the lattice in Figure 9.5 and only need to be renumbered. This delay ensures that S1 never transmits before the arrival of a pulse from M. In reality, a further known delay (mentioned above) ensures that the S1 always transmits after the arrival of the pulse from M.

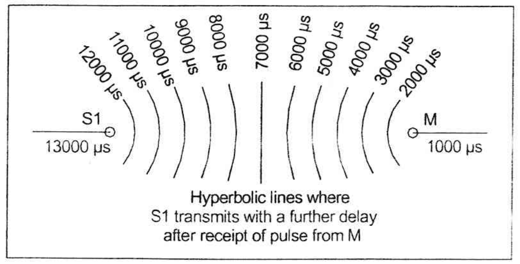


Figure 9.7 - Hyperbolic Lines (3)

9.2.1.3 System Composition

LORAN C functions through chains of stations. Within each chain there is a Master station and two, three or four slave stations. Adjacent chains may share slave stations. The slave stations are identified as W, X, Y and Z. Transmissions within each chain are in sequence starting with Master station transmission followed by the W, X, Y and Z .

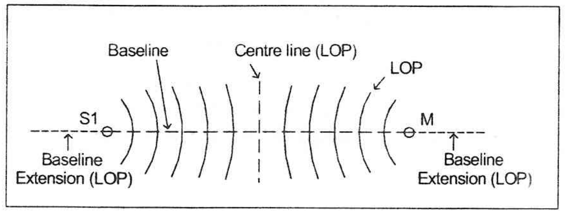


Figure 9.8 - Lattice Terminology

As all LORAN C stations transmit on the same frequency, a method has to be incorporated for identification of the relevant chains. This is achieved by introducing a specified interval between the successive transmissions of each station within a chain. This is known as the Group Repetition Interval (GRI) and is unique for an individual chain. The GRI should be such that transmissions from each station within the group are accommodated and it avoids interference with other chains. The total GRI divided by hundred provides the chain's designator. Thus the chain with GRI 798,000µs covering Southeast USA is designated 7980.

After the signal from the Master station reaches the first slave, it waits for an interval known as the Secondary Coding Delay. The total time between transmissions of Master and slave stations is called the 'emission delay'.

Emission Delay = signal travel time along base line + secondary coding delay

This waiting period or delay ensures that the pulses arrive in the correct sequence anywhere within the coverage of the chain. The sequence is Master pulses first, followed by slave W, followed by slave X, followed by slave Y and finally slave Z. The sequence is only repeated after all stations within the chain have transmitted.

The system includes monitoring stations that keep a check on the integrity of the chains.

9.2.1.4 LORAN C Pulse

The signal is transmitted in the form of pulses and not as continuous waves. This has the advantage of:

- lower power output requirement
- better signal identification
- precise timing of signals
- better comparison for time difference measurements.

The Master station transmits a block of eight plus one (nine) pulses and each slave transmits a block of eight pulses. The ninth pulse is used for the identification of the Master station. The interval between transmissions of individual pulses within the group of eight is 1000µs. The Master ninth pulse is transmitted after 2000µs of the Master eighth pulse.

The pulse has a length of 300µs. It is in the shape of an envelope which exhibits a steep rise to maximum amplitude within 65µs.

The time difference between the arrival of signals from two stations is determined by matching the eight pulses. The eight matches provide a better average. The measurements are a "coarse time difference measurement", which is achieved by matching pulse envelopes and then "fine time difference measurement", made by matching the phase of 100 kHz carrier within the envelope.

The receiver is programmed to detect the 3rd cycle of the carrier frequency of each pulse. This is done for two reasons. At this stage the pulse has built up enough signal strength for it to be detected. The leading edge of the pulse is not a good choice as it may be deformed.

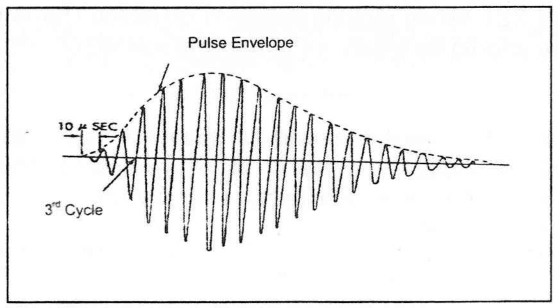


Figure 9.9 - LORAN-C

The second reason is that it is early enough in the pulse to ensure that the receiver is matching the ground-wave and not the sky-wave. The earliest a sky-wave can reach a receiver is 35µs after the ground-wave. This way the receiver would have carried out the matching in advance of arrival of the sky-wave.

The arrival of sky-waves may be as late as 1000µs. Another feature of the pulse that is used to eliminate sky-wave is the 'Phase Coding'. The phase of the carrier signal is changed systematically from pulse to pulse. Upon receipt, sky-wave pulses would be out of phase with simultaneously received ground-wave pulses and will be rejected. The phase coding also assists with identification of Master and slave station pulses.

9.2.1.5 LORAN C Charts And Receivers

Some nautical charts have LOPs overlaid on them. The LOP might be designated 7980-X-15750. 7980 is the chain GRI designator, X indicates that it is the "Master - Slave X" LOP and the time difference is 15750µs. Interpolation must be performed when plotting positions between two LOPs. These LOPs are colour coded and can be identified by the colour symbols at the bottom left hand corner of chart, outside of the margin.

Most modern receivers determine and display the latitude and longitude of the receiver position. Required corrections (see 9.2.1.6) may be incorporated in the receiver memory and are applied automatically. Care should be taken to set the notch filters correctly and to not set the notch filter on 100 kHz frequency.

9.2.1.6 Errors

Any errors or problems with a slave station are indicated by blink of its first two pulses. The pulses are kept off for 3.6 seconds and on for 0.4 second. The Master station pulses are not blinked. Problems with LORAN-C system are notified through navigational warnings (NAVTEX "H", see 11.1.6.2.2 and 11.2.1).

Terrestrial radio signals are characterised as having varying accuracy depending on time of day, time of year and, at longer ranges, interference from sky-waves. The conductivity of terrain over which the LORAN C signal passes dictates the velocity. Additional Secondary Factor (ASF) corrections are provided to take account of velocity errors. These are available on LORAN lattice charts, as well as tabulated in US HO publication No 221. When plotting positions on lattice charts that incorporate such corrections, care should be taken not to apply tabulated corrections before plotting.

A small angle between LOPs can deteriorate the quality of a fix. Assuming that the LOP error is constant, the position uncertainty varies inversely by the sine of the angle between the two position lines. Similarly, using stations close to the baseline extension can have the same effect.

9.2.1.7 Accuracy

LORAN C is designed to provide accuracy of 0.25 nm when receiving ground-waves close to the baseline and centreline. This figure gets worse during night, at extended distances from the stations, during twilight or when ground waves are being tracked. The journey of the signal over land or sea and the time it spends over land can lower the accuracy. Similarly, any signal attenuation may affect accuracy. The receiver processor's capability will also affect results.

9.2.2 Eurofix

Since the current satellite navigation systems do not guarantee availability, it is important to consider back-up systems.

LORAN C and DGPS integration allows differential satellite corrections to be sent to receivers as time modulated signal information on the LORAN C signal, without affecting the navigation function of LORAN C.

Both LORAN C and satellite frequencies are received. The user can operate in any mode:

- DGPS
- GPS
- LORAN C
- Integrated function where LORAN C position is a coarse check on GPS and the user is not reliant on external warnings of satellite or LORAN C failure

The system is also expected to integrate with Galileo, once it is ready.

The Eurofix system has the advantage of feeding satellite problems to the user on terrestrial frequencies, based on observations at a land based station nearby.

9.3 Electronic Charts

An Electronic Chart Display and Information System (ECDIS) is an electronic chart system that meets the IMO specifications for carrying charts, as per SOLAS Chapter V. The ECDIS system has to be type approved to IEC61174.

9.3.1 ENC

An Electronic Navigational Chart (ENC) of content, structure and format issued by a government authorised Hydrographic Office is used for ECDIS.

The ECDIS performance standards developed by IMO and IHO for ENCs are:

S57 ENC Product Specification;
S52 ENC Symbols.

ENCs conform to IHO specifications and, where used with a type-approved ECDIS system with adequate back-up arrangements, meet the SOLAS Chapter V chart carriage requirement.

ENCs are vector charts and are compiled from a set of individual items or objects, arranged in layers from the database. A number of these layers may be added or removed by the operator. ENCs allow the interrogation of any object for the purpose of finding out more details about it.

An ENC can be displayed as a seamless chart. During ECDIS system use, the change over from one chart to the other would generally be automatic, unless the operator loads the chart manually.

The Hydrographic offices of individual governments have the responsibility to produce ENCs for their own coastal and inland waters, using up to date Hydrographic information. Not all governments have produced the required ENCs and a major part of the earth is presently not covered by ENCs.

9.3.2 RNC

A Raster Navigational Chart (RNC) is a scanned version of the corresponding paper chart. RNC's may also be used with the ECDIS system where ENC's are not available and an appropriate folio of up to date paper charts are available. RNCs do not make full use of ECDIS system functionality as a number of functions related to route checking and monitoring cannot be performed.

As the whole world is not covered by ENCs, Raster charts are likely to remain in use during the foreseeable future.

9.3.3 Use of ECDIS

The navigator of a vessel equipped with ECDIS can follow most stages of a passage if it is used correctly. Planning and monitoring can be performed on all makes of approved systems. ECDIS allows a route to be checked and verified when vector charts are being used. Where an ECDIS system is part of an integrated bridge system (IBS), the passage can be successfully executed.

9.3.3.1 Chart Selection

The more recent versions of ECDIS systems load charts on to the hard drive of a computer. This is normally a stand-alone PC for ECDIS-use only.

> Do not let this PC be used for any other purpose. There are many documented instances of ECDIS-failure where additional software for administration (or even games), have been loaded and used. Once the

> software is loaded, do not allow any other software to be loaded and back-up the PC with a suitable utility, such as Norton Ghost.

Load the ECDIS-only PC with a portfolio of electronic charts, especially the ones required for the voyage. They can be selected from an electronic catalogue included on the ECDIS system and can be loaded either automatically or manually, at the discretion of the navigator.

From the point it begins to load the charts, the system automatically displays the chart that best suits the view area. Automatic display allows the charts to be scrolled as the ship navigates from one chart area to another. Some systems only use the selected portfolio as a safety-check on the voyage being planned and will ignore all other ECDIS-system charts.

The navigator must be certain that the selected charts are current editions with up-to-date corrections applied. (see 9.3.4)

9.3.3.2 Manoeuvring Data

When it is commissioned, the ECDIS system receives the ship's manoeuvring data. But before passage planning can begin, the ship's exact condition for the intended voyage must be loaded. This helps the system as it calculates the wheel-over distances and the curved path followed by the ship when it alters course.

At the planning stage, the navigator uses the draught and air-draught of the ship to set the safe-depth/safe-height parameters for the current voyage. These may have to be changed for different stages of the voyage. For example, in open coastal waters, a larger margin may be allowed, while in narrows and pilotage waters the margin may have to be reduced.

Approved systems set a safety guard zone around the ship. This is based on its physical characteristics plus half-of-beam ahead, astern and either side. The ship's time course vector over the ground is also displayed, based upon look-ahead time and current speed.

9.3.3.3 Route Planning

On an ECDIS system, the route can be developed in two ways. In the first, you can either use a smaller display scale (or a small-scale paper chart) to plan the route. In the second method, you can select the waypoints at intended alterations and let the system calculate the course and distances between them. Use the keypad to enter waypoints, taking the numbers from the chart or using the cursor to select the on-screen digits. The navigator has other options to establish a waypoint, for example, ERBL, EBL or VRM.

To start planning, select and name the route. Then follow this checklist:

- Click on waypoint option
- Name the waypoint

- Enter waypoint latitude and longitude
- Choose RL or GC track
- Set port and starboard XTE
- Set UKC parameters
- Set arrival circle
- Set turn radius
- Set helm angle

You can change parameters for the XTE during the voyage. Settings are controlled either manually or automatically by the system:

- In automatic mode, the voyage plan safety zone = 2 x XTE, plus a ship-width on either side of the track. This safety zone may bypass the waypoints and is only established around the track.
- In manual setting, the navigator will define the port and starboard XTE limits.

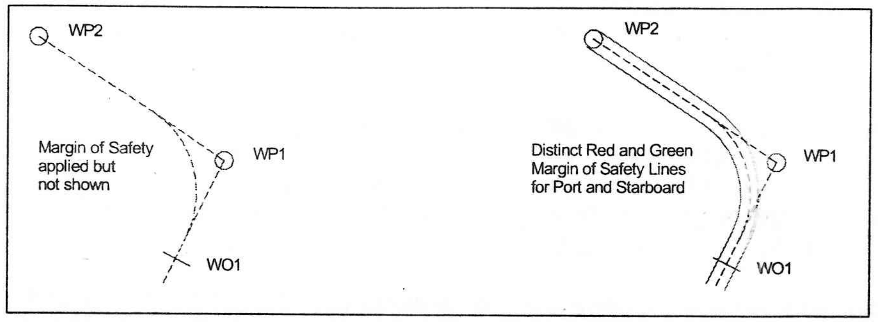


Figure 9.10 - Two Types of Presentations of Track

An ECDIS system (working with vector charts) will recognise and warn of dangers on the planned track and will not save the route. To accept the route, the navigator must adjust the course, distance or the waypoint.

Use the route-editing function in these circumstances:

- If a start or end waypoint has been created or added, check the newly-created leg of the route for dangers to navigation
- Where a waypoint in the middle of the route has been added or moved, check the route legs on either side and edit (if appropriate)
- Where XTE has been altered without changing the waypoint position.

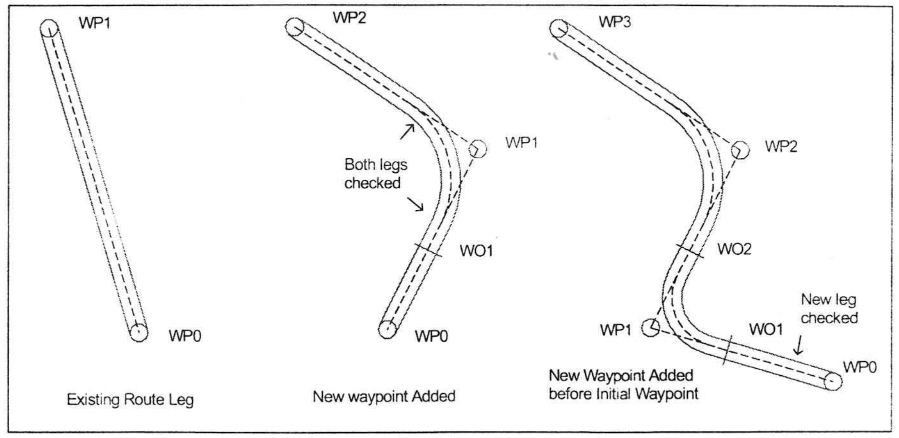


Figure 9.11 - Route Editing Between New or Amended Waypoints

9.3.3.4 Safety Zones

When a safety zone violation occurs, an ECDIS system working on vector charts triggers danger alarms for specified safety parameters, as well as a variety of other specific object types. The navigator can add danger areas and some other features to the raster chart to obtain danger warnings. The ECDIS system should have alarms for a number of events including:

- A Chart on a different datum than the positioning system
- Chart data displayed overscale
- A larger scale chart available
- Deviation from planned route
- Exceeding cross track limits
- Approach to waypoints or other critical stages
- Failure of the position fixing system that is providing data
- The ship crossing a safety contour
- A system failure or malfunction

It is possible to annotate the Electronic chart systems with messages in support of navigational activities. The navigator may add T&P notices, Master or pilot calls, etc. A vast number of options are available and these vary with the system in use.

9.3.3.5 Monitoring

For monitoring purposes, the selected position-fixing system integrated with the ECDIS system allows the real time position of the ship to be displayed on the chart.

These features allow the monitoring of:

- Heading Line
- COG Line
- Heading Vector
- XTE
- Arrival Circle
- Turns
- Waypoint Names
- ARPA data on ship's motion parameters
- ARPA cursor
- Target table
- Predicted positions of the ship during the manoeuvre

The navigator uses the various functions of the system to help them to monitor the voyage. One function allows scrolling the route to 'look-ahead' for dangers close to the route, course alterations or special instructions for the voyage.

Features like, EBRL, EBL and VRM are aids to monitoring. They allow visual or radar observations to confirm the integrity of the secondary systems and the overall monitoring process. The navigator may also overlay the radar/ARPA and AIS on ECDIS. The risk of information-overload on the ECDIS system is countered by reducing the number of devices or displays that have to be monitored.

9.3.4 Correction Of Electronic Charts

9.3.4.1 Interactive Entry

The operator applies the correction based upon the Notices to Mariners. The corrections are applied using the tool kit in the chart system software. It is labour intensive and operator error is likely.

9.3.4.2 Semi-Automatic Entry

Updates are taken from electronic corrections held on a floppy disk, CD or modem. The ECDIS system processes the corrections and provides an updated chart with the amended data.

9.3.4.3 Fully Automatic Entry

A direct telecommunications link receives the official digital update and inputs into the ECDIS system. No operator interface is required.

It is important to note that Temporary and Preliminary Notices would always have to be entered manually using the interactive toolkit. Similarly, navigational warnings received would also have to be entered manually.

9.3.5 Precautions during the use of ECDIS Systems

- The operators should be fully familiarised and trained in the use of equipment, as per the manufacturer's instructions
- The chart supply and correction arrangement should remain active
- The back-up systems and an alternate power supply should be checked and tested regularly
- The position displayed by the ECDIS system is only as good as that of the input system and over-reliance should be avoided
- The position displayed should be cross checked using the monitoring tools of the ECDIS system(see 9.3.3.5), to confirm integrity of all systems
- Unnecessary overlay of external data should be avoided

The mariner needs to be aware of a number of issues when using ENCs:

- The symbols and colours used do not necessarily match across paper charts and ENCs. Colours would be different for day and night displays
- When the scale of the chart is changed on an ECDIS system, the size of symbols will not change. This may cause problems when working on smaller scales as some objects from a lower layer may be hidden under objects on the upper layers
- Too many layers may hide data or clutter the display, especially on a smaller scale
- De-layering may remove data that could be of significance to safe navigation
- Objects or data could be hidden behind overlaid radar/ARPA or AIS data
- The alarms will only activate against set parameters. If they have been set incorrectly, alarms may not activate in enough time to take avoiding action.

The mariner needs to be aware of a number of key issues that make the RNC use different from the ENC:

- An RNC can only be used in conjunction with an appropriate portfolio of up to date paper charts
- With RNC use, automatic alarms will not be triggered. Some user-inserted information can generate alarms, e.g. ship safety contour lines, clearing lines, danger areas, etc
- In congested waters, the accuracy of chart data may be less than that of the position-fixing system used for the ECDIS system
- The horizontal chart datum may be different to that of the position-fixing system. The datum may also differ between RNCs

- RNCs are not seamless
- The RNC should be displayed on the scale of the paper chart. An increase or decrease in scale by excessive zooming-in or zooming-out can seriously degrade the quality of the display, as the size of charted features changes with the scale
- Without selecting different scales, the look-ahead capability may be limited. The determination of range and bearing of distant objects may be more difficult
- The colours displayed may not be the same as those on the paper charts and may be different for day and night displays
- Chart features cannot be removed or simplified to meet specific navigational situations
- Interrogation of the charted features may not be possible and additional information about them cannot be obtained
- Orientation of the display, other than chart-up, may make it difficult to interpret chart symbols and read text.

9.4 Integrated Bridge Systems

To reduce the time spent on data processing by the OOW, ships bridges are being automated at an increasing rate. The bridge team is also being provided with displays that allow for a quick evaluation of the navigation picture.

The integrated bridge system may be based upon a number of different combinations of equipment and systems, which will be designed for an individual vessel's needs. Accessibility is an important issue. Some basic elements are:

- Computer processor and network
- Chart arrangement
- Display arrangements
- Planning station
- Radar and ARPA
- Control System

The most important element is the operator. The design of the system should provide intelligent options to the operator to minimise workload and free up the bridge team.

Fully integrated bridge systems can steer the vessel on its planned route. It is very important to ensure that systems are maintained within specifications and that no changes that may adversely affect the integration are made during service or refit.

The integration should ensure that electronic signals are transmitted to at least the NMEA 0183 format, which defines how data is to be transmitted from a navigational device. The standard allows the integrated use of different manufacturer's navigation devices and the design and manufacture of compatible modular marine electronic equipment.

The integrated bridge should be seen only as a mechanism to assist with decision making, and not one for making decisions.

9.5 Echo Sounder

An echo sounder works on the principle of measurement of the time taken by a sound pulse to return from the seabed. As the velocity of sound in sea water is known, this time can be translated into distance. As the sound pulse has to travel the same distance twice – ship to seabed to ship – the depth will be half this distance and so the echo sounders automatically halve it before it is displayed.

In order to obtain reliable depths, the echo sounder should be carefully adjusted and the relevant errors should be taken into account and applied correctly. There is also a possibility of false echoes or traces.

The sound pulse is generated by a transducer fitted in the ships bottom. Some ships' transducers transmit and receive, while others have separate transducers for transmission and reception. Where transmission and reception transducers are different, the vertical depth has to be determined using tables provided to the ship.

When the echo sounder operates, its transmissions are picked up straight away by the receiving transducer. This signal makes a mark on the recording paper in the form of a transmission line and is the benchmark for depths below the keel. With some echo sounders, the line may have to be adjusted to match the depth of the transducer or to allow for the draught of the ship in order to obtain the total depth. Draught adjustment may be made as a number setting on digital display type devices.

The distance travelled in a given time depends upon the speed. The salinity, temperature and pressure of sea water can all change the speed of sound through it. Generally, a figure of 1500 m/sec is applied as the standard velocity of sound in sea water. Regardless of the actual conditions, this value should allow depths to be determined to +/- 5% of true depths. Corrections may be obtained from correction tables for accurate results. On some devices, the speed of the motor controlling the stylus belt may be adjusted to allow for speed of sound.

9.5.1 False Echoes

An echo sounder may display traces showing the incorrect depth for a number of reasons:

- Layers of water having different speeds of sound through them
- Sub-marine springs of water at different density
- Shoals of fish
- Seaweed
- Faults
- Artificial noises
- Tidal streams or eddies causing turbulence when making contact with solid particles in suspension
- Side echoes from objects not exactly below the vessel

9.5.1.1 Double Echo

Some sounders may display an echo at twice the actual depth. This is caused by the returning echo bouncing off the hull, back to seabed and then being received by the transducer. It is always weaker than the true echo and fades out first when sensitivity is decreased.

9.5.1.2 Multiple Echoes

It is possible that the transmission pulse may be reflected several times between the seabed and the surface of the sea or the ships bottom, even in depths of several hundred metres. Every reflection received by the transducer causes a trace, although they can be eliminated by reducing the sensitivity.

9.5.1.3 Round the Clock Echoes

If the returning echo is not received until after the stylus has completed one or more of its cycles, false readings may be obtained. The stylus re-passes the transmission line and another pulse has been transmitted. A sounding of, for example, 20 m may appear as 20m, 320m or 620m on a sounder that has its scale divided. These echoes can be identified as being weaker than the true echoes, or having feathery appearance or pass through the transmission line.

AUTHORS NOTE
Navigation systems have developed significantly over recent years and continue to evolve. The equipment must be set up correctly to obtain the best results. The data provided by these systems is generally of a very high quality, but the limitations and inherent errors must be appreciated and applied correctly. In order to gain full confidence, the integrity of systems should be established with cross checks. Remember we all trust what we see through our eyes, but we should be able to trust something else when we are not able to see things in the vicinity for some reasons.

10 Tides and Tidal Streams

Tides are defined as the periodic motion of the waters of the sea caused by changes in the forces of attraction of the moon and the sun upon the rotating earth. This movement of water is the vertical rise or fall of the water level, which is normally accompanied by horizontal movement of water called a tidal stream or tidal current.

Tides and tidal streams are an important element of voyage planning and play a significant part in navigational safety. In addition to tides, the rise or fall of water levels may also be caused by weather, seismic events or other natural forces. Similarly, the tidal streams are additional to river or channel flows, flood waters, etc.

10.1 Causes Of Tides

There are two main causes of tides:

- gravitational forces of moon and sun on the earth
- centrifugal forces on the earth caused by the revolution of the earth about the common centres of gravity of the earth-moon and earth-sun systems.

The Earth-Moon system rotates about one common centre of gravity and the Earth-Sun system rotates around another. The common centre of gravity is called the barycentre. Earth-Moon and Earth-Sun systems each have a different barycentre. The Earth describes a very small ellipse and the Moon describes a larger ellipse about the Earth-Moon barycentre.

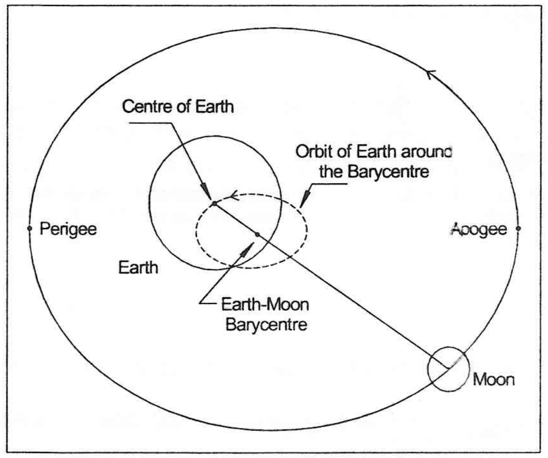


Figure 10.1 - Earth-Moon System

In the absence of the force of gravity, centrifugal force would cause the earth to break away from the sun and move into space in a straight line. Similarly, because of gravity, the moon is in orbit around the earth and not breaking away. The gravity keeps them from moving off and the centrifugal forces keep them from crashing into each other.

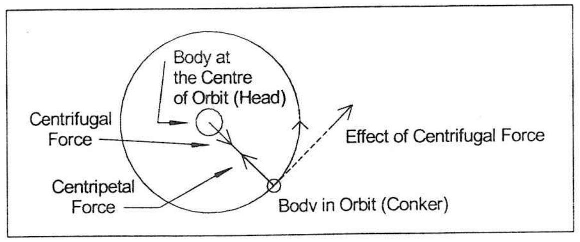


Figure 10.2 - Orbital Forces

According to the universal law of gravity, the force of gravity FG is proportional to the product of the mass of the bodies and inversely proportional to the square of the distance between their centres. m1 and m2 represent the masses of the two bodies and d is the distance between their centres.

$$F_G = G \quad (m_1 \times m_2) \div d2 \quad \text{(G= Gravitational constant)}$$

Since the earth-moon distance is much less than the earth-sun distance, the moon has the largest effect on the tides. The sun's effect is about 45% that of the moon's.

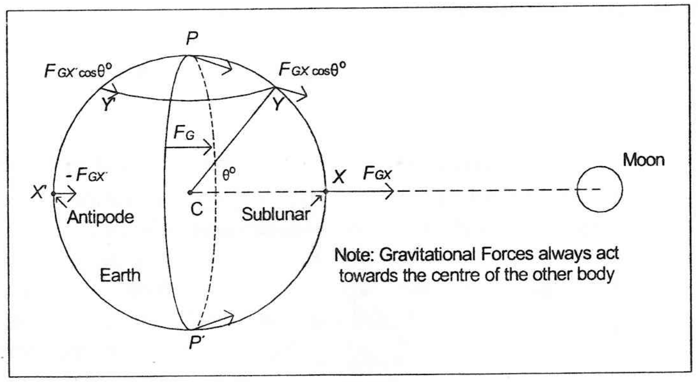


Figure 10.3 - Earth-Moon Gravitational Forces at Various Points on the Earth

The force of gravity between the earth and the moon acts on the whole of the earth and everything on it, including the water. Assume that at any given time, the moon is above a point X on the earth's surface. This point is called the sub-lunar point. If the line from the moon to X ran through to the other side of the earth, it would emerge at the point X′, which is called the antipode. The distance XX′ equals the earth's diameter. A plane perpendicular to this line, through the centre of the earth, divides the earth into two halves, forming a Great Circle PP′ on the surface of the earth. The

distance from the moon at all points on PP′ to the centre of the earth may be considered the same, which implies that the gravitational pull at all points on PP′ and the centre of the earth would be the same, i.e. FG. The point X is nearer to the moon as compared to PP′ and the centre of the earth, and the gravitational pull here is more than at the centre of earth, FGX. For the same reasons the gravitational pull is less at X′ and has a negative comparative value - FGX′. Another way to term this negative value is that it applies in an opposite direction from the moon. An alternate explanation for tide raising force is that it is the difference between the force of gravity and the centrifugal force. The centripetal force between two bodies is always uniform at any of the points.

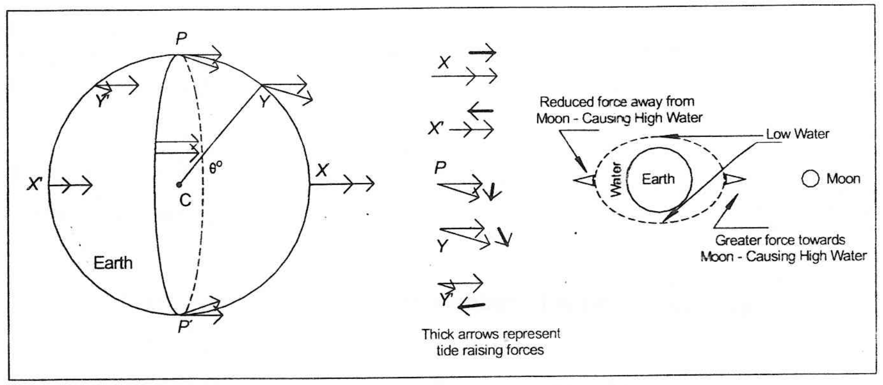


Figure 10.4 - Tide Raising Forces at Various Points on the Earth

At some point Y on the earth's surface away from X, X′ and PP′, the gravitational pull will be less than at X and more than at PP′. If Y is at an angle of θ° from the line XX′, the force at Y is equal to FGX cos θ°. For the same reasons, the gravitational pull at Y′ will be FGX′ cos θ°.

The gravitational pull at Y and Y′ can be resolved into its horizontal and vertical components FGXH and FGXV. The vertical component is only a small proportion of the earth's gravity. The actual tide causing force is the horizontal component which causes the water to move across the earth and pile up at X and X′.

10.2 Variation in Tides

The tide raising forces depend upon a number of factors, including:

- the mass of the earth, moon and sun
- the distance of the centres of the moon and sun from the earth's centre
- the size of the earth relative to its distance from the moon and its distance from the sun
- the angle between the moon and sun, as measured at the earth's centre.

10.2.1 Rotation of the Earth

High water occurs shortly after the moon's upper and lower transit. The delay is due to the rotation effect of the earth as the GHA of the moon changes. The earth rotates in approximately 24h and 50m relative to the moon. An observer on the earth would experience two high waters at an interval of 12h 25m and two low waters, also at an interval of 12h 25m. These are known as semi-diurnal tides.

The earth rotates to the east and the so moon moves relatively to the west. Similarly, the occurrence of tides also moves westwards.

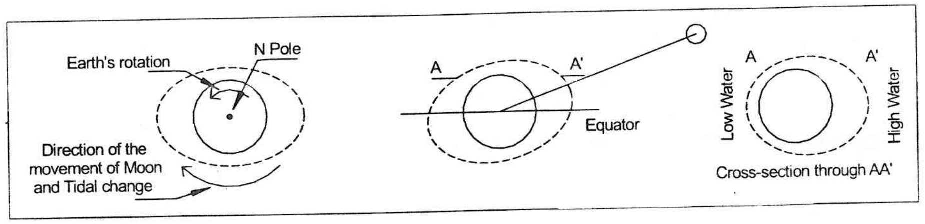


Figure 10.5 - Earths Rotation Effect and Declination Effect

10.2.2 Declination of the Moon

One high and one low water are caused every lunar day due to the declination effect of the moon. The tide so caused is the diurnal tide.

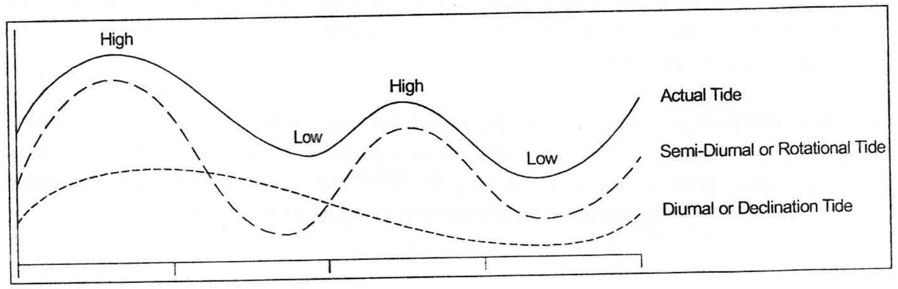


Figure 10.6 - Diurnal and Semi Diurnal Effect in Tides

The actual tide is the sum of the semi-diurnal and diurnal tides. The usual effect is for the two high waters to be of different height.

10.2.3 Distance of the Moon

The moon rotates around the earth in approximately 27½ days. When the moon is closest to the earth, i.e. at perigee, the tide-raising force is at its maximum and when the moon is furthest from the earth, i.e. at apogee, the tide raising force is at its weakest.

10.2.4 Earth-Sun System

This is another tide-raising system, having a tide raising force of about 45% that of Earth-Moon system. A solar day is 24 hours in duration and causes two high waters 12 hours apart, with two low waters in between. The change in the sun's declination is very slow and only has a slow changing effect on solar tide. Similarly, the distance of the sun from the earth is not constant, but since it is so large it causes a very small force of about 3% of the total.

10.2.5 Spring Tides

When the moon is in conjunction or in opposition with the sun, i.e. twice every lunar month at new moon or full moon, the lunar and solar tidal forces are in line and this causes high tides higher than average and low tides lower than average.

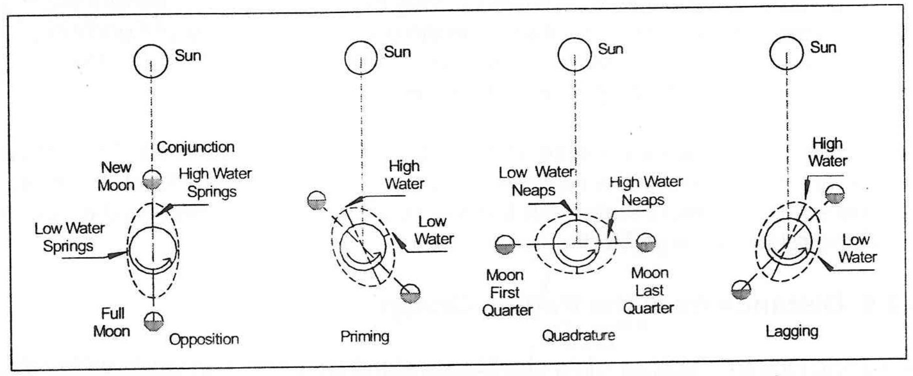


Figure 10.7 - Springs, Priming, Neaps and Lagging

10.2.6 Neap Tides

When the moon is in quadrature with the sun, i.e. twice every lunar month at 1st quarter or 3rd quarter, the lunar and solar tidal forces are at right angles and this causes high tides lower than average and low tides higher than average.

The combined tide-raising effect of the sun and moon will be further pronounced when their declination is the same.

10.2.7 Priming and Lagging

High waters due to lunar tides are caused at intervals of 12h 25m and those due to solar tides at 12h. The effects of both sun and moon together alter the intervals between successive high and low waters.

When the moon is between new and first quarter, and between full and last quarter, the tide is said to prime and the high tide during this period occurs before the moon's transit of the meridian.

When the moon is between first quarter and full, and between last quarter and new, the tide is said to lag and the high tide during this period occurs after the moon's transit of the meridian.

10.2.8 Land Effect

Tide may be modified further by the shape of land. The average daily range in areas not affected by the shape of land is about 2 metres at spring tides and about 1 metre on average. The configuration of the land and sea in the vicinity of the place for which the predictions have been made has a very large influence on both the heights and times of tide. An estuary which is wide at the opening to sea and narrow at the other end, e.g., Bristol Channel, causes the tide to heap up as the land squeezes the tidal heap into a smaller space, resulting in very high tides being experienced, e.g. such as those at Avonmouth. Similarly, the dimensions of the Bay of Fundy in Western Nova Scotia cause synchronisation of the tidal movements and the moon's rotation resulting in the highest tides on the earth.

Another area of significance will be a small inlet to a much larger area. The Straits of Gibraltar are narrow and allow relatively little water to flow into the Mediterranean Sea. The small amount of water that flows in has a very small effect on the height of tides in the relatively large Mediterranean Sea.

10.2.9 Distance from the Pacific Ocean

The Pacific Ocean, because of its size, has a significant effect on world-wide tides. The further that a place is from the Pacific, the later the spring tides will be, relative to the date of the new or full moon. In European waters, spring tides usually occur two days after the new and full moon.

10.2.10 Meteorological Conditions

Seasonal meteorological conditions are predictable and seasonal corrections are listed in the tidal difference pages of the tide tables. When there is low pressure, an increase in height would be caused in all states of tides and when the pressure is high, a reduction in height would be caused in all states of tides. A fall of 30 hPa will cause up to 30cm increase in the height of water in all states of the tide. The wind has a variable effect on tidal times and heights.

Daily variations in weather cannot be predicted at the stage of tide table compilation. Strong onshore and offshore winds, or significantly unusual pressure, may cause the water level to be higher or lower than predicted. Similarly, storm surges are experienced with tropical revolving storms.

10.3 Tidal Definitions

Tidal change occurs twice a day at most places. The tide rises until it reaches its maximum level called high water or high tide, and then falls to a minimum level called low water or low tide.

Chart datum or sounding datum is the level to which soundings and drying heights on the chart, and heights in the tide tables, are referred to. The chart datum is generally referred to as MLWS. In some parts of the world, it is the level of the lowest astronomical tide (LAT). Under average meteorological conditions and any combination of astronomical conditions, this is the lowest level to which tides can be expected to fall. Because of changes in sea level, chart datum is subject to re-examination from time to time.

A long period of observation for tides is 18.6 years, although some administrations use 19 years.

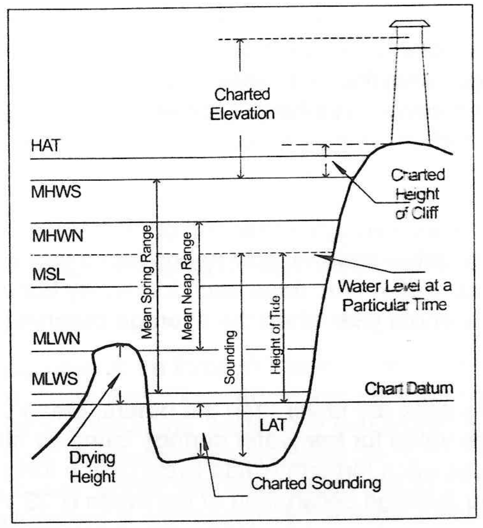


Figure 10.8 - Tide Levels, Heights and Ranges

Mean Sea Level (MSL) is the average level of the sea surface over a long time period, or the average level that would exist without tides

Charted Depth is the actual depth of water at a place without applying the height of tide and is the vertical distance downwards from the chart datum to the seabed

Drying height is the vertical distance from the chart datum upwards, to any surface that has a vertical height between chart datum and the MHWS

The Height of Objects on the metric charts is measured in metres above MHWS. Examples of such heights include the height of the focal plane of lighthouses, mountains, towers, clearance under bridges, clearance under overhead cables, and any other spot height of significance to the navigator

The Height of Tide is the height of water above the chart datum at any given moment

The depth of water is equal to the charted depth plus the height of the tide

A Spring tide occurs when the moon is new or full, i.e. the moon is in conjunction with the sun and earth or in opposition with the sun and earth

A Neap tide occurs twice each month, when the moon is at the first or third quarter, i.e., it is in quadrature with sun and earth

Some high water spring tides are higher than the others. Mean High Water Springs (MHWS) is the average value for high water springs found by taking the two consecutive highest tides from each fortnightly tide cycle over a long period or taken over a whole year when the average declination of the moon is at 23 ½°.

Some high water neap tides are lower than the others. Mean High Water Neaps (MHWN) is the average value for high water neaps, found by taking the two consecutive lowest high water neap tides each fortnightly tide cycle over a long period, or taken over a whole year when the average declination of the moon is 23 ½°.

Some low water neap tides are higher than the others. Mean Low Water Neaps (MLWN) is the average value for low water neaps found by taking the two consecutive highest low water neap tides each fortnightly tide cycle over a long period, or taken over a whole year when the average declination of the moon is 23 ½°.

Some low water spring tides are lower than the others. Mean Low Water Springs (MLWS) is the average value for low water springs found by taking the two consecutive lowest tides each fortnightly tide cycle over a long period, or taken over a whole year when the average declination of the moon is 23 ½°.

Mean Higher High Water (MHHW) is the average height of the higher high waters of each tidal day over a long period of time.

Mean Lower High Water (MLHW) is the average height of the lower of high waters of each tidal day over a long period of time.

Mean Higher Low Water (MHLW) is the average height of the higher of low waters of each tidal day over a long period of time.

Mean Lower Low Water (MLLW) is the average height of the lower low waters of each tidal day over a long period of time.

Mean High Water (MHW) is the average height of all high waters over a long period at a given place.

Mean Low Water (MLW) is the average height of all low waters over a long period at a given place.

Mean Tidal Level (MTL) is the average of the heights of MHWS, MHWN, MLWN and MLWS.

Range is the difference in height between consecutive high and low waters, i.e. between one high water and the next low water, or between a low water to the next high water. The value of range may change from tide to tide. Daily Range is the range experienced on any one day.

Spring Range is the range of tide at the time of the spring tides.

Neap Range is the range of tide at the time of the neap tides.

Mean Spring Range is the difference between MHWS and MLWS.

Mean Neap Range is the difference between MHWN and MLWN.

Mean High Water Interval (MHWI) is the mean time interval between the Moon's meridian passage over Greenwich and the time of next high water at the place concerned.

10.4 Underkeel Clearance and Air Draught

Most voyages at sea will have to be through shallow water at some time. The navigator needs to make sure that adequate clearance is maintained under the keel at all times. In some parts of the world, especially port areas, harbours, rivers, canals, and certain offshore areas, the authorities lay down the minimum under-keel allowance. In all other cases, under-keel clearances should be determined by the mariner. Under-keel allowance is expressed as the depth below the keel of the ship when stationary.

The factors in deciding this allowance will depend upon:

- Uncertainties in charted depth
- Uncertainties in the vessel's draught, especially after a long passage
- Squat at a given speed
- Risk of negative tidal surges
- The vessel's course relative to the prevailing weather. This will have to be considered separately for each leg of the passage
- The vessel's movement in heavy weather. Pitching, heaving and rolling of the vessel will significantly reduce under-keel clearance

- Possible alterations in depth since the last chart survey
- Areas of offshore exploration. Pipelines on the seabed can reduce under-keel clearance by up to 2 metres. Slant drilling can also considerably reduce under-keel clearance
- Areas of a mobile sea bottom such as sand waves
- Areas of volcanic activity
- The possibility of inaccuracies of offshore tidal predictions
- Non-availability of tidal predictions in certain areas, especially in offshore regions
- The extent of the survey when determining deepwater routes
- Variation in consumption and the resulting errors in draught
- Inaccuracies in determination of the initial draught
- Changes of trim or draught that are unknown to the mariner
- High or low pressure can cause a significant difference
- Human error in calculating the tidal heights and times from published data and the skill with which it is related to the chart datum
- The likelihood of new dangers developing in the area and delay in notification of this information to the mariner.

Because of swells and the reliability of surveys, Under-keel Clearance required in offshore areas is likely to be greater than that required in harbour areas.

DRAUGHT + UNDER-KEEL ALLOWANCE = LEAST CHARTED DEPTH + HEIGHT OF TIDE

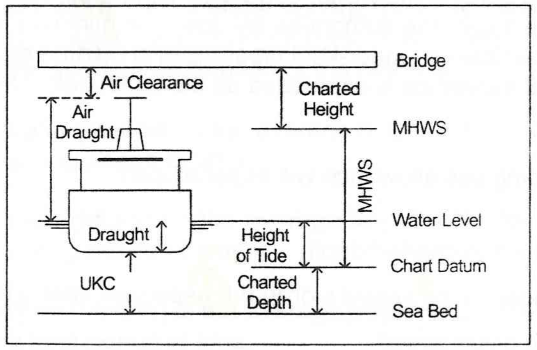


Figure 10.9 - Draught and UKC

AIR DRAUGHT + AIR CLEARANCE = (MHWS + CHARTED HEIGHT) – HEIGHT OF TIDE

Similarly, clearance above the highest point of the vessel may be important. Maintenance work being carried out on the underside of overhead objects will further reduce the overhead clearance.

10.5 Tidal Calculations

The basic principles of obtaining tidal heights are the same, regardless of the method used. In the case of Tide Tables, the data for times and heights can be read off directly from the daily pages and the intermediate values can be obtained through graphs and calculations. In other cases, computer software is used to provide the predictions. The UKHO provides the 'TotalTide' CD and Easy Tide on the web. Other providers also make use of simple programmes to work out predictions, mainly based upon the harmonic constants. Harmonic constants from tide tables can be used directly to work out tides.

The mariner has an interest in the times and heights of high and low waters, as well as the time the tide will be a certain height or the height of a tide at a certain time. Calculations may involve the standard or secondary port.

The tides may be for European ports or Pacific Tide ports. For all cases, the calculations have been explained using the following examples.

10.5.1 European Tides – Standard Port

Example 10.1
A ship drawing 9.0m is unable to make the 1st high water on the 28th January 2006 at Greenock. She is required to pass over a shoal charted at 8.5m with a UKC of 2.0m.
Find the latest time that she can pass the charted shoal with the required UKC during the 1st PM falling tide.
Will the ship be able to pass over the shoal during the 1st PM falling tide with the required clearance if the ETA was 1400 hours local time?

Solution and Comments

1. The first stage is to determine the height of the tide using the equation:

DRAUGHT + UNDER-KEEL ALLOWANCE = LEAST CHARTED DEPTH + HEIGHT OF TIDE

9.0 + 2.0	= 8.5 + Height of Tide
Height of Tide	= (9.0 + 2.0) – 8.5 = 2.5m

2. The next stage is to extract data from the tide tables. Care should be taken to refer to the correct port and date. From ATT Vol 1, p 139, for 28th January 2006 at Greenock:

0426	0.8	
1135	3.3	1st HW is at 1135
1707	0.4	1st falling tide during PM is between 1135 and 1707
2353	3.2	

Range = 3.3 ~ 0.4 = 2.9 (Interpolation required between spring and neap curves, where applicable)

3. Reference should now be made to the spring and neap curves for the port. On the left hand side of the graph, mark the predicted height of HW along the top line at 3.3m. Care should be taken to read the scale as some graphs have divisions of 1m while others have 2m. Similarly, mark LW along the bottom line at 0.4m. Join the two marks.

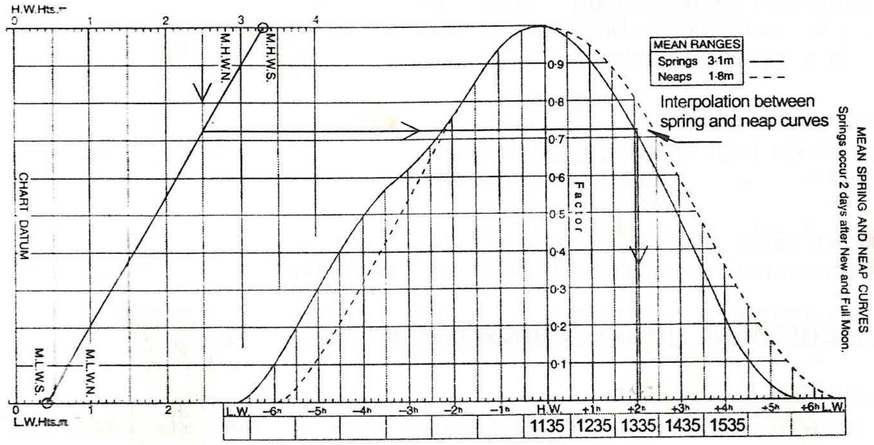


Figure 10.10 - Graph for Example 10.1

4. On the right hand side of the graph, note the predicted time of HW in the central box under HW. Add hourly incremental times in the boxes to the right.
5. Drop a line vertically from the 2.5m mark to the diagonal line between HW and LW. At the intersection, draw a line horizontally to the spring and neap curves.
6. Since the range is not the same as spring or neap, interpolation is required. The difference between spring and neap range is 3.1 ~ 1.8 = 1.3. From spring range to current range the difference is 3.1 ~ 2.9 = 0.2. Therefore, the fraction required is 0.2/1.3 of the distance between spring and neap curves.
7. At this point, drop a vertical to reach the time scale. The middle of each box marks the time written in it. The small marks on the boxes are at 10 minute intervals.

From the tidal curve, the required time is +2h and 5 minutes after HW, i.e., **1340 hours.**

As the tide is falling further, at 1400 the ship will not be able to pass over the shoal with the required clearance.

10.5.2 European Tides – Secondary Port

Example 10.2

On 27th April 2006 at 1530 local time, a ship with a draught of 4.0m obtains a sounding of 2.5m below the keel. Find the charted depth for this observation at Port Glasgow.

Solution and Comments

1. Charted depth can be determined using the equation:

DRAUGHT + UNDER-KEEL ALLOWANCE = LEAST CHARTED DEPTH + HEIGHT OF TIDE

4.0 + 2.5 = Charted Depth + Height of Tide

But first the Height of Tide needs to be calculated for 1530.

2. Port Glasgow is a secondary port with Greenock being the standard port. The ATT reference numbers are:
   404 Greenock
   405 Port Glasgow

3. From ATT Vol 1, p 139, for 27th April 2006 at Greenock (In April, UK local time is BST and not GMT: 1530 local = 1430 GMT):
   0503 (= 0603 BST) 0.2
   1203 (= 1303 BST) 3.5
   1727 (= 1827 BST) - 0.1

The time in question (1430 GMT) falls between HW 1203 and LW 1727.

ATT Vol 1, Page 316 **SCOTLAND; WEST COAST**

No.	PLACE	Lat. N	Long. W	TIME DIFFERENCES High Water Zone UT(GMT)		Low Water		HEIGHT DIFFERENCES (IN METRES) MHWS	MHWN	MLWN	MLWS	ML Z_0 m
404	GREENOCK	(see page 138)		0000 and 1200	0600 and 1800	0000 and 1200	[illegible] and 1800	3.4	2.8	1.0	0.3	
405	Port Glasgow	55 56	4 41	+0010	+0005	+0010	-0020	+0.2	-0.1	0.0	0.0	⊙
406	Bowling	55 56	4 29	+0020	+0010	+0030	-0055	+0.6	-0.5	+0.3	+0.1	⊙
406a	Clydebank (Rothesay Dock)	55 54	4 24	+0025	+0015	+0035	-0100	+1.0	-0.8	+0.5	+0.4	2.70
407	Glasgow	55 51	4 16	+0025	+0015	+0035	-0105	+1.3	-1.1	+0.7	+0.4	2.90

4. Data should now be extracted from ATT for the standard and secondary port differences, along with seasonal changes.

5. The time and height differences to be applied to the Greenock predictions for the Port Glasgow data should now be worked out. This may not seem common sense, but the suggested format will help avoid errors and speed up calculations.

For HW – Time difference:

Tabular time before 1203 is 1200: a Correction = + 0010: c
Tabular time after 1203 is 1800: b Correction = + 0005: d
Differences (a – b) = -06h (-360 min): e (c – d) = 5′: f
Difference between 1200 and 1203 = - 0h 03min (- 3′): g
Time correction for HW at 1203 = c – [(g x f) ÷ e]
= 10 - (3 x 5) ÷ - 360 = - 0.04 (negligible) = 10′

For LW – Time difference:

Tabular time before 1727 is 1200: a Correction = + 0010: c
Tabular time after 1727 is 1800: b Correction = + 0020: d
Differences a – b = -06h (-360 min): e c – d = - 10′: f
Difference between 1200 and 1727 = - 5h 27min (- 327′): g
Time correction for LW at 1727 = c – [(g x f) ÷ e]
= 10 – (- 327 x -10) ÷ - 360 = 10 + 9 (9′.08) = 19′

	HW	LW
	3.5	- 0.1
- Seasonal changes	- 0.1	- 0.1
	3.6	0.0 (These heights are to be used for interpolation)

ATT Vol 1. Page 317

SEASONAL CHANGES IN MEAN LEVEL

No	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Sep. 1	Oct. 1	Nov. 1	Dec. 1	Jan. 1
394 - 398	+0.1	0.0	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	+0.1	+0.1	+0.1
399 - 407	+0.2	+0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	+0.1	+0.2	+0.2
408 - 414a	+0.1	0.0	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	+0.1	+0.1	+0.1
415 - 444	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	+0.1	+0.1	0.0

For HW corrections:

Standard Port	MHWS – MHWN	= h
Secondary Port differences	MHWS – MHWN	= j
Standard Port	MHWS – Standard Port HW	= k

HW Correction = Secondary port MHWS Correction – [(h x j) ÷ k]
h = 3.4 – 2.8 = 0.6 j = 0.2 – 0.1 = 0.1 k = 3.4 – 3.6 = - 0.2
HW Correction = 0.2 – [(0.6 x 0.1) ÷ - 0.2] = 0.23 = 0.2

For LW corrections:

Standard Port	MLWN – MLWS	= h
Secondary Port differences	MLWN – MLWS	= j
Standard Port	MLWN – Standard Port LW	= k

LW Correction = Secondary port MLWN Correction – [(h x j) ÷ k]
h = 1.0 – 0.3 = 0.7 j = 0.0 – 0.0 = 0.0 k = 1.0 – 0.0 = 1.0
LW Correction = 0.0 – [(0.7 x 0.0) ÷ 1.0] = 0.0

6. Using the calculations in Step 5 above, the times and heights of HW and LW are obtained as follows:

	HW	LW
Standard Port Times	1203	1727
Secondary Port Corrections	+ 0010	+ 0019
Secondary Port Times	1213	1746
Standard Port Heights	3.5	-0.1
Seasonal Correction (-)	-0.1	-0.1
	3.6	0.0 (- & - = +)
Secondary Port Correction	0.2	0.0
Secondary Port Heights	3.8	0.0 (un-corrected)
Seasonal Correction	-0.1	-0.1
Secondary Port Heights	3.7	-0.1

Range = 3.7 ~ - 0.1 = 3.8 (since it is above the spring range, the spring curve would be used without any extrapolation)

7. Times and heights should now be marked on the Greenock graph, and height marks should be joined. (Notice -0.1 to the left of 0.0 mark)
8. From 1430, i.e. 27 minutes after 1403, draw a vertical line to the spring curve. At the intersection, draw a horizontal line to reach the heights diagonal line. At this intersection draw a vertical line to reach the scale. Read the height of tide 2.2m.

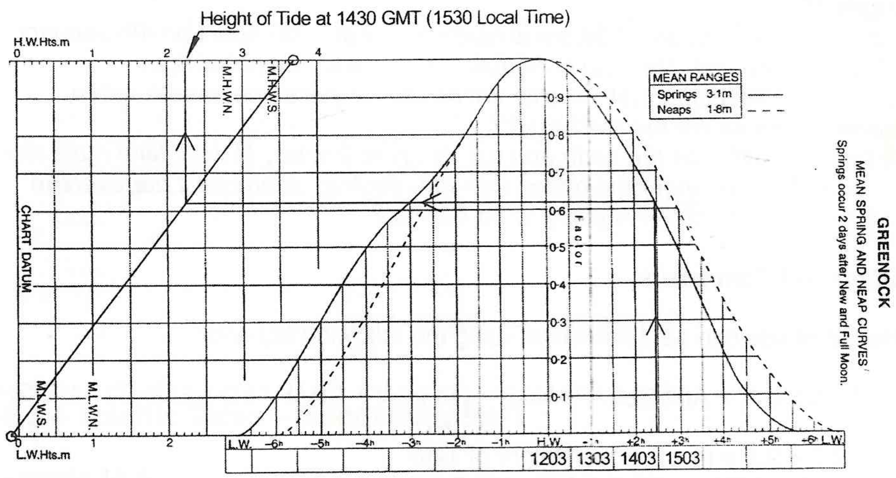


Figure 10.11 - Graph for example 10.2

Total depth	= Draught + UKC	**= 6.5 m**
Charted depth	= 6.5 – 2.2	**= 4.3m**

The tidal data is to one decimal place of a metre only. All fractions above the first decimal place are rounded off to the nearest decimetre, i.e., one decimal of a metre.

10.5.3 Pacific Tides – Standard Port

In most Pacific Tide ports (but not necessarily in the Pacific Ocean) the terminology used is different and different levels are referred to. The equivalents are:

MHWS	=	MHHW
MHWN	=	MLHW
MLWN	=	MHLW
MLWS	=	MLLW

Unlike European Tides, only one graph is provided for all ports, which will have three curves representing a time difference between the successive tides of 5h, 6h and 7h. If the difference in time falls between two successive curves, interpolation is carried out. If the time difference is less than 5h or more than 7h, curves cannot be used, as extrapolation cannot be carried out. In such cases the tides between HW and LW can only be worked out using harmonic constants.

Not all Pacific ports have two high and two low waters as some ports only have diurnal tides. For secondary ports, time differences take into account the time zone changes between the standard and secondary ports and need not be applied separately.

Example 10.3
A ship with an air draught of 59.5m is ready to sail at 2000 hours on 4th January 2006 from Vancouver. Vancouver bridge has a charted height of 60m.
What is the earliest time that the ship will be able to pass underneath with a clearance of 2m above the mast truck?
If the distance between the berth and the bridge is 9 miles, at what time must she sail in order to pass under the bridge with the required clearance if her average speed during the passage is going to be 6 knots?

Solution and Comments

1. Height of tide can be determined using the following equation:

AIR DRAUGHT + AIR CLEARANCE = (MHHW + CHARTED HEIGHT) – HEIGHT OF TIDE

59.5 + 2.0 = (4.4 + 60) – Height of Tide
Height of Tide = (60.0 + 4.4) - (59.5 + 2.0) = 2.9m
At tidal levels up to 2.9m, the ship will be able to clear the bridge with the required clearance. At tidal levels higher than 2.9m, the ship will not be able to clear the bridge with the required clearance.

2. Tidal data Vancouver: 4th and 5th January 2006 from ATT Vol 4, p 165

4th	0220	0.7	5th	0303	1.2
	0935	5.0		1010	5.0
	1554	2.8		1656	2.4
	2028	3.7		2154	3.4

Since the ship is ready to sail at 2000, the tides to be taken into account are for 2028 on the 4th and 0303 on the 5th.

3. Time differences 2028 ~ 0303 = 6h 35m
Interpolation is required between 6 hour and 7 hour curves.

4. Mark the height and times on the graph and draw the required vertical and horizontal lines to determine the time when the tide will be 2.9 m.

From the graph (Figure 10.12), the time when the tide is at 2.9 m is 2301. At this time or afterwards the ship can pass under the bridge with the required clearance.

Steaming time from berth to bridge = 9 / 6 = 1h 30m
The ship should leave the berth at 2301 – 1h 30m = **2131** hours.

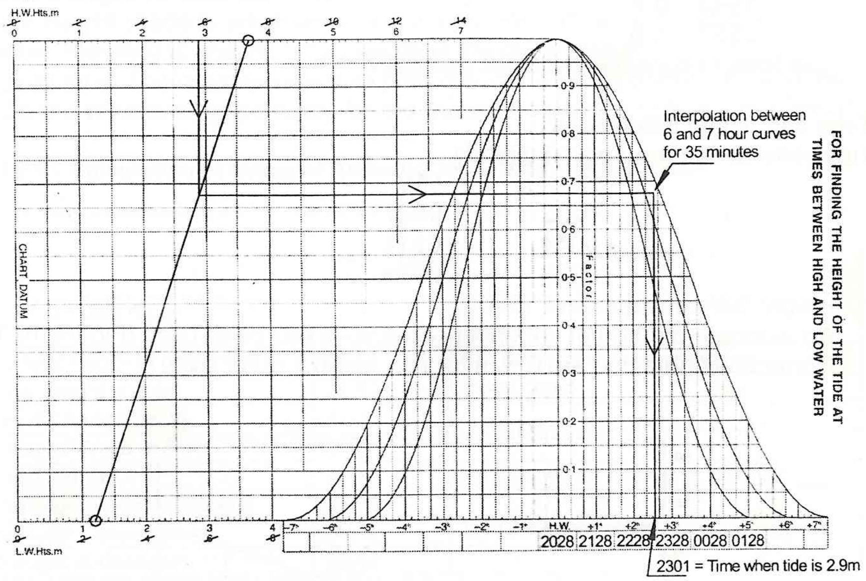


Figure 10.12 - Graph for Example 10.3

10.5.4 Pacific Tides – Secondary Port

Example 10.4
A fully loaded ship with a draught of 5.0m has grounded on a shoal charted at 2.2m at San Mateo Bridge, California on 8th February 2006 at 0600 local time. If the ship has a TPC of 18 t, find the minimum amount of cargo to tranship if the ship is to refloat by HW the next day.

Solution and Comments
1. First stage is to determine the height of tide using the equation:
DRAUGHT + UNDER-KEEL ALLOWANCE = LEAST CHARTED DEPTH + HEIGHT OF TIDE

5.0 + 0.0 = 2.2 + Height of Tide
Height of Tide = (5.0 + 0.0) – 2.2 = 2.8m

2. Tidal data:

	HHW	LLW	MHHW	MLHW	MHLW	MLLW
Standard Port data						
9305 San Francisco			1.7	1.4	0.7	0.0
Secondary Port data						
9307a San Mateo Bridge	+0044	+0111	+0.6	+ 0.5	+0.1	0.0

Seasonal Changes: 9305 and 9307a Negligible

San Francisco (Golden gate) tides for day after grounding:

9th	0232	1.0
	0827	1.8
	1543	-0.1
	2257	1.5

The tides to consider are 0232 and 0827

3. Time and height differences:
Time differences are applied directly

LW	HW
0232	0827
+ 0044	+ 0111
0316	0938

Height Differences:
An alternate method of obtaining corrections has been used (Figure 10.13).
Corrections obtained are 0.6 m for HW and 0.1 m for LW.

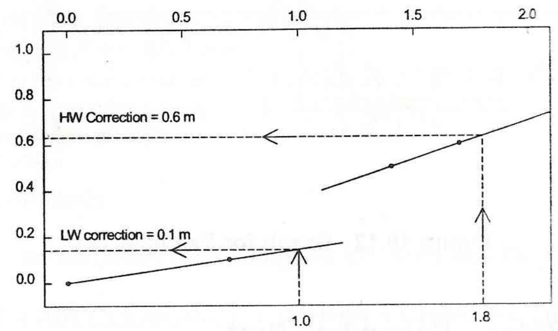


Figure 10.13 - Graph for Example 10.4

Standard Port Heights	1.0	1.8
Seasonal Correction (-)	Negligible	Negligible
	1.0	1.8
Secondary Port Correction	0.1	0.6
Secondary Port Heights	1.1	2.4 (un-corrected)
Seasonal Correction	Negligible	Negligible
Secondary Port Heights	1.1	2.4

Required height of tide	= 2.8m
Available height of tide at 0938 on the 9th	= 2.4 m
Change of sinkage required	= 0.4 m
Cargo to tranship	= 0.4 m x 100 cm x 18 t = 720t

In order to float off, the ship should tranship more than **720t of cargo.**

10.5.5 Tidal Window on Passage

The deep draught vessels can only transit certain parts of the world at certain times, when the height of tide is adequate to allow passage with a safe under- keel allowance. Planning is important to maximise the cargo and proceed with a minimum wastage of time. The mariner needs to plan draught working backwards and then calculate the window of opportunity for the transit through the critical depth areas.

Table 10.1 - Calculation of Draught Allowing for Critical Depth Points

	Value (m)	**Comments**
HW from data range	05.78	For the standard port near the offshore area
Co-tidal Factor to be applied	00.83	For the point of least depth
Tidal Height in area	04.80	Least depth
Least Charted Depth	23.00	
Depth of Water in Area	27.80	
Required UKC	03.50	As planned for this leg of passage
Maximum Possible Draught	24.30	
Passage Consumption	00.12	Up to the point under consideration
Draught at Departure	24.42	

Permissible draughts should be determined for all critical areas with reduced depth. The next stage is to determine the ETA at these points and work out the tides around the ETA.

For example, for a ship requiring a height of tide of 3.5m, the tidal window for the transit through the point of interest is as follows.

It can be seen, from the calculations at Table 10.2, that the ship will have to adjust ETA to 0122 hours on the 13-1-06, through an adjustment of speed.

Table 10.2 - Tidal Window Calculation

	Date	Time	Height	ETA 12-1-06 : 2200 hours
LW	12-1-06	2135	1.2	Corrected for offshore area
HW	13-1-06	0355	4.8	Corrected for offshore area
LW	13-1-06	0907	1.7	Corrected for offshore area
Rising Duration		6h 20m		For Pacific Tides
Range			3.6	For European Tides
Falling Duration		5h 12m		For Pacific Tides
Range			3.1	For European Tides
From Graph				See Figure 10.17
Interval Before HW		2h 33m		From graph
Interval After HW		2h 21m		From graph
Earliest Transit time	13-1-06	0122	3.5	
Latest Transit time	13-1-06	0616	3.5	

Since a number of times and heights will have to be determined on a long passage that has a number of critical depths, the above calculations are best done using a computer programme.

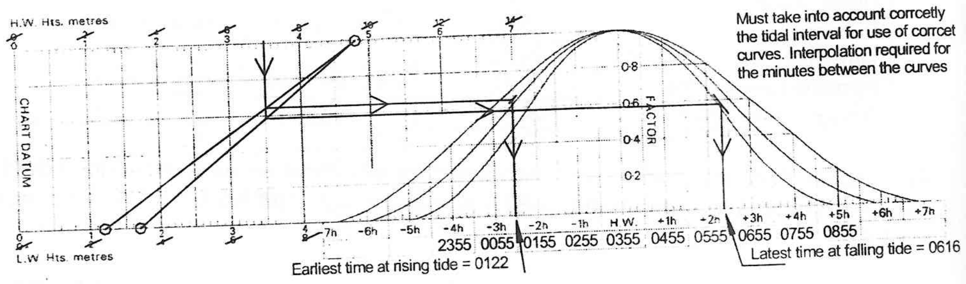


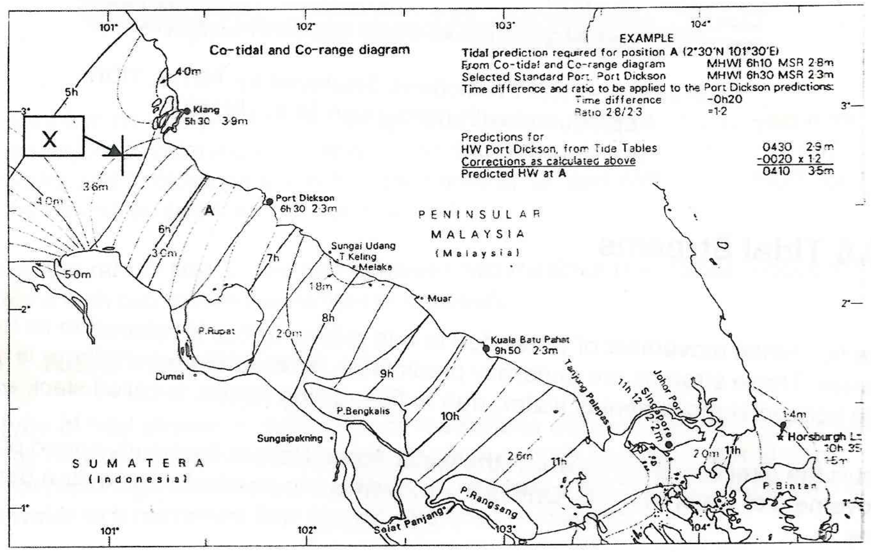
Figure 10.14 - Graph for Tidal Window

10.5.6 Offshore Tides

In order to determine the height of tides in certain areas of navigational significance, use can be made of the Co-tidal and Co-range charts. These charts show lines of equal time and range of tides. Co-tidal lines are drawn through points of equal MHWI and Co-range lines are drawn through points of equal MSR.

A number of Co-tidal and Co-range charts are available for the offshore areas of navigational significance. Additionally, such charts are also added in a smaller scale on passage planning guide charts, e.g. 5500, 5502. A section of BA 5502 has been added as Figure 10.18, and contains an example of the calculation of tides in the offshore regions. For point "X" marked on the chart, and using standard port "Klang":

	MHWI	MSR
Point "X"	5h 25	3.6m
Klang	5h 30	3.9m
Time difference	= -0h 05	Ratio 3.6/3.9 = 0.92
Prediction for Klang	1345	3.7m
Corrections	-0005	x 0.92
Predicted tide at "X"	1340	3.4m



Co-Tidal Co-Range Chartlet from BA 5502

10.5.7 Tide Computations

Computer software is being increasingly being used to provide tidal predictions. UKHO provides 'TotalTide' on CD and 'Easy Tide' on the web. Other providers also make use of simple programmes for tidal calculations.

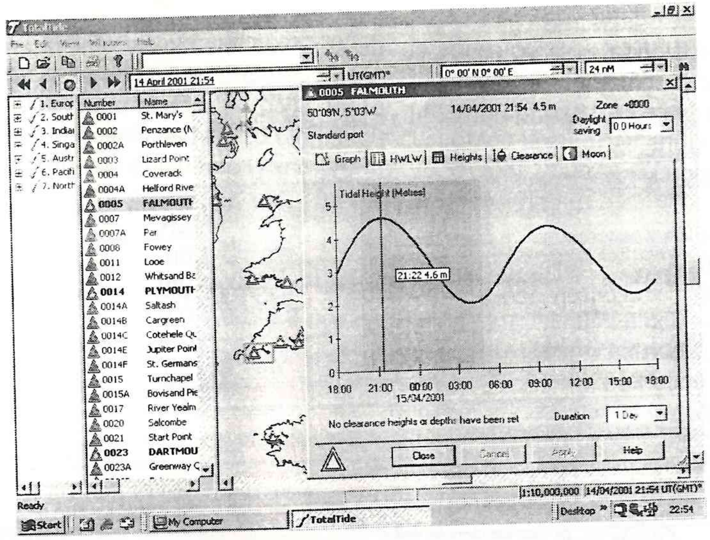


Figure 10.15 - Tidal Predictions Displayed by TOTAL TIDE
(reproduced with permission from UKHO)

10.6 Tidal Streams

The horizontal movement of water due to tide raising forces is referred to as the tidal stream. These streams are generally predictable. The interval where there is no or little horizontal movement of water, due to tide raising forces, is called slack water.

Set is the direction towards which the water flows. Rate is the hourly speed of the movement of water in knots. Drift is the movement in nautical miles over a period of time.

Tidal stream data refers to the uppermost 10 metres layer of the sea. Streams at depths below this layer may not always be the same. This could have an effect on vessels with a deep draught or those engaged in underwater operations.

10.6.1 Rotary Streams

In offshore areas the tidal stream flows continuously in a rotary cycle as there is no restriction on the direction of flow. The rotation is caused by the earth's rotation and is clockwise in the northern hemisphere and anticlockwise in the southern hemisphere, unless modified by local conditions. The hypothetical data related to the Tidal diamond "D" is rotary and can be represented with a current ellipse.

D Lat Long

		T	Sp	Np
Before HW	6	042	2.6	1.9
	5	074	2.1	1.6
	4	107	2.0	1.5
	3	141	2.1	1.6
	2	165	2.4	1.7
	1	192	2.6	1.9
	HW	212	2.7	2.0
After HW	1	234	2.6	1.9
	2	263	2.2	1.3
	3	288	2.0	0.9
	4	314	1.9	0.4
	5	347	2.2	0.2
	6	022	2.5	1.9

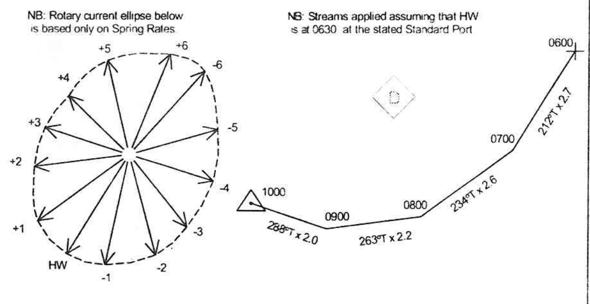


Figure 10.16 - Example of a Rotary Tidal Stream

The rates can be interpolated, but for general use the rates can be applied from 30 minutes before to 30 minutes after a stated data value. In Figure 10.20, at 0600 a ship is stopped in close proximity to tidal diamond "D" and drifts up to 1000, for which time the estimated position has been plotted.

Usually, the rate of flow varies and achieves two maximums in almost opposite directions with two minimums almost in between.

10.6.2 Rectilinear Streams

This type of tidal stream reverses due to restrictions within a river, channel or estuary and has only two directions, separated by slack periods or slack water at each reversal (both high and low water). The rate varies in each direction from zero at slack water to a maximum flow around mid-flood or mid-ebb.

The movement of a tidal stream before high water, i.e., towards shore or upstream, is called the flood tide as it causes the water to rush in to pile up in a certain region. Similarly the movement of water before low water, i.e., away from shore or downstream, is called the ebb.

The maximum rate of tidal stream in each direction is called the strength of flood or ebb. The permanent current in rivers or channels is included in such tidal stream data.

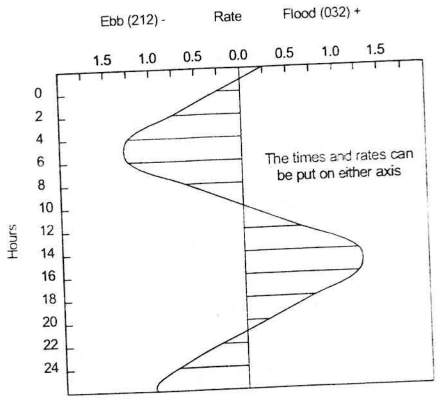


Figure 10.17 - Rectilinear Tidal Stream

10.6.3 Tidal Stream Data

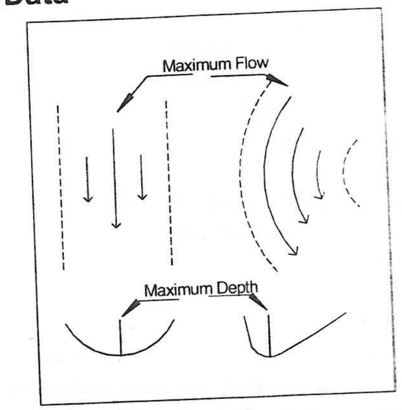


Figure 10.18 - Flow at Various Parts of a Channel

Tidal stream data only refers to the geographical point it is stated for and at times may not be valid at even a small distance away from it. This is because the rates of flow are not uniform in a particular area. For example, the flow is maximum in the middle of a channel and almost zero at the edge of the same channel. But in the case of a bend, the rate is maximum at the outer edge and minimum or zero at the inner edge of the bend. The maximum flow is usually in the deepest part of the channel.

Just like tidal heights, the tidal streams have diurnal and semi-diurnal components. The rates are related to the range of the tide and the times of slack water are related (but not necessarily identical) to the times of high and low water at the nearest standard port.

With semi-diurnal tides, there is no necessity for daily predictions. The data is related to a standard port and may be published on the navigational chart. The rates are provided for spring and neap tides. Interpolation must be performed for rates other

than springs and neaps. At places where the diurnal inequality is large, this procedure cannot be used. Daily predictions are provided for certain important areas that have a large diurnal inequality. Tidal stream atlases cover a wide area relating the data to a nearby standard port.

10.6.4 Harmonic Constants

These can be used for calculating the rate at a given diamond or position. The data can also be input into computer programmes for working out the rate and direction at a given time.

10.6.5 Use of Software

TotalTide is a good example of software providing tidal stream. The information may be displayed in the form of vectors and data from the tidal diamond. The information can also be displayed on a compass rose type panel along with the rate.

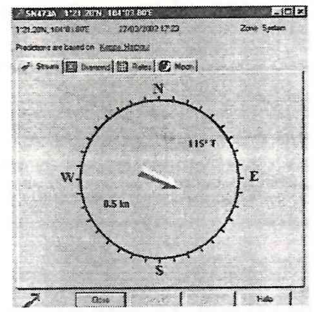


Figure 10.19 - Tidal Stream Displayed by TotalTide
(Reproduced with permission from UKHO)

Example 10.5
Using the data provided, determine the direction and rate of tidal stream at San Francisco Bay Entrance (Golden Gate) on 1st of March 2006 at 1300 California standard time and time when tidal stream is 245°T at 2 knots.

Solution and Comments

Data for the 1st of March 2006 has been boxed below. Using the data, the curve for the tidal stream will be produced. To enhance the curve, times outside of the desired window may be plotted.

UNITED STATES– SAN FRANCISCO BAY ENTRANCE (GOLDEN GATE)

LAT 37°49'N LONG 122°30'W

TIDAL STREAM PREDICTIONS (RATES IN KNOTS)

TIME ZONE +0800 POSITIVE (+) DIRECTION 065 NEGATIVE (-) DIRECTION 245 YEAR 2006

JANUARY

Day	SLACK Time	MAXIMUM Time	Rate	Day	SLACK Time	MAXIMUM Time	Rate
1	0249	0453	-2.2	16	0307	0515	-1.9
	0745	1043	2.8		0826	1113	2.2
SU	1325	1700	-5.7	M	1358	1719	-4.3
	2056				2119		

FEBRUARY

Day	SLACK Time	MAXIMUM Time	Rate	Day	SLACK Time	MAXIMUM Time	Rate
1		0014	4.2	16		0002	2.5
	0332	0606	-3.5		0314	0555	-3.0
W	0928	1220	3.3	TH	0922	1213	2.4
	1517	1820	-4.5		1510	1806	-3.2

MARCH

Day	SLACK Time	MAXIMUM Time	Rate	Day	SLACK Time	MAXIMUM Time	Rate
1	0206	0450	-4.3	16	0153	0443	-3.7
	0814	1111	4.0		0816	1110	3.0
W	1415	1709	-4.7	TH	1418	1701	-3.3
	2042	2336	4.0		2023	2318	2.8

Mark the slack times and the maximum flow times on the graph. Join the marks using a curve that is gently rounded off at the plotted marks.

From 1300, draw a line horizontally to the curve. At the intersection, draw a vertical line to reach rate scale. Stream is 065°T at 1.7 knots.

From 2 knots on the 245° side, draw a vertical line to reach the hour scale. At the intersection, draw a horizontal line to reach the hour scale. The time is 1522.

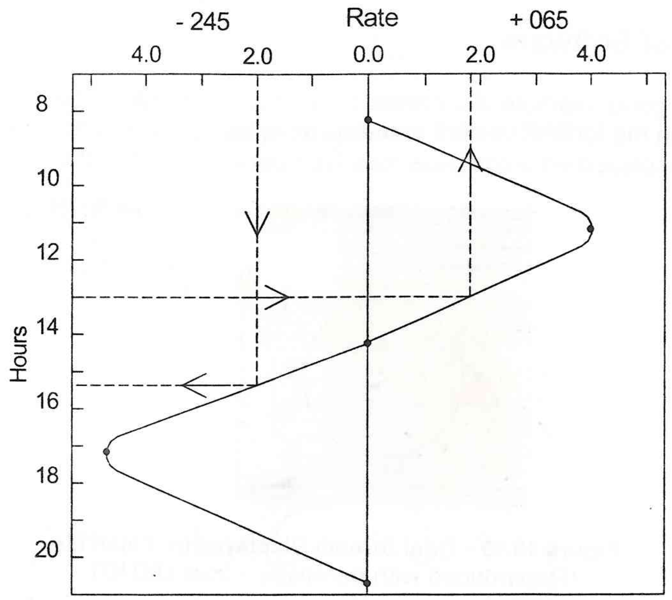


Figure 10.20 - Graph for Example 10.5

11 MARINE COMMUNICATIONS

Good communications are vital for the success of a maritime venture. Instructions from operators and the authorities responsible for handling the ship and safety information needs to be received by the ship in a timely manner. With the recent advances in technology, communications at sea have experienced a significant improvement and, in particular, the Global Maritime Distress and Safety System (GMDSS) has provided a great advancement in maritime safety.

11.1 GMDSS

GMDSS provisions apply to cargo ships of 300 GT and over and ships carrying more than 12 passengers on international voyages. Under GMDSS, equipment carriage requirements are linked to the area of operation. The sea areas are designated as:

Sea Area A1
This is the area that is within radiotelephone coverage of at least one VHF coast station. The station must have continuous DSC availability. The limit of this area extends to about 20-50 NM offshore from the coast.

Sea Area A2
This is the area, excluding sea area A1, that is within the radiotelephone coverage of at least one MF coast station. This station has to have continuous DSC availability. The limit of this area extends to about 150 NM offshore from the limit of sea area A1.

Sea Area A3
This is the area, excluding sea areas A1 and A2, within the coverage of an INMARSAT geostationary satellite, where continuous alerting is available. This area is within about 70°N to 70°S.

Sea Area A4
This area covers the polar-regions, where geostationary satellite coverage is not possible and it is outside the sea areas A1, A2 and A3.

Radio watch-keeping is automatic under GMDSS. When keeping watch, the OOW or Master must ensure that the on board equipment is in service and fully operational. The equipment should be correctly set up to perform all of the mandatory GMDSS functions. This is achievable by carrying out regular checks and tests.

Considering the operational needs of different circumstances, GMDSS requires compliance with the following functional requirements:

- The transmission of ship-to-shore radio distress alerts by at least two separate and independent means, each using a different radio service
- The reception of shore-to-ship radio distress alerts
- Transmission and reception of ship-to-ship radio distress alerts
- Transmission and reception of Search and Rescue co-ordinating radio communications
- Transmission and reception of on-scene radio communications
- Transmission and reception of locating signals
- Transmission and reception of radio Maritime Safety Information (MSI)
- Transmission and reception of general radio communications, linking with shore-based systems and networks
- Transmission and reception of bridge-to-bridge radio communications.

In order to meet the functional requirements above in the appropriate sea areas, ships that are required to comply need to be equipped as follows:

- VHF radio transceiver with DSC on Ch 70 and radiotelephony on channels 6, 13 and 16
- A radio receiver capable of continuous DSC watch on VHF channel 70
- Search and rescue transponders (SART) operating in the 9 GHz band (Ships 500 GT or over to have two and ships under 500 GT to have one)
- A satellite emergency position indicating radio beacon (EPIRB) which can be manually activated and float-free self-activation
- Two-way hand held VHF radios (Ships 500 GT or over and all passenger ships to have three and ships 300-500 GT to have two)
- A receiver with the capability to access NAVTEX broadcasts wherever the NAVTEX service is available
- Receiving equipment with capability of receiving SafetyNET where the NAVTEX service is not available.

Individual sea areas have specific requirements under GMDSS.

Sea Area A1

- VHF RT apparatus
- Float-free EPIRB – either DSC VHF channel 70 or satellite frequency
- Initiating distress alert from a navigational position using DSC on VHF, HF or MF, by activating EPIRB manually, or by Ship Earth Station.

Sea Areas A1 and A2

- MF RT on 2182 kHz and DSC on 2187.5 kHz
- Radio equipment capable of continuous DSC watch on 2187.5 kHz
- INMARSAT SES or general working radio communications in the MF band 1605-4000 kHz
- Initiating distress alert by HF, by activating EPIRB manually, or by INMARSAT SES.

Sea Areas A1, A2 and A3

- MF RT on 2182 kHz and DSC on 2187.5 kHz
- Radio equipment capable of continuous DSC watch on 2187.5 kHz
- INMARSAT A, B or C (class 2) SES Enhanced Group Call (EGC), or HF as required for sea area A4
- Initiating distress alert by any two from within HF/DSC radio communications, by activating EPIRB manually, or by INMARSAT A, B or C (class 2) SES.

Sea Area A4

- HF/MF transceiver within a band 1605-27500 kHz, using DSC, RT and direct printing
- Radio equipment capable of selecting any safety and distress DSC frequency for band 4000-27500 kHz, maintaining DSC watch on 2187.5, 8414.5 kHz and at least one additional safety and distress DSC frequency within the band
- Initiating distress alert from a navigational position through the Polar Orbiting System on 406 MHz.

11.1.1 INMARSAT

INMARSAT is an internationally owned co-operative that provides mobile communications worldwide, excluding latitudes outside of 70° N and S. It was launched in 1979 to serve the maritime industry and has since evolved to become a provider of global mobile satellite communications for commercial, distress and safety applications whether at sea, on land or in the air.

The INMARSAT satellite network supports, but is not limited to, the following key services for maritime users:

- Direct-dial telephone
- Facsimile
- Telex
- Email
- Data transmission

The INMARSAT system makes use of its existing services on a priority basis to provide for distress and safety communications. It eliminates the need for dedicated frequencies.

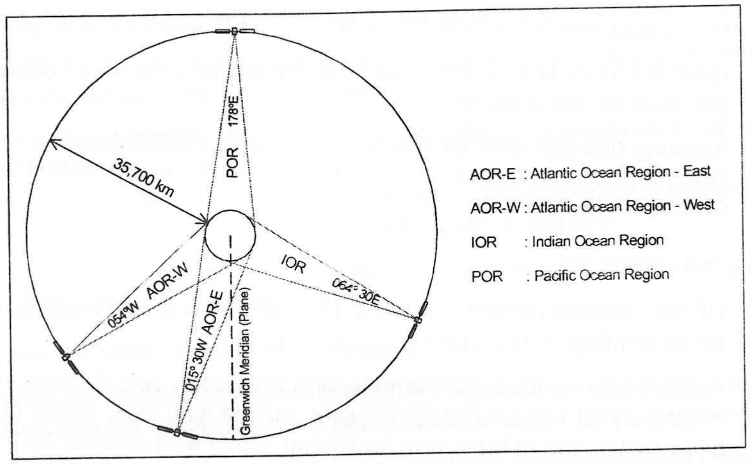


Figure 11.1 - Plan View of the Plane of Equator with INMARSAT Satellites

11.1.1.1 Satellites

INMARSAT has 4 geostationary satellites at an altitude of 35,700 km. Standard data services of up to 64 kbit/sec are provided. More modern I-3 satellites have a spot band facility that enables focus on areas of heavy usage. I-4 satellites, available since 2004, have a much higher data rate capability at 432 kbits/sec, allowing full mobile provision for internet, multi-media and other advanced applications. INMARSAT satellites are configured in four coverage regions scanning up to 70° N or 70° S.

Detailed diagrams, providing coverage data as well as the azimuth and altitude of the satellite from within the coverage area, are made available in the appropriate literature normally carried by ships.

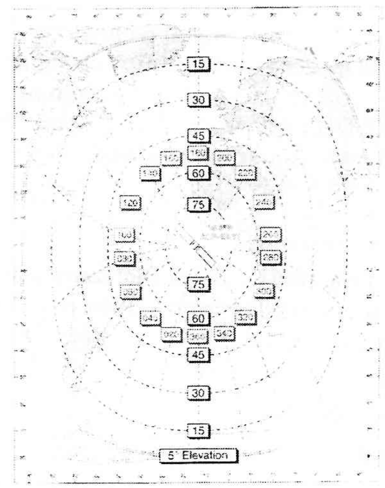


Figure 11.2 - Coverage of an INMARSAT Satellite

11.1.1.2 Tracking and Telemetry Control (TTC)

Satellites are controlled by 4 TTC stations, plus one back-up

11.1.1.3 Land Earth Stations (LES)

LES or Coast Earth Stations (CES) in the maritime world, known as ground earth stations (GES) in aeronautical circles, link INMARSAT's satellites with telecommunication networks.

11.1.1.4 Ship Earth Stations (SES)

SES or mobile earth stations, often referred to as mobile terminals, are the user terminals that connect to the satellites, providing communications to the mobile end user.

Several different mobile communications systems are offered by INMARSAT in order to provide users with a wide variety of mobile terminals and services. Each system uses a distinct INMARSAT Number series that allows the functionality to be recognised from the number allocated to specific terminals.

11.1.1.5 INMARSAT-A

INMARSAT-A is an analogue signal based system. It provides two-way telephone, fax, telex, email and data communications (56 and 64 kbits/sec) and is a GMDSS approved system. INMARSAT-A mobile terminals receive and transmit signals in the L-band (1.5 – 1.6 GHz). Scheduled for phase-out by 31 December 2007.

11.1.1.6 INMARSAT-B

This system extends the advantage of digital technology to mobile satellite communications. The digital system makes much better use of satellite power and bandwidth at a much lower cost to users, whilst maintaining high quality and reliable communications. INMARSAT-B also supports automatic, direct-dial telephone and fax, as well as telex. It is approved under GMDSS.

11.1.1.7 INMARSAT-C and mini-C

This is a small and light-weight two-way satellite communications system. It provides store-and-forward message or text communications at a data rate of 600 bits/sec, and also gives access to international telex/telex networks. It does not handle voice. INMARSAT C terminals are able to receive multiple address messages (EGC).

11.1.1.8 INMARSAT-E

This is a safety only system and it provides global alerting for GMDSS to all ships and safety centres by picking up signals from EPIRBs.

11.1.1.9 INMARSAT Fleet 77

Fleet 77 service allows for call prioritisation to 4 levels and real-time, hierarchical two-way call pre-emption with high system availability. The 4 levels of priority are:

Distress:	(P3) INMARSAT Priority 3
Urgency:	(P2) INMARSAT Priority 2
Safety:	(P1) INMARSAT Priority 1
General/Routine:	(P0) INMARSAT Priority 0

The traffic originated by RCCs or other Search and Rescue authorities (see chapter 12) get appropriate access for communications in both ship-to-shore and shore-to-ship directions. The system also meets commercial needs of voice, fax, email and data.

In addition, there are certain non-GMDSS systems available under INMARSAT.

11.1.2 Digital Selective Calling (DSC)

In order to make the initial contact between two stations, or groups of stations, an automatic calling system – DSC – is employed. DSC works on dedicated radio frequencies, which are available in all bands, i.e., VHF, MF and HF for short, medium and long ranges.

The transmitting station sends a short message to the receiving station(s). The receivers display the information on a screen and activate an alarm. The information on display indicates the purpose of the call and the mode of further communications.

For urgency and safety, the transmitting station should:

- Announce the message
- Transmit the message

The receiving ships, where the message is addressed to more than one ship, should not acknowledge the receipt of DSC call but should tune in to the appropriate RTF frequency for the message.

Depending on the frequency used for the DSC alert, the receiver would have to take some basic actions. In the form of flow charts, these actions must be displayed close to the DSC equipment.

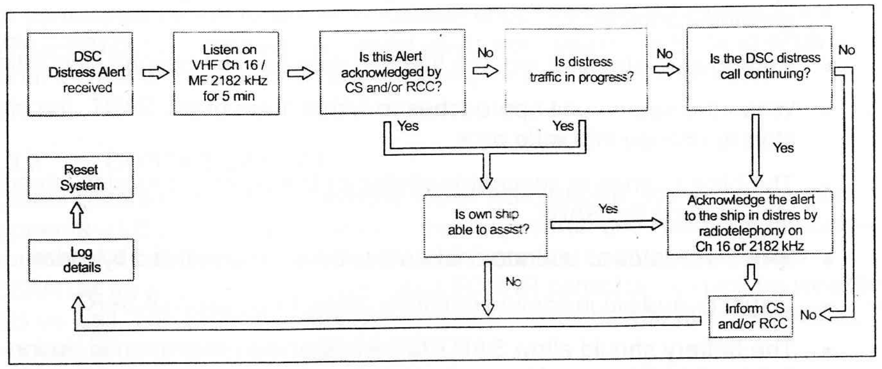


Figure 11.3 - Actions by Ships on Receipt of VHF/MF DCS Distress Alert

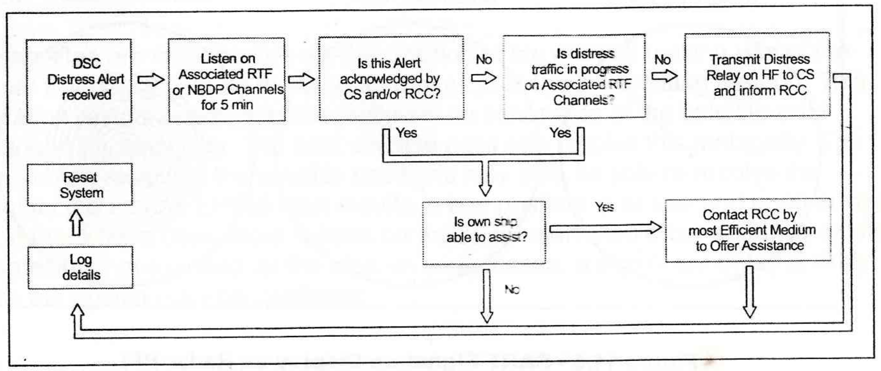


Figure 11.4 - Actions by Ships on Receipt of HF DSC Alert

11.1.3 SART

Under GMDSS, a simple way of locating either the ships in distress or their survival craft, is the use of a SART – Search and Rescue Radar Transponder.

- SART operates in the 9 GHz band
- X-band (3 cm) radar can interrogate when the SART is switched on within line of sight (usually 8 nm)
- A line as a 12 blip code appears on the radar display, outwards from the SART position along its line of bearing
- Spacing between each pair of blips will be 0.64 nm and the radar should be operated within the 6 to 12 nm range scales to distinguish SART from other possible contacts
- At ranges of about 12 nm, the first blip may be 0.64 beyond its position
- When the search unit approaches to within 1 nm of the SART, the blips will start to change into wide arcs
- The blips change to concentric circles as the search units close in and are almost upon the SART
- SART indicates to operators when it is being interrogated by radar
- Visual or audible indication confirms correct operation of SART
- The battery should allow SART to be in stand-by mode for 96 hours, followed by 8 hours of transmission when being interrogated by radar
- Radar control settings should be optimum to raise small echoes at sea.

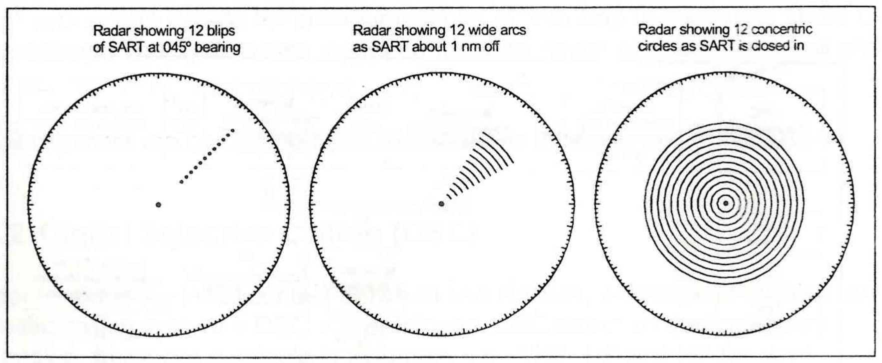


Figure 11.5 - SART Signature Display on Radar PPI

11.1.3.1 SART Detection ranges

- The IMO recommendation is to mount the SART at least 1m above sea level
- With scanner heights of 15 m, a SART 1m above sea level should be detected at 5nm
- Air units at an altitude of 3000 ft (914.4m) can detect a SART up to 40nm.

11.1.3.2 EPIRB

An Emergency Position Indicating Radio Beacon can alert shore stations when a signal transmitted by it is received by satellite under INMARSAT EPIRB E and COSPAS-SARSAT. Satellites can detect alerts from sea (EPIRB), land (PLB – personal locator beacon) and air (ELT - emergency locating transmitter).

11.1.3.3 COSPAS-SARSAT

Full global coverage is possible with the COSPAS-SARSAT system. It has two components – LEOSAR and GEOSAR. The LEOSearch and Rescue segment makes use of 4 satellites on polar orbits, which are low earth orbit satellites (LEOSAR) at an altitude of about 850 km. LEOSAR satellites can pick up weaker signals as well. The EPIRBs under this system transmit on 406 MHz. Aircraft ELTs also include a homing signal on 121.5 MHz.

The orbital period of the satellite is about 100 minutes and it sweeps a track about 4000 km wide over the earth. Though the system provides global coverage, it is not continuous. For an alert to be detected, a satellite has to be in view. For the satellite to download data to a receiving station, the satellite must be in view of the ground station.

The satellites are able to work out the position of the alert by making use of the Doppler frequency shift as the satellite moves past the transmitting beacon. This calculation results in two possible positions on either side of the satellite orbit resulting in an ambiguity. The next satellite pass can resolve this ambiguity. The shore station receiving the satellite positions may also be able to resolve the ambiguity if a marine EPIRB alert results in one position over sea and another over land, if there have been more reports on the same alert from other sources, or where two satellites have picked up the alert. In some cases, a significant delay is likely before the position can be confirmed.

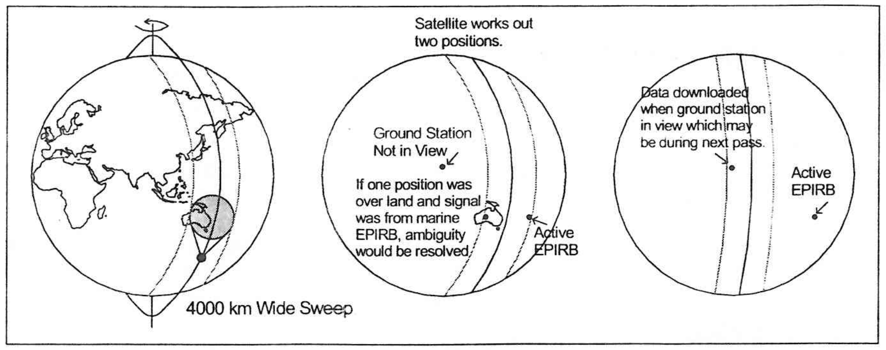


Figure 11.6 - COSPAS-SARSAT Satellite Sweep and Detection

GEOSAR makes use of 5 geostationary satellites. More satellites are likely to be launched in the near future. The coverage is limited to between 70° N and 70° S. The satellites cannot work out the position of the alert (the same as with INMARSAT EPIRB E). Modern EPIRBs have the capability to transmit position which could have been entered manually or by GPS input and the GEOSAR satellites can relay it. This segment cannot cover sea area A4. It has the advantage of directing the alert to RCCs without delay.

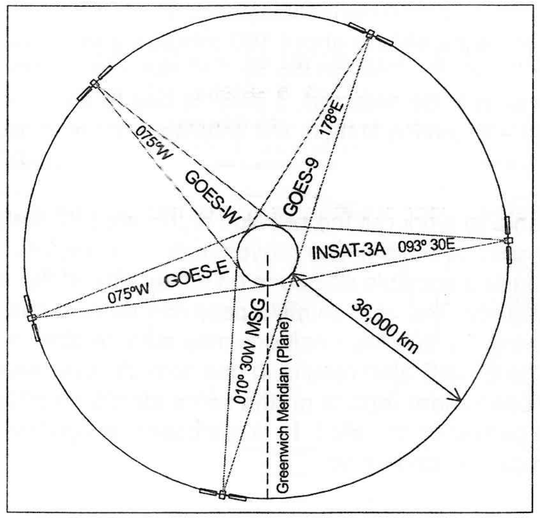


Figure 11.7 - Plan View of the Plane of Equator with GEOSAR Satellites

11.1.3.4 L-BAND

L-Band satellite EPIRBs make use of the 4 INMARSAT geostationary satellites. The EPIRB operates at L-band (1.6 GHz). The satellites cannot work out the position of the alert. Modern EPIRBs have the capability to transmit position from a GPS input. Some L-Band EPIRBs have the added feature of SART for homing using X-band radar.

For sea area A1, a VHF EPIRB may be used. It is a portable unit that transmits a DSC distress alert on VHF, which indicates "EPIRB emission" in place and the nature of distress. The unit then transmits the SART signal, which can be homed in on by search units using 3 cm (X-band) radar, making electronic detection possible.

EPIRBs should be float-free and are usually mounted in exposed locations. It is likely that the unit may fall off into the sea accidentally, causing it to transmit. It may also be accidentally turned on when moved for test, service or battery replacement. Ships officers should be alert to this possibility and exercise care and vigilance otherwise unnecessary Search and Rescue actions may be initiated due to false alerts. Modern devices are available that can detect whether an EPIRB has been activated in the ship's vicinity and if it belongs to own ship.

EPIRBs need to be registered and if any details change in the future, e.g. name, ownership, etc., the registration authorities need to be duly notified.

11.1.4 Enhanced Group Calling (EGC)

The enhanced group call is a method used to address particular regions or all or specific ships.

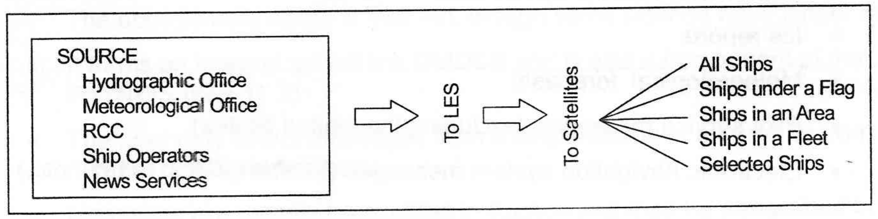
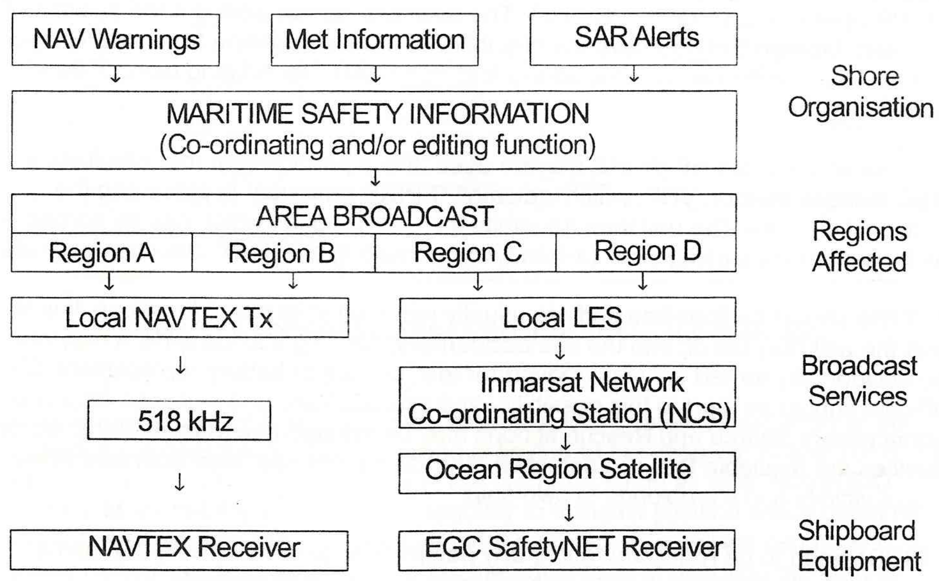


Figure 11.8 - EGC Message Co-ordination

11.1.5 Maritime Safety Information (MSI)



The following are the major categories of MSI for NAVTEX, AIS and SafetyNET:

- Navigational warnings
- Meteorological warnings
- Search and Rescue information
- Ice reports
- Meteorological forecasts
- Pilot service messages (excluding the United States)
- Electronic navigation system messages (LORAN, GPS, DGPS, etc.)

In order to ensure safety of navigation, the navigator should receive an MSI message without any delay. This is one of the main objectives of GMDSS and is achieved in two ways, using SafetyNET and NAVTEX.

11.1.5.1 SafetyNET

SafetyNET is a service of the INMARSAT-C – EGC system. The SafetyNET service is designated by the IMO under GMDSS through which ships receive MSI. It makes use of an international direct-printing satellite based service.

The information distributed includes:

- Distress alerts
- Navigational warnings
- Meteorological warnings
- Forecasts
- Other safety messages

It is mandatory for all ships sailing outside NAVTEX coverage to have the ability to receive SafetyNET. Similarly, it is recommended for all administrations outside NAVTEX coverage. Messages can be originated by a registered information provider anywhere in the world and then broadcast to the appropriate ocean area through INMARSAT-C. A commercial service available under the EGC is FleetNET, which is used by ship operators to directly and privately contact the ships in their fleet.

11.1.5.2 NAVTEX

An international automated direct printing NAVTEX service for notification of navigational and meteorological warnings and urgent safety information to vessels has been made available. Its main features are:

- It uses the Narrow Band Direct Printing (NBDP) principle
- It enables the automatic reception of maritime safety information (MSI)
- The system uses a single frequency of 518 kHz
- Transmissions are from nominated stations within each NAVAREA / METAREA, on a time-sharing basis to avoid mutual interference (see 11.2)
- The approximate range is 400 nm, though some stations have longer range
- It forms an integral part of the GMDSS and is also a component of the WWNWS (see 11.2)
- The user may select messages from a single station in an area or from a number of different stations
- Messages are usually transmitted in English and may be transmitted in additional languages to meet the requirements of the host governments. National NAVTEX services may transmit on 490 kHz, 4209.5 kHz or another allocated frequency
- Messages are prioritised to dictate the timing of the first transmission of a new warning within NAVTEX:
  - VITAL - For immediate transmission (but avoiding interference to ongoing transmission)
  - IMPORTANT - For transmission at the next available period when no transmissions are being made
  - ROUTINE - At the next scheduled transmission period
- A NAVTEX receiver can select messages to be printed based upon:

- the technical code in the preamble of each message
- whether the particular message has been already printed or not

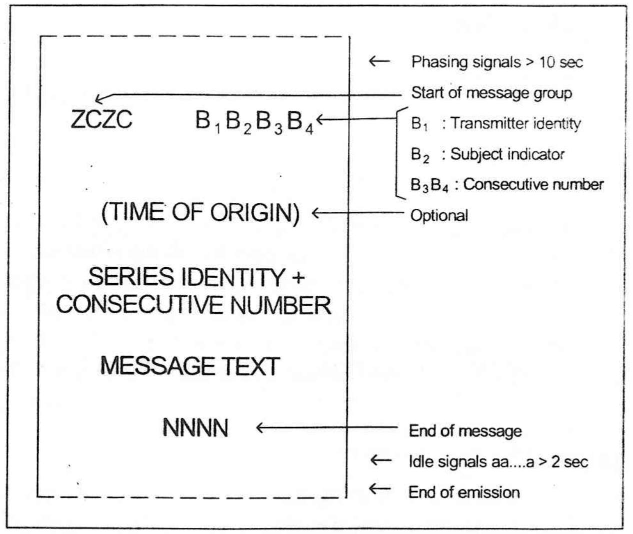


Figure 11.9 - Standard Format of NAVTEX Messages

Transmitter Identification Character (B1)

Each transmitting station is allocated a single unique alphabetical identification character. Within each NAVAREA and METAREA, identification characters are allocated randomly and consecutive characters are not allocated to adjacent stations. It is also ensured that there is enough distance between two stations allocated to the same character, so that the ship receiver is not within the range of both at the same time. The station required can be selected by choosing the appropriate alphabetical identifier on the NAVTEX receiver.

Subject Indicator Characters (B2)

The subject indicators that cannot be excluded from the reception list by the NAVTEX operator have been marked by *** in the list below and are also marked in bold.

A = Navigational Warnings ***
B = Meteorological Warnings ***
C = Ice Reports
D = Search and Rescue information and pirate attack warnings ***
E = Meteorological Forecasts
F = Pilot Service Messages
G = AIS
H = LORAN Messages
I = Spare
J = SATNAV Messages

K = Other Electronic Navaid Messages
L = Navigations Warnings – additional to A ***
V = Special services – allocation by the NAVTEX Panel
W = Special services – allocation by the NAVTEX Panel
X = Special services – allocation by the NAVTEX Panel
Y = Special services – allocation by the NAVTEX Panel
Z = No messages on hand

V, W, X and Y may be used for regional languages.

Message Numbering (B3B4)

A serial number between 01 and 99 is allocated to each subject group. It is not necessarily related to serial numbers in other radio navigational warning systems. When the numbers reach 99, the numbers not currently in use are assigned, starting from 01. Where there are more than 99 messages, the excess are allocated to other relevant message groups, e.g., from A to L.

11.2 WWNWS

The International Hydrographic Service (IHO) and the International Maritime Organisation (IMO) have jointly established a World-Wide Navigational Warning Service (WWNWS). Its key features are as follows:

- The world is divided into 16 regions known as NAVAREAs identified by roman numerals from I to XVI
- Each NAVAREA has an Area Co-ordinator that is responsible for collating and issuing radio navigational warnings for the entire area. The Co-ordinator also receives information from the National Coordinators of individual countries who want to notify items of navigational significance
- NAVAREA warnings refer to the area concerned, and part of the adjacent area, to cover 24 hours of steaming by a fast ship, i.e., about 700 nm
- At least two daily transmissions are necessary and schedules are prepared to avoid coinciding with that of the adjacent areas
- Warnings are consecutively numbered through the calendar year
- Warnings are in English and may also be in one or more of other official languages of the United Nations
- Warnings may be transmitted using radiotelephony, radiotelex, facsimile
- Warnings are transmitted at specific times and are repeated in the broadcast immediately following the original transmission. Warnings may be repeated further where it is considered necessary

- NAVAREA warnings address areas of information that ocean-going mariners need for safe navigation, e.g. change in status of navigational aids information likely to affect navigational routes
- There are three main types of radio navigational warnings:
    - NAVAREA warnings
    - Coastal warnings
    - Local warnings

11.2.1 NAVAREA Warnings

The following are some common examples:

- Change or establishment of navigational aids, particularly when such change could be misleading to shipping
- Change of operational status or a malfunction/casualty to lights, fog signals, buoys, etc. that affects the main shipping lanes
- Dangerous wrecks in or near the main shipping lanes, with relevant marking details given
- Areas of Search and Rescue activity
- Areas where anti-pollution operations are being carried out and whether such an area is closed to shipping
- Drifting mines
- Large restricted tows in congested waters
- Relay of information from MRCC about any ship, or aircraft over sea that is reported missing, or seriously overdue
- Suspension or unexpected alteration of established routes
- Newly discovered rocks, reefs, shoals, wrecks, etc., likely to constitute a danger to shipping and where available, their marking details
- New offshore structures have been established in or near shipping lanes or movement of offshore installations near shipping lanes
- Any laying of submarine cables or pipelines
- Underwater operations, use of submersibles, towing of large submerged objects, etc. that constitutes a potential danger in or near shipping lanes
- Any malfunction of a radio navigational warning to a significant level
- Any special operations that might affect the safety of shipping, particularly over wider areas, e.g. naval exercise areas, missile firing, nuclear tests, space missions. In such cases the degree of hazard should be stated, if known, and the warning should remain in force to the time of completion of the event.

11.2.2 Coastal Warnings

- Coastal warnings cover a region or portion of the NAVAREA
- These are issued by the National Coordinator of the country of origin
- The information is usually broadcast over NAVTEX but may be broadcast by radiotelephony
- The area covered is from pilot ground or fairway buoy to the limit of the NAVTEX (usually 250 nm), unless it is between two regions and the limits have been agreed
- Coastal warnings cover the whole of the service/coverage area, unlike the NAVAREA warnings
- The broadcasts are at scheduled times or on receipt, subject to the urgency
- The messages are in English. Administrations may set up national services on different frequencies, which are outside of WWNWS
- Coastal Warnings often supplement the information in NAVAREA warnings.
- Coastal Warnings are for similar topics to NAVAREA, the difference being that coastal shipping is likely to be effected.

11.2.3 Local Warnings

- These warnings are usually issued by the Port, Pilotage or Coastguard authorities
- The information contained in these warnings is not normally required by ocean-going vessels and usually supplements the coastal warnings
- Local warnings are not part of WWNWS
- Local warnings cover inland waters up to pilot ground or fairway buoy.

Details of all Radio Navigational Warning systems are contained in the relevant ALRS. Information can also be obtained from the Annual Summary of Admiralty Notices to Mariners. Serial numbers of all NAVAREA I warnings and those issued during the week are reprinted in Section III of the Admiralty Weekly Notices to Mariners. It also lists the additional NAVAREA messages received.

The US also issues long-range warnings in the form of HYDROLANTs and HYDROPACs. Information concerning current warnings can be obtained from US Weekly Notices to Mariners. Information is also contained in Section III of Admiralty Weekly Notices to Mariners.

11.3 Weather Reports

The distribution of weather reports and forecasts is carried out in a similar manner to navigational warnings. The world is divided into regions and coastal radio stations provide meteorological information to mariners in their area of coverage and responsibility. For identification purposes and convenience, the areas are further subdivided into small regions. The weather reports are divided into three categories:

- Ocean
- Coastal
- Local

Ocean weather reports cover offshore and ocean areas and are transmitted by designated stations at routine times. Similarly, facsimile transmissions are also made at specified times.

Coastal weather reports are also transmitted by designated stations and cover areas on the coast.

Local reports are issued by Port, VTS or Coastguard authorities.

NAVTEX is commonly used by ships to receive meteorological information. In addition, INMARSAT is increasingly used to obtain meteorological information when in an ocean area outside the range of NAVTEX. The weather facsimile receiver is still the most popular choice for receipt of weather information because information can be comprehended easily in its map form. Conventional radio transmissions are also broadcast. Information may be obtained from the relevant ALRS Signals and the accompanying diagram booklets.

Vessels encountering a TRS, ice, storm force winds or subfreezing air temperatures in association with gale force winds must make obligatory reports to the nearest CRS and to ships in the vicinity. Such information should warn the mariner of meteorological dangers in the immediate area.

11.4 Ship Reporting Systems

Ship reporting systems are designed and operated to maximise the co-ordination of search and rescue for ships either in the immediate vicinity of or close to a distress incident. The most well known service is the Automated Mutual Assistance Vessel Rescue System (AMVER). There are a number of other systems in operation in most areas of the world. Details are available in ALRS Vol 1.

11.4.1 AMVER Organisation

The AMVER system provides worldwide coverage and is operated by the US Coast Guard for the benefit of all vessels, regardless of nationality. Vessels of 1000 GT or over on deep sea voyage may participate on a voluntary basis.

The operation is conducted through selected radio stations or INMARSAT, through which vessels can despatch their reports. The service is free of charge only through designated stations as not all of them accept messages free of charge. All UK stations, including the 'GOONHILLY' CES, charge for servicing AMVER messages.

The purpose of AMVER is to:

- Maximise efficiency in co-ordinating assistance in the case of Search and Rescue incidents
- Have knowledge of the route being followed and the positions of both assisting vessels and vessels that require assistance
- Minimise the time between the incident and the initiation of Search and Rescue
- Make best use of all available resources:
  - Vessel availability
  - Medical facilities
  - Onboard resources
  - Vessel details
  - The potential of early arrival on scene

AMVER operates from the US Coastguard Operations Systems Centre in Martinsburg, West Virginia. The data is confidential and no details are disclosed except for the particulars required for Search and Rescue operations.
AMVER will usually initiate enquiries once a vessel's report is 48 hours overdue.

Participating vessels are required to transmit a number of messages to the AMVER centres. The vessels transmit these messages during normal communication schedules. Schedules are listed in ALRS Vol. 1, with details in the Annual Summary of Admiralty Notices to Mariners.

Standard format messages are sent by vessels. The following identifiers and lines are used:

A/	Vessel's name/radio call sign//
B/	Date and time (UTC)//
C/	Latitude/Longitude//
E/	Current course//
F/	Estimated average speed//
G/	Port of departure/Latitude/Longitude//
I/	Port of destination/Latitude/Longitude//
K/	Port name/Latitude/Longitude/Time of arrival//

L/ Route information//
M/ Current CRS or satellite number/next station, if any//
V/ On board medical resources//
X/ Up to 65 characters of amplifying comments//
Y/ For forwarding messages to JASREP or MAREP (on request)// (Y is required by US vessels only)
Z/ EOR (end of report) – for computer processing of messages//

The following reports are also required to be transmitted by participating vessels

11.4.1.1 Sailing Plan Report – AMVER/SP//

This plan can be transmitted days or weeks prior departure of the vessel. It should contain the vessel's name, call sign, time of departure, port of departure, port of destination, provisional ETA, proposed routeing track and any special resources on board. (Required: A, B, E, F, G, I, L, Z. Optional: M, V, X, Y).

11.4.1.2 Position Report – AMVER/PR//

This report should be despatched within 24 hours of departure and then within every 48 hours after that. It contains the vessel's name, time and position (Lat/Long), port of destination and ETA. In addition, speed, present course and any other relevant comments can be added. (Required: A, B, C, E, F, Z. Optional: I – and strongly recommended – M, X, Y).

11.4.1.3 Arrival Report – AMVER/FR//

This is usually sent on arrival, or just prior to arrival, at the port of destination. It contains the vessel's name, call sign, arrival position or port and the time of arrival. (Required: A, K, Z. Optional: X, Y).

11.4.1.4 Deviation Report - AMVER/DR//

This is used to inform the AMVER centre of any changes to the passage plan. It contains details of new track, course and any speed changes and revised ETA. (Required: A, B, C, E, F, Z. Optional: I, L).

If a participating vessel is in distress, the distress alert should be sent to RCC and not the AMVER co-ordinator.

11.4.2 AUSREP

The Australian Maritime Safety Authority operates the Australian Ship Reporting System (AUSREP) within the Australian Search and Rescue Area.
Reporting is mandatory for all Australian vessels when navigating within the designated area and for all foreign ships from arrival in their first Australian port until their departure from the last Australian port.

The objectives of this reporting system are:

- To limit the time between the loss of a vessel and the initiation of Search and Rescue action in cases where no distress signal is transmitted
- To limit the search area
- To provide up to date information on shipping in the event of a Search and Rescue incident developing

Vessels send reports under AUSREP to RCC AUSTRALIA as follows:

- If in port by INMARSAT-C, reverse charge telephone call or fax message
- At sea, using INMARSAT-C via POR or IOR satellites. (Calls would be free if recommended procedures are followed – details are available in the ALRS Vol. 1.)

The system requires the following messages to be transmitted.

11.4.2.1 Sailing Plan (SP) Report

This is transmitted either when entering the area or during the period up to 2 hours after departure from the port. It should contain:

- AUSREP SP
- Vessel's name
- Call sign
- Port of departure or, if entering AUSREP area, the vessel's position
- Date and time (UTC) of departure or of position
- Port of destination
- Date and time of ETA (UTC). If leaving the area, the ETA at the boundary limits.
- Intended route
- Estimated speed of vessel
- A nominated daily reporting time (UTC)
- Relevant remarks, such as intermediate port stops

11.4.2.2 Position Report (PR)

This should be transmitted daily at the nominated time (UTC). It should contain:

- AUSREP PR
- The vessel's name and call sign
- Position, course and speed
- Date and time (UTC) of the vessel's position

- Remarks such as changes in SP or nominated time
- The last PR should also confirm ETA or, if leaving the area, should include "FINAL REPORT"

11.4.2.3 Arrival Report (AR)

This should be transmitted once the vessel is within 2 hours of steaming from the pilot station. It should contain:

- AUSREP AR
- Vessel's name
- Call sign
- Port of arrival
- Date and time (UTC) of report

Additional reports may be required concerning dangerous goods, harmful substances and maritime pollution.

11.4.2.4 Actions by RCC Australia

If a PR or FR is not received within 2 hours of the expected time, action is taken to ascertain the vessel's whereabouts and the safety of the crew. The process would start with internal checks followed by attempts to contact the vessel by INMARSAT or HF DSC. If a report is overdue by 6 hours, the RCC will broadcast a priority signal, requesting a REPORT IMMEDIATE. Operators and other vessels should report any sightings and communications with the overdue vessel. If the report is 21 hours overdue, the signal will be upgraded to URGENCY.

There are a number of other Ship Reporting Systems in existence. Details are available in ALRS Vol 1.

11.5 Ship Movement Report Systems

Ship movement reporting schemes operate in many areas of the world with different objectives. In some areas the main purpose is to enhance the safety of navigation, for example MAREP in the English Channel which is operated jointly by the UK and French administrations. Another similar service is in the River St. Lawrence, operated by the Canadian administration. Details are available in ALRS Vol 6.

11.5.1 MAREP

MAREP is a voluntary system that applies to vessels requiring special attention. This includes:

- Merchant vessels over 300 GT
- Vessels not under command or at anchor within the TSS or inshore traffic zone
- Vessels restricted in their ability to manoeuvre
- Vessels with defective navigation equipment.

Vessels are required to keep a listening watch on designated frequencies and make the following reports, depending upon their particular circumstances, prefixed with "MAREP":

- POSREP
  - Position Report for vessels with no defects
- DEFREP
  - Report from vessels with defects, or that are restricted in their ability to manoeuvre
- CHANGEREP
  - A report made to amend information included in any previous report(s).

The report includes the following, preceded by phonetics of the letters:

A	Name and call sign of vessel
B	Date and time (UTC)
C	Latitude / Longitude
D	True bearing and distance from a recognised landmark
E	True course
F	Speed
G	Last port of call
I	Destination
M	VHF channels being monitored
O	Maximum draught
P	Type and quantity of cargo
Q	Defects
X	Other useful information.

11.5.2 SURNAV

This system aims to monitor the movement and condition of vessels navigating in the approaches to the French coast that are carrying hydrocarbons, dangerous or noxious substances. The regions covered are the French coast of the North Sea, the English Channel and the Atlantic Ocean.

The reports are required to be made at appropriate stages of the vessel's voyage to four of the Regional Surveillance and Rescue Operations Centres (CROSS) on the French coast.

11.6 Radio Medical Advice

Very few merchant ships have a doctor or physician on board and although ships' senior officers possess Medical Care on Board Ship qualifications, it is known that some medical problems are beyond their training and capabilities. For this reason, provision is available to seek medical advice by radio and there are a number of countries that provide it. Details are available in ALRS Vol 1. Unless otherwise stated, there is usually no charge for the messages sent or advice received.

11.6.1 International Radio Medical Centre (C.I.R.M.)

This service is free of charge and is available to ships of any nationality, 24 hours a day. If required, the service arranges for the evacuation of the patient in co-ordination with the area MRCC.

11.7 Other Reports

- Piracy and Armed robbery
  - A report should be made through RCC to law enforcement agencies and coastal state authorities. In the case of any onboard casualty, a report should also be sent to the ship's maritime administration
  - The International Maritime Bureau (IMB), based in Kuala Lumpur, is the world's focal point as an information centre for acts of piracy and armed robbery
- Alien Smuggling
  - Under an IMO resolution on alien smuggling, reports are co-ordinated by the USCG
- Quarantine reports from vessels at sea
  - A number of countries have specific reporting requirements, including ballast water management
- Pollution reports
  - A number of countries have specific reporting requirements

Details of all of the above are available in ALRS Vol 1.

11.8 Automatic Identification System (AIS)

Carriage of an AIS has been made mandatory by the IMO in the revised SOLAS Chapter V. There are a number of reasons for the development and implementation of AIS systems for marine use. The interested parties are:

- The mariner at sea
- Administrations and authorities
- Commercial organisations

Mariners have felt the need to be able to identify vessels reliably and effectively for collision avoidance purposes. This is to:

- Avoid VHF calls requesting identification and intention
- Identify any vessel contravening the collision avoidance regulations and standing-on
- Eliminate errors in making collision avoidance arrangements with the wrong vessel

However, it must be appreciated that these practices are not recommended.

The coastal states monitor marine activities and vessel movement in order to exercise control and enforcement of law. The areas of major concern driving this monitoring activity are:

- Safety at sea
- Vessel traffic management
- Pollution monitoring and control
- Maritime security
- Trafficking of illicit materials and crime at sea
- Conservation of natural resources.

Physical sighting and identification demands a lot of resources

There are other areas of operation that benefit significantly from AIS, but these are only possible if information is made available in a timely manner. In particular, and for reasons of both safety and commerce, this applies to:

- Ship operators
- Port authorities
- Pilotage services

AIS allows identification without reliance on voice communications. The IMO adopted the Universal AIS (UAIS) as an aid to safety of navigation. Other objectives included efficient navigation, improvement to the protection of the marine environment and to aid the effective operation of VTS.

11.8.1 Carriage Requirements

The IMO has set clear implementation dates for carriage requirements for AIS. All ships of 300 GT and above on international voyages, cargo ships of 500 GT and above not engaged on international voyages and all passenger ships have to be fitted with AIS as follows:

- All ships constructed on or after 1st July 2002
- All ships on international voyages constructed before 1st July 2003:
    - All passenger ships and tankers, not later than 1st July 2003
    - All ships above 50,000 GT and above other than tankers, not later than 1st July 2004
    - All ships of 10,000 GT and above but less than 50,000 GT, other than tankers, not later than 1st July 2005
    - All ships of 3,000 GT and above but less than 10,000 GT, other than tankers, not later than 1st July 2006
    - All ships of 300 GT and above but less than 3,000 GT, other than tankers, not later than 1st July 2007
- Ships requiring AIS that are not engaged on international voyages but were constructed before 1st July 2002 and not later than 1st July 2008.

11.8.2 Equipment

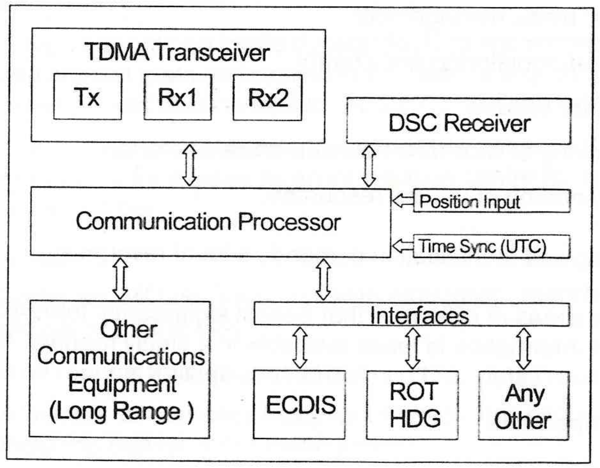


Figure 11.10 - AIS Shipboard Unit Block Diagram

The shipboard AIS unit has two dedicated VHF receivers and one transmitter. The ITU has allocated two dedicated frequencies for transmission. These frequencies may not be available in all parts of the world:

- 161.975 MHz
- 162.025 MHz

The transponder may also be equipped with a positioning device (normally GPS). An alternative is to connect the AIS to an external GPS/DGPS device on board the ship. Both serve the purpose of supplying 'own ship's' position, as well as time synchronisation. Interfaces are available to a number of devices on the bridge.

VHF DSC allows polling by competent authorities, or at the request of other vessels, whereas long range communications equipment is mainly linked with commercial interests. The equipment is connected to a power source, an antenna, and a variety of shipboard equipment or integrated navigation equipment.

11.8.3 Operating Principle

The AIS function is based on VHF radio transponders within the VHF maritime mobile band. It uses a Self-Organised Time Division Multiple Access system (SOTDMA), which is based upon the concept of a frame of one minute. The time frame is synchronised to UTC, divided into 2250 slots with each slot equalling 22.67 milliseconds (ms). A transmission speed of 9.6 kbps is adopted, which allows sufficient time for transfer of 256 bits per time-slot.

The AIS unit makes it possible onboard to monitor other ships through the use of a shipboard transponder system. Ships equipped with AIS are required to transmit continually on designated frequencies. The range of the AIS is equal to the VHF horizon of the antenna on board the ship. Each ship is at the centre of an 'own communication cell'. At the start of a passage, or when entering a different area, the ship's AIS equipment captures a vacant slot for transmission of data. AIS stations continuously synchronise with other stations within the detection range.

When a ship's AIS unit makes initial contact with another ship, it takes up an unoccupied time-slot and automatically reserves the future time slot for the next contact. This selection will depend upon the status of the ship and the standards of scheduled reporting (see 11.8.5). The size of a ship's communication cell will adjust to the traffic density. In a case where slot capacity is running out, the equipment discards the targets at greater ranges and assigns the slots to priority targets. When a vessel changes its slot assignment, the AIS unit advises of both the new location and the timeout for that location. This allows new stations, and those that suddenly appear within the radio range close to other vessels, to be received. The system has enough capacity to allow nearly 100% throughput, for vessels within 8 to 10 nm of each other in a ship-to-ship mode.

The operating modes dictate the process of occupying time-slots.

11.8.4 Operating Modes

- Continuous autonomous mode:
  - Ship-to-ship, generally for identification and collision avoidance
  - For use in all areas.

- Assigned mode:
  - Can be set up by a competent authority for operation within their specific area
  - Is used for monitoring traffic
  - Allows control of data transmission intervals and/or time slots.
  - Allows the authority to change the VHF channels used to avoid interference from adjacent areas.

- Polling mode:
  - This is the controlled mode where data transmission is in response to interrogation from a competent authority of a littoral state (a state at, or in the vicinity of, the shore)
  - The design of AIS allows polling through VHF DSC. The information displayed is illustrated in Figure 11.12.

MMSI Number
Ship's Name
Type
COG - - - SOG - -.-
Time DD MM YYYY HR:MN:SC

Figure 11.11 - DSC Polled Data Displayed on Screen of Receiver

11.8.5 AIS Data Messages

The information broadcast by AIS equipment is sorted into three independent reports. The reports are transmitted at set schedules, using 12.5 watts of power.

Report Type and Description	Information	Reporting schedule
Static Data This is pre-programmed on installation or on a change of the ship particulars, e.g., sale, renamed, alterations	• MMSI number • ship's name and call sign • IMO number • length and beam • location of antenna • ship's type	Updated every 6 minutes
Voyage Related Data The is input every new voyage before or at commencement	• draught • cargo information • destination and ETA • other relevant information	Updated every 6 minutes
Dynamic Data This is automatically derived from ship's interfaces	• MMSI number • time • ship's position and accuracy • course over ground • speed over ground • gyro heading and rate of turn • navigational status (as per Colregs 1972, as amended)	Updated depending upon the ship's speed and navigational status Status / Speed — time • At anchor — 3 min • 0 – 14 knots — 10 sec • 0 – 14 knots & changing course — 3.3 sec • 14 – 23 knots — 6 sec • 14 – 23 knots & changing course — 2 sec • 23 + knots — 2 sec • 23 + knots & changing course — 2 sec

11.8.6 Additional Messages

AIS equipment has the ability to transmit and receive short safety related messages, which is an additional way of transmitting MSI. These messages can either be addressed to a specified destination through use of MMSI, or broadcast to all AIS fitted vessels in the area. The message should be as short as possible and can include up to 160 six-bit characters. These messages should be relevant to the safety of navigation (light status, derelict or ice berg sighting, etc) and can either be of a fixed format, or as text messages. The receiving operator may be required to acknowledge the message.

The Aid to Navigation Message provides information on:

- the location and identification of hazards
- matters of a meteorological or oceanographic nature of interest to the mariner
- marks used for navigation

- the operational status of navigational aids
- the location and identification of specific geographical reference points, along with meteorological and hydrographic data at that site; identity, dimensions and position of offshore structures in the form of pseudo aids to navigation message.

A Route Plan Message (or Advice of VTS Waypoints) is used by a VTS centre to advise ships of the routeing instructions in the particular area. The message either includes up to 12 advised waypoints, or can be a text description of the route. A recommended turning radius may be included for each waypoint.

11.8.7 AIS Types

ITU recommendation M.1371-1 describes two types of AIS.
Class A: Shipborne mobile equipment meeting the IMO AIS carriage requirement for vessels.

Class B: Shipborne mobile equipment providing facilities not necessarily in accord with IMO AIS carriage requirements. Class B is nearly identical to Class A, however Class B equipment:

- Does not transmit the vessel's IMO number or call sign
- Does not transmit destination and ETA
- Does not transmit navigational status
- Does not transmit rate of turn information
- Does not transmit draught
- Has a reporting rate less than a Class A
- Is only required to receive, not transmit, text safety messages
- Is only required to receive, not transmit, application identifiers.

11.8.8 Data Entry

An AIS unit should be fitted with a minimum keyboard and display (MKD), which can be used to input static information. Upon installation, static information on the vessel is entered into the AIS shipboard equipment. This must be tested as a number of incidents are on record where incorrect set up on installation left the vessels transmitting incorrect data. The MKD can be used to input:

- Voyage related information
- Safety related messages
- A change of mode of response to long-range (LR)
- The setting to automatic or manual response to LR interrogations, with indication of interrogation and means of acknowledgement

The MKD can be used to control the AIS channel switching, operational frequencies and power setting.

11.8.9 Display Of AIS Information

Information can be displayed on MKD or a dedicated dynamic display interfaced with AIS:

- AIS display should provide at least three lines of 16 alphanumeric characters, which is enough to obtain the target vessel's identity and position
- The minimum display should provide not less than three lines of data, consisting of bearing, range and name of selected ship
- The minimum keyboard and display indicates:
  - alarm conditions
  - the means to display, view and acknowledge alarms
  - selected alarms that can be acknowledged
- Data can be viewed by scrolling horizontally, but bearing and range cannot be scrolled
- All the ships in contact with the AIS can be seen by vertical scrolling
- 'Own ship' position should be displayed continually where it is from an AIS integral GPS
- A dedicated dynamic display should:
  - display the unit's operational status
  - display target information

The AIS should be integrated to one of the existing graphical displays on the bridge or to a dedicated graphical display. It is best if the display is on radar/ARPA, ECDIS or in any other graphical format.

11.8.10 Graphic / Radar Display

The Graphic display should provide the following information:

- Vessel position
- Course and speed over ground
- Heading and rate of turn
- Positional information, displayed relative to the observing vessel.

The operator should be aware of the active display mode and whether it is radar or AIS. They must also be aware of the dangers of overloading the screen.

Technologically advanced equipment has the capability to display the projected positions of a vessel during manoeuvre by using AIS information. The projection is usually displayed in a large scale window and can be used by VTS, the pilot and any AIS equipped ship.

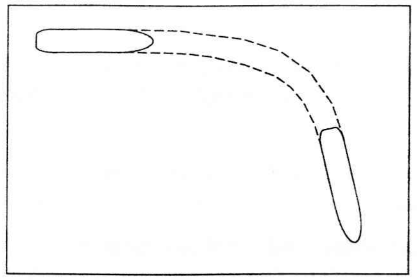


Figure 11.12 - Projected Manoeuvre using AIS Information

11.8.10.1 Targets On Radar

- Where AIS information is graphically displayed on radar, the radar echoes should not be masked, obscured or degraded
- Target data that is derived from radar or AIS should be clearly distinguishable
- The source of any target data should be clearly indicated, whether it originates from radar or AIS
- Where an AIS target is marked for data display, the operator may still be able to access data about the targets from other sources.

11.8.10.2 VTS Information

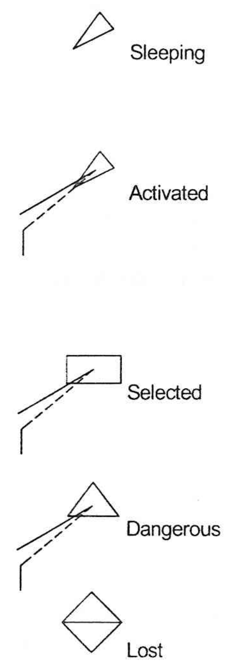
Vessels with AIS can view all VTS-held radar targets (as pseudo-targets) and AIS targets, as well as those on their own radar, using approved "VTS foot-printing" or "radar target broadcasting".

11.8.10.3 Pilot Usage

On ships not yet fitted with an AIS, the pilot may carry a workstation combined with a portable AIS. The pilot pack contains GPS/DGPS, AIS, heading sensor (optional) and a workstation.

11.8.10.4 AIS TARGET CATEGORIES

1. A Sleeping target is shown as an acute angled isosceles triangle, with its apex pointing as heading. It is termed sleeping because the target is seen as outside the avoidance consideration.
2. An Activated target is specified as such when the target moves into the avoidance consideration. Three vectors are added at this stage:
    - A dashed line from triangle apex for heading
    - A short vector, from the end of heading vector, to indicate the rate of turn
    - A plain line indicating course and speed over ground
3. A Selected target is one at where the CPA and TCPA have been calculated and made available as an alpha-numeric window. At this stage the triangle changes to a rectangle.
4. A Dangerous target is one which passes the pre-set CPA and TCPA limits. The rectangle changes to an equilateral triangle and an alarm is initiated.
5. A Lost target is shown as a diamond using two back to back equilateral triangles.



11.8.10.5 AIS Operational Requirements

- The AIS should operate in autonomous and continuous mode and provide information automatically and continuously without further involvement of ship's personnel
- If, in the Master's opinion, the continued operation of the AIS compromises the ship's security, whether at sea or in port, the AIS may be switched off. It should be reactivated as soon as the danger has been eliminated
- During some cargo handling operations, it may be necessary to either switch off or reduce the transmission power of the AIS
- If a sensor is not installed or fails to provide data, the AIS should automatically transmit the "not available" data value
- The static and voyage-related information should remain stored while the AIS is switched off.

11.8.11 National Arrangements

In accordance with SOLAS Chapter V, appropriately equipped shore-based stations shall be able to automatically receive standard information transmitted by the ship's AIS.

The MCA has established an AIS network of base station transponders capable of automatically receiving all message types and, in particular, AIS messages on Ship Static and Voyage related data, scheduled at 6 minute intervals. The automated procedure enables identification and tracking of suitably equipped vessels without further intervention from the vessel's bridge team or the Coastguard personnel.

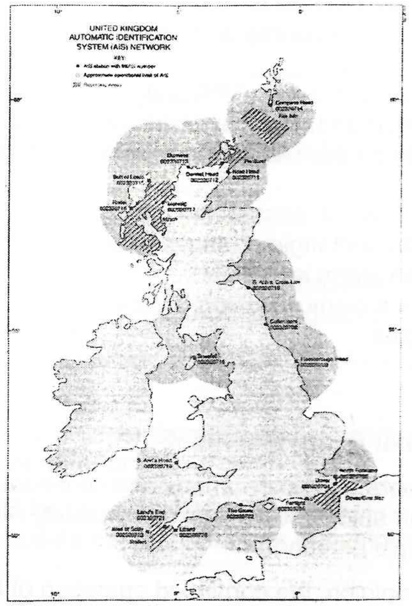


Figure 11.13 - UK AIS Network (2004/5)

In addition, AIS stations using the TDMA have been established at a number of lighthouses round the UK, broadcasting the Base Station Message that provides identity and location. Another category of station transmits the Aid to Navigation Message and Addressed Safety Related Messages.

11.8.12 International Arrangements

Administrations can use AIS to gather evidence on incidents leading to collision and pollution, and can subsequently use it for prosecution purposes.

Through the use of long range communications equipment, AIS information can be transmitted to services that collate and provide information to relevant interested parties. This avoids the need for costly routine reports.

Private establishments are currently publishing AIS information about 'ships in port' on the web, posing serious security risks, particularly to high profile ships. Such misuse of AIS data causes concern amongst the maritime community. The IMO strongly recommends that AIS information should not be made available on the worldwide web and national authorities are required to prevent the posting of such information to it.

11.8.13 AIS and Collision Avoidance

Use of AIS should ensure improvement of navigational safety worldwide because of the improved situation awareness and the near elimination of VHF R/T traffic. This should reduce workload, with significant benefits to bridge watchkeepers and VTS operators. Doubts about the identity of vessels in an area and uncertainty about their actions can be eliminated. The AIS display negates certain radar limitations by:

- detecting targets within sea and rain clutter
- detecting targets within radar blind and shadow sectors
- detecting targets behind islands, capes, round bends, in rivers, etc.
- eliminating line of sight detection only.

An AIS will receive course and speed alterations in far less time than it takes ARPA to compute. AIS shows the course alteration virtually from the moment the wheel was put over or the ship started to change speed. AIS display also eliminates the danger from target swap with another vessel, floating aids to navigation, headlands, small islands or bridges.

It should be noted that AIS collision avoidance data is based upon the course and speed over the ground of the 'own vessel' and the target vessel. As discussed under radar navigation (see 6.1.3 and Figure 6.3), this method may provide incorrect information related to target aspect. Care should be taken when relying on collision avoidance data from AIS sources. Information obtained from radar plotting is based upon data measured by 'own ship's' radar and provides an accurate relative approach, which is one of the most important factors in determining the risk of collision and the action that must be taken to avoid it.

11.8.14 Issues With AIS

- All information required by shore authorities may not be available on all models, so additional reporting may be required
- Small vessels and warships may not be fitted with an AIS, so may not be tracked. Similarly, vessels that have switched off AIS or are experiencing equipment breakdown may not be tracked
- The datum used by the position fixing system could be different to GPS and might result in discrepancy with radar targets

- Because of the above limitations the actual situation may not be same as indicated on the AIS
- Faulty AIS input results in faulty information
- The pilot connector socket, along with the power source, should be available at a convenient location
- The quality and reliability of position information from targets depends upon the system in use on board the target ships
- The use of VHF to discuss action with approaching vessels, based upon AIS information, does not remove the danger of agreeing action with the wrong vessel. Collision avoidance manoeuvres should be in line with the IRPCS.

Author's Note

Communications technology continues to develop at an enormous rate and there is no shortage of new developments and equipment. The mariner needs to be aware of the usage of onboard equipment and correct application of the information obtained. Safety of a marine venture depends upon timely transmission, receipt and correct application of information. The bridge team needs to be aware of the most suitable means of obtaining information at all times.

12 Search and Rescue at Sea

Maritime emergencies are unique in that they may occur at distances where shore assistance is not always possible or readily available. The centuries old tradition of mariners helping fellow mariners in the hour of need still remains the back bone of many rescue efforts at sea. SOLAS 1974 imposes obligation on Masters to provide assistance to those who are in need of assistance at sea, whenever they can do so.

The International Convention on Maritime Search and Rescue establishes international practice for Search and Rescue and has developed an International Aeronautical and Maritime Search and Rescue Manual (IAMSAR) in 3 volumes, as follows:

- Volume I Organisation and Management (for administrations)
- Volume II Mission Co-ordination (for Rescue Coordination Centre (RCC) Personnel)
- Volume III Mobile Facilities (for Ships, Aircraft, and Coastal Radio Station (CRS) Personnel)

Each volume of the IAMSAR and Rescue Manual is drafted with specific Search and Rescue system duties in mind and is intended for use either as a stand-alone document, or in conjunction with the other two volumes. A mariner at sea is mainly concerned with the Mobile Facilities volume (Vol. III). It is intended to be carried aboard rescue units, aircraft, and vessels to help with the performance of a search and rescue on-scene co-ordinator function or with aspects of Search and Rescue that pertain to their own emergencies. It contains an overview, listing responsibilities and the obligations to assist:

- Rendering assistance
- On-scene co-ordination
- On-board emergencies

Search and Rescue incidents are the result of units or individuals in distress or urgency or when vessels or aircraft are reported missing or overdue. Participants are likely to learn of the incident through GMDSS communications or audio/visual signals. It is likely that a number of units may be involved in a Search and Rescue, indicating the need for co-ordination.

12.1 Search and Rescue Co-Ordination

Universally, the Search and Rescue system has three general levels of co-ordination:

- Search and Rescue co-ordinators (SCs)
- Search and Rescue mission co-ordinator (SMCs)
- On-scene co-ordinator (OSCs)

In addition, some co-ordination is possible through ship reporting systems, AMVER and aircraft reporting system.

SCs are the top-level managers associated with a Search and Rescue system. Each state will normally have one or more persons or agencies designated.
Each Search and Rescue operation is carried out under the guidance of an SMC. This function exists only for the duration of a specific Search and Rescue incident and is normally performed by the RCC chief or a designee. The SMC guides a Search and Rescue operation until a rescue has been effected or it becomes apparent that further efforts would not be productive. The SMC should be well trained in all Search and Rescue processes and be thoroughly familiar with the applicable Search and Rescue plans. The main responsibilities of the SMC are to:

- Gather information about distress situations
- Develop accurate and workable Search and Rescue action plans
- Dispatch and co-ordinate the resources to carry out Search and Rescue missions.

12.1.1 On-Scene Co-Ordination

The Master or officer in charge of facilities involved in the response and the region of the Search and Rescue incident will provide on-scene co-ordination. In most oceanic and coastal regions, ships will normally be available, depending on shipping density. In remote regions, Search and Rescue aircraft may not always be available to participate. When two or more Search and Rescue units are participating in the same mission, one person on-scene may be required to co-ordinate activities.

12.1.1.1 Designation Of On Scene Co-ordinator (OSC)

The SMC usually designates an OSC, who may be the person in charge of:

- A Search and Rescue Unit (SRU), ship or aircraft participating in the search
- A nearby facility in a position to handle OSC duties

The SMC should designate an OSC. If this is not practicable, or not yet done, units involved should designate an OSC by mutual agreement. This should be done at an early stage, preferably prior to arrival within the area. Until an OSC has been

designated, the person in charge of the first unit to arrive at the scene should normally assume the OSC role. The SMC will arrange for that person to be relieved.

The responsibility that is delegated to the OSC by the SMC depends upon the communications and capabilities of the personnel manning the unit. Generally, the poorer the communications, the more authority the OSC will need. It is often possible to deploy shore based search and rescue units in a coastal incident. The area MRCC/CS will automatically take up the role of SMC. Very little authority will be delegated to the OSC.

Ocean incidents are out of the range of shore-based units and are well away from land. An RCC covering the ocean area, will most probably co-ordinate the Search and Rescue activity. The bulk of co-ordination work will be delegated to the nominated OSC and a lot of delegated authority comes with the nomination.

12.1.1.2 Factors for Designating the OSC

At this stage the role is co-ordination, which relies upon:

- The experience and training of the Master of the vessel
- The communication facilities of the vessel, including language
- Qualified staff on board the vessel
- The amount of time the vessel can spend on the scene
- Location/proximity of the vessel with relation to the Search and Rescue area
- The nature of work being carried out and the work load

12.1.1.3 Duties of the OSC

The duties of an OSC will include the following:

- Co-ordination of all Search and Rescue operations for facilities on-scene and shore
- Obtaining the search action plan or rescue plan from the SMC. Alternatively, prepare the plan if it is not otherwise available
- Modification of the search action or rescue plan as the situation on-scene dictates, in consultation with, or providing advice to, the SMC
- Co-ordination of all on-scene communications
- Monitoring of the performance of other participating facilities, ensuring that operations are conducted safely while paying particular attention to maintaining safe operations across all facilities, both surface and air
- Making periodic situation reports (SITREPs) to the SMC. The reports should include, but not be limited to:
    - Weather and sea conditions
    - The results of search to date

  - Any actions taken
  - Any future plans or recommendations
- Maintenance of a detailed record of the operation:
  - On-scene arrival and departure times of Search and Rescue facilities, other vessels and aircraft engaged in the operation
  - Areas searched
  - Track spacing used
  - Sightings and leads reported
  - Actions taken
  - Results obtained
- Advising the SMC when to release the facilities that are no longer required
- Requesting additional SMC assistance where necessary (e.g. for medical evacuation)
- Reporting of the number and names of survivors to the SMC, providing the SMC with the identity of units with survivors on board along with details of the survivors in each unit, the destination of unit and its ETA.

12.2 Search and Rescue Communications

12.2.1 Initial Communications

Depending upon the frequency used, the mode of communication and the global location, the receiving unit should acknowledge the distress call. For example, a unit in area A3 that receives a distress call on VHF RT on Ch 16, would acknowledge immediately. The unit will allow a few minutes for the coast station to acknowledge first for the same signal in area A1. Where RT has been used, the receiving unit should log (note) the call, particularly the position. The Officer of the Watch in receipt of the distress message must notify the Master immediately. Upon receipt of the distress call, the receiving unit should maintain a continuous listening watch on 2182 kHz, VHF Ch 16, other GMDSS equipment and 121.5 MHz (for aircraft distress). The purpose is to determine whether other units or stations have acknowledged and whether a RCC has been alerted. If not, the receiving unit should transmit a Distress Relay to the units in the vicinity and the RCC covering the area.

Once a decision has been made to assist, the following information should be transmitted to the distressed craft, (or coast station where there is no further contact with the distressed craft):

- Own vessel's identity
- Own vessel's position
- Own vessel's speed and ETA to the distressed craft's reported site

- Distressed craft's true bearing and distance from own ship

A coast station will take up the role of SMC. An OSC will be nominated. The OSC should co-ordinate communications on scene and ensure that reliable communications are maintained.

- Search and Rescue facilities normally report to the OSC on an assigned frequency
- If a frequency shift is carried out, instructions should be provided about what to do if intended communications cannot be re-established on the new frequency
- All Search and Rescue facilities should maintain a continuous watch on distress frequencies.

12.2.2 Information on Distressed Unit

Most incidents involving Search and Rescue are initiated by a radio distress, urgency message or alerts from EPIRB. The basic information to be transmitted in a distress message should include:

- Distress identifier (MAYDAY)
- Identity (name or call sign)
- Position
- Nature of distress
- Type of assistance required
- Number of persons at risk
- Additional information
  - Weather in the immediate vicinity
  - Number and type of survival craft carried, and the type and number being launched
  - Number of victims
  - The distressed craft's course or speed
  - Type of craft, and the cargo it is carrying
  - Type of location aids available and deployed
  - Has the parent craft been abandoned or is about to be abandoned
  - Has the parent craft sunk
  - Any other pertinent information that might facilitate the rescue.

The distress message should contain most of this information. However, reports indicate that in time of distress the information is usually incomplete and vessels/persons seldom transmit a standard distress message because of panic. Detailed information should be obtained about the casualty if communication is still possible. Contact should be maintained throughout if possible. Alternately a reasonable amount of information can usually be obtained from the owners or managers, the flag state administration or a ship reporting service.

Position

Normally this is transmitted as latitude and longitude up to 2 or 3 decimal places. However, decimal places, or the fact that it is a lat/long, does not confirm its accuracy. It is important to know whether it is a fix, an EP or a DR. If it is a fix, what is it based upon? Perhaps it is a DGPS fix with an accuracy of few centimetres, or a fix using a LORAN C system 1200 miles from the chain. Can the observer relate it to a landmark as a bearing and distance? Another important fact about a position is the time. Is it the current position? Is it the last known position? All this information will assist the responding vessels or Co-ordinator to establish an accurate datum.

12.2.3 Information on Other Units

Basic information (not exhaustive) should be obtained from other units:

- Identity of crafts
- Position of crafts
- Estimated time of arrival (ETA) of crafts at the scene of incident
- Number of crew
- Experience of the Master and crew with Search and Rescue
- Navigational appliances fitted and their accuracy
- Communication facilities
- Medical (doctor, hospital and first aid) facilities
- Lifting appliances
- Life saving appliances
- Size of the craft
- Type of the craft
- Draught of the craft
- Freeboard
- Manoeuvring restrictions/capabilities
- Duration for which the craft can stay on scene for participation in Search and Rescue
- Type and quantity of cargo carried
- Destination.

The above information will help the SMC to decide on the best unit to co-ordinate the activity on scene, those that can easily participate in the search if required and the best choice for the rescue units.

12.3 Onboard Preparation

This preparation will depend upon the emergency organisation onboard the ship, whether the Master has been nominated as the OSC and any instructions from the SMC. Some aspects of seamanship have been added as the command position will have to order the same.

Participating vessels should establish a traffic co-ordinating system among themselves. A vessel responding to a Search and Rescue incident should make preparations on board. It is best to raise the alarm to muster all concerned, i.e. emergency, engine room, back up and first aid parties. Additional officer(s) and lookouts should be summoned to the bridge. There should be two-way communications between the bridge and all parties involved on board.
After deciding to proceed, the course should be adjusted and the engine room should be advised to make good all available speed and be ready for manoeuvring in the vicinity of the Search and Rescue area.

BRIDGE/NAVIGATION

- Brief and advise Watch officers and lookouts
- Up-to-date weather information for the route and the distress position
- Determine datum and update it as necessary (see 12.4.1)
- Operate radar(s) especially X band, 3 cm
- Call or designate a communications officer
- Make sure binoculars are available
- Plot the position of 'own ship' frequently to maintain the quickest route to the scene. Make course adjustments as necessary
- Plot the positions of other ships attending the distress call
- Consider using search or deck lights during hours of darkness.

COMMUNICATIONS

- Monitor all distress frequencies
- Try to maintain continuous contact with the ship in distress
- Update CRS/RCC with any developments and obtain current information from the service
- Have copies of the International Code of Signals available
- Locate the daylight signalling lamp, search lights, flashlights, hand held VHF radios and loud hailer
- Establish communications with emergency/deck (rescue) team.

ENGINE ROOM

- Advise to maintain maximum possible speed
- Advise when the engine(s) are to be on stand-by and ready for manoeuvring
- Order other services in good time, e.g. fire pump, power for deck machinery, etc.

DECK

- Prepare rescue boat (and lifeboat if required) for launching, subject to weather condition
- Have a liferaft ready (without inflating it) and consider using it, if required, as a boarding station
- Rig scrambling nets on both sides of the ship
- Rig rope ladders on both sides of the ship
- Rig boat ropes on both sides of the ship
- Have life jackets and life buoys in readiness
- Have heaving lines, rescue quoits, line throwing apparatus and messenger ropes in readiness
- Rig man ropes on both sides
- Provide survival/immersion suits for the crew of the rescue boat or those who may be required to enter the water
- Get ready the boat and grappling hooks, hatchets, rescue baskets and litters and fire fighting equipment
- Check cargo lifting appliances (crane, derrick, gantry, etc.) on each side of the ship, with cargo net and spreaders for recovery of survivors.

MEDICAL ASSISTANCE (made ready)

- Stretchers
- Blankets
- Medical supplies, first aid kits, resuscitator and medicines
- Dry clothing
- Food and hot drinks
- Hospital
- Shelter.

12.4 Search Planning

Careful planning is the key to a successful Search and Rescue operation. The plan is prepared in a number of stages and every stage requires information. Generally, the SMC will prepare a search action plan and pass it to the OSC. If the plan is not available, the OSC should develop one. Most well-run coastguards and rescue services use computer programmes for developing the plan. However, the basic principles of both remain the same and it is essential to know:

- The most probable position of the casualty to commence the search
- The size of the search area
- What type of search patterns will be used and the spacing to use in the search area
- The type of search target(s) and the number of available Search and Rescue units.

12.4.1 Datum

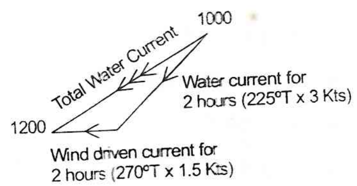
The first stage in every Search and Rescue incident is the establishment of a geographical reference or DATUM for commencing the search. This depends upon:

- The reported position
- The time of the incident
- Any bearings or sightings
- The time interval between the incident and arrival of Search and Rescue facilities
- The size, type and condition of the search object
- The estimated surface movements of the distressed craft or survival craft, depending on drift

Drift is caused by wind and water movement and is based upon:

- Leeway caused downwind, due to wind
- Total water current (which comprises of two components – current /tidal stream and wind driven current)

For the purpose of planning, lets assume that the distress signal was sent stating the distress vessels position for 1000 and the first unit will take 2 hours to arrive on-scene. Assumed rates are stated on the sketch.



Working out a wind-driven current involves a complicated calculation. If the datum has not been provided by the SMC, and the OSC has to work it out onboard, the wind driven current could be ignored, as the OSC may not have the appropriate facilities data and experience to work it out.

The time interval is the interval between the incident time, or last computed datum, and the commencement of search time. This emphasises the need to work out the ETA as precisely as possible.

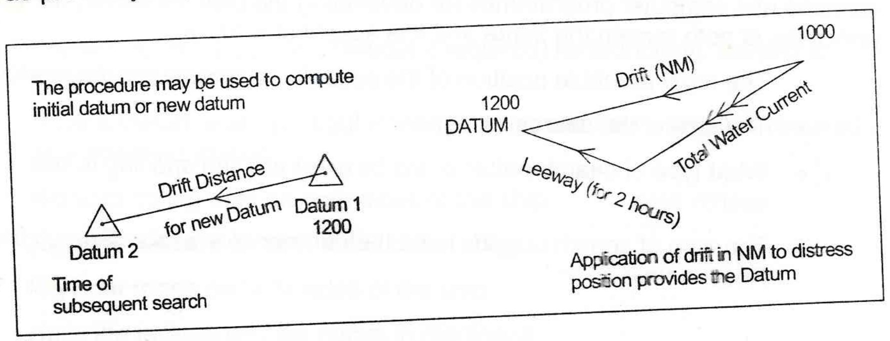


Figure 12.1 - Drift Distance Calculations

If the search is for a liferaft, without drogue and the wind is force 5, leeway is 1.35 kts downwind. Note: These are estimations only and the actual values may vary.

Some ships carry drift predictions for different vessels at sea, but it must be understood that these are estimations only and the actual response under the given circumstances may be different.

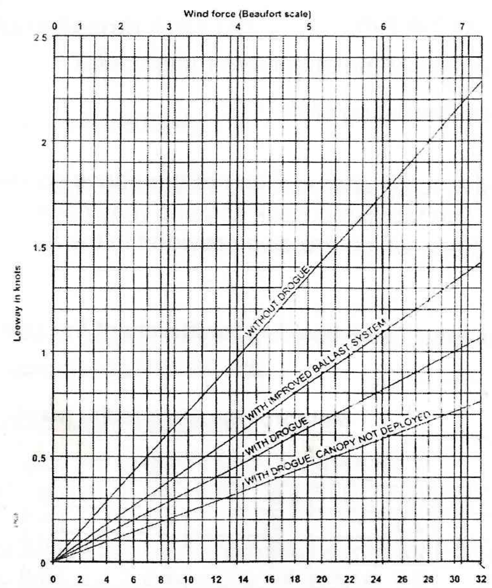


Figure 12.2 - Liferaft Leeway

(Source IAMSAR Vol III , Page 3-17)

12.4.2 Search Area

The underlying and driving principle by which the search area is worked out is simple, detection cannot be compromised. If there are a number of units available, the area can be shared among them and they can each search a comparatively smaller area. If there is a single unit, it should never attempt to search a larger area than is reasonable to have searched normally in the given time. The calculation of the search area, therefore, depends upon a number of factors.

12.4.2.1 Track Spacing (S)

In order to search effectively, units have to cover the search area following designated tracks. The distance between adjacent tracks is called track spacing. The IAMSAR manual provides tables for recommended track spacing based upon meteorological visibility.

Track spacing is dependent upon:

- The size of the search object
- The type of the search object
- Meteorological visibility

- The sea state/condition
- Time of the day (day/night/twilight)
- The position of the sun
- The effectiveness of the observers (height, etc)
- The number of assisting craft

Track spacing may have to be altered if any of the above conditions vary during the course of the search. The tabulated track spacing may have to be adjusted for weather correction factors, which are also provided in the IAMSAR.

Table 12.1 - Recommended Track Spacing for Merchant Vessels (IAMSAR)

	Meteorological visibility (nautical miles)				
Search Object	3	5	10	15	20
Person in water	0.4	0.5	0.6	0.7	0.7
4-person liferaft	2.3	3.2	4.2	4.9	5.5
6-person liferaft	2.5	3.6	5.0	6.2	6.9
15-person liferaft	2.6	4.0	5.1	6.4	7.3
25-person liferaft	2.7	4.2	5.2	6.5	7.5
Boat < 5 m (17 ft)	1.1	1.4	1.9	2.1	2.3
Boat 7 m (23 ft)	2.0	2.9	4.3	5.2	5.8
Boat 12 m (40 ft)	2.8	4.5	7.6	9.4	11.6
Boat 24 m (79 ft)	3.2	5.6	10.7	14.7	18.1

Table 12.2 - Weather Correction Factors for all Search Units (IAMSAR)

Weather **Winds km/h (kts or seas m (ft)**	**Search object**	
	Person in water	Liferaft
Winds 0 – 28 km/h (0-15 kt) or seas 0 – 1 m (0 – 3 ft)	1.0	1.0
Winds 28 – 46 k/h (15 – 25 kt) or seas 1 – 1.5 m (3 – 5 ft)	0.5	0.9
Winds > 46 km/h (>25 kt) or seas >1.5 m (>5 ft)	0.25	0.6

Track spacing (S) = Recommendation x Weather correction factor

Searching for a 25 person liferaft, where wind is 20 kt and visibility is 10 NM, the track spacing to be used is = 5.2 x 0.9 = 4.7 NM

12.4.2.2 Search Speed (V)

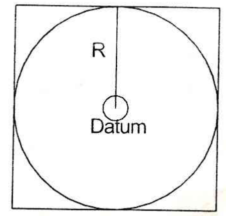
When carrying out a parallel track search jointly (in a co-ordinated manner), all units should proceed at the same speed, as advised by OSC. This speed will normally be the maximum speed of the slowest ship participating in the search. For safety

reasons, e.g., in reduced visibility, a safer reduced speed may be ordered by the OSC.

12.4.2.3 Immediate Search Area (A)

If search must commence immediately,
assume R = 10 NM

Draw circle of 10 NM radius and close box with tangents



Most probable area

This area should be used if search units are in the immediate vicinity and arrive on scene very rapidly to commence the search.

12.4.2.4 Calculated Search Area (A)

Where time is available for the computation, the area is:

A = Track space (S) x Search speed (V) x Time (T)

A ship with a speed of 14 knots and planning to search for 2 hours for the 25 person liferaft, can search an area = 4.7 x 14 x 2 = 131.6 NM^2

Where more than one unit is available, the individual areas can be added to obtain the total area that can be searched:

$A_t = A_1 + A_2 + etc$

But if the search speed is the same: $A_t = N \times A$ (where N is the number of units)

In this case the search radius: $R = \sqrt{(A_t)} / 2$ (half the square root of Area)

For a 131.6 NM2 area: $R = \sqrt{(131.6)} / 2 = 5.7$ NM

12.4.3 Search Patterns

12.4.3.1 Expanding Square Search

- All course alterations are of 90 degrees
- The first two legs will be of same length 'S', which is the track space.
  - Legs 3 and 4 will be a length of 2S
  - Legs 5 and 6 will be a length of 3S
  - Legs 7 and 8 will be a length of 4S
  - and so on until the area is fully searched.
- The commence search point (CSP) is always the datum position

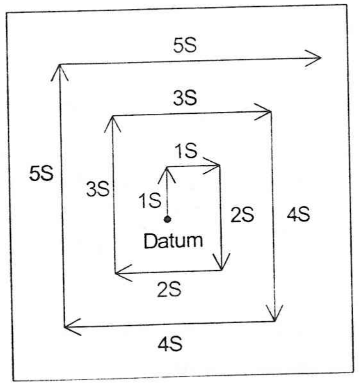


Figure 12.3 - Expanding Square Search

An expanding square can only be used by a single ship and is often appropriate for vessels or small boats to use when searching either for persons in the water or for other search objects with little or no leeway. It is most effective when the location of the search object is known within relatively close limits.

Generally, accurate navigation is required. To enhance visual referencing at sea the first leg is usually oriented directly into the wind if some sea is running, to minimize navigational errors.

12.4.3.2 Sector Search

This is used to search a circular area centred at the datum and can only be used by only one craft at a time at a certain location. A suitable marker may be dropped at the datum and used as a reference point.

An aircraft and a vessel may be used to perform independent sector searches of the same area.

- CSP is where the search unit enters the area
- Sectors are marked from datum as 1st, 2nd, 3rd and the course alterations are 120°
- After initial search, the pattern is oriented 30° in the direction of turn.

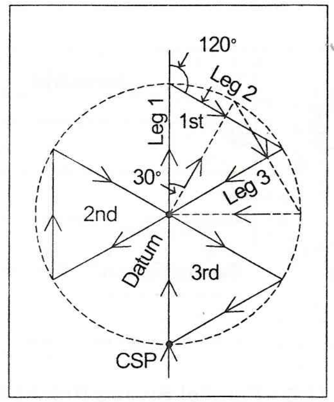


Figure 12.4 - Sector Search

A sector search is most effective when the position of the search object is accurately known and the search area is small. Typically, this might be after a man overboard incident as part of the immediate action in searching for the person. For a man overboard incident, the search legs should be defined in terms of time rather than distance.

12.4.3.3 Creeping Line Search, Co-ordinated

In this case, an OSC has to be present to give direction to and provide communications to the participating craft.

The aircraft does most of the searching while the ship steams along a course at a speed directed by the OSC, so that the aircraft can use it as a navigational checkpoint and, eventually, for rescue.

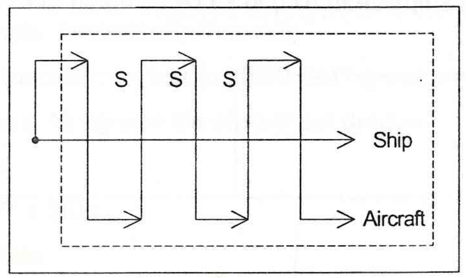


Figure 12.5 - Creeping Line Search

The CSP is where the ship or aircraft enters the area to be searched. The aircraft, as it passes over the ship, can easily make corrections to stay on the track of its search pattern. This search pattern gives a higher probability of detection compared to a single aircraft searching alone. Ship speed varies according to the speed of the aircraft and the size of the area to be searched.