Technical Manual
Set up and Configuration of the Imagenex DT101Xi / DT102Xi Multibeam Echosounder

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DT101Xi / DT102Xi Multibeam Echosounder

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1. Introduction

1.1. Document Identification

This document describes the recommended configuration and set-up of the DT101Xi and DT120Xi Multibeam Echo Sounders and outlines considerations to be made whilst planning and conducting a multibeam bathymetric survey.

1.2. System Overview

The DT101Xi and DT102Xi are advanced Multibeam Echo Sounder systems with optional integrated motion reference units and sound velocity sensors.

1.3. Document Overview

This document provides recommendations for the setting up, configuration and operation of the DT101Xi and DT102Xi Multibeam Echo Sounders. The document covers general theory of operations, best practices and recommended settings for DT101Xi and DT102Xi, to enable the user to obtain the best possible results. The document is targeted at users, and is not intended as a high-level reference. Since users make use of several sensors, data acquisition packages etc., the document is generic in nature.

1.4. Reference Documents

The following documents were used during the compilation of this guide:

- The Calibration of Shallow Water Multibeam Echo-Sounding Systems – A Godin, March 1998
- Manual on Hydrography - International Hydrographic Organization Publication C-13, May 2005
- Multibeam Sonar Performance Analysis Value and Use of Statistical Techniques - C. Whittaker, May 2011
- Estimation of Effective Swath Width for Dual-Head Multibeam Echosounder - Grządziel, Wąż 2016

1.4.1. Acronyms and Abbreviations

Acronym	Meaning
MBES	Multibeam Echo Sounder
MRU	Motion Reference Unit
SVS	Sound Velocity Sensor
SV	Sound Velocity
ROV	Remotely Operated Vehicle
AUV	Autonomous Underwater Vehicle
USV	Unmanned Surface Vehicle
ASV	Autonomous Surface Vehicle
IMU	Inertial Measurement Unit
CRP	Common Reference Point
CoG	Centre of Gravity
LOS	Line of Sight
GPS	Global Navigation System
GNSS	Global Navigation Satellite System
RTCM	Radio Technical Commission for Maritime Services
UPS	Uninterruptable Power Supply
AC	Alternating Current
DC	Direct Current
CRP	Common Reference Point
GA	General Arrangement
ENC	Electronic Navigational Chart
UDP	User Datagram Protocol
IP	Internet Protocol
BNC	Bayonet Neill–Concelman
UTC	Coordinated Universal Time
RTN	Real Time Network

2. System Description

2.1. Introduction

Both the DT101Xi and DT102Xi are beamforming multibeam echosounders (MBES) with optional internally integrated motion reference unit (MRU) and sound velocity sensor (SVS). The DT101Xi is a 120° X 3° system while the DT102Xi is a 180° X 3° system. Both DT101Xi and DT102Xi MBESs are a single instrument optionally integrating the sonar, MRU and SVS into one sleek and compact unit. The DT101Xi and DT102Xi require one cable for operating all three sensors and they are a portable solution for any survey. They are compatible with the DT100 SIR (Sensor Interface Relay) power supply/timing box. Full specifications on both DT101Xi and DT102Xi are provided in APPENDIX A.

2.2. Operational Scenarios

A multibeam echosounder is a device that simultaneously acquires a multitude of depth measurements, regularly spread athwart-ship, in a fan-shape pattern. The reason for using these sonars is to sweep a swath-like corridor of the bottom so as to ensure a complete coverage of the seafloor.

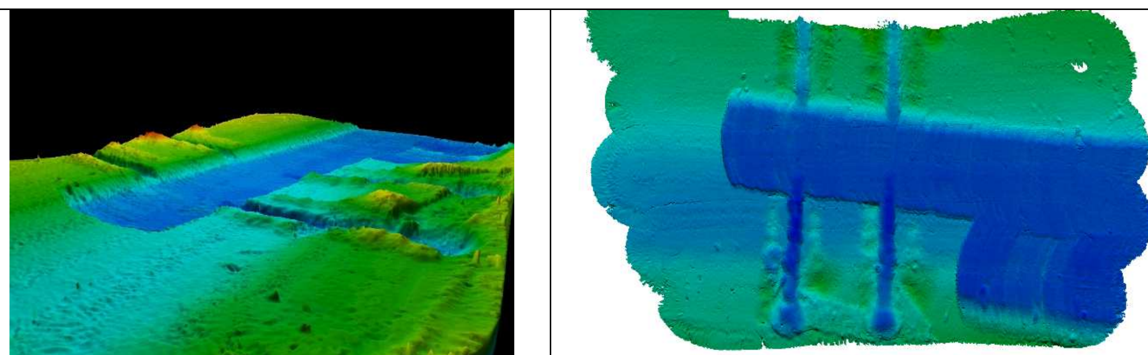


Figure 2-1 Examples of MBES data acquired with a DT101Xi on a small survey vessel

MBESs (like the DT101Xi and DT 102Xi) can be mobilized on small and large vessels, Remotely Operated Vehicles (ROV), Autonomous Underwater Vehicles (AUV), Unmanned Surface Vehicles (USV) and Autonomous Surface Vehicles (ASV).

Since the mobilization onto autonomous, remotely controlled and unmanned vehicles is highly specialized and very platform specific, this manual shall focus on mobilization onto smaller manned vessels only. The content however does have relevance to more specialized craft.

2.3. System Requirements

The minimum requirements to gather bathymetric data using a MBES system is as follows:

- A platform (vessel / vehicle)
- A MBES
- A sound velocity (SV) sensor
- A motion reference unit (MRU) or Inertial Measurement Unit (IMU)
- A heading reference sensor
- A positioning system
- A navigation software package
- A multibeam data acquisition software package

Things to be considered during the installation of sensors and operation of systems as a whole are discussed in the following text.

3. Preparation

3.1. The vessel

Scenarios around the use and choice of vessel differ significantly depending on an array of factors, however if a vessel of opportunity is sought, the following factors should be considered:

- Stability. A vessel with the ability to experience minimal movement in the six degrees of freedom (pitch, roll, yaw, surge, sway and heave) is always advantageous.
- Vibration. Vibration will invariably translate into artefacts in the data logged. Vibration mitigation (such as resilient mounts) should be considered if possible.
- Bracket mounting options. If a pole mount is to be used to mount the transducer, there must be a rigid point of attachment to the vessel that minimizes pole movement. Braces should be used if possible, to ensure no movement of the pole is observed when survey speed is reached. There should be no propeller / thruster wash over the transducer and no cooling water outlet close by that could adversely affect the SVS reading.
- Masts. Line of sight (LOS) to GNSS satellites as well as RTCM transmitters is essential and suitable locations for these antennas is required. They should have unobstructed LOS and not be subject to excessive vibration nor exhaust / funnel discharge.
- Power. A suitable source of power is essential. The power should be clean, uninterrupted, overload protected and the source be capable of supplying sufficient voltage at the required amperage (i.e. wattage). The Sensor Interface Relay (DT100 SIR) unit provides power for the integrated MRU and SV sensor (if fitted) as well as the sonar head so no additional power is required for the Imagenex supplied equipment. Power is also made available on the GNSS (GPS), Heading and Sound Velocity ports (at user selectable 12 and 24 VDC See APPENDIX C 6. Power). These power supplies can supply 20 Watts and this should not be exceeded. Additional power may be required for the heading reference, GNSS system and the computers running the navigation and MBES control software as well as external SV sensors and MRUs (if required). The SIR box requires 100 – 240 VAC or 12 – 36 VDC and consumes 35 Watts (nominal) or 80 Watts (maximum) of power. It is recommended that devices such as surge protectors, Uninterrupted Power Supplies (UPS) and / or invertors be used to ensure clean and reliable power.
- Access to vessel centre of gravity (COG). Although not essential, it is recommended practice to install the MRU as close as possible to the COG of the vessel. Since measurements to this point are required during the navigation software set-up to establish the vessel reference frame, it is advantageous to have this location accessible, at least during mobilization.
- Work area. There should be a work area set aside from the normal vessel operation that affords the Surveyor a suitable work environment that is quiet and free from distractions. Good housekeeping should be practiced to ensure that hardware, wiring etc. are not disturbed during operations.

3.2. Survey Planning

3.2.1. Mobilization

A common sense and good seamanship approach is required to ensure a reliable and quality mobilization.

The following bullet points highlight some considerations:

- Cable runs. Cables should be installed such that they are not subjected to mechanical stress, do not exceed their minimum bend radii, are not of excessive length and do not pose a risk to personnel. The maximum cable length for the DT101Xi and DT102Xi is 100 m through Ethernet Cat 5e, although longer runs are available using additional hardware. The cable between the MBES and the SIR box should never be allowed to be stepped on. Where possible, glands should be used to transit bulkheads and the water tight integrity of the vessel should never be compromised.
- DT101Xi and DT102Xi both use underwater wet-mateable 8 conductor SubConn connectors. It is recommended that connectors be thoroughly cleaned using a spray-based cleaner like Isopropyl alcohol; or liquid soap and hot water. Acetone, gasoline or similar products are not recommended.

Once clean, a small bead of silicon grease (like Molykote 44) should be placed on the flat mating surfaces prior to mating. Products like WD-40 or a compound grease product are not recommended.

- A 15 m interface cable is provided for the MBES. If the MBES is, for example, set up on an ROV, a whip may be used to interface the MBES through the ROV tether to the topside SIR box. The pin outs of the 8conductor SubConn connector are shown in APPENDIX B and the interface of the SIR unit with associated sensors is detailed in APPENDIX C.
- The MBES unit forward / aft line should be mounted and orientated as parallel as possible to the vessels fore aft line, as indicated in Figure 3-1 Orientation of the DT101Xi and Figure 3-2 Orientation of the DT102Xi ([mm] and inches):

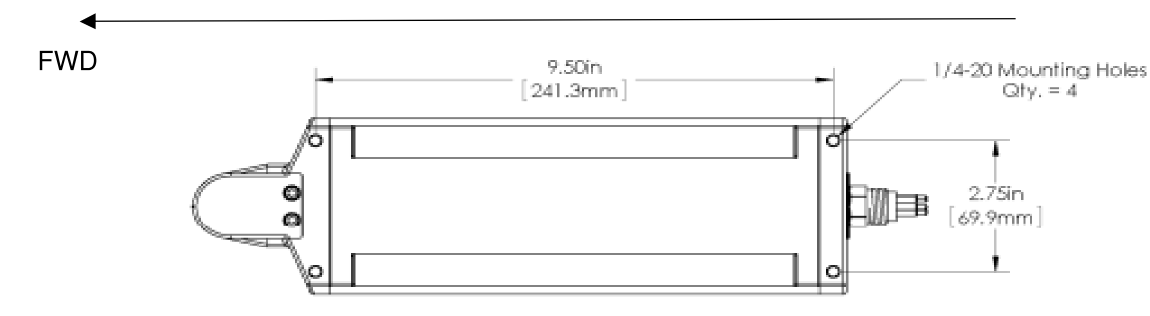


Figure 3-1 Orientation of the DT101Xi

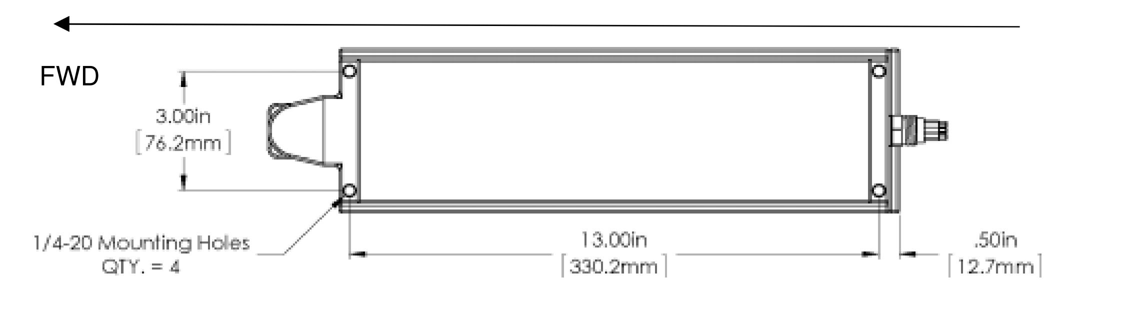


Figure 3-2 Orientation of the DT102Xi

- For a pole mount mobilization, the cable going into the MBES should be secured in such a way that the water pressure during vessel transit does not act on the cable and stress the connection. It is essential that the MBES be orientated such that the connector is facing astern to offer protection from such stress, as well as to ensure the MBES functions correctly. The pole should be braced to prevent movement or excessive vibration.

- It is good practice, where possible, to mount the MRU as close as possible to the intersection of the roll and pitch axes or at the centre of gravity (COG) of the vessel. This minimized the heave induced by the lever arms (the physical 3-dimensional offsets between the MRU centre of rotation and the acoustic centre of MBES). If the DT101Xi / DT102Xi has an integrated MRU, the axis of rotation of the MRU are indicated below in MRU Axes of Rotation ([mm] and inches): Figure 3-3 MRU Axes of Rotation:

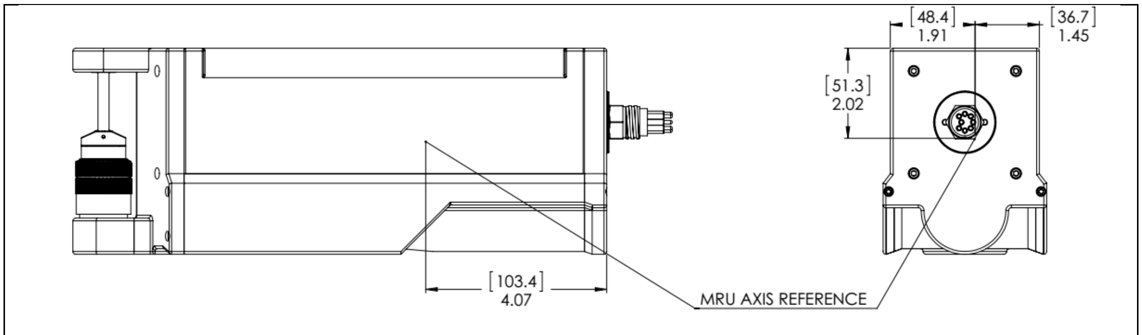


Figure 3-3 MRU Axes of Rotation ([mm] and inches):

- Heave may also be measured using a high accuracy positioning system like Real Time Kinematic GPS (RTK). If this system is to be used, the appropriate software should be configured during mobilization.
- The heading reference unit (like gyro or GPS based system) forward line should be orientated as parallel as possible to the vessel heading fore / aft line. It should be securely mounted to the vessel and not be subjected to excessive vibration. If a gyro is used, it is usually required to update the gyro's latitude, which can usually be done manually or using a positional input into the gyro unit.
- Interface of the SIR unit with associated sensors is detailed in APPENDIX C.
- The DT100 SIR unit has a number of options, for example, source of Pulse Per Second (PPS), Heading source, MRU, SV source, etc. These are done by the changing of jumpers in the SIR unit see APPENDIX C. The PPS pulse should be 3.5 V to 5 V (TTL) and be at least 1 millisecond in duration.
- Sensor power is supplied via the SIR box and can potentially be used by the following external sensors (as well as the DT101Xi / DT102Xi sonar head):
  - GNSS
  - MRU
  - SVS
  - Heading Sensor

  These power supplies are set to 24 VDC by default, but a 12 VDC is available by the changing of jumpers detailed in APPENDIX C.
- There is a ground connector on the SIR unit and it is *essential* that this be connected to a good source of ground on the vessel / vehicle. If the vessel is not metallic, it is advisable to safely dangle a wire connected to the ground point on the SIR box in the water.
- Communication with the SIR unit is achieved via an Ethernet port and User Datagram Protocol (UDP). To communicate between the SIR unit and associated computer, the IP is achieved by setting the IP address and subnet mask of the computer. The process is detailed in APPENDIX D.
- Some modern laptop computers aren't supplied with an Ethernet port and users will be required to use an Ethernet to USB adapter. If this is the case, a high spec adapter, and the USB 3 port must be used. If a discreet hardware port is not available, a high specification USB to Ethernet 3 adapter is recommended. The TP-LINK Model UE300 appears to work well.

- The minimum specification for the DT100 SIR box control computer is as follows:
  - Intel i5 processor
  - 8 GB Ram
  - USB 3.0
  - A discreet hardware Ethernet port supported by a Realtek PCIE GBE family chipset (not an FE family chipset) (see bullet point above).

3.2.2. Establishing of Vessel Reference Frame and Sensor Static Offsets

Once all interfacing has been completed and tested, a vessel reference frame should be established. In order to integrate the sonar vectors with the other sensor outputs, the static offsets between the MRU, the MBES and the positioning system antennae must be measured accurately and referred to a common reference point (CRP).

The CRP can be arbitrarily located anywhere on the survey platform, but it is good practice (where possible) to locate it at the intersection of the roll and pitch axes or at the centre of gravity of the vessel. It must be chosen so it is readily accessible and in a place from which sensor offsets can easily be measured.

Note: The position of the intersection of the roll and pitch axes is not often obvious. Customarily, the roll axis is coincident with the water plane (varies with loading conditions) while the pitch axis passes through the centre of floatation. The ship's builder or general arrangement (GA) drawings should be checked for the accurate location of these two axes.

Land survey techniques can be used to establish the platform's sensor static offsets reference frame and this will ensure the highest degree of accuracy and with a large vessel, this may be the only way to derive such values. Alternately, steel tape measurements may be taken, or the vessel's GA drawings used to derive the offsets. The convention for X, Y and Z (+ and -) are dependent on the navigation software used (refer to the navigation software documentation). The most common convention is illustrated in Figure 3-4 General convention for sensor static offsets.

Land survey techniques may also be used to establish a rotational offset in the horizontal plane (yaw), between the vessels fore and aft line and that of the heading reference and MBES transducer. Prior to this operation (if used), it is essential that the gyro be warmed up and settled. The rotational offset between the heading reference and the MBES projection transducer will also be established during the patch test (see Section 4.2), but this should be a fine adjustment only.

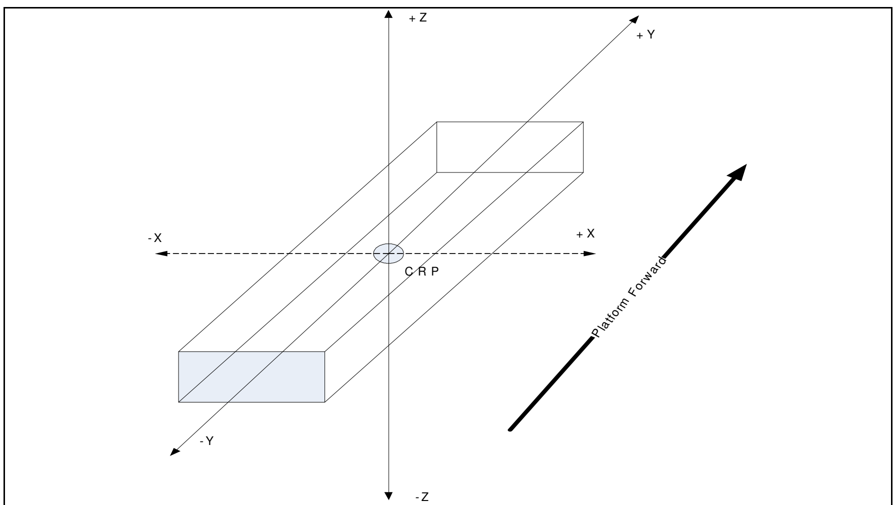


Figure 3-4 General convention for sensor static offsets

Note that Hypack adopts a different convention in the vertical (Z). See below from the Hypack systems manual:

> *The vertical offset is the distance below the static waterline of the vessel. This is the waterline location when the boat is stationary. Of course, this point changes under various conditions (weight of passengers, fuel and cargo), but you have to start somewhere.* ***Enter the antenna height above the water line as a negative value. The distance from the waterline to the transducer head will be positive.***

Although Z is applied as –(minus) going up, Hypack applies a ***heave*** *as* ***positive up****. The integrated SBG Ekinox-A heave sensor outputs* ***heave*** *as* ***positive down,*** *so if used, heave should be inverted during processing in Hypack.*

In addition to the Z offset between the CRP and the receiving transducer of the MBES, the transducer elevation with respect to the water surface (static transducer draft) should be measured. Most surveys will seek to determine the depth between tidally corrected mean sea level and mean seabed. In order to achieve this, the distance between transducer acoustic centre (Figure 3-5 Acoustic centre of transducer ([mm] and inches) and mean sea level must be known, which will necessarily change with fuel and water consumption, ballasting, sea water density and vessel speed through the water.

If possible, this Z value should be measured with respect to the vessel's draft marks in dry dock and a table created. This table should be referenced during operations and values updated in the log to compensate for draft changes (as a result of fuel used for example). If such measurements cannot be taken, it is recommended that elevation between transducer and sea level be measured as closely as possible to operational vessel loaded conditions.

To ensure maximum accuracy, vessel settlement (squat or lift), which is a function of the vessels speed through the water, may need to be measured. This is because the vertical component of this motion is the bandwidth of the heave sensor's high pass filter, and therefore not measurable. The evaluation of the ship's settlement should be made for various speeds (or RPMs) and a look-up table should be produced, to be used for correcting the transducer draught. Since the settlement varies with the speed of the vessel on the water, surface velocity (not the speed over ground) should be obtained with the aid of an accurate log. [The Calibration of Shallow Water Multibeam Echo-Sounding Systems – A Godin, March 1998].

Note: Systems are commercially available that measure draft, squat and lift in different locations around the vessel and model the vessel's attitude as a result of changes in water density, vessel speed, vessel load, etc., and output a real time depth difference between the water surface and a datum point (for example the MBES acoustic centre).

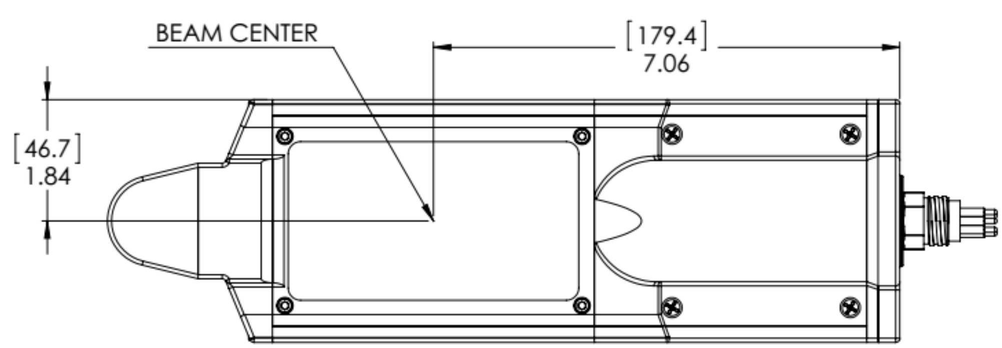


Figure 3-5 Acoustic centre of transducer ([mm] and inches)

Note: The Z reference point is the transducer face.

The survey platform CRP should be physically marked and identified on the vessel for further reference, if possible, and the marking should be made permanent. If it is not possible to mark the exact location of the point (e.g. in a void space), a remote point can be marked and the actual CRP be referred to this remote point by XYZ offsets. The offsets should be physically indicated (magnitude and direction) near the remote reference point. [The Calibration of Shallow Water Multibeam Echo-Sounding Systems – A Godin, March 1998]

3.2.3. Vessel Dimensional Control / Shape File

Most navigation packages allow the user to input the size / shape of the vessel and define various points of interest by means of a shape file. It is recommended that the Surveyor generates such a shape file as a means of quality control and that during survey operations, the locations of, for example the MBES, GPS antenna, etc., are shown on the nav screen. This also allows the coxswain of the vessel to have a refence which will assist in keeping the MBES transducer nadir on the survey line.

3.2.4. Survey Line Generation

Most navigation packages allow the Surveyor to generate survey run-lines. Since the swath width projected by the MBES is a function of water depth, swath angle, tilt angle, sound velocity, temperature, salinity, sea state and bottom type, the width covered will vary through the survey and between surveys.

Note: Some software packages assess attained coverage in real time and adjust run-lines according to a user defined coverage % parameter. In additions, some users may not pre-plan lines, but observe a coverage plot within the MBES acquisition software, and decide on run-lines in real time. This method is clearly limited to small survey areas and small vessels

The equation describing swath width is shown below (Eq 1):

$$Sw = 2.Z.\tan\left(\frac{\Delta\emptyset}{2}\right) \quad \text{(Eq 1)}$$

Where

Sw = Swath width (m)

Z = Water depth (m)

ΔØ = Angular coverage (°)

The DT101Xi and DT102Xi have the option of dynamic roll correction (either through an integrated MRU if fitted, or external MRU) through the sonar control software. In this configuration, beam steering is adjusted as a function of roll. This allows the outer beams to be held parallel to the run-line and improve coverage even during excessive roll. If this feature is **not** enabled, consideration should be made to compensate for shifting swath during excessive roll.

Through the Sonar Control Software, a sonar tilt angle of between +/- 30° may be set. If such an angle is set, consideration should be made when planning line spacing

It is recommended with a MBES system, to steer lines parallel to the mean depth contours. This will mean that the depth variation along-track will be kept to a minimum and allow for robust planning of survey run-lines as can be seen in Figure 3-6 Line spacing example [Manual on Hydrography]

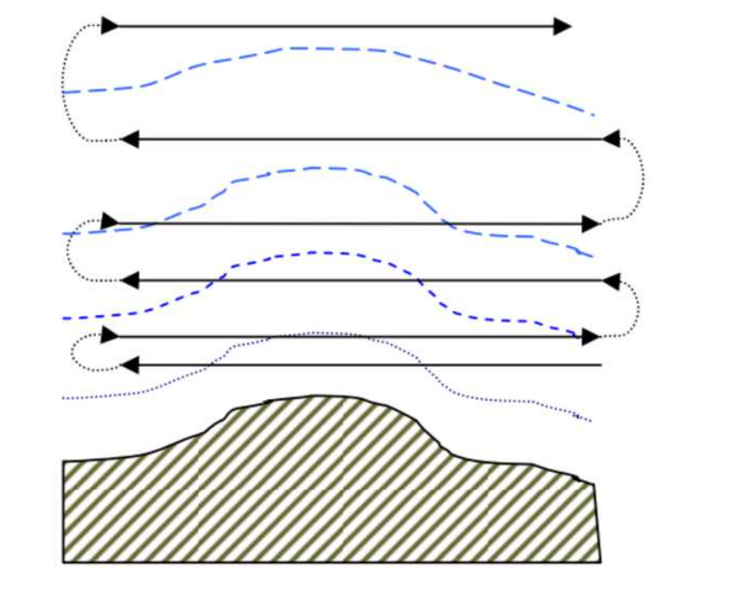


Figure 3-6 Line spacing example [Manual on Hydrography]

For Special Order and Order 1a surveys, no recommended maximum line spacing is given as there is an overriding requirement for full sea floor search and it is generally recommended that line spacing be such that 100% overlap per swath is achieved. This is because outer beams on all MBES systems are prone to anomalies and degradation [Grządziel, Wąż 2016], in all water depths. As a result of amongst others, environmental issues like SV, and reflective considerations like beam grazing on acoustically inert seabed's, outer beams can be rendered unusable. A large percentage overlap can allow trimming of offending outer beams, and thus improve quality of acquired data. See Figure 3-7 100% Beam Overlap.

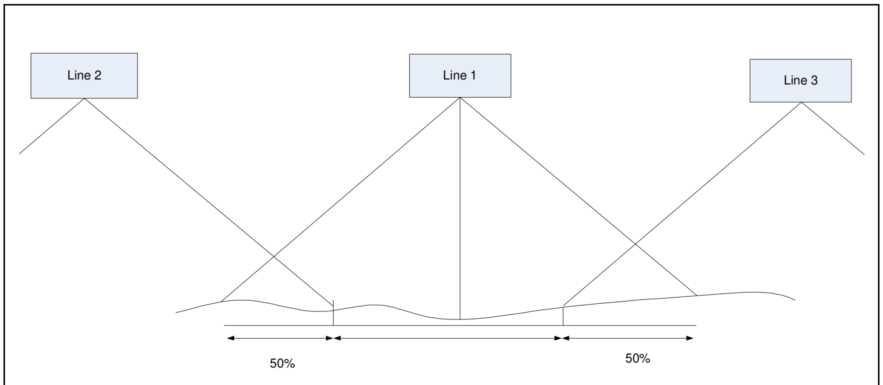


Figure 3-7 100% Beam Overlap

As a general guide, the equation below (Eq 2) may be used to approximate the line spacing:

$$LS = \frac{1 + A}{2} . Z . \tan\left(\frac{\emptyset}{2}\right) \quad \text{(Eq 2)}$$

Where:

LS = Line spacing (m)

A = overlap required (e.g. 75% coverage; A = 0.75, 100% coverage A=1)

Z = Approximate depth below transducer (m)

Ø = Set Beam Angle - (e.g. 120) (°)

3.2.5. Ping Rate and Survey Speed

There is a relationship between the survey speed, water depth, fore / aft beam width, overall swath width and ping rate. The ping rate in the DT101Xi and DT102Xi is automatically set and is based on the range setting, number of beams selected and specification of the computer system used to run the control software. The real-time ping rate can be viewed in the Sonar Status window (Real Time PRF) – Options > Sonar Status. Both the two way turn around time (in ms) and frequency (Hz) are displayed.

The maximum speed of the vehicle should be planned and adjusted to ensure 100% forward overlap of the beam footprint. The maximum speed for a MBES can be calculated using the following equation (Eq 3):

$$v = S \times d \times \tan(\beta/2) \qquad \text{(Eq 3)}$$

Where:

v = speed (m/s)

S = MBES ping rate (ping/sec)

d = depth (m)

β = fore aft beam-width (3° for DT101Xi and DT102Xi)

Survey speed should also be such that:

- The sonar head is not subjected to excessive force from water flow
- Water flow over the transducers does not cause aeration and a loss of performance
- The transducer pole (if applicable) does not experience excessive vibration. Vibration of the pole (if fitted) is a big contributing factor to data artefacts
- If data is being logged during turns, it should be remembered that outer beams will have less coverage during a turn. Speed should therefore be reduced to allow full coverage of the seabed

3.2.6. Sounding Grid Size

A sounding grid (also called a sounding matrix) is a series of adjoining squares that cover the area being surveyed and is used in data processing to have a bathymetrically representative model of the survey area but with significantly less data points than were originally logged. A grid size is generally defined and is a function of required resolution. If, for example, a 0.5 m grid size is defined, then the processing package will calculate a representative depth (e.g. median depth) for all soundings that were measured within those spatial parameters (i.e. within a 0.5 m square). A balance should be sought between size (and therefore manageability) of the model and required resolution and detail required to be reported. The grid size is generally defined by the deliverable specification, but as a rule of thumb, the grid size should not exceed the average footprint size of the MBES on the seabed. Given a flat seabed, the following equations (Eq 4, Eq 5, Eq 6, Eq 7, Eq 8, and Eq 9) can be used to calculate the footprint size (the shape of which approximates an ellipse):

Cross-track

$$ct = \frac{(a_y + b_y)}{2} \quad \text{(Eq 4)}$$

And

$$a_y = \frac{2z}{\cos^2(\beta/2)} \times \tan\left(\frac{\emptyset_r}{2}\right) \quad \text{(Eq 5)}$$

$$b_y = \frac{2z}{\tan(90 - 2\emptyset_r)} \quad \text{(Eq 6)}$$

Where:

ct = cross-track footprint length (m)

a_y = cross-track ensonification size at outer beam (m)

b_y = cross-track ensonification size at nadir (m)

z = water depth (m)

β = swath angle (°) e.g. 120°

$\emptyset_r$ = cross-track beam angle (°) – (0.75° for DT101/102).

Note that the average is taken between the size at nadir and that at the outer beams.

Long-track

The size of the footprint in the along-track direction is similar to the cross-track and is described by the following equations (Eq 7, Eq 8, Eq 9):

$$lt = \frac{(a_y + b_y)}{2} \quad \text{(Eq 7)}$$

And

$$a_x = \frac{2z}{\cos^2(\beta/2)} \times \tan\left(\frac{\emptyset_t}{2}\right) \quad \text{(Eq 8)}$$

$$b_x = \frac{2z}{\tan(90 - 2\emptyset_t)} \quad \text{(Eq 9)}$$

lt = long-track footprint length (m)

a_x = long-track ensonification size at outer beam (m)

b_x = long-track ensonification size at nadir (m)

z = water depth (m)

β = swath angle (°) e.g. 120°

$\emptyset_t$ = along-track beam angle (°) – (3° for DT101Xi/102Xi).

The footprint on the seabed approximates an ellipse with semi-minor axis = *ct* (Eq 4) and semi-major axis = *lt* (Eq 7). The semi-minor axis is the axis of interest as the long-track direction will be saturated with scans if the correct survey speed is achieved (See Section 3.2.5 Ping Rate and Survey Speed). Since the sounding grid is square, and not elliptical, a factor of 0.5 is recommended to reduce the square size to a square inscribed by the ellipse (as shown in Figure 3-8 Square Inscribed by Ellipse)

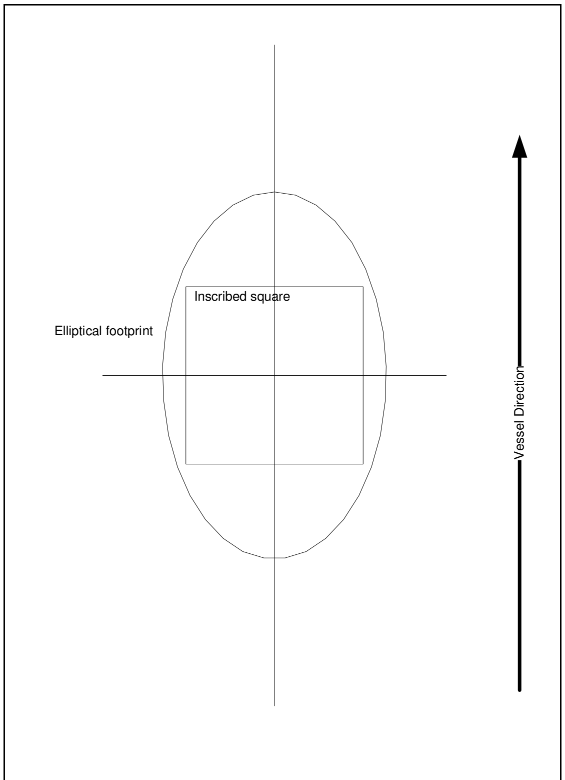


Figure 3-8 Square Inscribed by Ellipse

The equation to approximate sounding grid size is therefore:

$$Sounding\ Grid\ Size = ct \times 0.5 \qquad \text{(Eq 10)}$$

Where

ct = cross-track size (Eq 4)

3.2.7. Datum Set-up

Both the vertical (tide) and horizontal (geodetic) datums should be defined and set-up in the navigation software. If a tide gauge is used to measure tide, it should be set to work prior to the commencement of the operation. If predicted tide is to be used, the appropriate tide tables / predictions should be sourced in anticipation of the survey. Tide files should be at the appropriate density to reflect the tidal regime in question. High accuracy GPS such as RTK may also be used for tide measurement and the preparation for this should be done in the appropriate software.

3.2.8. Navigation

There are many options to improve the quality and accuracy of GNSS. These include Differential GPS (DGPS), Wide Area DGPS, RTN and RTK. There are many options for the reception of correction messages associated with these systems including satellite, radio modems and GSM networks. Preparations for the transmission and testing of these services should be completed during mobilization.

3.2.9. Background Graphics

Most navigation software allows for the loading of electronic navigational charts (ENCs). If used, ENCs normally need to be purchased and loaded as an aid during survey. If ENCs are not to be used, it is recommended to digitize and load the coastline and any navigation hazards that may exist in the survey area.

3.2.10. Time Synchronization

The DT101Xi and DT102Xi MBES have a well-designed and robust synchronization system that time stamps all positional, attitude, heading and MBES systems via the supplied SIR unit. The PPS signal and NMEA $GPZDA string for UTC (Coordinated Universal Time) are derived from the GNSS (GPS). This system ensures highly accurate and synchronised timing for the application of auxiliary sensor data to the MBES bathymetry.

The DT101Xi and DT102Xi provides a Transmit Sync Pulse to the SIR for accurate time stamping of each ping. Sensor messages are time stamped and stored at their native update rates with a timestamp accuracy of 100 microseconds. The navigation software then performs interpolation if required, and all sensors inputs are calculated and logged for the correct instant in time. By convention, most software vendors log each input at the times detailed in Table 3-1

Input Event	Logged at
Heave	Average of ping and receive time
Pitch	Ping time
Roll	Receive time
Heading	Ping time
Position	Ping time + 1-way travel time

Table 3-1

If there is a departure from the standard configuration, the Surveyor should ensure synchronization of all sensors and equipment and ensure no latency exists. This is critical. Roll applied at an incorrect time segment, for example, will lead to noticeable artefacts and a degradation in data quality. All PC clocks should be set to the same time zone.

3.2.11. Survey Log

It is highly recommended that a comprehensive and detailed survey log be kept, either in handwritten or electronic format. The format of such a log varies widely from operation to operation, but as a minimum, the following should be included:

- Make, model and serial numbers of equipment
- Certification expiry dates
- Software versions
- Names of survey party members
- Times, dates and locations of significant events
- Static offsets (including a sketch)
- Geodetic parameters
- Tide stations (if used)
- Patch test results
- Start on line, end of line dates and times

4. Pre-survey Observations

Prior to commencement of the survey operation, two very important tasks should be undertaken, namely, a sound velocity cast and a patch test:

4.1. Sound Velocity Cast

A sound velocity measurement is essential for the operation of any MBES. Both DT101Xi and DT102Xi have the option of an integrated AML OEM SV sensor. This sensor however is for the measurement of SV at the transducer, and not as a means of determining an SV profile from the surface to the seabed.

Note: The time of flight sensor's calibration certificate is supplied as part of the MBES system and is valid for 1 year. The Surveyor should ensure the calibration certificate is in date, and send the sensor away for re-calibration if the certification has expired. Removal of the OEM SV sensor from the sonar head is not complicated.

The required temporal and spatial distribution of casts is determined by several environmental factors and varies significantly. It is recommended that an SV cast be at least every 12 hours and more frequently if large variance is observed between casts.

There are two methods of determining SV through the water column namely:

- Time of flight sensor
- Conductivity, temperature and depth sensor (CTD)

A modern time of flight sensor is calibrated under stringent laboratory conditions and is thought to be more accurate than a CTD, which relies on formulae based on curve fitted empirical coefficients.

Most SV sensors can be set to log at set depths or continuously. The set depth is a better option as the profile is generally smoother.

Imagenex has free software to process CTD casts and collate the output as set intervals. There are various formulae (for example Del Grosso, Chen and Millero, Mackenzie etc.) for calculating sound velocity and are maximum depth and region specific. If the region of operation is oceanographically significant (e.g. the Arctic Ocean or Black Sea), local formulae may need to be applied. In order to operate correctly, a CTD will normally need to have a correct atmospheric offset applied. This should be taken from a reliable and calibrated atmospheric pressure sensor.

It is recommended that after a SV cast has been done, the SV at the surface (of the cast) be checked against the integrated SV sensor (if fitted), and any discrepancies investigated.

In addition to the calculation for converting two-way travel time (TWTT) to a range (Eq 11), ray bending due to refraction from the differences in sound velocity through the water column should also be applied. Most MBES processing software has the ability to read an SV profile and apply SV changes to compensate for ray bending (Eq 12, Eq 13) and overall sound propagation. The Surveyor should check that the software in question applies a ray bending algorithm. It is strongly recommended that an SV cast be done and checked prior to any patch test.

Note: The ray bending application within the Imagenex control software has been disabled, so ray bending needs to be applied within the MBES logging or processing software.

$$Range = \frac{\mathrm{SV} \times \mathrm{T}}{2} \qquad \text{(Eq 11)}$$

Where

SV = Sound velocity (ms^{-1})

T = Two-way travel time

The angular deflection of the sound impulse as a result of the temperature gradient is given by Snell's Law:

$$\frac{\sin \emptyset_2}{\sin \emptyset_1} = \frac{V2}{V1} \qquad \text{(Eq 12)}$$

Or

$$\emptyset_2 = \arcsin\left(\frac{V2 \times \sin \emptyset_1}{V1}\right) \qquad \text{(Eq 13)}$$

Where

$\emptyset_2$ = Angle of refracted beam (rad)

$\emptyset_1$ = Angle of incident beam (rad)

V2 = Sound velocity second layer

V1 = Sound velocity second layer

As sated above, it is recommended that a sound velocity cast be done prior to the start of the survey, at least every 12 hours thereafter, and at the very end of data collection.

Ideally; and for surveys of large areas, there should be a comprehensive distribution of sound velocity profile casts, both temporally and spatially, to maintain a representative currency of the sound velocity profiles for the survey area. These should be recorded in an organised way for application later.

One SV cast should as a minimum, be done at the deepest location of the survey.

4.2. MBES Patch Test

The alignment of any MBES with the motion reference unit and gyro is critical to the accuracy of the bathymetry system, both in terms of depth and position of acquired soundings. It is seldom possible to exactly align the MBES head with the sensors measuring heading, pitch and roll, so an alignment error (residual bias) must be determined. In addition, there may be a latency in the positioning system that impacts the positional accuracy of acquired data.

Before calibration, it is necessary to check the installation parameters and to perform a sound velocity cast to update the conversion of two-way travel time to range and calculation of the refraction solution. It is advised to verify that the SV sensor of the MBES system (if fitted) correlates well with the surface SV of the independent SV sensor used in the cast. Any discrepancies should be investigated.

In addition, accurate positioning is essential. An RTK GPS or inertially aided DGPS is recommended.

Good weather is required for the patch test.

The patch test should be performed in the deepest water available in the survey area.

The length of survey line for each aspect of the patch test are dependent on the size of the vessel / vehicle. It is recommended that the survey lines be no shorter than 100 m and that the vessel / vehicle has sufficiently completed any turn to come on line and that motion and heading reference units have settled.

The speed for the patch test is determined by the vessel in question's characteristics. It should be conducted at survey speed, such that the trim of the vessel be similar to that expected during survey.

The vessel should be in the ballast configuration expected during the survey. The Surveyor should for example be aware that with a small vessel, the movement of personnel will affect the vessel trim and therefore the patch test results. With a larger vessel, movement of fuel and water for example, may affect the trim and render the measured values incorrect.

The purpose of the patch test is to measure these errors and derive compensation values for Latency, Pitch, Roll, and Yaw. The following table (Table 4-1) describes the parameters affected by the various rotations and latency:

Parameter	Affects
Latency	Sounding position
Roll	Sounding position and depth
Pitch	Sounding position and depth
Yaw	Sounding position

Table 4-1

A patch test should ideally be performed as follows:

- Upon commissioning of a new system
- After long periods of inoperability
- Every time the MBES head has been removed and reinstalled
- Whenever the MRU, heading reference or positioning system has been removed and reinstalled.

During data acquisition, the Surveyor should compare the overlapping outer beams of adjacent swaths and to check for any trend of curvature upward or downward of each ping. This may suggest a sound velocity issue.

Most MBES processing packages will have patch test functionality. Although not essential, it is recommended to remove any legacy corrections in the navigation system prior to commencement of the patch test.

The data may be acquired in any order, but should be processed and applied as follows:

1. **Latency**
2. Apply latency offset, then process **roll** test
3. Apply pitch, then process **pitch** test
4. Apply roll, then process **yaw** test

4.2.1. Latency

Coincident lines of approximately 100 m are run at different speeds (4 knots and 8 knots) over a sloping terrain or a conspicuous topographic feature.

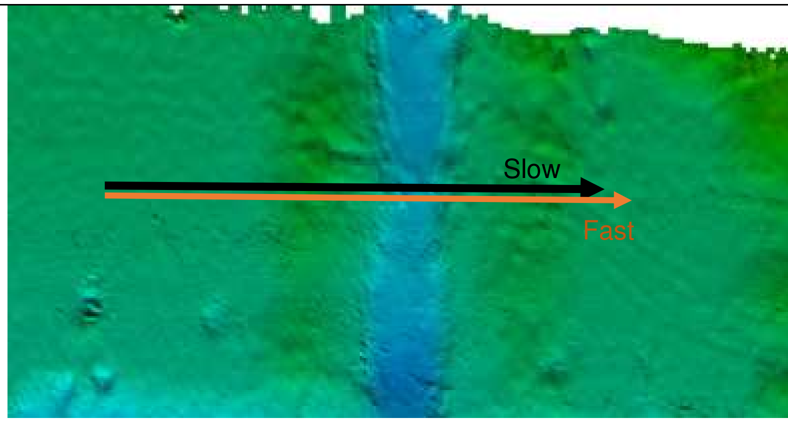


Figure 4-1 Latency lines

Lines must be run in the same direction, in order to eliminate the effect of a potential pitch offset, which would leak into the along-track displacements. With lines run in the same direction, the time delay can be computed using the equation Eq 14:

$$TD = \frac{d_a}{(v_h - v_l)} \qquad \text{(Eq 14)}$$

Where:

TD = is the time delay (s)

d_a = along track displacement (m)

v_h is the higher speed (m/s)

v_1 is the lower speed (m/s)

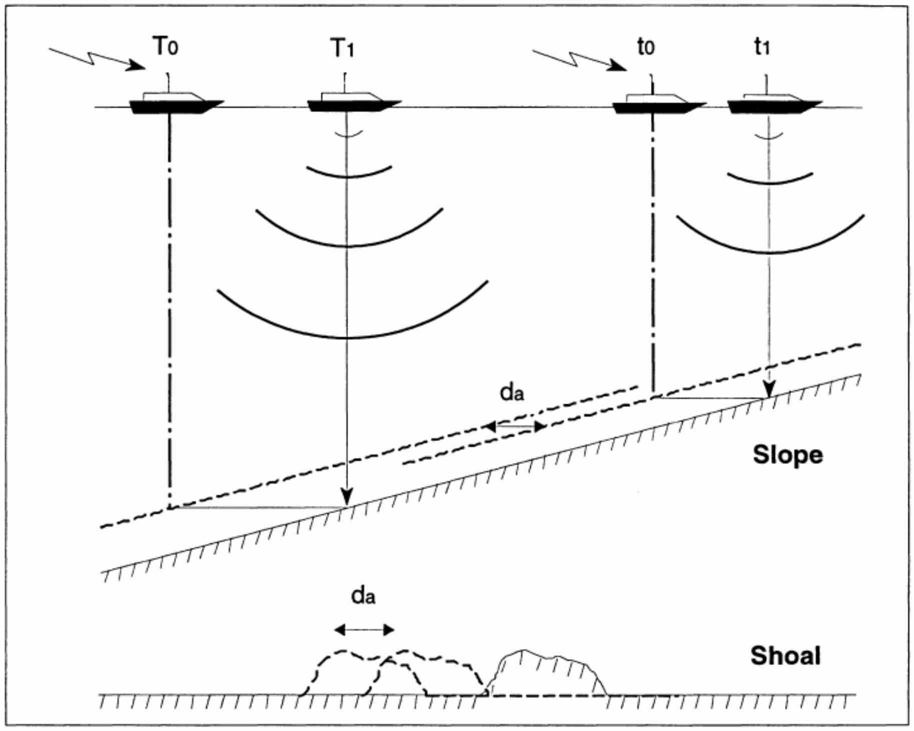


Figure 4-2 [Sketch courtesy of A Godin]

Data should be logged keeping speed changes (per run) to a minimum.

During processing, a subset of the feature / slope along the most pronounced point at nadir should be extracted and processed using the patch test utility in the MBES processing package.

The output of this process should be the latency offset, that when applied would bring the feature / slope points (at the different speed runs) to the same spatial location.

It is recommended that more than one set of high and low speed lines are run over the feature / slope selected. Each set should be processed, an average value derived and used.

The Surveyor should verify that the along-track profile obtained by the highest speed, precedes the lowest speed profile. If not, the time delay will be positive (MBES clock is late with respect to positioning system clock) or the time delay applied during acquisition was overestimated.

The lines with the time delay correction entered should be re-merged and the along-track profiles replotted. Time delay correction should be fine-tuned until one obtains the best match. Once satisfied and correctly entered, a note of the latency correction should be made in the log book.

4.2.1. Roll

A section of **flat** seabed should be selected and lines run at the same speed but on reciprocal headings:

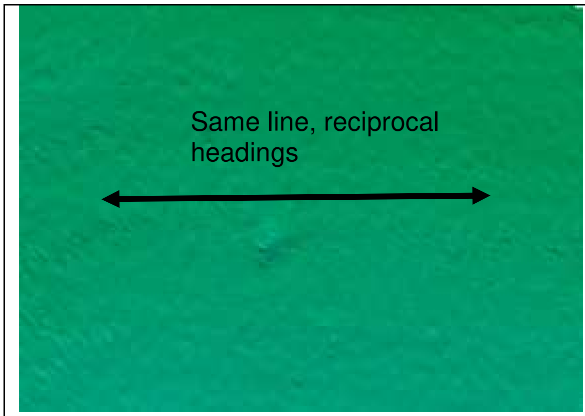


Figure 4-3 Roll lines

The roll offset can be approximated, using the following equation (Eq 15):

$$\rho = \frac{\tan^{-1}\left(\frac{d_z}{d_a}\right)}{2} \quad \text{(Eq 15)}$$

Where

ρ = Roll offset (deg)

d_z = depth difference (m)

d_s = across-track distance (m)

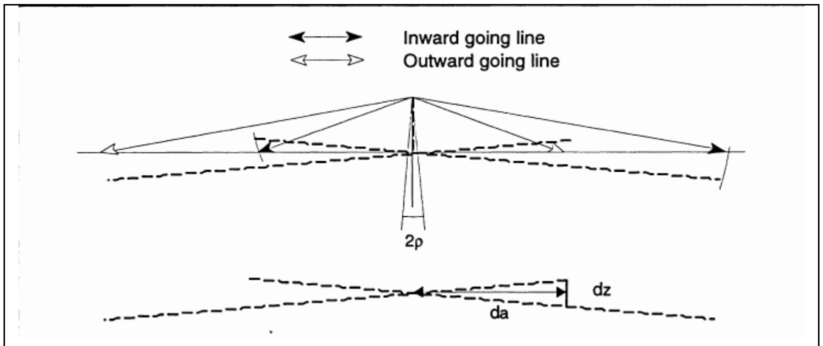


Figure 4-4 [Sketch courtesy of A Godin]

Prior to processing, the pitch correction derived in Section 4.2.2 should be applied.

The inconsistency in observed cross profiles angle is as a result of an error in roll alignment between MRU and MBES head. During processing, an arbitrary subset of the flat seabed observed in both directions and **perpendicular** to the run-line direction should be extracted and processed using the patch test utility in the MBES processing package.

The output of this process should be the roll correction, that when applied would bring the seabed cross profiles to the same angle.

It is recommended to repeat the exercise using various cross profiles and the average derived and applied.

The Surveyor should verify the sign of the roll corrections. Hypack automatically corrects for the sign and the reported pitch correction should be applied as is. Other patch test software may require an inversion of the sign and the Surveyor must be aware of this.

4.2.2. Pitch

The two pairs of reciprocal lines, run over a feature / slope at the same speed, will be used to assess the pitch correction. Again, the deepest section of survey area should be selected as the error's visibility increases with depth.

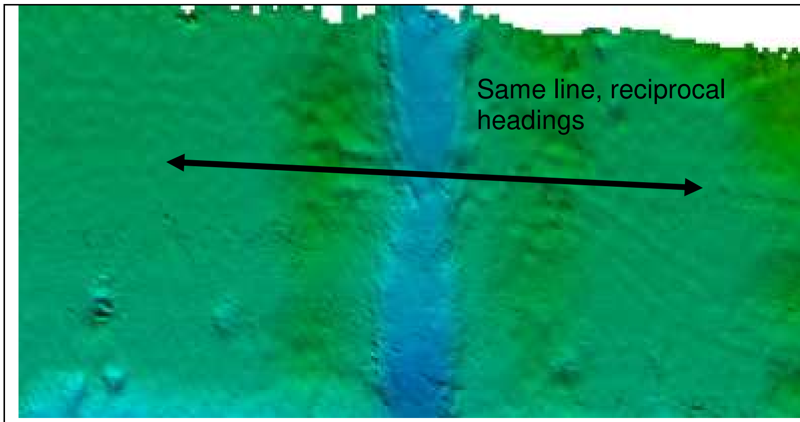


Figure 4-5 Pitch lines

The pitch correction is described by the following equation (Eq 16):

$$\alpha = \tan^{-1}\left(\frac{d_a/2}{depth}\right) \qquad \text{(Eq 16)}$$

Where

α = Pitch offset (deg)

d_a = Along-track displacement (m)

depth = Water depth (m)

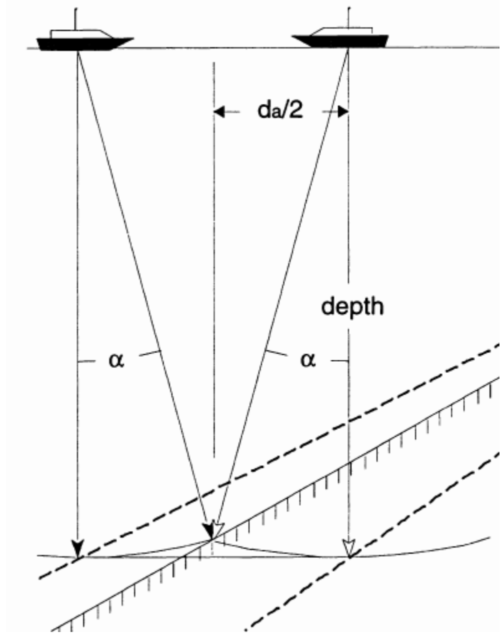


Figure 4-6 [sketch courtesy of A Godin]

The latency derived in Section 4.2.1 should be applied prior to any processing.

The inconsistencies in position of the feature / slope is as a result of an error in pitch alignment between MRU and MBES head. During processing, a subset of the feature / slope along the most pronounced point at nadir should be extracted and processed using the patch test utility in the MBES processing package.

The output of this process should be the pitch correction, that when applied would bring the feature / slope points (on reciprocal headings) to the same spatial location.

It is recommended to repeat the exercise at a different speed (for example 6 knots), or at the very least define another long profile within the previously used data set, including the same slope / feature. The same process may now be repeated (several times if possible) and the average derived and applied.

The Surveyor should verify the sign of the pitch corrections. Hypack automatically corrects for the sign and the reported pitch correction should be applied as is. Other patch test software may require an inversion of the sign and the Surveyor must be aware of this.

4.2.3. Yaw

The two pairs of adjacent lines, run in the same direction and on each side of a conspicuous topographic feature with line spacing such that there is overlap between adjacent data.

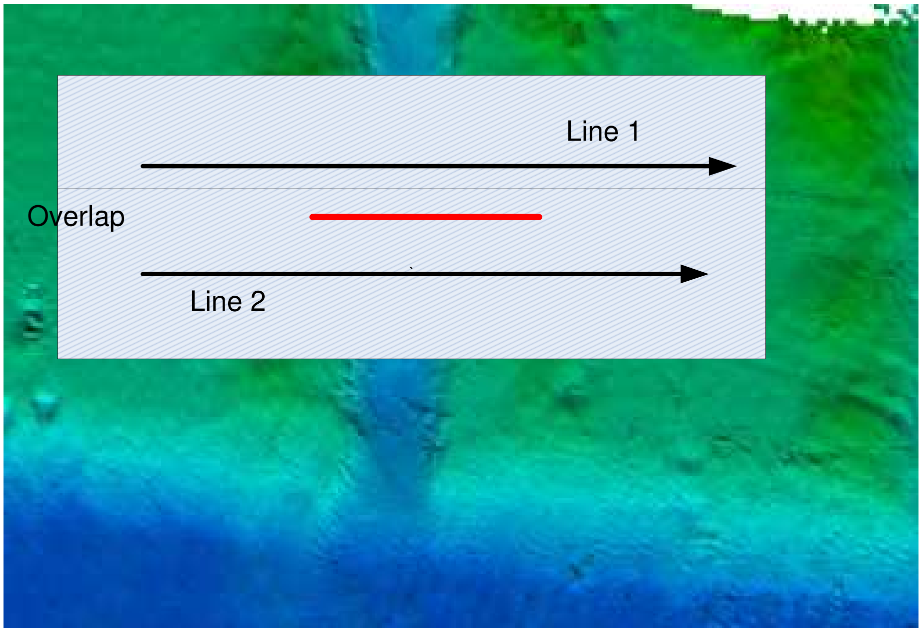


Figure 4-7 Yaw lines

The yaw offset can be approximated, using the following equation (Eq 17):

$$\gamma = \sin^{-1}\left(\frac{d_a/2}{x_i}\right) \qquad \text{(Eq 17)}$$

Where

γ= Yaw offset (deg)

d_a = along-track displacement h

x_i = The relative cross track distance for beam i (m)

Figure 4-8 shows the along-track profiles and represent the apparent seafloor swept by the outer beams. The along-track displacement d_a in the apparent seafloor is caused by the azimuthal offset γ.

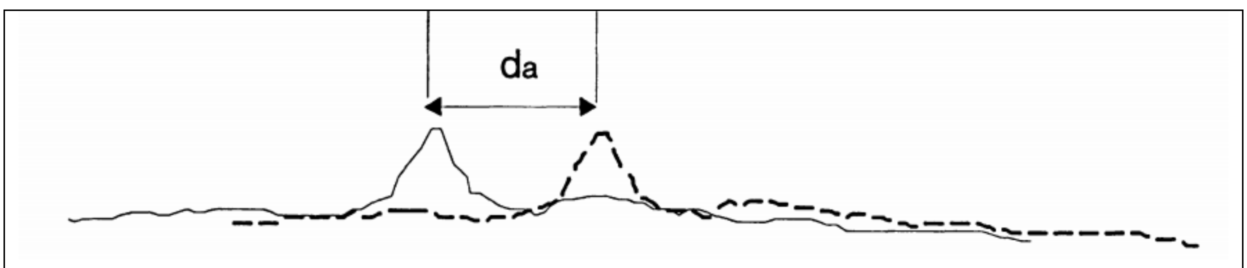


Figure 4-8 [sketch courtesy of A Godin]

Prior to processing, the pitch correction derived in Section 4.2.2 4.2.1should be applied.

A data set should be extracted and processed as indicated by the red line in Figure 4-7 and processed using the patch test utility in the MBES processing package.

The output of this process will be the yaw correction, that when applied would bring the along-track profiles together.

It is recommended that another set of lines be run in the same configuration and re-processed to verify the calibration. If not possible, it is recommended that additional along-track overlapping datasets are processed and the average applied.

4.3. Bar Check

Although no longer common, some Surveyors perform a bar check, which consists of the lowering of a bar beneath the MBES transducer and comparing the known lowered depth to the depth reported by the MBES. This is useful for checking Z offset between transducer and waterline, although it can only be done when the vessel is stationary and therefore doesn't account for changes in draft due to vessel movement and other factors.

4.4. Performance Test

Upon completion of the patch test and the calibration values have been entered, it is recommended that a performance test (also called a Beam Angle Test (BAT)), be carried out prior to any survey campaign. Its main purpose is an empirical and quantitative measure of system repeatability at various beam angles and for individual beams. Statistics are all calculated from the depth difference between the reference surface and the check-lines as a function of beam angle.

Performance test data are comprised of:

- Reference surface data
- Check line data.

4.4.1. Reference Surface

An area of flat or near-flat (<5% slope) and smooth seabed should be selected and an SV cast undertaken. It is recommended to conduct the survey at or near either high or low tide.

Four or five parallel lines (> 300 m long) should be run in shallow water (20 to 50 m), with 115% to 160% inter-swath overlap. The area must be covered with the inner beams, with a swath width representing 2 or 3 times the water depth. (Figure 4-9)

Four or five parallel lines (> 300 m long), perpendicular to the previous lines must then be run, with 115% to 160% inter-swath overlap. An example line spacing is presented in Table 4-2 below:

Overlap	1.15
Water depth (m)	30
Set beam angle	90°
Line spacing (m)	**12.75**

Table 4-2 Example line spacing

Note: See (Section Eq 2)

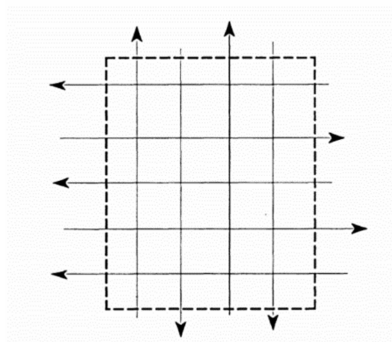


Figure 4-9 Reference surface lines

4.4.2. Check lines

A new sound velocity cast within the reference surface area should be undertaken.

A pair of parallel lines (>300m long), inside the reference surface should be run as shown in Figure 4-10. Inter-swath overlap is not required.

Vessel speed should be as per the reference model and data logged to a separate location or filename than the reference model.

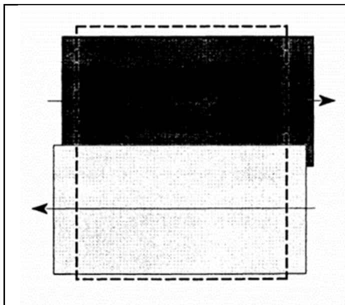


Figure 4-10 Check lines

4.4.3. Processing Performance Test

The post-processing of these data sets is done in two steps namely:

- Data cleaning
- Gridding and differencing

The reference surface represents the ground truth data and should be free of biases and outliers. Check lines will be used to verify the overall performance of the MBES system and thus thinning and/or smoothing is avoided. During differencing, check lines should be processed one at a time and the quality of data assessed for each line.

4.4.3.1. Reference Model Processing

A sounding grid should be defined (in Hypack this is done prior to commencement of the survey and is called an MTX file) that is within the test area with a cell size of 0.3 m x 0.3 m.

Tides and sound velocity should be applied to all logged data.

MBES processing software should be used to remove outer beams that are outside of 3 times the average water depth (or approximately 45° angle limit). Positions, attitude and bathymetric data should be thoroughly cleaned using the manual cleaning tools (as opposed to automatic) provided in the processing package used.

In Hypack, the XYZ should be saved as one point per cell, and 'Minimum # Points for Average' = 3 (see Figure 4-11)

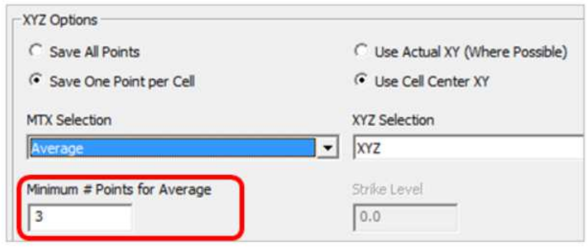


Figure 4-11 Hypack XYZ options

4.4.3.2. Check lines Processing

Next, the check lines should be processed. All beams should be kept (i.e. do not impose angle limits) and only **obvious** positional and bathymetric outliers should be removed. If any systematic artefacts are found in the profiles, they should not be cleaned as they will be used to quantify variance.

The tool provided (in most MBES processing packages) is now used to compare the check-lines (with all data) the reference model (with outer beams removed) and generate numerous statistics.

In Hypack, the same user defined Matrix file (MTX) as for the reference model is selected and the check-line data loaded into it. The beam angle test is now run and a variety of statistics and graphics are presented showing the comparison between the reference model and check lines.

An example of a statistical output is as follows (Figure 4-12), and shows % depth residual on the Y axis and beam angle on the X. As can be seen, there is a 1.2% depth residual at the outer beams and approximately 0.4% residual at nadir.

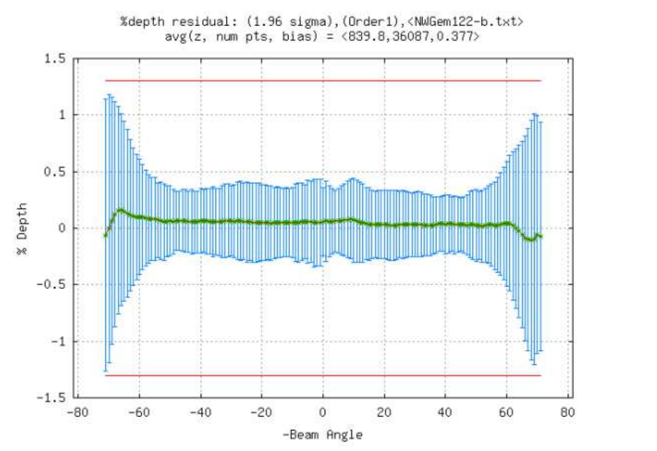


Figure 4-12 Image courtesy of [Whittaker et al]

Another output is shown below (Figure 4-13) and is produced by Hypack. The X axis shows the distance from nadir and Y axis (left) shows the residual (or uncertainty) between computed reference average depth and check lines at the 95% confidence level. As can be seen (and expected), the residual increases with distance from nadir. The right axis shows the depth bias and shows a similar trend.

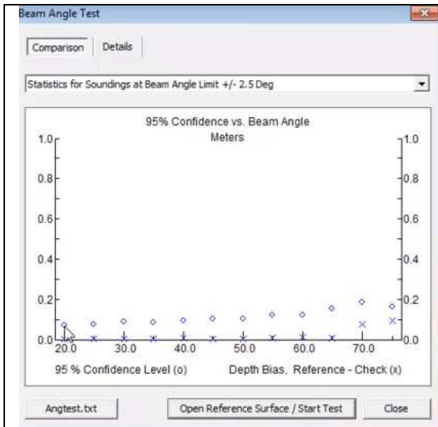


Figure 4-13 Hypack example

A number of other statistics and graphs (e.g. histograms) are produced by most MBES processing packages and it is difficult to specify definitive acceptable statistical criteria since depth, bottom types, swath angle, etc. all contribute to a changing picture. The Surveyor will make the decision as to whether the system is performing within tolerance.

Note that Hypack (MBMAX64) provides a feature to process and analyse data from a single and dual head MBES.

5. Operations

To cover all aspects and considerations is not possible due to the wide variety of environmental conditions, job specifications, vehicle type and size, etc. The bullet points below represent some considerations to be made during the data acquisition phase of the project:

- It is highly recommended that during all data acquisition the Imagenex proprietary .IGX format file is logged. In the Imagenex DT100 SIR software, the user selects File > Record Start… and a file with parameters determined by Setup > Automatic Filenames, Automatic Filename Type and Set Maximum Filesize will be logged. These files may act as a diagnostic tool in the case of technical issues, or as a back-up from which point and beam data (e.g. backscatter) may be extracted. The IGX file may also be converted to a D1P format (via a utility in DT100 SIR) and in turn into an HSX file via a Hypack utility. Since the IGX file logs only geographical coordinates (lat and long), the user should be conscious of horizontal datum / geodesy and set the correct attributes during the conversion to ensure no distortion of positional data occurs.
- Latency, roll, pitch, and yaw corrections should be applied as per the patch test described in Section 4.2 and checked before commencement of any survey tasks.
- SV cast at the start, upon completion and during the survey at appropriate intervals. The depth of the cast should be appropriate to the survey depth; and at appropriate locations. (see Section 4.1).
- Ray bending correction is disabled in the DT101Xi and DT102Xi and must therefore be applied either in real-time during logging or afterwards during post processing by the MBES logging package.
- Strategy for tidal correction should be defined and executed, including the possible use of external tide gauges, RTK, etc. (see Section 3.2.7 – Datum Set-up).
- The setting of a sounding grid cell size should be done (see Section 3.2.6).
- Survey line spacing should be adequate to acquire sufficient coverage and data density. See (see 3.2.4).
- Survey speed should be such that the sonar head is not subjected to excessive force, vibration or induced noise and cavitation. (See Section 3.2.1).
- Where possible, it is recommended to commence work in deeper water and work towards shallow water. This is advantageous in terms of SV casts, as well as obstacle avoidance.
- Constant monitoring of the navigation inputs should be undertaken. It is recommended to set up an XY plot of the vessel position in the nav system and monitor any position jumps, navigation statistics and additional data during data acquisition.
- Gain and range should be adjusted so as to ensure good quality of data and depth determination throughout. It is recommended that a real-time point-cloud be setup and monitored to ensure data quality.
- During data collection it is recommended that a waterfall display be opened in the MBES data acquisition software so any SV anomalies will be detected. SV anomalies will manifest themselves in ‘smiley’ or ‘frowny faces’ that are more pronounced at the edges of the swath and with deeper water.
- On a small vessel, it is recommended that movement of personnel be limited during data acquisition to keep the patch test correction current. Periodic observations should be made of the draft marks with respect to the mean sea level (Section 3.2.2)
- Positioning, heading and attitude system should be monitored by means of time series plots, if possible.
- A comprehensive log should be kept at all times recording important settings, changes to any settings, and a diary of events for use during processing.

6. Data Processing

The processing of multibeam data is a specialized undertaking and cannot comprehensively be covered in this document. The following bullet points are fundamental considerations to be made during data processing:

- Data should be loaded with the correct sounding grid cell size (see Section 3.2.6).
- Some packages allow for the processing of depth as elevation, but generally allow for the selection of depth mode or elevation mode. Since DT101Xi and DT102Xi output depth, depth mode should be selected.
- Tide mode should be set and the tide file covering the entire time of survey and at the appropriate interval loaded. Usually there is a tide time plot available to QC the tide data. This should be opened and it should be verified that no tidal anomalies exist.
- The sound velocity file(s) from the SV casts should be loaded to compensate for ray bending and enable overall propagation calculations. Usually there is an SV time plot available to QC the SV data. This should be opened and it should be verified that no SV anomalies exist.
- It may be possible to set a static or dynamic draft in the processing package, that will apply a Z offset according to draft changes. If these data is available, it should be used.
- Various devices are usually set in the processing package that indicate the data source for things like navigation, MRU, heading and sonar heads. This is usually where the offsets derived during the establishment of the reference frame are set. (see Section 3.2.2).
- Usually there is an MRU (heave, pitch and roll) time plot available to QC the MRU data. This should be opened and it should be verified that no anomalies exist.
- The results of the patch test are usually entered in the processing package.
- The heave device and method to be used is usually entered in the processing package. It should be ensured that the sign convention is correctly set (noting the heave sensor's sign convention) as some packages (including Hypack) apply heave in an unconventional way.
- Once the preliminary settings are completed, the data (position and sonar) may be processed by a combination of automatic filters and manual means. The job requirements should be consulted to ensure compliance with specifications during processing.

Note: as previously stated, processing of data differs widely depending on the processing suite used, the survey type, the output requirements and a host of other factors; and is therefore outwith the scope of this document.

APPENDIX A **DT101Xi / DT102Xi SPEC SHEETS**

DT101Xi

IMAGENEX

DT101Xi

445-105 MARCH 2018

IMAGENEX MODEL DT101Xi MULTIBEAM PROFILING SONAR with Optional Internally Integrated Motion Reference Unit & Sound Velocity Sensor

The new DT101Xi Multibeam Profiling Sonar (i.e. Multibeam Echo Sounder) is a single instrument integrating the sonar, motion reference unit (MRU), and sound velocity sensor into one sleek and compact unit. The DT101Xi requires only one cable for operating all three sensors and is a portable solution for any survey. Compatible with the DT100 SIR (Sensor Interface Relay) power supply/timing box, simply connecting a dual antenna GNSS/GPS receiver is all that is required to perform bathymetric surveys.

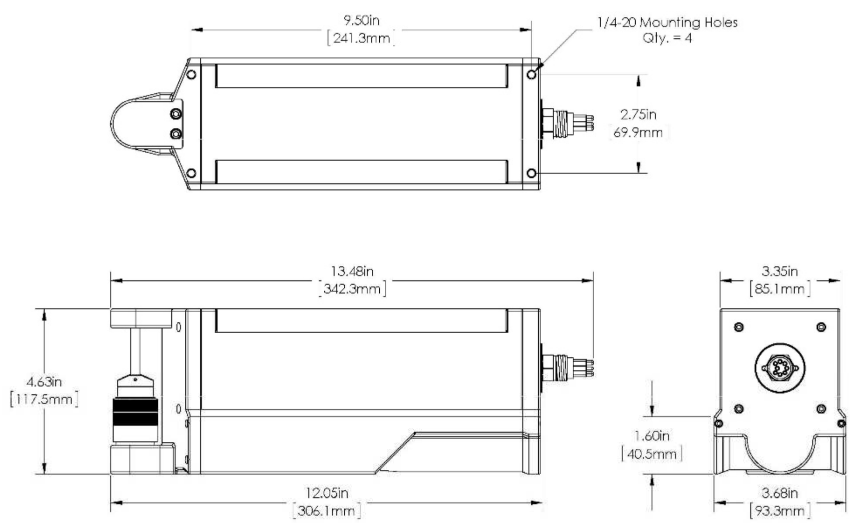
Patent Pending

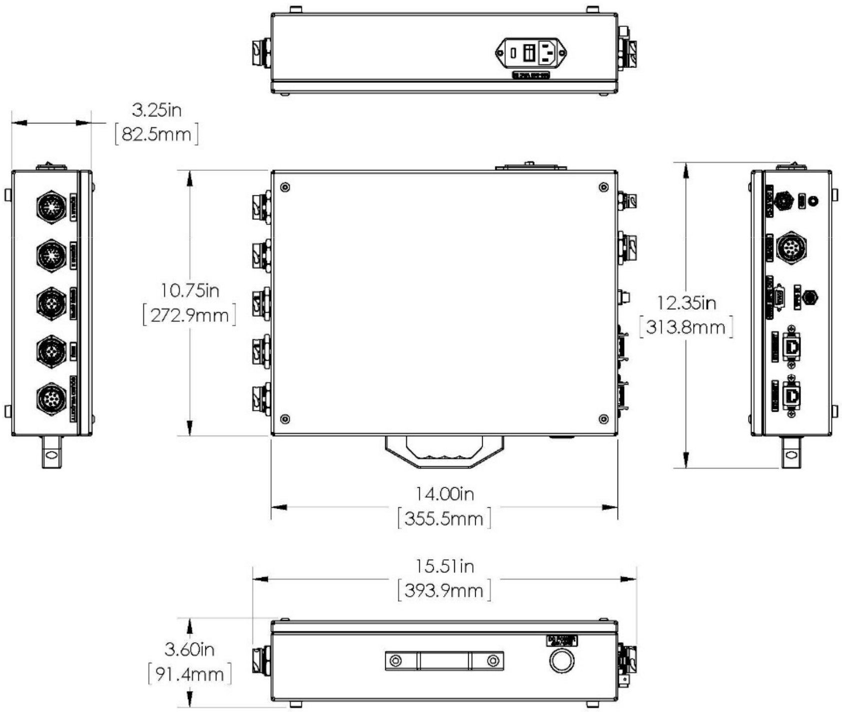
Specifications subject to change without notice

IMAGENEX
www.imagenex.com

HARDWARE SPECIFICATIONS:	
FREQUENCY	240 kHz
SWATH WIDTH (nominal beam geometry)	Transmit: 120° x 3° Receive: 120° x 3°
EFFECTIVE BEAM WIDTHS	Narrow: 0.75° Medium: 1.5° Wide: 3°
NUMBER OF BEAMS	Default: 480 Selectable: 240, 120
RANGE RESOLUTION: **SCREEN** **OUTPUT**	 0.1% of range 0.01% of range
RANGE	75 m (246') water depth 150 m (492') slant range
MIN. DETECTABLE RANGE	0.5 m (1.6') below transducer
MOTION REFERENCE UNIT **Pitch and Roll Accuracy:** **Heave:**	Internally mounted OEM version 0.04° 5 cm or 5% (whichever is greater)
SOUND VELOCITY SENSOR	Internally mounted OEM version of AML Micro•X 1400 m/s to 1600 m/s +/- 0.025 m/s
MAX. OPERATING DEPTH (Submersion depth)	300 m (984') Contact Imagenex if a greater depth rating is required
INTERFACE TO PC	Ethernet (100 Mbps) using TCP/IP
MAX. CABLE LENGTH	100 m (328') on CAT5-e, longer cable runs possible with additional hardware
CONNECTOR	Underwater wet-mateable 8 conductor
POWER SUPPLY (sonar head only)	22 - 50 VDC at less than 10 Watts
DIMENSIONS	306 mm (12.05") L x 118 mm (4.63") H x 94 mm (3.68") W
WEIGHT: In Air **In Water**	4.2 kg (9.5 lbs) 1.9 kg (4.2 lbs)
MATERIALS	Polyoxymethylene (i.e. Delrin), Titanium, PVC, Titanium connector
POWER SUPPLY/ TIMING BOX: **DT100 Sensor Interface Relay (DT100 SIR)**	2 port Ethernet switch (DT101xi PC and Survey PC) Interfaces to: DT101xi GNSS (GPS) Gyro / Heading Sensor 100 – 240 VAC or 12 – 36 VDC input range Dimensions: 394 mm (15.5") x 314 mm (12.4") x 92 mm (3.6")
MAX. PING RATE	20 Hz

SOFTWARE SPECIFICATIONS:	DT101Xi_SIR.exe
WINDOWS™ OPERATING SYSTEM	Windows™ XP, Vista, 7, 8, 10
DISPLAY MODES	Sector, Linear, Perspective, Profile, Beam Test
PERSISTENCE (TRAIL)	1 – 300 seconds
RANGE SCALES	5 m, 10 m, 20 m, 30 m, 40 m, 50 m, 60 m, 80 m, 100 m, 150 m
SECTOR SIZES	30°, 60°, 90°, 120°
FILE FORMAT: RAW DATA PROFILE POINT	 (filename).D1R (filename).D1P
RECOMMENDED MINIMUM COMPUTER REQUIREMENTS:	2 GHz Pentium 4 256 MB RAM 20 GB Hard Disk 1024 x 768 screen resolution





ORDERING INFORMATION:		
300 m UNIT	Standard	838-000-101
Sensor Interface Relay box (DT100 SIR)	Standard	837-000-007
IP Address*	Option	-020

*Note: Standard IP Address is 192.168.0.2
A different IP Address may be specified upon ordering.

DT102Xi
445-106 MARCH 2018

IMAGENEX MODEL DT102Xi 180° MULTIBEAM PROFILING SONAR with Optional Internally Integrated Motion Reference Unit & Sound Velocity Sensor

The new DT102Xi 180° Multibeam Profiling Sonar (i.e. Multibeam Echo Sounder) is a single instrument integrating the sonar, motion reference unit (MRU), and sound velocity sensor into one sleek and compact unit. The DT102Xi requires only one cable for operating all three sensors and is a portable solution for any survey. Compatible with the DT100 SIR (Sensor Interface Relay) power supply/timing box, simply connecting a dual antenna GNSS/GPS receiver is all that is required to perform bathymetric surveys.

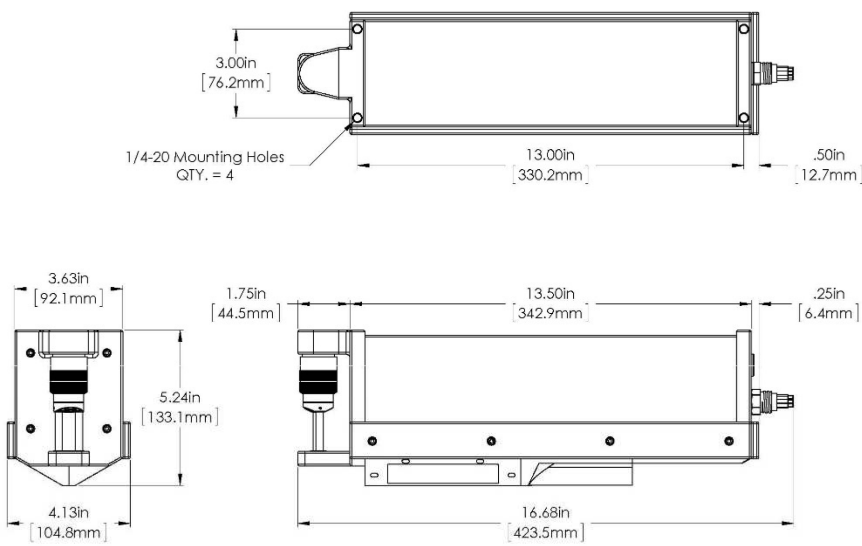
Patent Pending

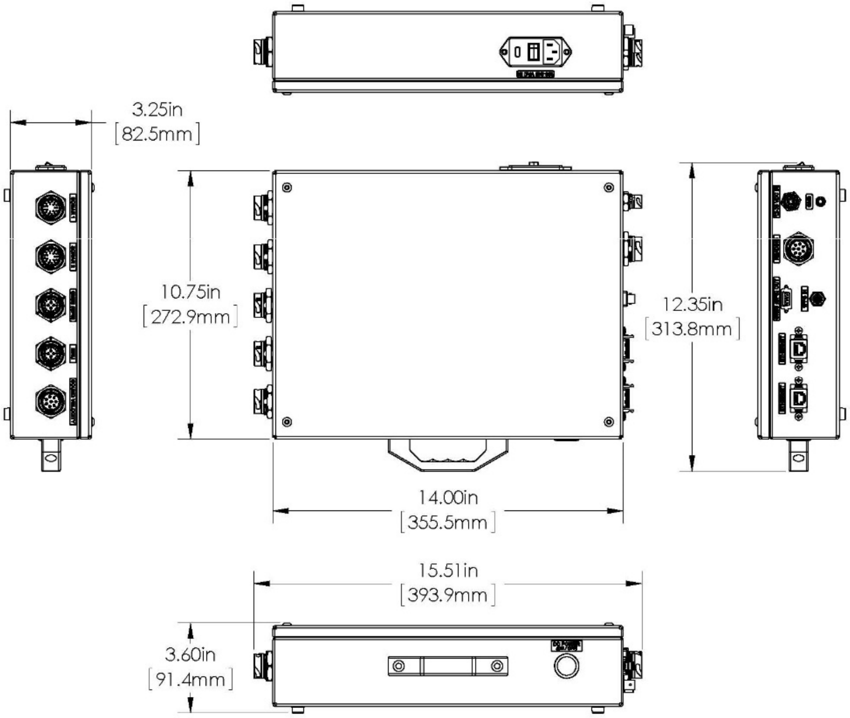
Specifications subject to change without notice

www.imagenex.com

HARDWARE SPECIFICATIONS:	
FREQUENCY	675 kHz
SWATH WIDTH (nominal beam geometry)	Transmit: 180° x 3° Receive: 180° x 3°
EFFECTIVE BEAM WIDTHS	Narrow: 0.75° Medium: 1.5° Wide: 3°
NUMBER OF BEAMS	Default: 720 Selectable: 360, 180
RANGE RESOLUTION: **SCREEN** **OUTPUT**	 0.1% of range 0.01% of range
RANGE	TBA water depth TBA slant range
MIN. DETECTABLE RANGE	0.5 m (1.6') below transducer
MOTION REFERENCE UNIT **Pitch and Roll Accuracy:** **Heave:**	Internally mounted OEM version 0.04° 5 cm or 5% (whichever is greater)
SOUND VELOCITY SENSOR	Internally mounted OEM version of AML Micro•X 1400 m/s to 1600 m/s +/- 0.025 m/s
MAX. OPERATING DEPTH (Submersion depth)	300 m (984') Contact Imagenex if a greater depth rating is required
INTERFACE TO PC	Ethernet (100 Mbps) using TCP/IP
MAX. CABLE LENGTH	100 m (328') on CAT5-e, longer cable runs possible with additional hardware
CONNECTOR	Underwater wet-mateable 8 conductor
POWER SUPPLY (sonar head only)	22 - 50 VDC at less than 15 Watts
DIMENSIONS	424 mm (16.68") L x 133 mm (5.24") H x 105 mm (4.13") W
WEIGHT: In Air **In Water**	~4.7 kg (~10.3 lbs) ~0.8 kg (~1.8 lbs)
MATERIALS	316 Stainless Steel, PVC, Stainless Steel connector
POWER SUPPLY/ TIMING BOX: **DT100 Sensor Interface Relay (DT100 SIR)**	2 port Ethernet switch (DT102Xi PC and Survey PC) Interfaces to: DT102Xi GNSS (GPS) Gyro / Heading Sensor 100 – 240 VAC or 12 – 36 VDC input range Dimensions: 394 mm (15.5") x 314 mm (12.4") x 92 mm (3.6")
MAX. PING RATE	20 Hz

SOFTWARE SPECIFICATIONS:	DT102.exe
WINDOWS™ OPERATING SYSTEM	Windows™ XP, Vista, 7, 8, 10
DISPLAY MODES	Sector, Linear, Perspective, Profile, Beam Test
PERSISTENCE (TRAIL)	1 – 300 seconds
RANGE SCALES	5 m, 10 m, 20 m, 30 m, 40 m, 50 m, 60 m, 80 m, 100 m
SECTOR SIZES	30°, 60°, 90°, 120°
FILE FORMAT: RAW DATA PROFILE POINT	 (filename).D1R (filename).D1P
RECOMMENDED MINIMUM COMPUTER REQUIREMENTS:	2 GHz Pentium 4 256 MB RAM 20 GB Hard Disk 1024 x 768 screen resolution





ORDERING INFORMATION:		
300 m UNIT	Standard	838-000-102
Sensor Interface Relay box (DT100 SIR)	Standard	837-000-007
IP Address*	Option	-020

*Note: Standard IP Address is 192.168.0.2
A different IP Address may be specified upon ordering.

1. DT100 SIR – DT101Xi Sonar Cable

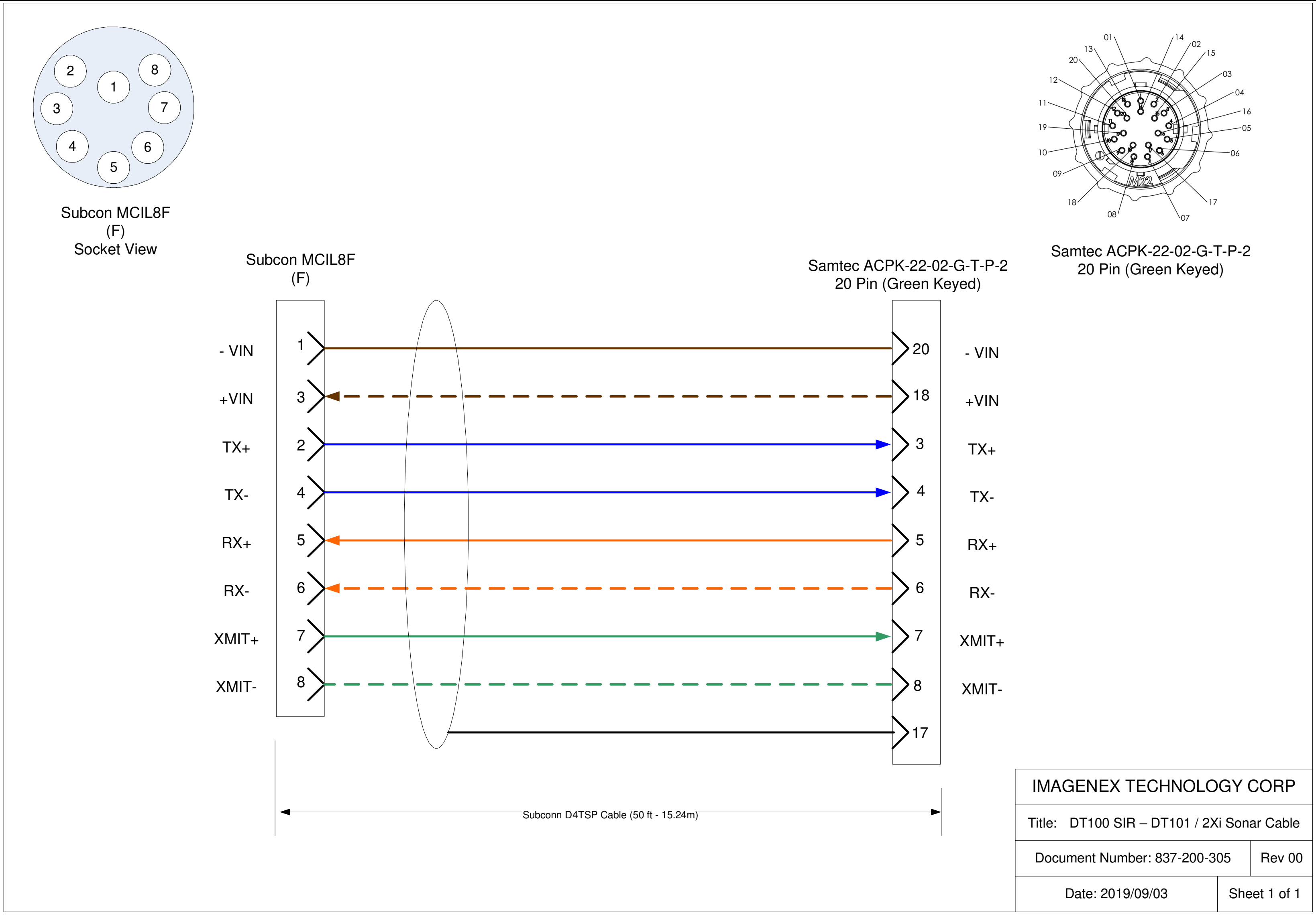


Figure 6-1 Sonar Cable Schematic

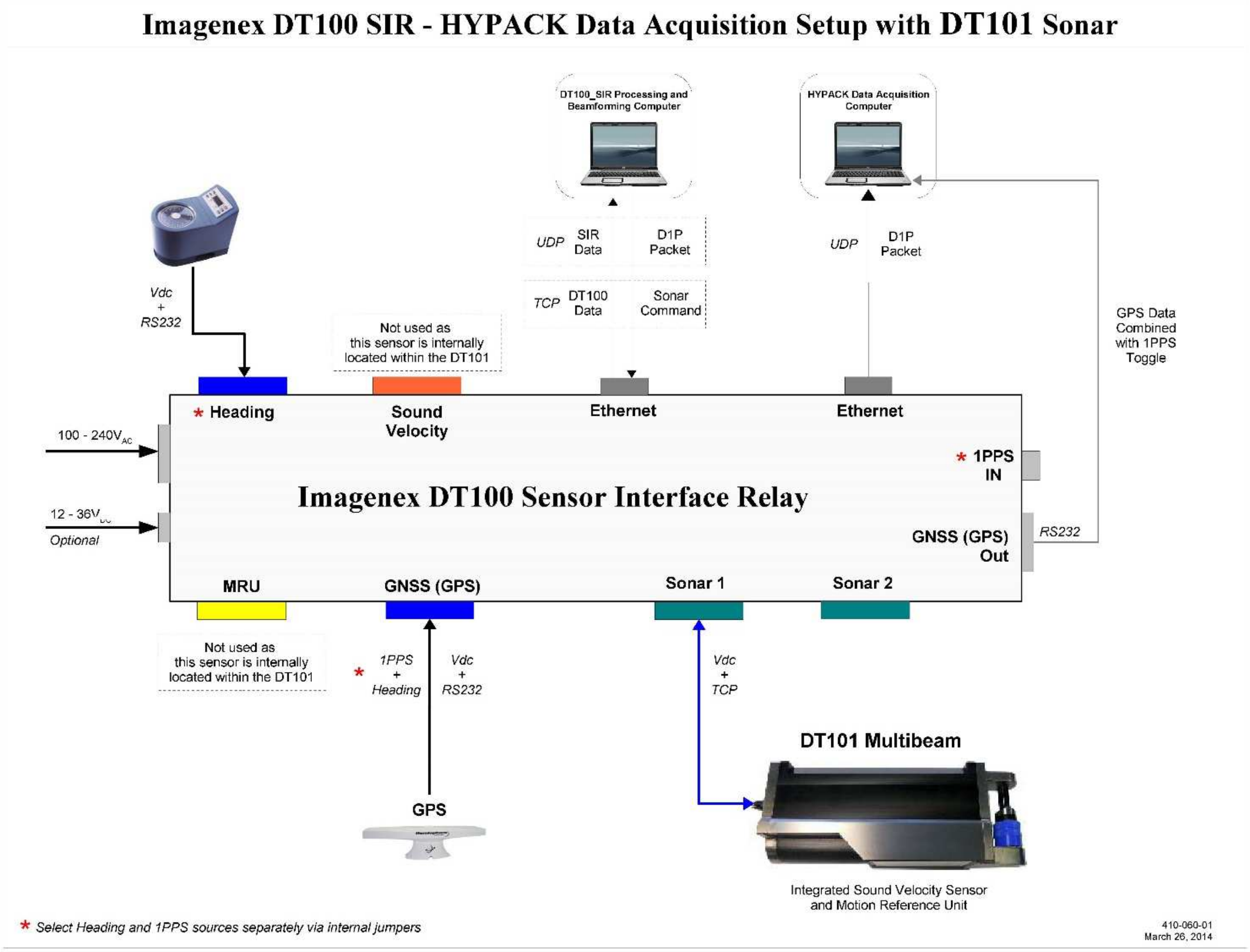


Figure 6-2 Sensor Interface Relay Schematic

The connection of sensors to the DT100 SIR unit is detailed below:

1. **Sonar Head**

- Connection is made via the supplied DT100 SIR – DT101 / 2Xi interface cable via the 20 pin Samtec (green keyed) connector:

Panel = Samtec ACRK-22-02-G-S-C-P-2 20 pin (Green Keyed)			
Cable = Samtec ACPK-22-02-G-T-P-2			
Pin	**Direction (*Relative to SIR*)**	**Function**	**Note**
1	N/C		
2	N/C		
3	In	RX+	Ethernet
4	In	RX-	Ethernet
5	Out	TX+	Ethernet
6	Out	TX-	Ethernet
7	In	Transmission Sync	5V Logic
8	Out	COM	Signal Common
9	N/C		
10	N/C		
11	N/C		
12	N/C		
13	N/C		
14	N/C		
15	N/C		
16	N/C		
17	N/A	SHLD	Shield
18	Out	+24V	Power
19			
20	Out	COM	Power Common

Table 6-1

- A 15 m cable per head is supplied.
- See sonar cable schematic (Figure 6-1), Samtec ACPK-22-02-G-T-P-2 to SUBCONN MCIL8F(F)

2. GNSS (GPS)

- The GNSS is connected via a Samtec 20 pin (4+16) (blue keyed) connector:

Panel = Samtec ACRK-22-05-G-S-C-P-3 4+16 pin (Blue Keyed)			
Cable = Samtec ACPK-22-05-G-T-P-3			
Pin	**Direction (*Relative to SIR*)**	**Function**	**Note**
1	N/C		
2	N/C		
3	In	GPS Heading	RS232
4	In	GPS (($GPGGA, $GPVTG, $GPZDA)	RS232
5	Out	Reserved	
6	Out	COM	Signal Common
7	In	1PPS	3.3 / 5 V TTL Logic
8	Out	COM	Signal Common
9	N/C		
10	N/C		
11	N/C		
12	N/C		
13	N/C		
14	N/C		
15	N/C		
16	N/C		
17	N/A	SHLD	Shield
18	Out	+24V	Power
19			
20	Out	COM	Power Common

Table 6-2

- Communication parameters are set as follows in the SIR unit:

Item	Settings
Baud rate	19200
Number of bits	8
Stop bit	1
Parity bit	None
Supported strings	Valid NMEA ($GPGGA, $GPVTG, $GPZDA and optional $HEHDT)

Table 6-3

- Power is available on Pin 18, Pin 20 (12 VDC or 24 VDC option depending on jumper setting (see Figure 6-8)) for powering of GNSS if required:
- In addition to GNSS data, it is possible to configure this port to accept GPS derived heading and PPS by configuration of the jumpers as indicated in the diagram below (Figure 6-7).
    - If PPS is received via this port, Pin 7 (see Table 6-2) must be driven via a TTL (3.3 V / 5 V) active high trigger. The pulse duration should be greater than 1 millisecond.
    - $GPZDA (GPS Time) is received via this port and, together with PPS, is essential for system timing.
    - If heading is input via this port, an RS-232 $HEHDT is expected on Pin 3 (Samtec 20 pin) (see Table 6-2).

The following diagrams show various GNSS interface options:

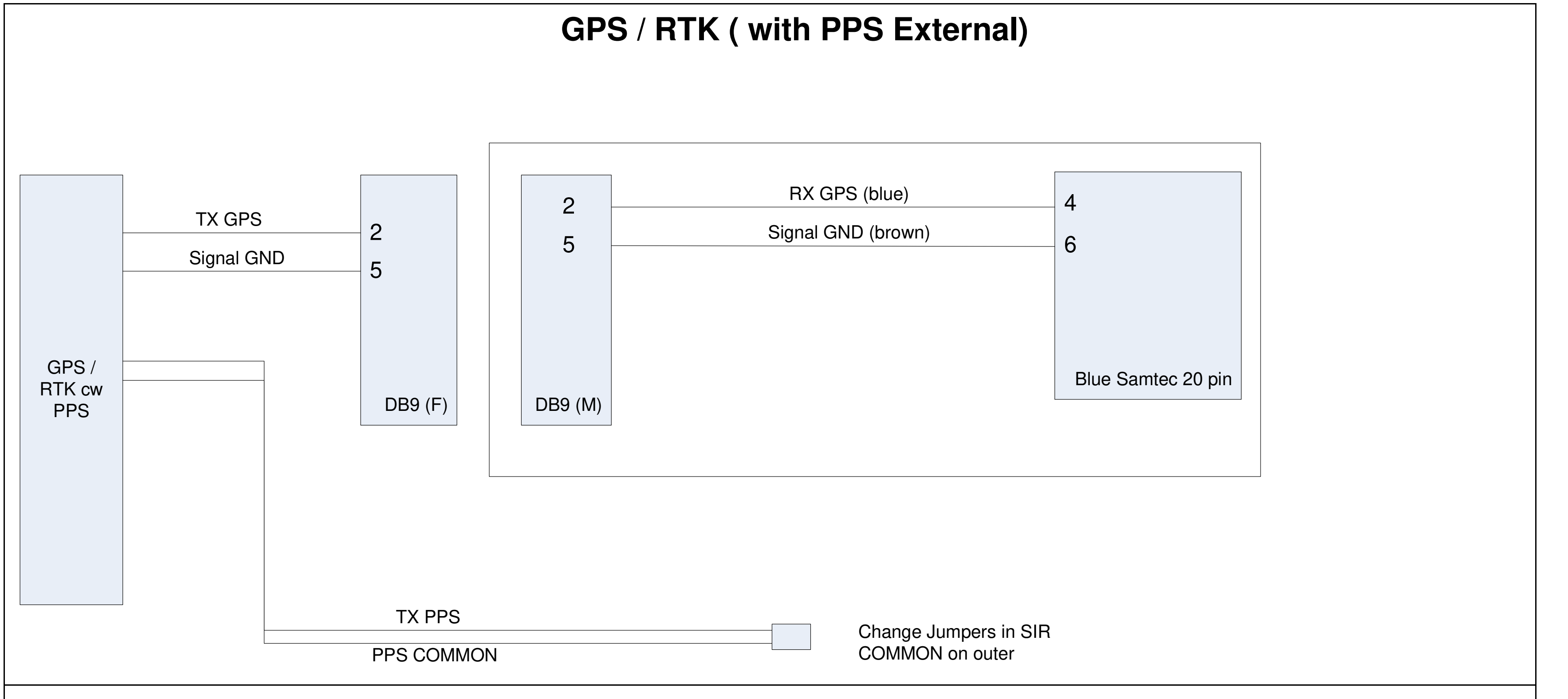


Figure 6-3 GPS cw PPS External

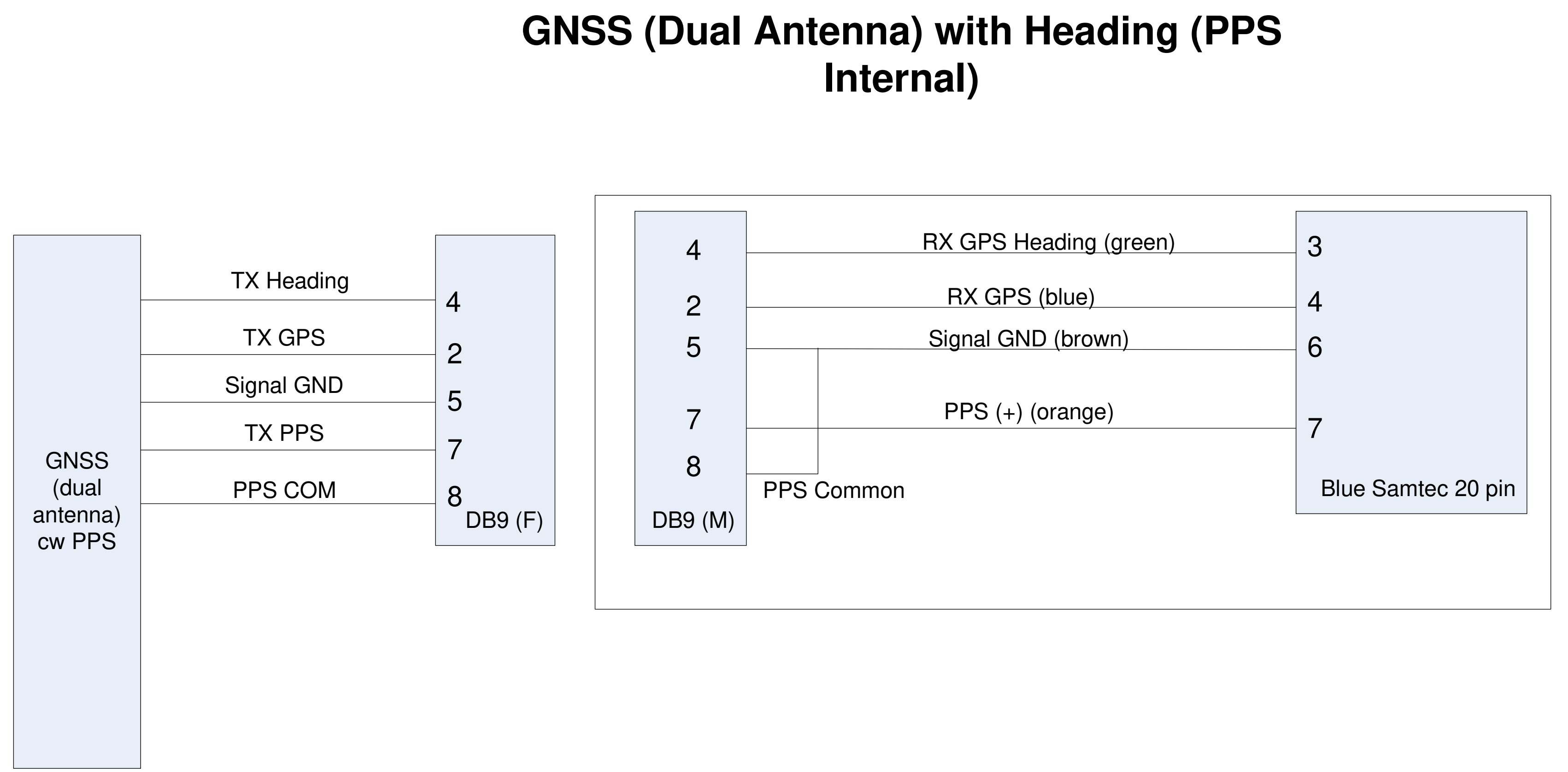


Figure 6-4 Dual Antenna GNSS cw PPS External

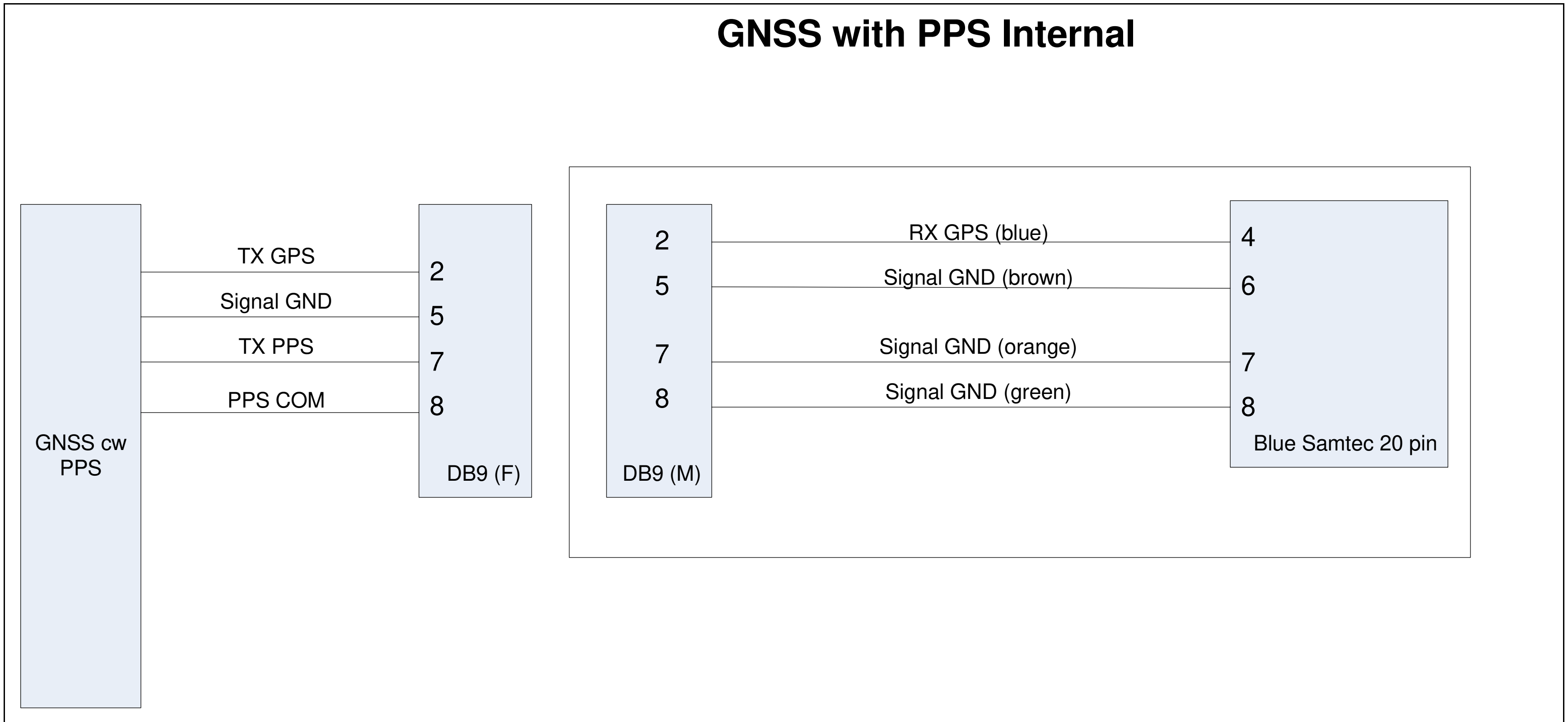


Figure 6-5 GNSS with Internal PPS

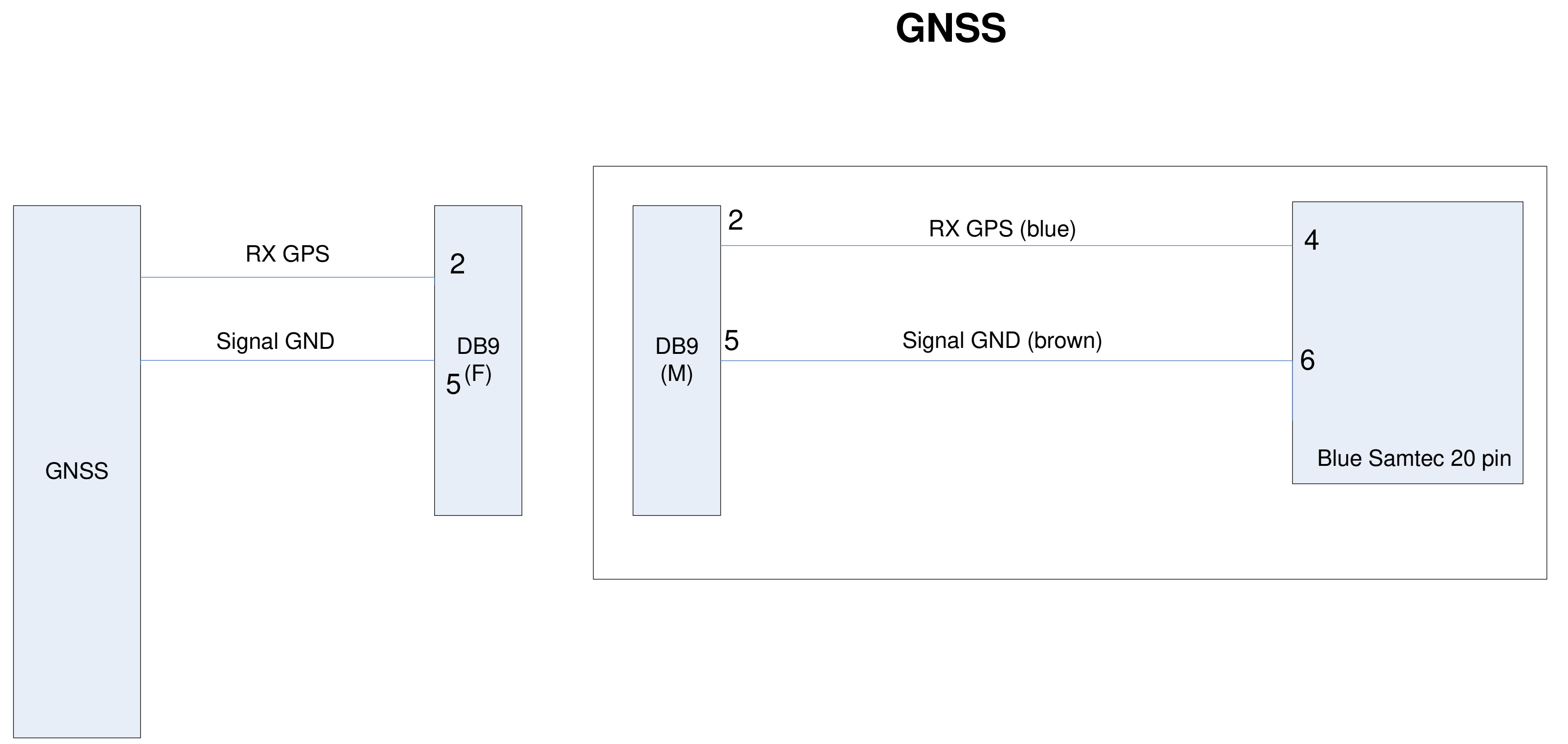


Figure 6-6 GNSS (no heading nor internal PPS)

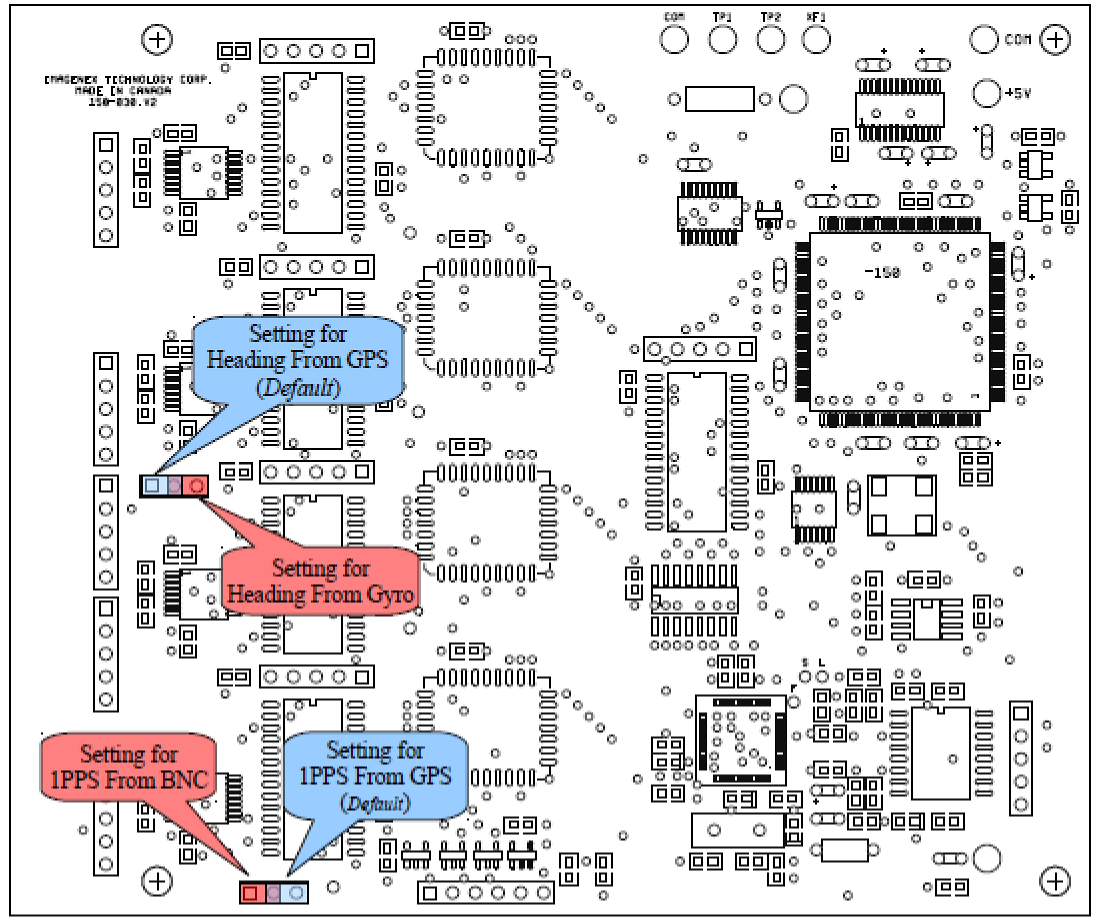


Figure 6-7 Jumpers for Heading and PPS Selection

3. Motion Reference Unit (MRU)

- The MRU is connected via a Samtec 20 pin (4+16) (yellow keyed) connector:

Panel = Samtec ACRK-22-05-G-S-C-P-4 4+16 pin (Yellow Keyed)			
Cable = Samtec ACPK-22-05-G-T-P-4			
Pin	**Direction (*Relative to SIR*)**	**Function**	**Note**
1	N/C		
2	N/C		
3	In		
4	In	MRU	RS232
5	Out	Reserved	
6	Out	COM	Signal Common
7	Out	Heading Assist	RS232
8	Out	COM	Signal Common
9	Out	GPS Assist	RS232
10	N/C	1PPS	5V Logic
11	N/C	COM	Signal Common
12	N/C		
13	N/C		
14	N/C		
15	N/C		
16	N/C		
17	N/A	SHLD	Shield
18	Out	+24V	Power
19			
20	Out	COM	Power Common

Table 6-4

- Power is available on Pin 18, Pin 20 (12 VDC or 24 VDC option depending on jumper setting (see Figure 6-8)) for powering of MRU if required:
- The MRU port receives data as a TSS1 format string (`XXAAAASMHHHHQMRRRRSMPPPP<CR><LF>`) on Pin 4, 6 (see Table 6-4).
- Communication parameters are set as follows in the SIR unit (Table 6-5):

Item	**Settings**
Baud rate	19200
Number of bits	8
Stop bit	1
Parity bit	None
Supported strings	TSS1 Format

Table 6-5

- If a PPS is required for the MRU used, it is available Pin 10. (Table 6-4)
- Note that GPS and Heading assist allows for enabled MRUs to receive NMEA stings to assist with motion reference. If used, Pin 7 (Heading) and Pin 9 (GPS) should be used to supply NMEA strings to the Enabled MRU.

4. Heading

- Heading is connected via a Samtec 8 pin (blue keyed) connector:

Panel = Samtec ACRK-22-03-G-S-C-P-3 8 pin (*Blue Keyed)*			
Cable = Samtec ACPK-22-03-G-T-P-3			
Pin	**Direction (*Relative to SIR*)**	**Function**	**Note**
1	Out	24V	Power
2	Out	COM	Power
3	N/C		
4	In	HEADING	RS232
5	Out	Reserved	
6	Out	COM	Signal Common
7	N/C		
8	N/A	SHLD	Shield
Table 6-6			

- Power is available on Pin 1, Pin 2 (12 VDC or 24 VDC option depending on jumper setting (see Figure 6-8)) for powering of heading sensor if required:
- The Heading port receives sound heading data as an NMEA $HEHDT format string ($HEHDT, x.xx,T,*hh<CR><LF>).
- Power is also on Pin 1, Pin 2 (12 VDC or 24 VDC option depending on setting Figure 6-8):
- Refer to jumper described in Section 2 GNSS (GPS) for enabling of this port
- Communication parameters are set as follows in the SIR unit:

Item	**Settings**
Baud rate	19200
Number of bits	8
Stop bit	1
Parity bit	None
Supported strings	$HEHDT, x.xx,T,*hh<CR><LF>
Table 6-7	

5. Sound Velocity Sensor (SVS)

- Sound Velocity is connected via a Samtec 8 pin (orange keyed) connector:

Panel = Samtec ACRK-22-03-G-S-C-P-1 8 pin (*Orange Keyed*)			
Cable = Samtec ACPK-22-03-G-T-P-1			
Pin	**Direction (*Relative to SIR*)**	**Function**	**Note**
1	Out	+24 VDC	Power
2	Out	COM	Power Common
3	N/C		
4	In	SV	RS232
5	Out	Reserved	
6	Out	COM	Signal Common
7	N/C		
8	N/A	SHLD	Signal Common

Table 6-8

- Power is available on Pin 1, Pin 2 (12 VDC or 24 VDC option depending on jumper setting (see Figure 6-8)) for powering of SV sensor if required:
- The SV port receives sound velocity data as an AML format string (nnnn.n<CR><LF>) on pin 4 (see Table 6-8).
- Communication parameters are set as follows in the SIR unit:

Item	Settings
Baud rate	19200
Number of bits	8
Stop bit	1
Parity bit	None
Supported strings	AML

Table 6-9

6. Power

- Power is supplied via a 100 – 240 VAC (C13) ‘kettle cord’ connector;
- Or a 9 – 36 VDC Samtec 6 Pin (orange keyed) connector:

Panel = Samtec ACRK-12-05-G-T-C-P-1 6 pin (Orange Keyed)			
Cable = Samtec ACPK-12-05-G-S-P-1			
Pin	**Direction (*Relative to SIR*)**	**Function**	**Note**
1	In	+12 to + 36 VDC	Power
2	Out	COM	Power Common
3	N/C		
4	N/C		
5	N/C		
6	N/A	SHIELD	Shield

Table 6-10

- DC power is made available on the GNSS (GPS), MRU, Heading, and Sound Velocity ports at 12 VDC / 24 VDC option depending on jumper setting (see Figure 6-8)).

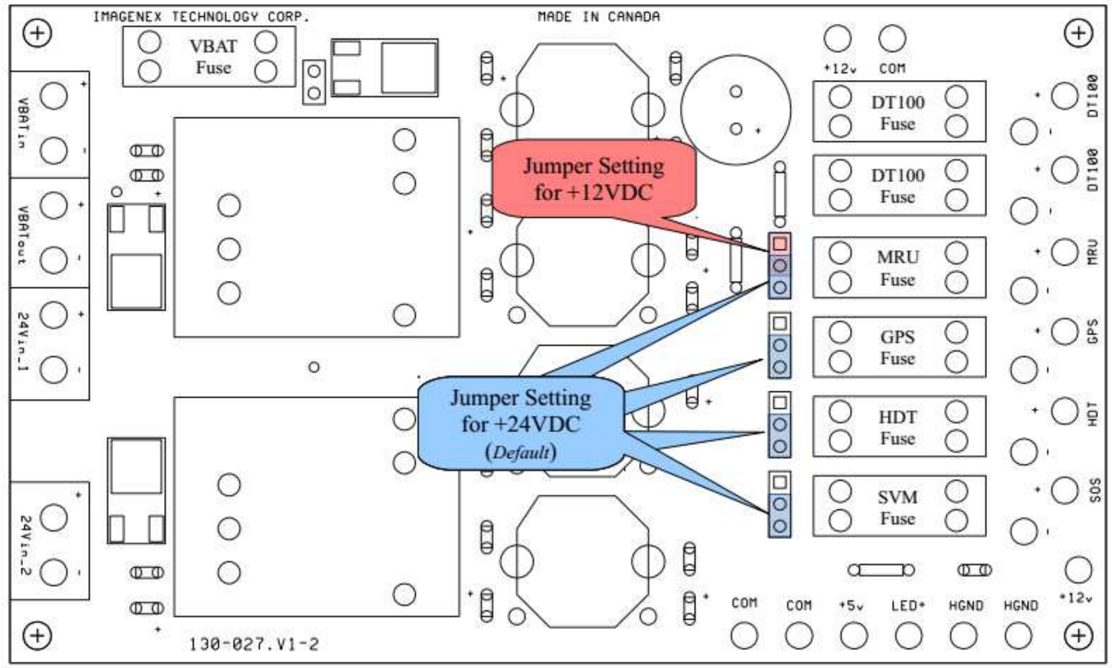


Figure 6-8 Power Supply Voltage Option

7. Ethernet (SIR Processing and Beamforming Computer)

- Standard 100 Mbps Ethernet via RJ45 connector. Recommended wired as **T-568B** (no crossover):

Pin	Colour
1	White/Orange (Transmit +)
2	Orange (Transmit -)
3	White/Green (Receive +)
4	Blue
5	White/Blue
6	Green (Receive -)
7	White/Brown
8	Brown

Table 6-11

- SIR Processing and Beamforming Computer to run DT101Xi_SIR software.
- TCP/IP and UDP setup see (APPENDIX D)

8. Ethernet (Data acquisition (navigation) computer)

- Standard 100 Mbps Ethernet via RJ45 connector. Recommended specification is Cat 5e and wiring scheme **T-568B** (no crossover):

Pin	Colour
1	White/Orange (Transmit +)
2	Orange (Transmit -)
3	White/Green (Receive +)
4	Blue
5	White/Blue
6	Green (Receive -)
7	White/Brown
8	Brown

Table 6-12

- Navigation computer running acquisition software and receiving D1P datagram (**Error! Reference source not found.**).
- For TCP/IP and UDP setup see APPENDIX D
- It is recommended that the proprietary IGX data format is logged during all operations as this format may be used to diagnose any issues that may have occurred, as well as generate (through utility programs) a D1P (point output) and a D1B (beam output). These formats may be useful for diagnostics and importation into other programs.

9. PPS BNC connector

- Depending on the user jumper settings (see Figure 6-7) the 1PPS input can be provided via either the GPS or the BNC connector.
- This optional input receives 0 – 5 VDC logic level 1PPS pulses.

10. GNSS (GPS) Out

- An additional **DB9** port is provided, that outputs buffered GNSS (GPS) data for use with, for example, navigation software. The RS-232 Clear to Send (CTS) line provides a 1 PPS toggle pulse with a synchronised 1PPS toggle (Table 6-13):

Panel = DB9 (M)			
Pin	**Direction (*Relative to SIR*)**	**Function**	**Note**
1	In	DCD	Data Carrier Connect
2	In	Rx	Recieve
3	Out	Tx	Transmit
4	Out	DTR	Data Terminal Ready
5	Out	COM	Signal Common
6	Out	DSR	Data Set Ready
7	Out	RTS	Ready to Send
8	Out	CTS	Clear to Send
9	In	RI	Ring Indicator

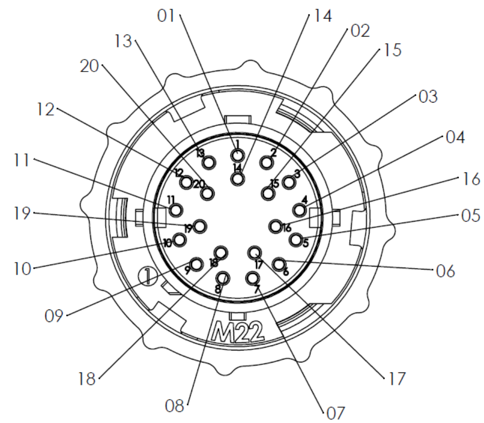
Table 6-13

- Communication parameters are set as follows in the SIR unit:

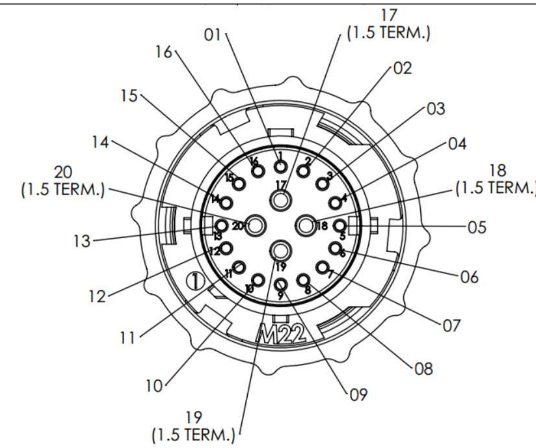
Item	Settings
Baud rate	19200
Number of bits	8
Stop bit	1
Parity bit	None
Transmitted Strings	NMEA ($GPGGA, $GPVTG, $GPZDA)

Table 6-14

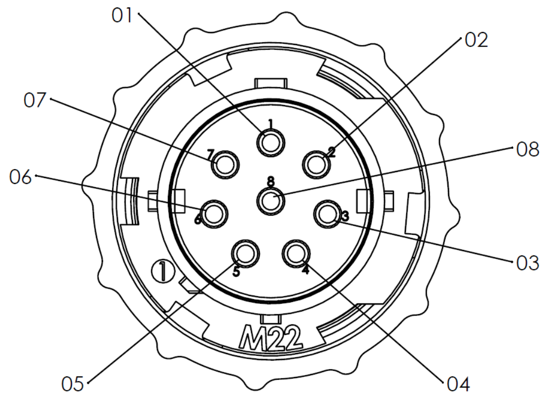
11. Samtec Connector Pin Outs



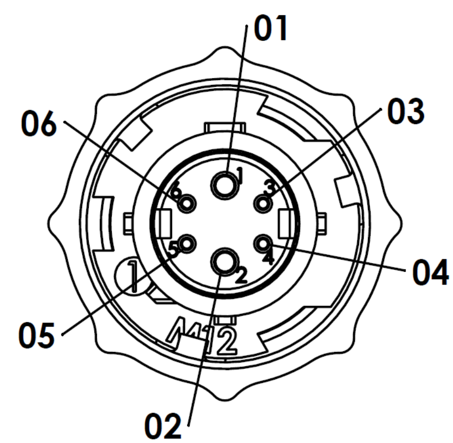
Sonar Head



GNSS (GPS), MRU



Heading, Sound Velocity



12-36 VDC Power

Table 6-15

APPENDIX D

WINDOWS™ TCP/IP SET-UP AND TROUBLESHOOTING

The SIR unit communicates with the DT101_SIR software running on an attached PC. The connection to the SIR unit is made via Ethernet and uses the TCP/IP protocol. In order for connection to occur, the TCP/IP parameters need to be set-up in Windows™. The following pages detail the set-up process:

Ethernet set-up

The DT101Xi / DT102Xi uses the following addresses:

IP Address	192.168.0.X
Subnet Mask	255.255.255.0

Where 'X' is a decimal number between 3 and 224. (The number '1' is reserved for a network server, '2' is reserved for the DT101Xi or DT102Xi sonar head, 10 is reserved for the SIR box, and 255 is reserved for broadcasting).

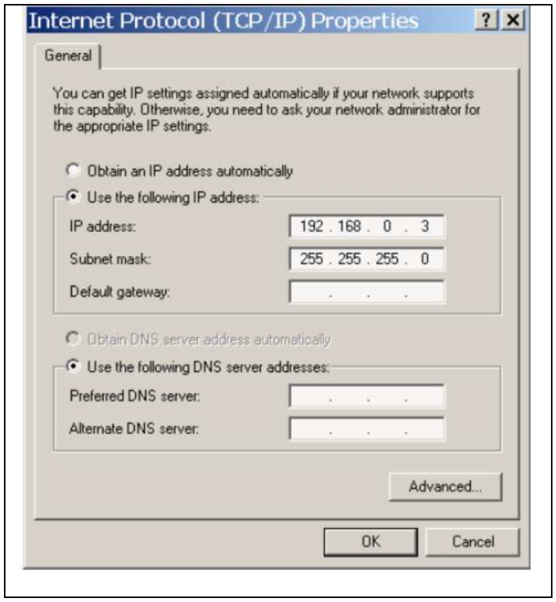
The DT100 sonar head has a statically assigned IP Address of **192.168.0.2**. This is the number to enter in the *Setup > IP Address* menu of the DT100_SIR program, and should not be changed.

The recommended PC IP Address and Subnet mask is as follows:

IP Address	192.168.0.3
Subnet Mask	255.255.255.0

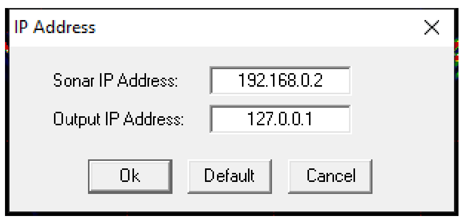
This is done as follows (Windows™ 10):

- Navigate to the Control Panel and double click 'Network and Sharing Centre'
- Click 'Change adapter settings'
- Right click on the Ethernet interface you wish to connect with and select 'Properties'
- Select 'Internet Protocol Version 4 (TCP/IPv4)'
- Click Properties
- Configure as follows and click OK:



Now the computer is on the same network as the sonar head. When starting the DT100_SIR program, the IP address stored in the “DT100.INI” file is read and a connection will be established.

A loopback IP address can also be set in the DT100_SIR program (*Setup > IP Address: Output IP Address)*. This sets an internal IP address so that both the DT100_SIR program **and** any navigation package may be run on the same computer. If used, this IP address should be set to 127.0.0.1. If not, it should be set to the static IP address of the computer running the navigation software.



The sonar head should function correctly however if communication does not function properly, try the suggestions listed in the troubleshooting guide below:

Disable any network bridges that are present

- A network bridge allows a separate port, such as “USB”, or “Firewire” to piggyback the Ethernet connection.
- Under “Network Connections”, if there is a network bridge icon, disable it.

Disable any other network devices that are present on the computer

- Often, if there are multiple network cards present, Windows™ may communicate through an incorrect one. This is more of an issue on laptops with wireless connections.
- Right-click on each connection and select “*Disable*”.

Under “Network Connections”, right-click on the Ethernet card and select properties.

Clear unnecessary network protocols

- De-select all services except for Internet Protocol Version 4 (TCP/IPv4)

Remove any firewalls present

- Select the “Advanced” Tab. De-select the Firewall option (if present).

Click ‘Configure’ (in the General tab).

- Set Link speed to “Auto” or “10Mbps”
- In the ‘Advanced’ tab, select ‘Link Speed / Duplex Mode’ and set to either ‘Auto Mode’ or ‘10 Full Mode’.
- Disable any power saving that shuts down the Ethernet card.
- In the “Advanced” tab, select “Link Down Power Saving” and set to “*Disable*”.
- In the “Power Management” tab, de-select any power saving option.
- Repair the Ethernet connection. Windows™ remembers the hardware address for each socket. To clear the Windows™ settings, right-click on the Local Area Connection and select ‘Repair’.

APPENDIX E

QUICK CHECK LIST

No	Check	Document No	Page
	Pre-Mobilization		
1.	DT100 Software PC Specification (Minimum i5, 8 GB Ram, USB 3)	430-040-00	6
2.	Cables	430-041-00	41-60
3.	Enable RTK / DGPS / DGNSS	430-041-00	16
4.	Tide Station / RTK	430-041-00	16
5.	ENC / Background Graphics	430-041-00	16
6.	Vessel outline measurements	430-041-00	12
7.	Measure offsets and update in navigation software	430-041-00	10

No	Check	Document No	Page
	Mobilization		
8.	Check most recent version of software (https://imagenex.com/interior-page/software-download)	430-040-00	6
9.	Set baud rate in external sensors (19200, 8, N, 1)	430-041-00	43
10	Connect sensors	430-041-00	8
11	Ground SIR box	430-041-00	10
12	Establish a source for PPS and $GPZDA. Connect to SIR BNC connector if relevant.	430-041-00	16
13	Mount sonar head	430-041-00	8
14	Set IP address in control PC (195.168.0.x) - x = unique number except 1, 2, 10 or 255	430-040-00	11
15	Configure internal SIR jumpers for required configuration	430-041-00	41-60
16	Update gyro latitude (if used)	430-041-00	9
17	Test data through SIR box	430-041-00	9
18	Set geodesy in nav package	430-041-00	16
19	Update vessel outline	430-041-00	12
20	Configure and test navigation software (head IP = 195.168.0.2)	430-040-00	
21	Plan run-lines	430-041-00	12

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	Calibration / Patch Test		
22	Conduct SV cast in deepest part of survey	430-041-00	18
23	Plan patch test in deepest part of survey	430-041-00	19
24	Apply Tilt Angle in DT100 SIR software	430-040-00	21
25	Latency – over feature, same direction, 2 different speeds	430-041-00	19
26	Roll – flat seabed, same run-line, opposite directions	430-041-00	19
27	Pitch – over feature, same run-line, opposite directions	430-041-00	19
28	Yaw – over feature – adjacent run-lines – opposite directions with overlap	430-041-00	19
29	Process patch test and update values	N/A	N/A

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Software configuration			
30.	Set Range (1.5 to 2 X water depth)	430-040-00	7
31.	Set Gain (start at 10 dB and adjust)	430-040-00	7
32.	Set Display Gain (50%)	430-040-00	
33.	Set-up IP addresses	430-040-00	11
34.	Set-up units	430-040-00	11
35.	Set-up max file size if required	430-040-00	11
36.	Set-up heading input port (Gyro or DGNSS)	430-040-00	12
37.	Set-up MRU Input port (Integrated or external MRU)	430-040-00	12
38.	Set-up sound velocity source	430-040-00	12
39.	Enable Overlap Sonar I/O (for faster ping rate)	430-040-00	12
40.	Set-up sector size	430-040-00	13
41.	Set-up number of beams	430-040-00	13
42.	Set-up averaging	430-040-00	13
43.	Enable gain equalization	430-040-00	13
44.	Enable Automatic Gain Control	430-040-00	17
45.	Select preferred profile point display (Usually High mix)	430-040-00	18
46.	Set Profile Point Detection Min and Max (text box or handles)	430-040-00	18
47.	Select Profile Point Filter type.	430-040-00	19
48.	Select Display settings	430-040-00	19
49.	Apply Roll Correction	430-040-00	20
50.	Apply tilt angle	430-040-00	21
51.	Ensure Data Output is set to D1P for most applications	430-040-00	22

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Operation			
52	Conduct regular SV cast	430-041-00	18
53	Log .IGX file	430-040-00	9