CHAPTER 5

ELECTRONIC NAVIGATION SYSTEMS

INTRODUCTION

On modern sea-going vessels there are a number of electronic navigation systems and equipment which are designed to assist the navigator to navigate his vessel safely. They are

a. The gyro compass.
b. Ship’s log.
c. Echo sounder (depth recorder).
d. Radar.
e. Automatic radar plotting assistant (ARPA).
f. Automatic identification system (AIS).
g. Global positioning system (GPS).
h. Electronic chart display and information system (ECDIS).
i. Radio direction finding system.
j. Hyperbolic radio navigation system.

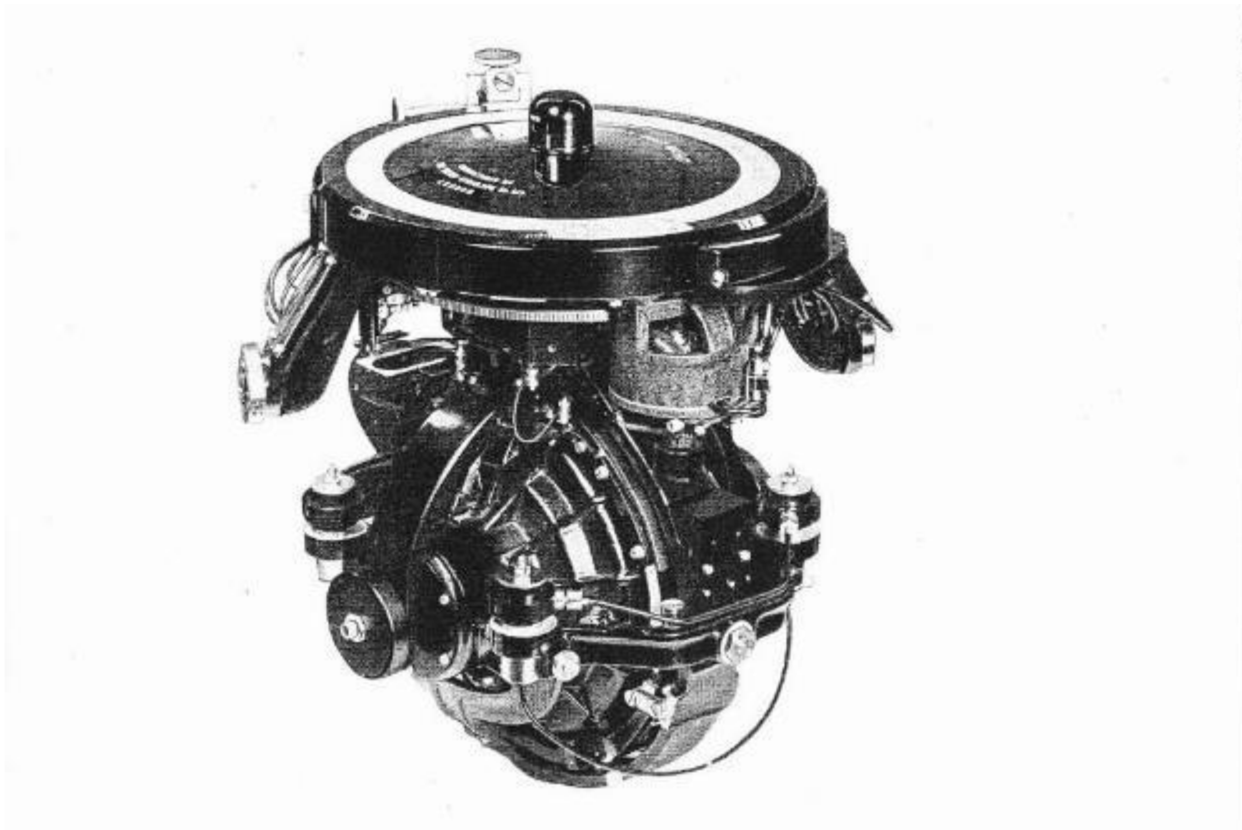
Whilst it is not intended to cover the above equipment/systems in great technical detail, the principles on which they operate and a broad description of each will be discussed. The last item on the above list has been included, although few vessels actually still use the system these days or are fitted with the specific equipment.

GYRO COMPASS

Except for small recreational vessels, most vessels are equipped with two types of compass, namely a gyro and a magnetic compass. The former is used as the primary compass with the latter as back-up in the event of gyro or power failure. Since the latter makes use of the earth’s magnetic field and is not reliant on electrical power it will not be discussed in this module.

Except for small vessels, most sea-going vessels carry two gyro compasses which operate independently of one another, thus providing the navigator with a back-up in the event that one of the gyros fails. They operate on the principle of a very fast spinning wheel which has the attribute of rigidity in space and keeps its direction provided no external force is applied to it. Good examples of this phenomena are the bicycle and the motorbike which make use of the gyroscopic effect of their swiftly rotating wheels to remain in a balanced upright position.
The gyro compass comprises a well balanced wheel spinning at a very high velocity around an axis mounted in bearings with minimal friction and suspended in gimbals which allow it to turn

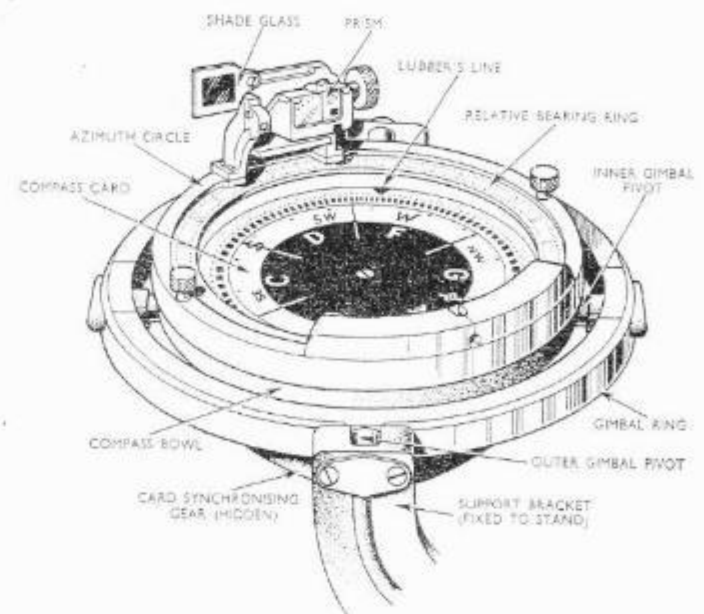
or tilt freely. In order to counter the east-west movement of the earth's rotation and the north-south movement of a vessel or craft carrying the gyro a liquid/mechanical correcting system is fitted to the compass which makes it north (true north) seeking. By attaching a compass card to the gimbals and aligning its north/south line with the axis of the spinning gyro, the gyro will become a compass from which true north can be obtained.



Old type Sperry gyro compass

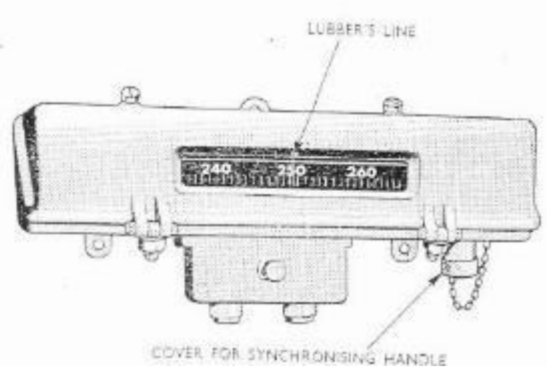
In order to reduce the effect of the rolling/pitching movement of the vessel, the gyros are usually mounted as near to the centre of the vessel as possible. From a static state it takes the gyro compass a while for it to stabilise and settle down after being switched on. Therefore it is usually switched on a few (4 -6) hours prior to sailing.

In order to use the direction supplied by the gyro compass, a sensor system is built in to the compass which feeds a number of repeaters situated on the bridge, bridge wings, steering positions, emergency conning and steering positions and other items of navigation equipment such as the radar, electronic chart displays and radio direction finders. In the case of the bearing repeaters situated on the bridge wings and the centre of the bridge, the repeaters are mounted in a special metal stand called a pelorus. They are mounted on gimbals to allow for the pitching and rolling of the ship and are equipped with a removable azimuth circle to facilitate the taking of bearings.



Gyro compass repeater mounted on the bridge wings

. The accuracy of the compass should be checked regularly against terrestrial navigation marks (transits) and when out of sight of land, by taking amplitudes and azimuths of the sun. Regular comparisons should also be taken of the heading of the gyro with that of the magnetic compass especially after altering course.



Gyro compass strip repeater usually mounted inside the bridge

SHIP'S LOG

The ship's log is basically the "speedometer and odometer" of a vessel. And performs exactly the same function as that of a motor car, ie it records the speed of the vessel and the distance travelled. Initially logs were purely mechanical and required no electrical power to operate. They only recorded the distance covered by the ship, whilst the speed was calculated by accurately measuring the time difference between successive readings of the log and dividing the distance covered by the time taken. An example of this type of log was the Trident towed log. Since it was a purely mechanical device, it will not be covered in this module.

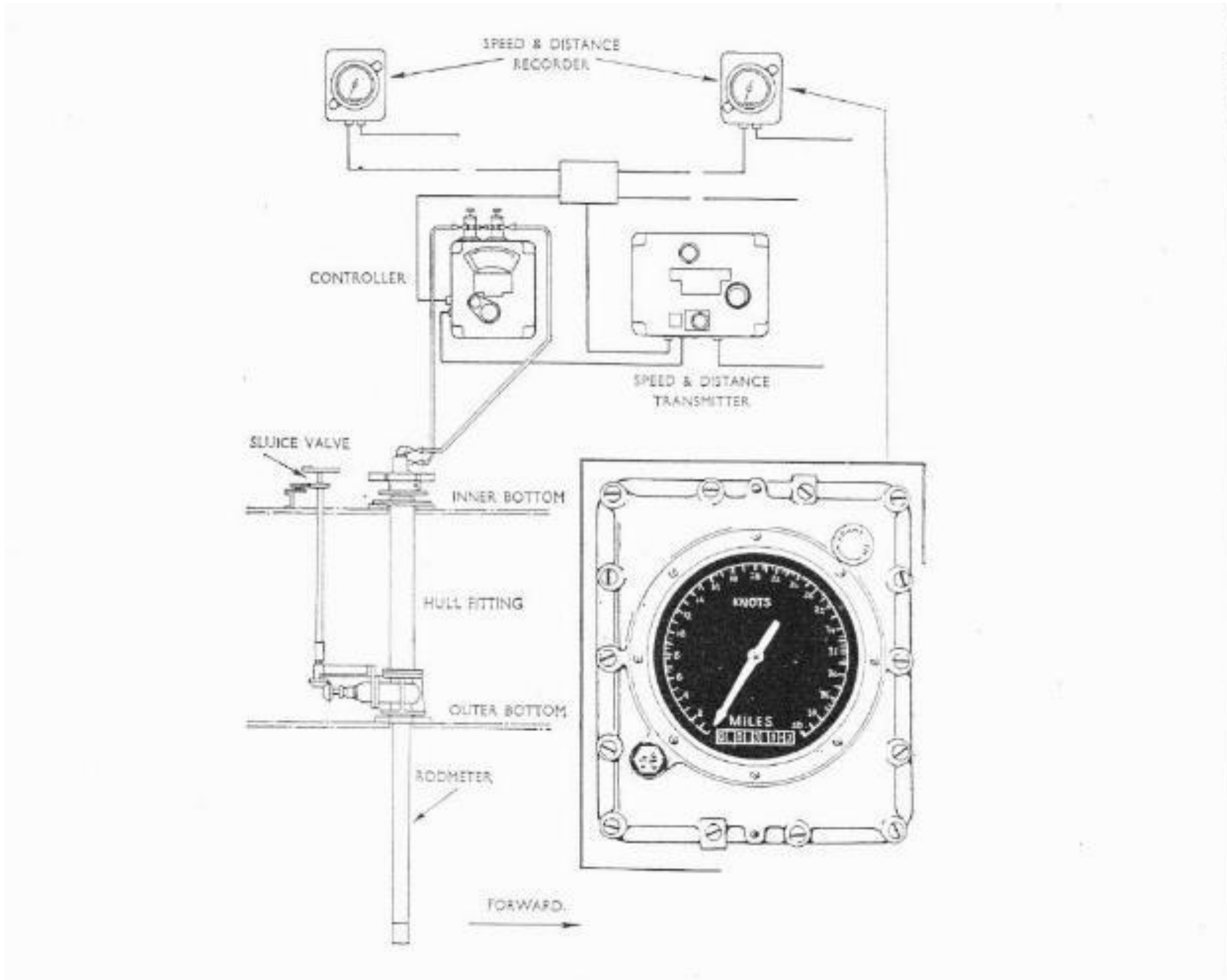
It should be noted that when ordering a particular speed to proceed at, use is made of the shafr revolutions to speed table. This table is compiled during the sea trials conducted after a vessel is built when the vessel carries out speed trials over a specially measured and demarcated range. The table provides the number of shaft revolutions required to propel the vessel at every speed within the vessel's speed range.

Of the electromechanical and electronic logs there are various types

a. The Pitometer log.
b. The Chernikeeff log.
c. The Electromagnetic log.
d. The Doppler log.

Pitometer Log

The Pitometer log is a "pressure type" log which measures the difference between the static water pressure at the depth of the log sensor and the pressure caused by the movement of the ship through the water.

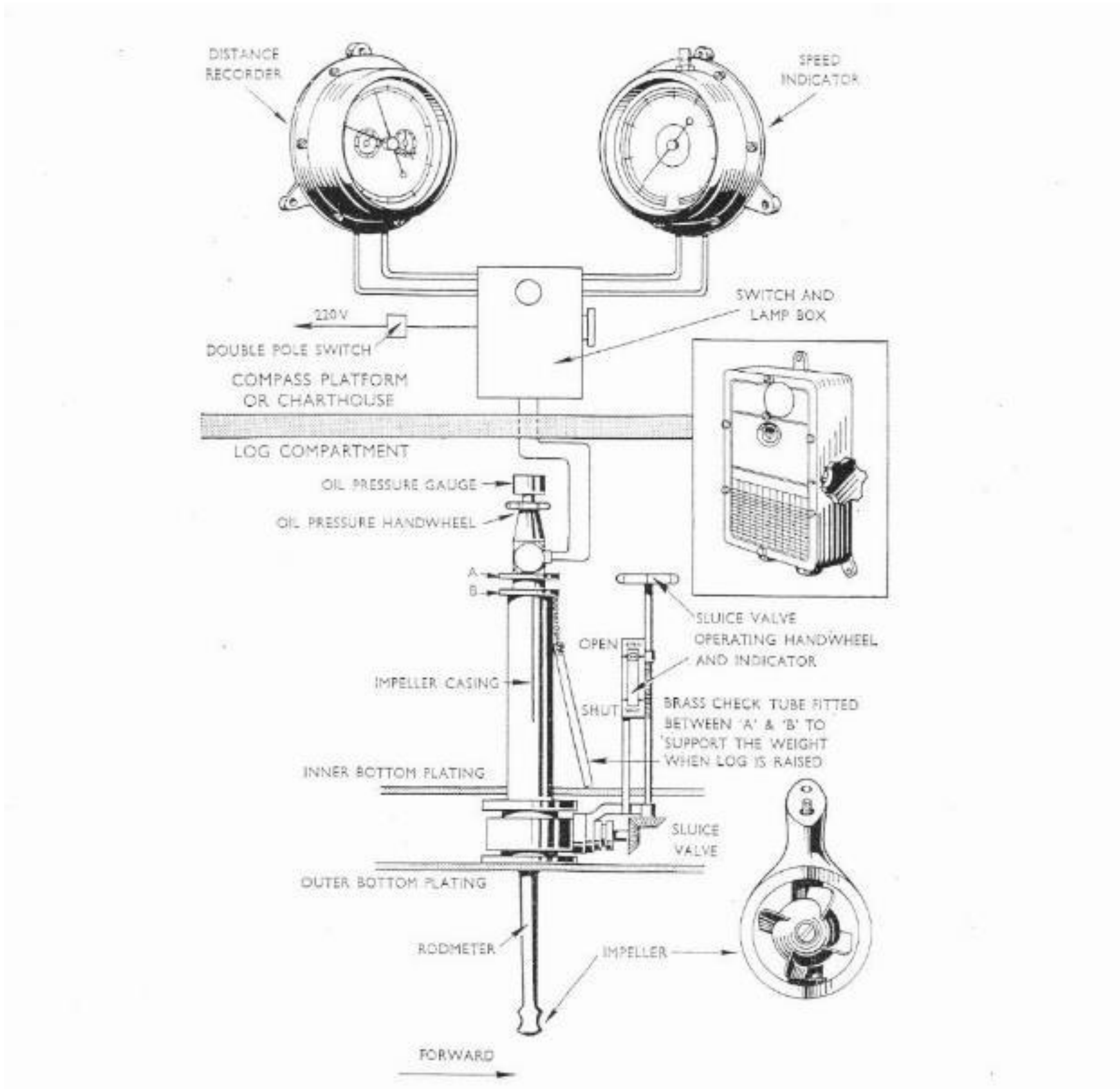


An analog pitometer log

The pressure sensors are contained in a hollow metal rod with an oval cross section which projects approximately 1 metre below the bottom of the hull. The unit is fitted near the pivoting point of the vessel and can be drawn into the hull, after which the aperture can be closed. This is done when the vessel is due to enter harbour or when proceeding in very shallow water when the log may be damaged.

The device which measures the pressure difference converts it to a distance and speed recorder where the results are displayed visually. In the past the processing and display of this data was done using analogue technology. These days it is processed and displayed digitally and can be fed to any other navigational system requiring a log input. An important item to note is that the speed and distance provided by the log is through the water and not over the ground.

Chernikeeff log.



An analog Chernikeeff log

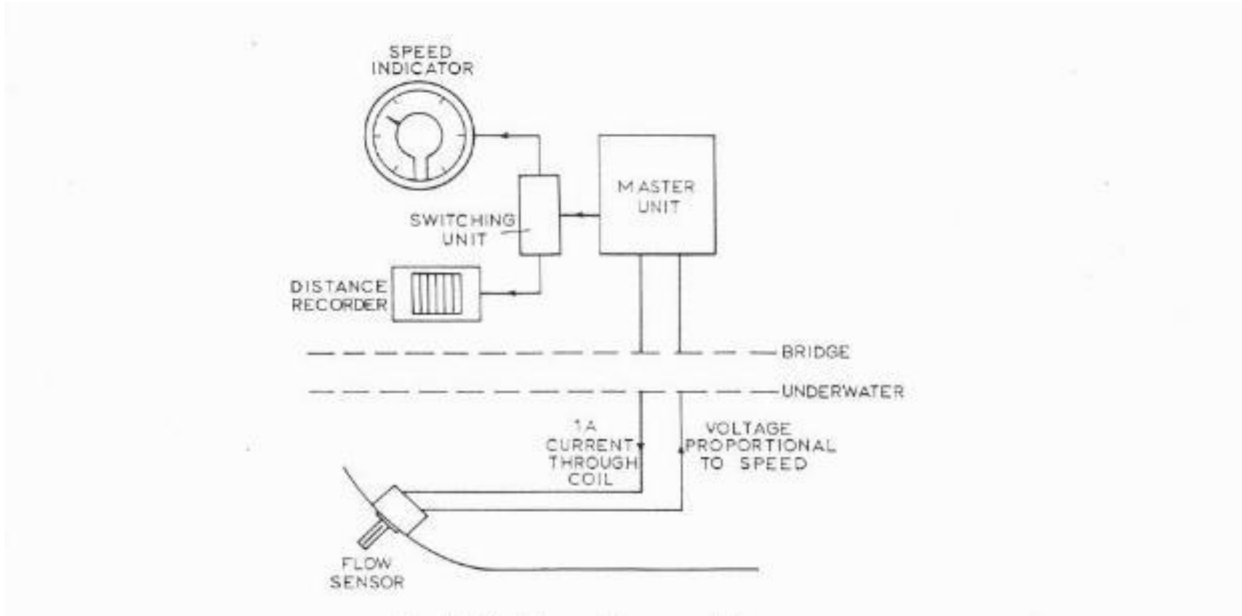
In the case of the Chernikeeff log, an impeller is fitted at the lower end of a similar rod to that of the Pitometer. The rod projects approximately ½ metre below the bottom of the hull. Like the Pitometer, it too can be withdrawn into the hull and the aperture closed.
The rotation of the impeller by the flow of water operates a make-and-break mechanism in the shaft which transmits the impulse electrically to the distance recorder which displays the distance covered. By counting the number of impulses over a predetermined time interval, the speed is determined and displayed. As for the Pitometer log, the processing and display of the data is

done digitally these days. The problem with a Chernikeeff log is the fact that it has a moving part, namely the impeller, which is susceptible to jamming by underwater debris.

Modern digital display for the ship's log

Electromagnetic log.

Again the electromagnetic log consists of a metal rod similar to that of the Pitometer, which projects below the bottom of the hull. An iron-core coil is mounted in a glass fibre housing at the bottom end of the rod. The coil is fed with an alternating current and, when moved through the water, produces a voltage in the surrounding water. The voltage, which is proportional to the flux and the relative speed of the rod through the water, is detected by two electrodes on the rod, and fed to a processor which converts it to distance and speed. This is then fed to displays on the bridge and to any navigation system requiring a log input.



An Electromagnetic log

Doppler log.

Up to now we have been discussing logs which provide the distance covered and the speed measured through the water. Since this does not take into account the effect of tidal streams and currents, it does not reflect the true movement of the vessel over the ground. In order to determine our position and movement geographically, we need a sensor that can measure movement relative to the sea bed.
By using similar technology to that used by the echo sounder (transmission and reception of sound through water), the Doppler log is able to measure movement of the vessel in relation to the sea bed. In the case of the echo sounder the propagation time of the transmitted sound pulse and its echo is measured and together with the known speed of sound through the water, the depth of water can be measured. In the case of the Doppler log, the difference in the frequency between the transmitted pulse and that of its echo is measured (the Doppler shift) and from this is calculated the speed of the vessel over the ground.

Unlike the echo sounder, the Doppler transducer transmits a continuous beam of sound at an angle of 60° to the keel of the ship in a forward direction. A second transducer receives the returning echoes resulting from the multi-path reflections from the sea bed. The difference between the frequency of the transmitted pulse and that of the echoes is measured and the speed of the vessel is determined.

The frequency used by the Doppler log is higher than that of the echo sounder. The reasons for this are

a. The shorter wavelength results in better diffusion of the reflection (multi-path reflections).
b. The shorter wavelength results in a smaller beam angle and reduces the physical dimensions of the radiating face of the transducer.
c. The radiated power of the sound beam spreads less and makes the echo stronger.

Because of the absorption by particles of the water at a depth of between 200 and 400 metres, the Doppler log only works to about 200 metres. The minimum depth at which it will operate is about ½ metre from the transducer. The velocity range is between 0 and somewhere between 30 and 100 knots in the fore and aft line and between 0 and between 8 and 10 knots athwartships. The frequency range in water is 100 to 600 Khz.

ECHO SOUNDER

An echo sounder is the instrument used to determine the depth of water beneath the keel. In order to do this it transmits pulses of sound which bounce off the sea bed. How does it work?

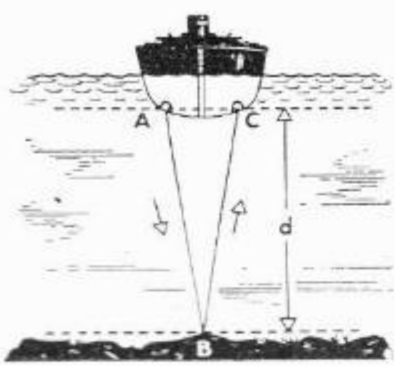
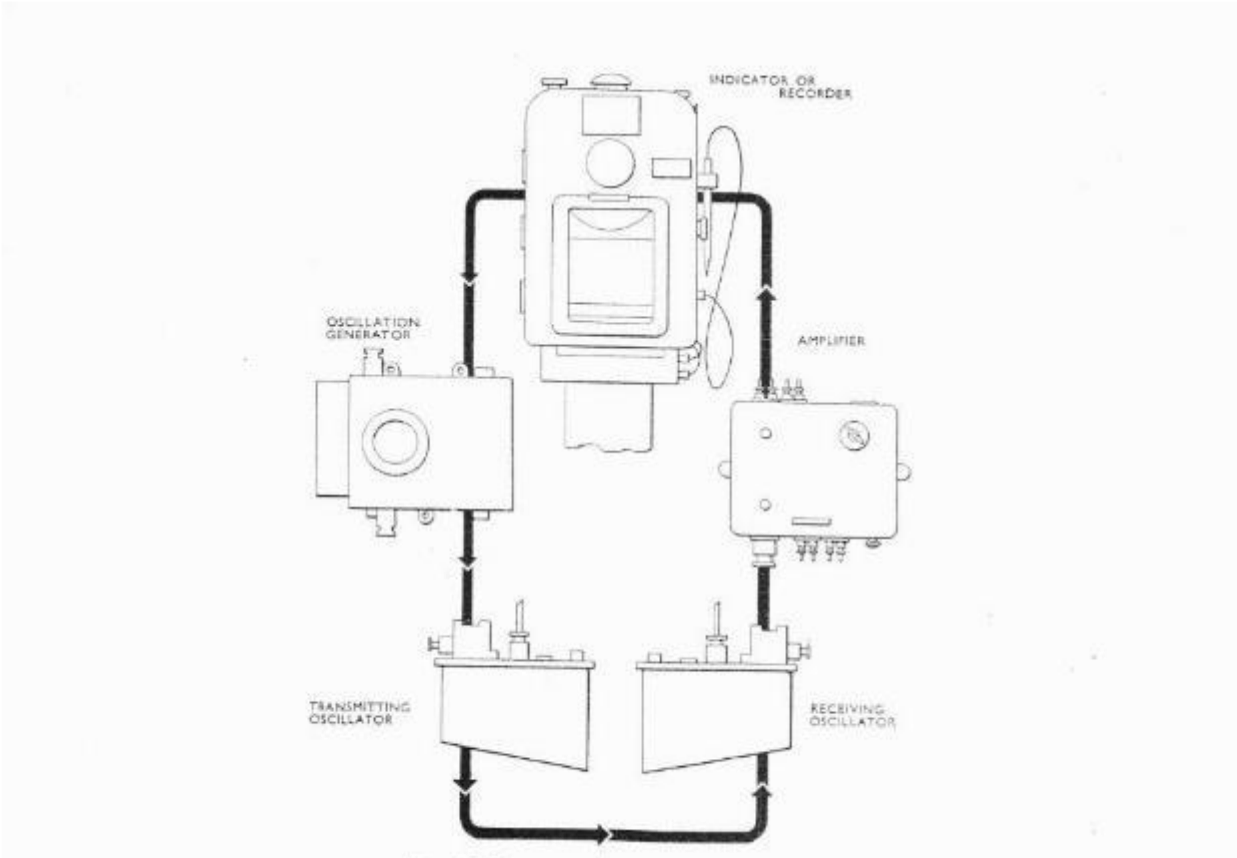


Figure 2.1 Principle of the echo sounder. A short pulse of sound vibration is produced at A, reflected by the sea-bed at B, and received at C. The depth d is proportional to the measured time interval between transmission and reception (courtesy Kelvin Hughes)

The echo sounder system comprises four components, namely a transmitter, a receiver, a transducer and a display unit. The transmitter creates a short pulse of AC current which it passes to the transducer which is situated at the bottom of the ship. The transducer converts this pulse into sound (like a loudspeaker) which it transmits towards the sea bed. When it reaches the sea bed, this pulse is reflected back to the transducer which now acts like a microphone and coverts it back into an electrical current. This is then passed to the receiver where it is amplified and converted into a useable format and displayed on the display unit. In the receiver there is also a very accurate timing device which measures the time taken between transmission of the pulse and reception of the echo. Since the speed of sound in water is known (approx 150 metres per second) the receiver can now calculate the depth of water between the transducer and the sea bed and this is what is displayed to the operator.



Basic diagram of the components of an echo sounder.

The display unit can be one of the following:

a. Flashing LED display. An arm rotated in a circular display at a constant speed. When the arm is at the top of the display it initiates the transmission of the pulse. When a signal is received a light emitting diode (LED) is switched on giving a flash at approx the same spot each time. This indicates the depth.

b. Digital display. Here the depth is displayed digitally (in figures) in metres.

c. Paper Recorders. With a paper recorder a mark is burned on a roll of paper indicating the depth at regular intervals. With this display a chart of the bottom is produced.

d. Video Display. With this display a similar picture is produced as that of the paper recorder. One can either have it in monochrome (shades of one colour) or in full colour. The colour option allows the operator to determine the nature of the bottom.

Except on digital displays, various range scales can be displayed, ie 0 to 10 metres, 0 to 20 metres, etc. Echo sounders usually operate in the 10 to 55 Khz frequency range. The human ear can only hear sound in the 8 Hz to 18 Khz range. The echo sounder frequency range is therefore referred to as ultra sonic.

RADAR

Radar has already been covered in a module devoted entirely to it, so it will not be discussed any further.

AUTOMATIC RADAR PLOTTING AID (ARPA)

As mentioned previously, most radars today are equipped with ARPA. ARPA performs many of the functions covered in the radar module automatically and continuously. This saves the officer of the watch from having to do so manually and enables him to focus on his other duties. What are the capabilities of ARPA?

Capabilities

a. It can track targets much faster and requires less plotting interval.

b. Twenty or more targets can be tracked at a time

c. Vectors are displayed and constantly updated, so the situation is graphically displayed with the latest information.

d. Full details regarding each target being plotted can be displayed on command.

e. The history of each target's movement can be graphically displayed.

f. It automatically acquires targets for tracking, which otherwise might have been missed by the officer of the watch.

g. It provides a warning in the event of collision risk, loss of target, target entering a guard zone, etc.

h. It provides a facility to predict the outcome of a manoeuvre under consideration.

Display of plotting data

Apart from the basic display of bearing and range of each target normally displayed by the radar, additional information is required to determine risk of collision and the avoiding action to be taken. ARPA can provide this information automatically. When graphic information is displayed, risk of collision will become apparent with the use of relative vectors. If more detailed information is required for decision making, then true vectors can be used.
ARPA will start plotting targets either if acquired manually through the use of a joystick or similar pointing device, or by any target entering a predetermined zone. Once a target is acquired, it will continue to be plotted until it is removed by the operator. ARPA will display the following information:

a. <u>Relative vectors.</u> This information is displayed relative to the observer's vessel. The length of the vector relates to a time interval and it's direction will indicate it's closest point of approach. The relative vector is therefore the OA line in a plotting triangle. If the direction of the vector points towards own ship, then risk of collision exists. Both the time interval represented by the vector and the length of the vector can be altered by the operator.

b. <u>True vectors.</u> True vectors represent the WA line of a plotting triangle. The length of each vector represents the distance the target will travel during the selected interval and its direction represents the true course of the target. In true vector display, the observer's own ship also displays its own true vector. Risk of collision in this mode can be recognised if the end of the target's vector lies in a direction which points to the end of the observer's own true vector.

c. <u>History of the target.</u> The progress of the targets on the screen can be displayed by invoking a history analysis (time-spaced dots representing past positions of the target). It should be noted that various inputs of the data to the ARPA cause the short term display to alter continuously. For this reason, any change in the target's course or speed might not be immediately apparent. The history analysis is of importance in this case.

d. <u>Potential collision points.</u> Some manufacturers feature Points of Potential Collision (PPC's) or predicted Areas of Danger (PAD's) which are locations or areas highlighted on the screen where collisions could occur, thus prompting the officer of the watch to avoid them.

e. <u>Numerical data of each target.</u> A full report of each target can be called up, giving details of the target's CPA, TCPA, course and speed. It is continuously being updated by the computer, so it will always be recent and valid.

f. <u>Trial manoeuvres.</u> It is possible to display a hypothetical situation on the radar screen (either in true vectors or relative vectors) resulting from an alteration being contemplated involving the course and/or speed of the observer's own vessel. In this way a rapid decision can be reached and executed in confidence. This does not mean however, that further close monitoring after performing the manoeuvre would no longer be necessary.

Other ARPA Facilities

a. <u>Guard zones.</u> Ares on the screen which can be considered to be more important by the operator can be demarcated in order to alert the officer to the presence of previously undetected targets that have entered this zone.

b. <u>Area rejection boundaries.</u> Areas can be selected where automatic acquisition is inhibited. In congested traffic, this has the advantage of allowing more room in the processor's memory for plotting target's elsewhere.

c. <u>Alarms.</u> Also called operational warnings. The operator is alerted:

i. whenever a target presents a danger of collision or close quarters situation;
ii. if a target enters a guard zone;
iii. whenever a target is lost;
iv. if data is incorrectly entered by the operator; and
v. it can sound an alarm to indicate system malfunctions.

d. <u>Ground referencing.</u> The secret of accurate plotting and forecasting is the accuracy of the ship's own speed and course fed into the processor. One option is to feed the data in manually, based on the observation of the navigator. However this can be burdensome. The facility of linking the velocity computations to a fixed target, such as a buoy or an identifiable prominent stationary topographical feature, will provide the computer with a known zero speed reference. With a ground reference display, land echoes will seem to drift.

e. <u>Navigational lines.</u> Lines and mapping details can be prepared and stored for future use which delineate channels, course lines, traffic separation schemes, navigational hazards, approach limits, etc. When ground referencing is invoked, the coast appears to drift and maps become displaced relative to the coastline.

f. <u>Integrated navigation.</u> The digital data from the ARPA can be fed via NMEA connectors to a fully integrated navigation system such as ECDIS on the bridge. Thus electronic charts can be superimposed on the radar screen and acquired targets can be represented on electronic charts. Other systems such as AIS can also be connected to the integrated system, providing information regarding the identification, course, speed, intentions, destination, etc can also be displayed.

Errors and problems of an ARPA

Certain inaccuracies in the ARPA plot could be caused by input errors, ie from the radar. Others could be errors in the computations and errors of interpretation.

a. Radar errors. These could be

i. bearing errors;
ii. range errors;
iii. gyro errors,
iv. course errors; and

v. speed errors.

b. ARPA errors. These could be

I, Random track errors. These are caused by input errors from the radar which causes unstable computations and erratic target behaviour.
ii. Target swap. When targets become very close to one another it could confuse the ARPA computer and cause it to swap the data computed for one to the other vessel.
iii. Target loss. The target data may be transferred to a transient echo (sea clutter) which then disappears.
iv. Missed targets. Weak echoes might miss the attention of the automatic acquisition facility.
v. Ground referencing problems. When a vector is computed from ground referenced data, the track relates to the ship's and the target's movement over the ground. There is no way therefore to gauge the effect of the current on the vectors and the aspect of the target could be affected.

c. Interpretational errors. These could be

i. Misreading a relative vector to indicate a true course and speed, or trying to obtain a CPA from a true vector.
ii. Relying too much on presented data can be dangerous. All machines can have faults and if this is not taken into account, the consequences could be dangerous.

AUTOMATIC IDENTIFICATION SYSTEM (AIS)

In the past a ship's identity and details had to be obtained by establishing communications with it either by flashing light or radio. As can be imagined this was time consuming and in a heavy traffic area a bit hazardous. This has now been replaced by an automated system referred to as AIS. Since December 2004 it has become mandatory for sea going vessels to have the system fitted. Besides being more convenient, the new system provides more information which enables the officer of the watch to make more informed decisions when proceeding through congested or busy seaways.
There are two types of onboard AIS:

a. Class A AIS which consists of

i. one 12.5 watt VHF transceiver;

ii.	one integral GPS receiver;
iii.	two VHF TDMA (time division multiple access) receivers;
iv.	one VHF DSC (digital selective calling) receiver; and
v.	a standard marine data interface (IEC 61162/NMEA 0183) to shipboard display and sensor systems.

Class A AIS

b.	Class B AIS which consists of:

i.	one 2 watt VHF transmitter;
ii.	a GPS receiver;
iii.	two VHF receivers, one of which must be able to decode DSC transmissions as well.

Class B AIS

Large ocean going vessels such as those subject to the SOLAS convention are obliged to use the class A system, while smaller vessels and recreational craft use class B.

<u>How does it work?</u>

The AIS transponder works in an autonomous and continuous mode. Although only one radio channel is necessary it transmits and receives over two radio channels to avoid interference problems and to allow channels to be shifted without communications loss from other ships. Class A AIS can tune over the whole 156.025 – 162.025 MHz band, while class B AIS is restricted to 161.5 – 162.025 MHz.
Class A stations determine their own transmission schedule, based upon data link traffic history and knowledge of future actions by other stations. Class B is a "polite" listen-before-transmitting system that will transmit on the first available slot. There are 2250 time slots established every 60 seconds and the AIS stations fit their transmissions into one of these slots during each transmission. They automatically and continuously synchronise their transmissions to avoid overlapping each other.

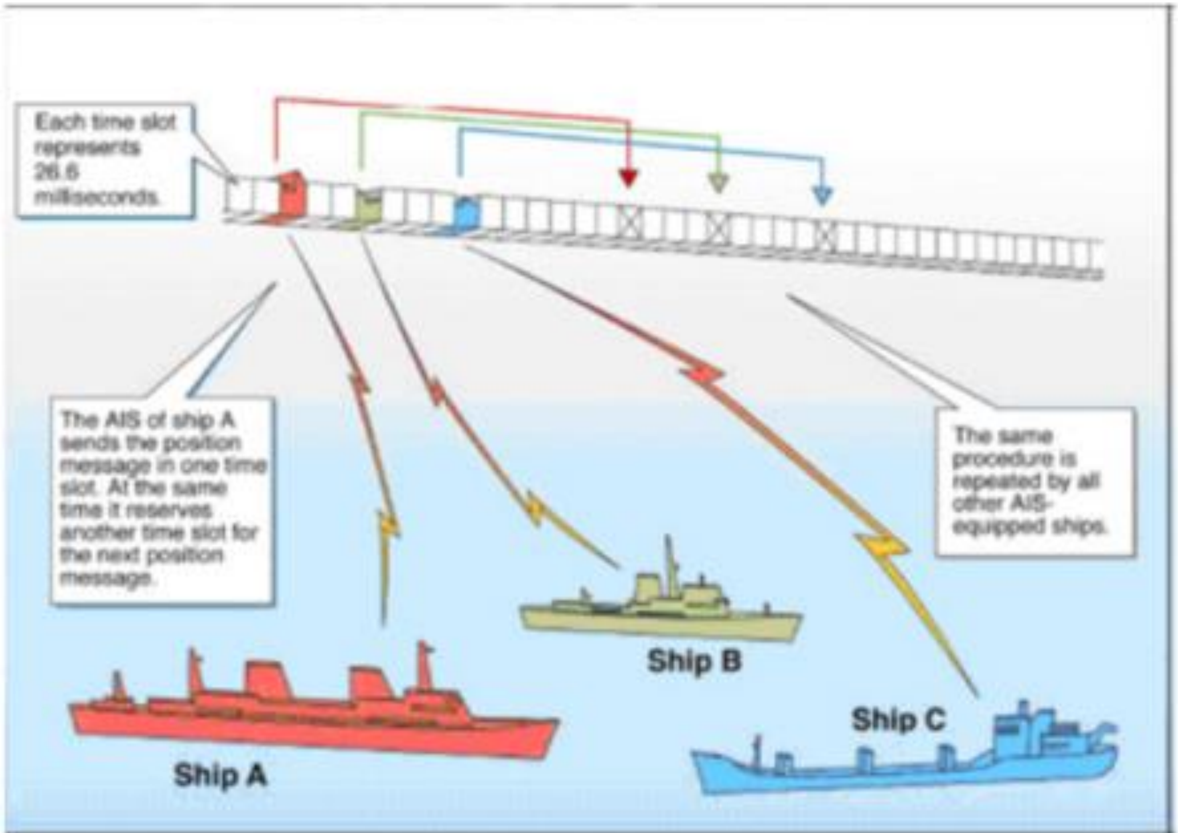
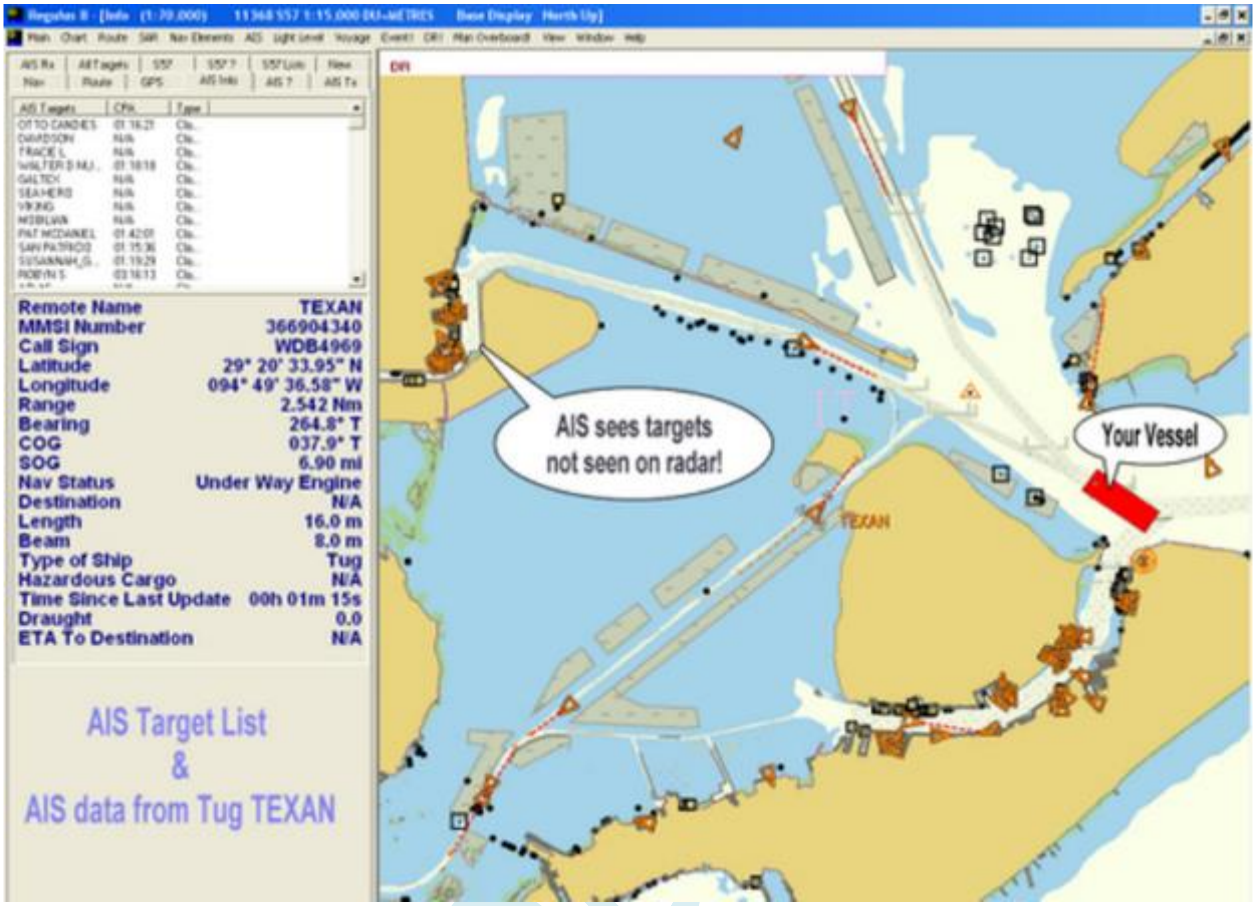


Diagram of the TDMA principle upon which the AIS depends
TDMA: Time Division Multiple Acssess)

The coverage of these transmissions depends upon the height of the antenna mainly and is typical of VHF transmissions, ie 20 to 30 miles. The transmissions consists mainly of the vessel's identity, type of vessel, its callsign, its dimensions and manoeuvring information, its cargo, its destination, its geographical position, its course and speed and its ETA at its destination. On class A ships the system is integrated with other sensor and display systems, ie radar and ECDIS and by merely clicking on a contact, all the information relating to that vessel is displayed. On class B vessels the information is displayed on an alpha numeric visual display.



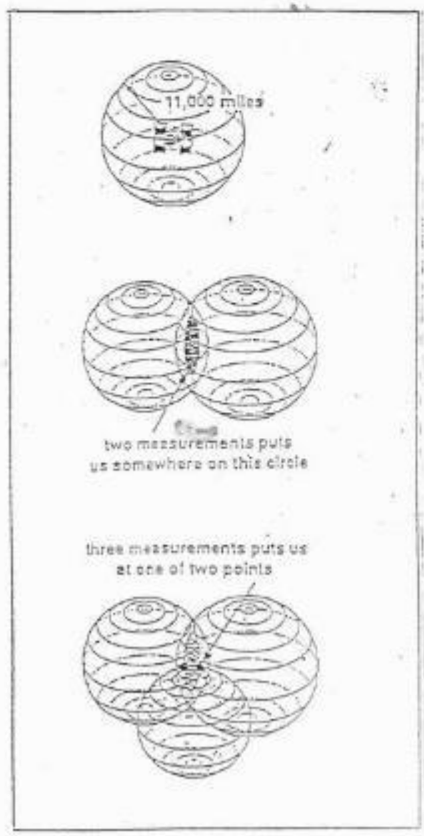
Example of the information which the AIS system displays (left side of screen)

GLOBAL POSITIONING SYSTEM

The global positioning system utilises a constellation of 31 satellites orbiting the earth at very high altitudes. It was developed in 1973 and became operational in 1994. Initially only 24 satellites were used but in 2000 it was decided to upgrade the system to GPSIII, The system is owned by the United States of America who provided all the development work, the launching of the satellites and at present maintains the system. The initial cost was in the order of 10 billion US dollars. Although it was initially developed for the US military, it was made available for civilian and commercial use as well. The initial signal for civilian and commercial use was purposefully degraded to prevent an adversary using it for military purposes. In 2000 however, this was removed and the accuracy is the same for both military and civilians. The satellites are high enough to avoid the problems experienced by the land based systems and they use technology which provides pin point accuracy anywhere in the world, 24 hours a day. The accuracy for everyday use is within 20 metres. Not only can it be used for surface navigation but, because it can locate things in three dimensions, it can be used for aircraft (and missiles) as well.

Typical GPS marine display

Concept (How does it work?)



The principle behind the GPS system (each sphere represents the transmission coverage of a satellite0

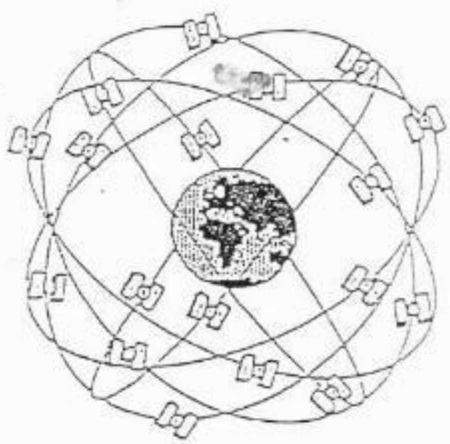
Basically the user (navigator) measures the distance between the satellite and himself. If he only used one satellite this would provide him with a position anywhere on a sphere constructed around the satellite (ie. the satellite is in the centre). If he used two he would narrow his position down to a circle which would result from the intersection of the two spheres. Using a third satellite would narrow it down further to two positions which would result from the intersection of the third sphere with the circle produced by the first two satellites.. How do we know which of the two points is our position? Usually one of the two points produced is a ridiculous position and can be discarded. By using various techniques, the computer inside the GPS receiver can distinguish the correct position from the incorrect one.

Measurement of distance

How do we measure the distance from the satellite? The GPS system measures the time a radio signal takes to travel from the satellite to the receiver. Since radio signals travel at the same speed as light (300 000 kilometres per second) all the receiver has to do is figure out exactly when the satellite transmitted its signal and measure the time it takes to reach it. This is done by installing very accurate clocks in both the satellites and the receivers and synchronising them. The clocks in the satellite are very sophisticated and extremely accurate and are also very expensive. Since it is not feasible from the cost point of view, to install the same type of clock in the ordinary GPS receiver, they are not as accurate as that in the satellites. In order to make up for the difference in accuracy between the satellites and the receivers, a technique is used to correct the errors caused by a lack of accurate synchronisation. This involves the use of data from a fourth satellite which provides a fix which the receiver realises is incorrect and through repeated correction/adjustment of the data from the four satellites is able to correct the error.

System overview

a. The space segment.



There are a total of 31 satellites (with two older deactivated satellites as ready spares) kept in 12 hour orbital planes. They are kept within one metre of their designated positions by the use of special onboard sensors and four hydrazine thrusters. The satellites are kept at an altitude of 20 200 kilometres. The orbits are chosen so that every satellite can be monitored and controlled by earth stations situated in United States territory. The orbital configuration of the satellite was designed so that at least four satellites with an elevation of greater than 9.5° will be in view of the receiving antennas at any point of the earth's surface at any time.

b. The ground segment. The ground segment consists of the following:

a. Master Control Station situated at Schriever Air Force base situated 25 km ESE of Colorado Springs.
b. Four dedicated ground antennas situated at Kwajalein, Ascension Island, Diego Garcia and Cape Canaveral.
c. Six dedicated monitoring stations situated at Hawaii, Ascension Island, Diego Garcia, Kwajalein, Colorado Springs and Cape Canaveral.

Satellite orbital parameters are constantly monitored by one or more of the ground tracking stations which pass the measured data to the MCS at Colorado Springs. From this data the MCS predicts future orbital data which is fed via the dedicated ground antennas to each satellite where it is stored in RAM and transmitted as a data frame to GPS receivers inside the coverage area of the satellite.

ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEM (ECDIS)

ECDIS is an integrated electronic navigation system which combines the data obtained from a number of electronic navigation sensors and displays it on a video display unit/monitor both in the form of a graphic image and alpha-numeric information. The sensors providing the data inputs to ECDIS are the following:

a. The global positioning system (GPS and/or DGPS).
b. The automatic identification system (AIS).
c. The radar and automatic radar plotting aid (ARPA).
d. The ship's gyro compass.
e. The echo sounder.
f. The ship's log.

The system makes use of electronic (digital) navigation charts (ENC's) in place of the normal paper charts which they are intended to replace. The position of the ship is plotted in real time and kept continuously up to date. The ship's track can be planned and plotted on the electronic chart either by use of the computer "mouse" and cursor or alpha-numeric keyboard. The voyage or passage plan can then be stored in the system's memory and when retrieved and executed, provides the planned track as would be the case with a paper chart.

Being in digital format, the track is plotted on a seamless series of charts. In the case of paper charts, the position would have to be transferred to the next chart in the series as the vessel proceeded along its planned track. The system can be instructed to provide a plotted position at predetermined time intervals, as would be the case with paper charts when positions are plotted manually.

One can also set other navigational parameters in the system, ie the maximum allowable deviation from the planned track, safety depth contours, arrivals at predetermined waypoints, alter course positions, etc. When these parameters are breeched, or a vessel reaches the predetermined waypoints/positions, it activates a visual and audio alarm to alert the officer of the watch/ navigator.

The ship's physical parameters (length, beam, draught, tonnage type and power of the engines, types of steering, manoeuvring characteristics, etc are also entered into the system so that it can predict the outcome of an intended manoeuvre, ie determining alter course positions.

Electronic charts can be constructed using either of two types of data, namely vector or raster. In the case of raster charts, a paper chart is scanned and converted to a digitised replica. This digitised image cannot be interrogated or changed, ie what is on the paper chart is displayed as is. In the case of the vector chart, all the information and symbols on the chart as well as their characteristics are digitally encoded individually and stored in the system's data base. This enables the operator to decide what he wants displayed and the level of detail he requires. This is to prevent the display being cluttered with unwanted or unnecessary data. To make vector charts is more costly and more time consuming than raster charts. Because of this, it will still take some time before all charts are replaced with vector charts. Until then ECDIS will also allow the display of approved raster charts which comply with IMO performance standards. Whereas chart corrections and updating was carried out manually, the correction of Electronic Navigation Charts can be done off-line (by CD-ROM or diskette) or on-line (via radio links or internet).

In addition to the purely navigational aspect, the system is designed to allow the overlay of the radar/ARPA picture on the chart graphics. The rest of the information provided by ARPA and the AIS system is displayed next to the graphic display in alpha-numeric format. By looking at one video display unit/monitor the navigator or officer of the watch can observe all the information provided by the various navigation sensors, instead of looking at the data displays of each one individually in different locations. As in the case of the navigational mode, the system can be set to provide visual and audible alarms when a dangerous situation develops, ie a vessel on a collision course or having a CPA closer than. It is a wonderful navigational tool which will save the officer of the watch much time, especially in a congested seaway where he can apply himself more efficiently in keeping a proper lookout of his environment. There is always a danger, however, that he or she becomes complacent and relies too heavily on the system for watchkeeping, instead of using it as an **aid** to or **enhancement** of his/her physical/visual watchkeeping. The phenomenon when a collision has occurred despite the availability of electronic navigation systems has been referred to as an "electronically assisted collision". One must always be aware of the possibility of a malfunction in the system and regular checks by an independent navigational source must be conducted. One should also continuously reconcile the electronic picture with that obtained visually by the watchkeeper.

The International Maritime Organisation (IMO) decided that it will be mandatory for all seagoing commercial vessels to carry ECDIS. Implementation was carried out in phases commencing 1 July 2012.

It should be noted that not all Electronic chart Systems (ECS) are ECDIS and only an ECDIS approved by the IMO is approved for navigational use. It is also an IMO requirement that a suitable and independent back=up navigation system be available in addition to the ECDIS.

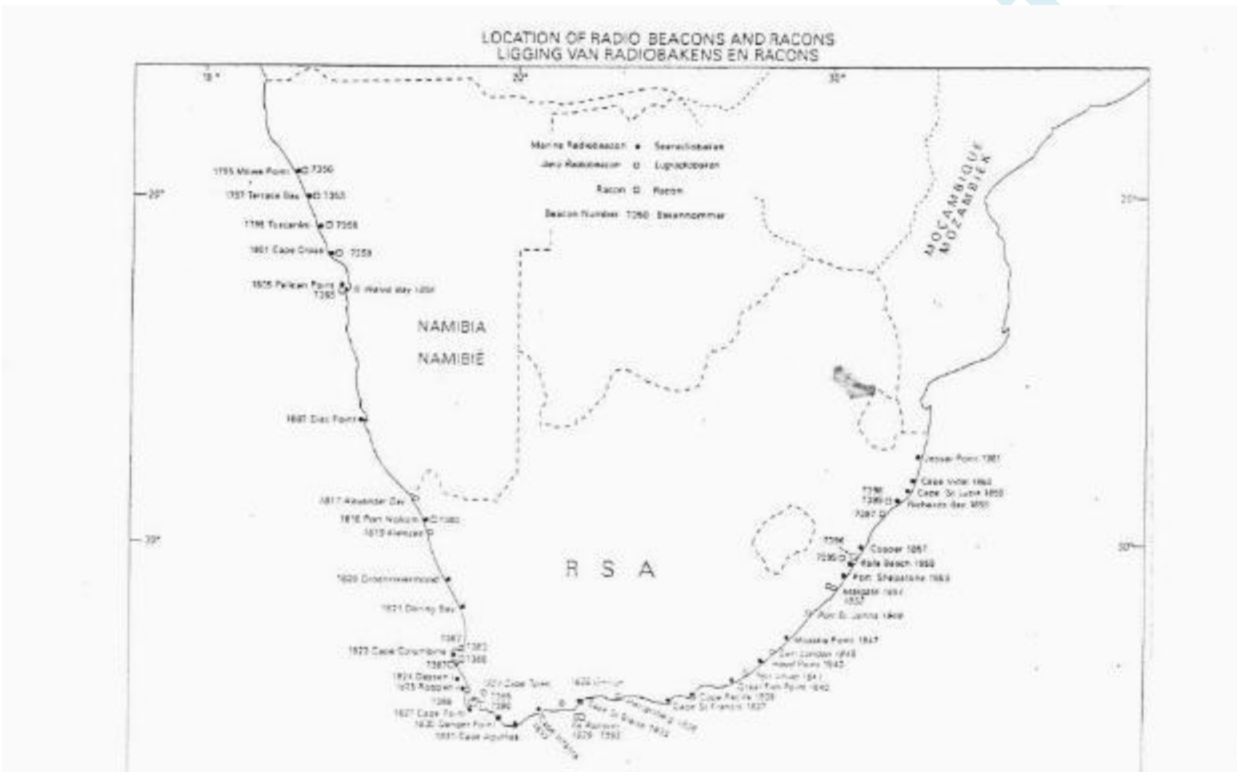
Side by side displays of the radar picture and the electronic chart display

MARINE RADIO BEACONS

One of the systems which were used along the Namibian and South African coasts was a series of marine radio beacons situated along the coastline and which provided vessels navigating in our waters with a means of obtaining radio bearings. Six of these stations were situated in Namibia and twenty four in South Africa.
The system operated in the MF (medium frequency) band (280 – 315 KHz) and had a range of between 25 and 100 nautical miles. Since the bearings obtained were great circle bearings, they

had to be corrected for convergency before they could be plotted on a Mercator chart. The systems two main shortcomings were

a. The signal was prone to distortion when it passed over the coastline. Radio waves travel more slowly over land than over the sea.
b. At night the sky waves interfere with the ground waves, causing fading when the two signals are received simultaneously. The sky waves also cause bearing errors.



The distribution of radio beacons and radar transponders was as indicated above

RADAR TRANSPONDER BEACONS

Another system which operated along the South African and Namibian coast was a series of Radio Transponder Beacons. There were five on the Namibian coast and fifteen on the South African coast.

The beacons operated in the 10 GHz (10cm) and 3 GHz (10 cm) radar bands. The beacons would emit a characteristic signal when activated by the emissions of a ship's radar. This would provide a range and bearing of the beacon on the radar Planned Position Indicator (PPI). What you would observe on the PPI is a line of dots extending from slightly beyond the radar echo (if any) of the beacon outwards towards the circumference of the PPI. The range would be taken to the beginning of the line but, since there is a delay in the response of the beacon, the range obtained would be approximately 75 to 100 metres greater than the actual range from the ship. The beacons have an average nominal range of 12 nautical miles. In order to identify the beacon the transmission received on the PPI would be in the form of a morse code letter, ie C **(-.-.).**

DECCA POSITION FIXING SYSTEM

This system was operated by the SA Air Force until the end of 1998. It covered the sea area off Namibia and South Africa and consisted of five Decca "chains". The chains were situated as follows:

a. Namibia – centred on Usakos.
b. Namaqualand – centred on Noordoewer,
c. Cape Province – centred on Matroosberg.
d. Eastern province – centred on Addo.
e. Kwazulu-Natal – centred on Matatiele.

Each chain consisted of a master and three slave stations. The master was situated in a central position and each slave was separated by more than 90° from each other measured from the master, and between 60 and 100 nautical miles from the master. The transmissions from the slaves were phase-locked with that of the master, ie they transmitted at the same time. The receiver on the ship received all the transmissions, measured the difference in phase between them and provided the results on three phase meters (one for each slave). The hydrographer provided charts with curves of equal phase difference for each of the slaves (red, green and purple). The readings of the phase meters were compared with these curves and where the three particular curves intersected was the position of the ship.

The system operated in the LF (Low Frequency) band (70 to 130 KHz). The range of the transmissions varied between day and night:

a. Day – 250 nautical miles from the master station.
b. Night – 100 nautical miles.

The system was also prone to the same shortcomings affecting radio beacons, ie coastal effect and sky wave interference. The accuracy was also affected by instrumental errors, lane width and the angle of cut of the curves (hyperbolae).

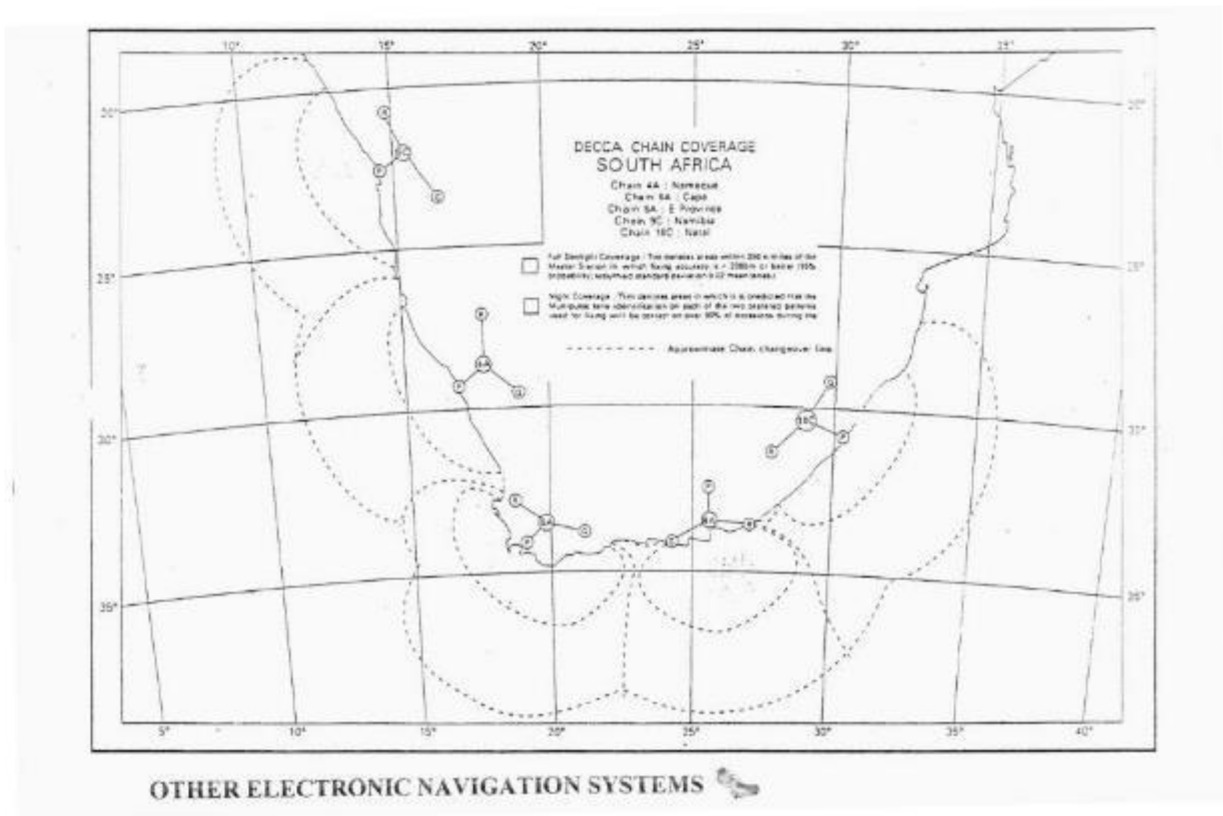


Diagram shows the disposition of master and slave stations of the 5 Decca chains covering the RSAand Namibian coasts

OTHER ELECTRONIC NAVIGATION SYSTEMS

Other electronic navigation systems employed in the past include Consol, Loran and Omega (similar to Decca) and the forerunner to GPS, the American Transit system. The latter consisted of 5ive low orbit (1100 kms) satellites orbiting the earth in approximately one and three quarter hours. The system made use of the Doppler effect, ie changes in frequency of the satellite's transmissions as they passed within range of the receiver was measured and compared. This was compared with a computed position obtained by DR in the receiver's computer and a fairly accurate position obtained. In order for the computer to produce a Dr position, it required inputs of start position and regular updates of courses and speeds. The chief shortcoming of this system was the limited number of satellites and their low altitude orbits. The orbits had to be between 10° and 70° above the receiver's horizon to provide usable data. Because of this, fixes were erratic, during a watch of four hours one might only obtain one fix and at other times there were a number in one hour.

There are a number of other satellite navigation systems such as the Russian GLONASS (GLObal Navigation Satellite System) and the planned European “Galileo” positioning system, Chinese “Compass” navigation system and the Indian regional navigational satellite system. Glonass has also been made available for private/commercial use.

Technology is advancing at a tremendous rate and it is essential that the maritime industry keep pace with the latest developments in electronic navigational equipment. However, no matter how advanced the technology becomes, it is only as good as the people who use it. The human element is still the core to safety at sea and will remain so for the foreseeable future.