“Understanding you Navigation Instruments, including the operation and limitations of: VHF/DSC Radios, GPS/DGPS, Depth Sounder, ENC, and Radar.”

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1. **Introduction**:

   -to presentation

   -my experience (21 yrs as ISPA Instructor, Judge @ Classic Boat Show, Master Mariner)

2. **Introduction to Electronic Navigation Instruments:**

   -Objective of presentation is to make you aware of the limitations of electronic navigation equipment and common operator errors.

   -I am assuming you have some knowledge of the equipment

   -Overview of systems to be discussed:

3. **VHF and DSC Radio Equipment**

4. **GPS and DGPS**

5. **Depth Sounder**

6. **Electronic Navigation Chart Systems**

7. **Radar**

8. **Summary and overview**

   -If you are reliant on electronic navigation equipment you must understand the operation and limitations of this equipment.

   -You will use equipment the most when conditions are the worst and when you are most reliant, therefore is it imperative that you use the equipment when conditions are good to test that the equipment is working properly and that you have a good understanding of how to operate it.

   -Make sure equipment is properly installed and grounded

   -Make sure initialization of equipment has been followed and operator's manual has been read and understood

9. **Conclusion and closing**

   -Rule #5 of Collision Regulations (lookout) states that "all vessels **shall** at all times maintain a proper lookout by sight and hearing as well s by all available means appropriate to the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision." (ie. In fog shall use your radar, depth sounder, GPS, ENC and VHF radio)

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VHF and DSC Radio Equipment:

What it is:

-Very High Frequency radio (VHF)

-Digital Selective Calling (DSC)

-Radio equipment used for short range (approximately 50nm) communication via either voice or digital messaging

-Equipment consists of: transceiver (a receiver and transmitter in one unit), power supply, antenna cable and vertical whip antenna.

How it works:

-VHF voice transceiver has several controls which allow for; increase/decreased squelch, power selection (high/low), and channel selection including Simplex (USA mode) or Duplex (International Mode)

-DSC transceiver allows for digital communication by sending or receiving messages, constant monitoring of stations, and alarm for GMDSS messages.

Note:

All radio waves are subject to interference from:

1. Geographical relation of receiver to transmitter (ie. Distance)
2. Path followed by radio wave (i.e. Land-sea-land)
3. Time of day (atmospheric disturbances during sunrise and sunset, best quality and range is during night time)
4. Clear path (i.e. no obstructions from mountains, buildings, mast)
5. Static in the air (i.e. Weather)

Equipment Deficiencies and Common Operator Error:

1. Range of VHF radio equipment is approximately 50nm, which is based on “line of sight” between receiver and transmitter, as well as: height of antenna, obstructions, path of signal, installation, weather, and atmospheric conditions.
2. Antenna must be properly installed, grounded, and kept separate

from other radio navigation receivers and transmitters (such as a radar scanner)

3. Antenna systems should be checked frequently: connections are tight and free of corrosion, cables are properly secured and there is no water damage.
4. Water resistant equipment only to be installed outside
5. Common Operator errors”

    -Power selection

    -Improper use of squelch

    -Wrong channel selection

    -Improper microphone use and bad pronunciation

GPS and DGPS Position fixing Equipment:

GPS:

What it is:

-GPS: Global Positioning System

-GPS is a space based navigation system which permits users with suitable receivers to establish a position (latitude and longitude), speed, altitude, and time.

-Developed by the USA department of defense and made available for non-military use in 1983

-3 segments make up the GPS system: Space, Control and User Segments.

-24 operational satellites (21 for navigation and 3 spares), circle earth in 6 orbits, at 55’ to the equator, and of 12 hrs duration per orbit.

-Receiver capable of receiving signal from 5-8 satellites 24/7

How it works:

- Satellites continuously transmit position and time data

-Receiver processes information to determine its 3-dimensional position

-Non-military transmissions are sent on L1 Band (1575.2MHz). L2 band = military use.

-The frequency carries both the navigation message and the Standard positioning System Code (SPS Code) and each satellite's signal is different via a Pseudo Random Noise Code (PRN Code) for Identification by the receiver.

-The receiver handles all the information and calculations and provides the information in digital form to the user.

GPS deficiencies:

1. *Selective Availability*: intentional downgrading of the L1 transmission reduced the accuracy to 100 meters/95% of the time. (SA was shut down in 2000 due to extensive DGPS availability and was no longer deemed useful).

2. *Uncorrected Satellite Clock Error*: errors originating at the satellite which can cause an additional 3 m of error. Master Control Stations correct the error.

3. *Signal Path Error*: receiver assumes speed of signal from satellite is constant, but when it travels though electrical particles in the ionosphere, or water vapor in the troposphere, the signal speed is affected causing an error in the calculation of range resulting in up to 10-12 meters of error.

4. *Multi-path Error*: error due to obstructions on the vessel which cause reflections of the signal to be sent to the receiver

5. *Geometric errors*: due to 2 satellites being on nearly the same bearing.

6. *Datum selection Errors*: when datum used by the receiver in calculating Lat/Long is different than the datum of the chart. The GPS receiver can be programmed to output data in different datum (i.e. WGS 84, NAD83). Canadian Hydrographic System (CHS) charts are NAD83 which

is similar to WGS 84. (World Geodetic System)

DGPS:

What it is:

-DGPS: Differential Global Positioning System

-DGPS is an extension of the GPS system, using land based radio beacons which compute errors in the system based on the known position of the land based station.

-Station transmits the position corrections to receivers using an MF radio signal.

-Initially established by USCG to correct for SA. Today various “Differential” GPS stations are established all over the world and continue to correct for errors, other than SA.

-Accuracy is 10m/95% of the time

How it works:

-DGPS stations are established along the coast, usually in key traffic areas creating a network of stations

-The station’s GPS receiver measures signals from all satellites in view and then calculates actual travel time of signals based on its own known position. (Position is based on time-distance calculations)

-The station then determines any errors and sends a correction message to your DGPS receiver. You receiver then incorporates only those corrections that are applicable to the satellites in use at the time.

-DGPS stations transmit on 285-325 KHz

- DGPS stations are linked to a Control Monitor which is linked to MCTS Centers

-DGPS is a highly reliable, autonomous system, it does not tolerate faults and sends an alarm if the system is out of tolerance.

-DGPS planned range is 150nm but has been reported to be accurate at 1000nm from station

DGPS Deficiencies:

1. DGPS system is fully reliant on the GPS system
2. Inaccurate output can result from not following manufacturer's instructions for proper: installation, operation, maintenance, and initialization.
3. Antenna location is pertinent and must be situated clear of obstructions, with a clear view of the horizon, and not in line with any other antenna (i.e. radar scanner)
4. Antenna must be properly grounded (this is the main reason for poor performance in all radio navigation equipment)
5. Receivers may be affected by: autopilot, depth sounder, compass, or wind measuring devices
6. VHF frequencies (harmonic) can interfere directly with GPS operating frequencies, therefore antennas must be separated
7. GPS signal can be affected by: hydro power lines, buildings, bridges, mountains etc
8. Waterproof receivers only to be installed outside
9. Excessive vibration can cause interference
10. If DGPS is essential to operations (ie survey work) a high quality receiver is recommended
11. Receivers can be operated in manual or automatic mode for station selection, make sure you are aware of which setting you are using and that the correct station is programmed in if you are using manual mode
12. When operating at the limits of the coverage area errors may be introduced due to degration of the signal
13. Caution should be exercised if the DGPS station becomes unhealthy, and the IM signal is displayed. (don't ignore it)

14. Paper and electronic charts used to plot a GPS/DGPS position may have errors that exceed the position accuracy of the DGPS service. (for example in high latitude charts and charts not using WGS84 format)

15. Coverage area is limited to land-based station range and subject to land based radio wave errors

Echo Sounder/Depth Sounder/Sonar

What it is:

-Electronic radio system which measures depth of water

How it works:

-The transducer generates sound waves which are directed through the water and reflected off the seabed

-Called a “hydro sonic” system and includes both depth and speed logs

-System measures the amount of time it takes for an echo to be received and based on an average velocity of sound though the water, calculates depth

-The transducer send short pulses of sounds vibration transmitted near vertically downwards

-Sound waves travel at 1500m/sec through the water (4.5 times faster than through the air)

-Since the signal travels to the seabed and back the time is dived by 2 to calculate the distance: i.e. if the total time for the signal to be received = 1 sec

Depth = (1sec divided by 2) x 1500m/sec

Depth = 750m

-remember to adjust for depth for depth from the keel not the transducer

Depth Sounder/Sonar Deficiencies:

1. Depth sounder incorporates a general average speed of sound in its calculations which does not allow for random variations in the speed due to vibration, salinity, temperature variations etc in the water which may slow or speed up the signal, therefore the final calculation will be slightly shallower than the actual depth
2. Like radio waves in the air, hydro sonic waves are subject to being absorbed, scattered and deflected by density differences in the water
3. Range limitation of the system will include maximum as well and minimum ranges
4. Type of sea bottom will affect the ability of the signal to be reflected back to the receiver (a hard bottom is a good reflector, a soft bottom will tend to absorb the signal)
5. Temperature differences in the water will affect the speed of the signal.

   i.e. in cold/dense water the signal will travel faster and will show a shallower depth. Warm water will slow down the signal and show a deeper depth. Cold/Dense water may also return the signal showing a false seabed. This is called “deep scatter layer. Difference in salinity will also affect the speed of the signal (i.e. brackish river water layered within cold seawater at a river mouth or estuary. i.e. Fraser River)

Navigating with a Depth Sounder:

The depth sounder is often overlooked as an essential piece of navigating equipment which can be used to check other position fixing equipment by checking depth in relation to charted depth once a position has been placed on a chart. Underwater topography can also be used as waypoints. (i.e. seamounts off the coast or pinnacles in coastal areas)

Electronic Navigation Charts (ENC) and ECDIS

What it is:

-Electronic Navigation Charts show the mariner where their ship is in real-time using a digitalized version of the paper chart.

-It is a presentation of hydrographic and navigational information in digital form.

- The primary function of the ENC is to contribute to safe navigation.

How it works:

-The ENC system is composed of a computer, software for displaying the chart, GPS/DGPS input, and other sensor interfaces depending on the extent of the system.

-The greatest advantage of the ENC is that they provide the user with the ability to create route planning.

-The hardware also allows the user to zoom in and out on a specific location relieving the user of the need for various scaled charts for the same area.

-There are a large number of manufacturers of electronic chart systems and equipment, many of whom, especially those available to the recreational boating industry, do not meet any Hydrographic or Government standards The Radio Telecommunications Services is working with these manufacturer's to establish minimum standards for use as guidelines in development and production of ENC systems.

Raster and Vector Charts:

-ENCs are available in 2 formats, raster and vector.

-The Raster format is a plain image of the paper chart, a copy so to speak. The navigation system cannot differentiate between the various objects composing the chart (i.e. it doesn't know the difference between a buoy and a depth area)

-The vector format is a digital layering of information which creates the completed chart. The system detects different objects imposed within the layering of information and can therefore present information about the objects. (i.e. position of lights)

What is an ECDIS:

-ECDIS stands for Chart Display Integrated System

-It is an approved integrated navigation system by the IMO (international Maritime Association) which allows ships to navigate without the need for paper charts.

-requirements include back-up systems, chart updates, extensive sensor input, regular audits on the system etc.

-Some yachts have a form of an integrated system where GPS, Depth Sounder, Radar, ad speed log sensor input has been integrated into he ENC system, but unless it is approved by the IMO it is not an official ECDIS. As approved |ENC must be of S-57 Vector format in order to comply.

ENC Deficiencies:

1. If an ENC is not approved by the IMO there are no regulations as to the accuracy, format used, and details of the charts used. As well there is also no requirement to, and often not even a means, to update the charts on a monthly basis using Notice to Mariners and monthly Chart updates. This means that the charts you purchase are only accurate to the date of manufacture. (Which is the same as purchasing a CHS chart, and not updating it using monthly chart corrections available

through the CHS. The chart should be used with caution).

2. ENC are subject to the same errors as the sensor input into the system. For example any errors in the GPS system, Radar, depth sounder etc will be transferred directly to the ENC display.

3. Since ENC are subject to manufacturer errors, errors due to inability to update chart information, and to sensor input errors it is imperative that the operator use the system when conditions are good to determine the errors in the system, so that when the mariner is more dependent on the system, i.e. in fog, they are aware of any inherent problems.

4. Since an ENC is not approved by the IMO, you must carry and use paper charts and paper publications, and you must check the accuracy of the system regularly against other position fixing means.

5. Overreliance by the mariner on electronic systems has caused many electronic navigation system aided collisions and groundings. Make sure your system is set up in a location where you can maintain a lookout at all times by sight and by hearing. As well carry a back-up power source in case the main power source fails, and always carry and maintain your paper charts and publications as a back-up system.

Radar and ARPA

What it is:

-Radar stands for: Radio Detecting and Ranging

-The first commercial application of Radar use was in the 1940's

-ARPA stands for Automatic Radar Plotting Aid and was developed in the 1970's

How RADAR works:

-The system sends out short bursts from a directional antennae and notes when an echo is returned using basic time-rate-distance calculations.

-The signal is sent via a pulse modulated transmission (where frequency and amplitude are modulated)

-RF pulse travels 7 times around the earth in 1 sec

-"Pulse length" which is the transmission time of the signal, is used to determine maximum and minimum range (i.e. short pulse for short distances)

-A window between transmission and receiving allows for the use of only one antenna

-Radar horizon is calculated by: 1.22 x square root of the antennae height in feet, x 15%

Common Operational Constants:

1. *Carrier Frequency*: is the frequency at which RF energy is generated. Therefore increased frequency = shorter wavelength, and therefore a smaller antennae can be used (i.e. X-Band or 3 cm radar transceiver versus S-Band 10cm receiver). Remember increased frequency = decreased range.
2. *Pulse Repetition Rate*: is the number of pulses transmitted per second. It determines how long radar waits for a return. Remember decreased pulse rate = increased range.
3. *Pulse Length:* is the transmission time of an RF signal. It determines the max range at which a target can be detected. Remember short pulse = short distance. When a short pulse is used the maximum range is compromised but a better resolution is obtained at short range.

Factors affecting radar waves:

1. Sub-refraction: decreases the radar distance
2. Super-refraction: increases the radar distance
3. Ducting (trapping): greatly increases the radar distance
4. Diffraction: bending of the radar signal around objects

Signal Interference:

1. (STC) Sea Clutter or Slow Time Constant: radar waves travel outward and downwards, and when reflected off the sea surface (waves), the radar waves are reflected upwards and interfere/mix with direct radar waves, causing fading and unwanted returns, called sea return. Adjusting sea clutter will reduce receiver sensitivity in the immediate area of the scanner.

2. (FTC) Rain Clutter or Fast Time Constant: caused by echoes bouncing off precipitation in the atmosphere. FTC reduces overall receiver sensitivity which ***affects the entire screen***.

3. Shadow areas: caused by interference with the propagation of RF energy and can cause indirect echoes (i.e. obstructions like vessel structure)

4. Electronic Interface: caused when operating near another radar antennae with the same carrier frequency. Causes spirals on the display and is solved by changing pulse length.

Factors affecting Maximum Range:

1. A lower frequency = increased long range detecting. i.e. S-Band Radar (10cm) versus X-Band radar 3 cm.

2. Increased peak output = increase range

3. The longer the pulse length the longer the range

4. Decreases pulse repetition = longer detection range

5. More concentrated the beam = greater range (beam width)

6. Increased antennae height = increases range

7. Slower antennae = increased range

Factors affecting minimum range:

1. Since minimum range is equal to half the pulse length, a shorter pulse length is used for shorter targets. Therefore a higher pulse repetition rate = shorter pulse length = shorter range.

2. Remember targets under the beam can escape detection and increasing STC can fade targets from the display screen.

Common Operator Errors:

1. STC or FTC is turned too high and targets are faded out and missed
2. Gain is set too high fading out targets
3. Wrong pulse Length used for set range (most units automatically change pulse length when range is changed)
4. Screen intensity is set too low and targets are missed
5. Night versus day screen light options not used and targets are missed
6. Operator does not adjust gain, STC and FTC every time they change the range
7. Not changing range often to detect targets at different ranges.

Automatic Radar Plotting Aid (ARPA):

-ARPA is an electronic device interfaced with the radar display that can continuously interpret motions of contacts on the radar display.

-The system is designed to automatically provide collision avoidance information with -the intent to decrease the work load of the wathkeeper.

-information output by the system is 100% reliant on the sensor input to the system (ie in commercial vessels a gyro compass is used for heading input, GPS for position input, and speed log for speed input, therefore any deficiencies in these systems are transmitted directly to the ARPA and therefore to the target information since the system measures collision avoidance based on own vessel’s speed, heading and position)