Synapse and
Synapse Horizontal Gradiometer

Quick Start Guide

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1 Introduction

Synapse is a high-sensitivity total field marine magnetometer packaged into a rugged marine towfish housing designed to be towed behind a vessel (manned or autonomous), an AUV or a side-scan sonar. Measurement of the magnetic field is performed completely inside the towfish. In addition to the magnetometer, each Synapse towfish can be equipped with a depth sensor, altimeter, IMU and leak detector. Power and communication are supplied to the towfish from the isolation transceiver via a single tow cable. The transceiver acts as a top-side unit and can communicate with any data logger computer via RS-232 or USB interface. For side-scan integrations, the isolation transceiver is embedded into the integration cable.

A Synapse array system may include 2 or more (up to 30) nodes interconnected via a single CAN bus daisy chain cable, and can be installed on frames of various geometries. Synapse arrays require that a single Master node be assigned to communicate with the top-side PC via the isolation transceiver. This Master node will synchronize the entire array and combine data from all nodes into a single data string. Any node in the array can be assigned to act as a Master node, but only one Master node can be present in the system for communication to work. User commands are communicated to all array nodes, but the Master node is the only node that will communicate back.

Each Synapse magnetometer can be equipped with a 200 kHz single-beam echo sounder altimeter. When two Synapse units are used as a pair, one of the altimeters should be deactivated to prevent mutual interference.

Synapse command protocol includes commands for enabling or disabling individual peripheral sensors within each towfish, as well as assigning the master node, selecting one of several available data formats and much more.

The total power consumption of a Synapse system consists of 7.5W for each of the Synapse towfish equipped with an altimeter (4.5W without an altimeter), and 1.5-2W for the isolation transceiver.

1.1 Magnetometer sensor technology

Synapse magnetometers can be equipped with either a Rubidium vapor optically-pumped sensor, or an Overhauser effect omnidirectional sensor.

Synapse Rubidium magnetometer is based on an advanced Rubidium vapor optically-pumped (OPM) microcell to measure the geomagnetic field with high precision and accuracy. The Rubidium OPM sensor combines small size, light weight, ruggedness and low power consumption with high sensitivity and fast sample rates of 10 Hz, 20 Hz or higher.

The Rubidium OPM sensor has a single dead zone: equatorial. This means that the sensor itself cannot be oriented perpendicular to the ambient magnetic field. All Synapse Rubidium towfish have magnetometer sensors oriented horizontally along the towfish axis, ensuring that they will work in a wide range of geographic latitudes, except equatorial waters within +/- 10 degrees of the magnetic equator. For use in those regions, the sensor orientation may be changed to horizontal (by Marine Magnetics, at the request of the customer).

Synapse Overhauser magnetometer is based on the omnidirectional Overhauser sensor known for its superb absolute accuracy and lack of dead zones that enable it to operate in any region of the World. The Overhauser sensor operates on the proton spin resonance principle, which is drastically different from a conventional proton magnetometer sensor. The proton-rich liquid within the sensor has been specifically engineered to allow a principle known as the Overhauser effect to occur within it. The Overhauser sensor delivers higher sampling rates and significantly better sensitivity (one to two orders of magnitude) while using only a tiny fraction of the power and maintaining the excellent absolute accuracy and operational characteristics that have made conventional proton sensors so popular.

Recent advances in electronics and computing power have enabled us to extract even more signal from this workhorse sensor technology.

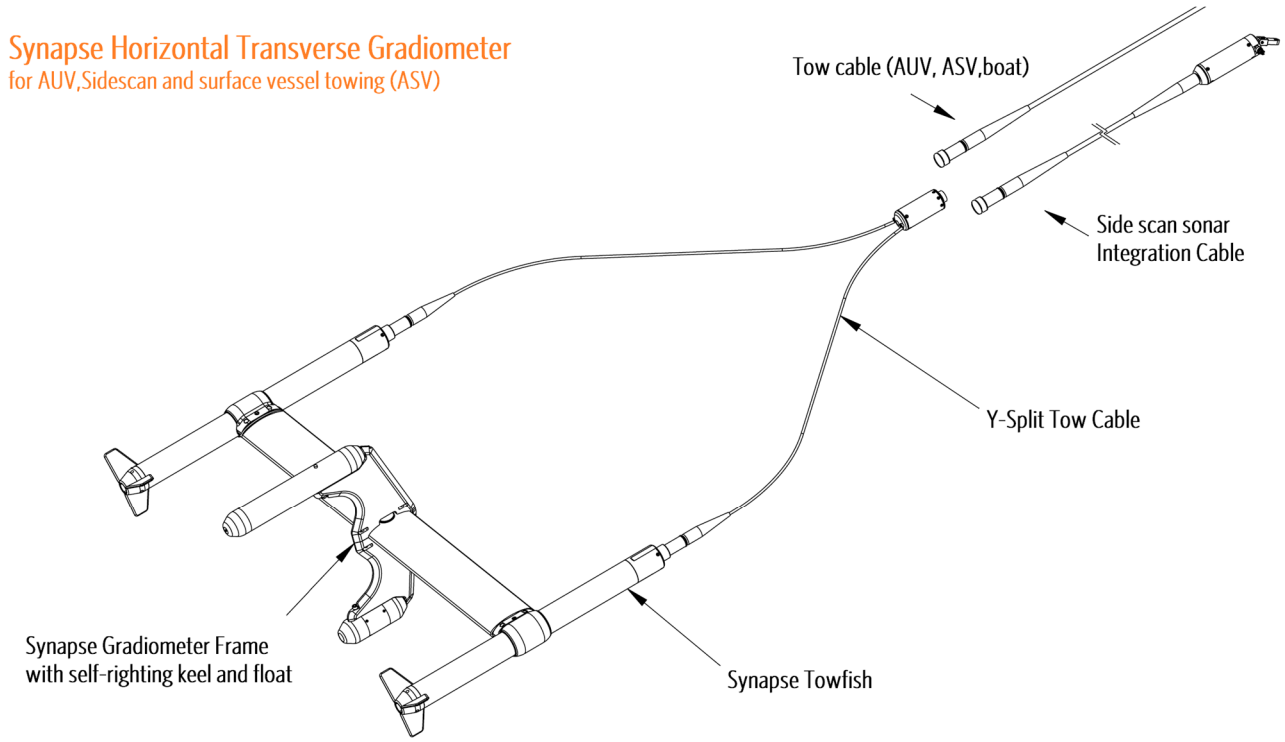
Marine Magnetics Overhauser sensors are omnidirectional and completely isotropic with respect to magnetic field direction. The only restriction that must be observed is that the towfish must not be oriented vertically with the nose (tow cable) facing directly upwards. This is a restriction with respect to the direction of gravity, not magnetic field.

1.2 Synapse Horizontal Transverse Gradiometer

The Synapse horizontal transverse gradiometer consists of two Synapse marine magnetometers that can be used individually or as a gradiometer pair when mounted on a lightweight and streamlined aluminum frame. For stability, the frame is equipped with vertical fins holding float and keel pods.

Synapse magnetometers are designed to be neutrally-buoyant in seawater (average density 1.025 g/cm^3). The horizontal aluminum frame can be filled with syntactic foam for overall neutral buoyancy for applications that demand it.

A Y-split tow cable adapter is used to connect the gradiometer pair to the tow cable, or side-scan sonar integration cable. When used independently, each Synapse magnetometer can be connected directly to either a tow cable or a side-scan integration cable.



2 Connection diagram

An isolation transceiver is required to operate the Synapse magnetometer system. In the case of the side-scan integration, the isolation transceiver electronics are included in the side-scan Integration Cable. The Synapse system combines data from all connected magnetometer nodes and sends it to the isolation transceiver via the tow connection. From the top-side data logging system's point of view, the interface is the same regardless of the number of magnetometer nodes connected.

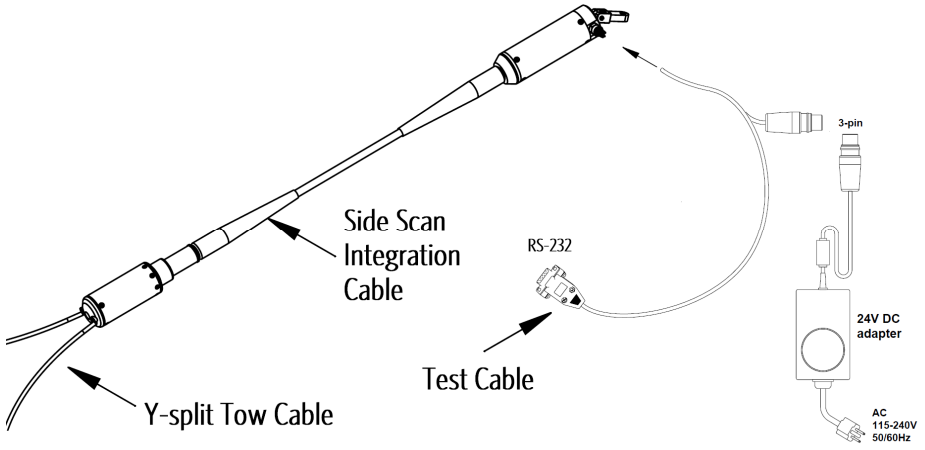


Figure 2-1 - Connection diagram for side-scan Integrations. The test cable and 24V DC adapter are only needed when testing communication without the side-scan sonar connected.

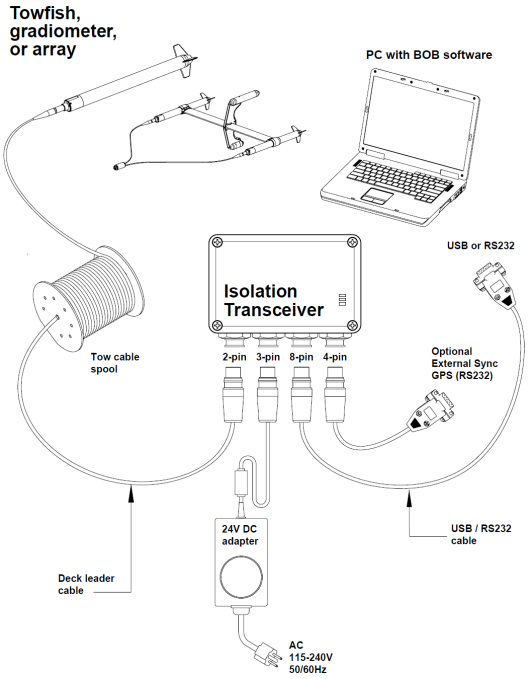


Figure 2-2 - Connection Diagram for surface towed applications. The 24V DC adapter is required to power the Isolation Transceiver at all times during system operation.

2.1 RS-232 Interface

The side-scan Integration cable contains an Isolation Transceiver similar to the one included with other towed magnetometers, but enclosed in a pressure housing. The isolation transceiver electronics provides a regulated and isolated power supply to the towfish and handles time synchronization as well as all communication with the towfish. Please refer to the RS-232 command interface and the Synapse communication protocol for details.

Default RS-232 Baud Rate: 115,200 baud

RS-232 baud rate can be configured using the **Ctrl+B** command in the RS-232 terminal. Refer to Section 7 for details.

2.2 Electrical Specifications

The electrical specifications for the isolation transceiver electronics in the side-scan integration cable are shown in Table 2-1.
Note that the minimum input voltage will increase towards 15V as the power demand increases towards the maximum rating of 25W.
If the output current to the magnetometer exceeds 0.75A, an internal fuse will trip and stay tripped until the output load returns to a reasonable level. It will then automatically reset itself. A short circuit in the tow cable or at the tow connector will not cause damage to either the interface electronics or the side-scan sonar, AUV or ROV system.

Parameter	Min	Typ.	Max	Units
Input Voltage	9-15	24	30	VDC
Input Power (1 mag)	-	10.3	10.3	W
Input Power (2-mag grad)	-	19	19	W
Input Current (1 mag / 1 mag +ALT)	-	0.42	0.43	A
Input Current (2 mag + 2 x ALT)	-	0.77	0.79	A
Output Voltage	-	45	-	VDC
Output Current – fused	-	-	750	mA
Output Power (1 mag / 1 mag +ALT)	4.5	8.3	8.3	W
Output Power (2 mag + 2 x ALT)	-	17	25	W
RS232 Baud Rate	2400*	115200	115200	bps

Table 2-1 - Electrical specifications of the Synapse side-scan Integration cable

*Although supported, baud rates below 9600 are not recommended for use with Synapse magnetometers, and can lead to communication delays and errors.

2.3 Synapse Node and Network Status LED

Each Synapse magnetometer has a bright 3-color status LED on the front bulkhead which indicates the state of its operation.

The LED shows a combination of background color and a flash color, which may be of variable duration. Together, the flash and background colors communicate information about the state of the node as well as its connectivity to the array network.
In general the background color reflects the state of the sensors in the node, while the flash color reflects the state of the network.

Table 2-2 - Synapse LED states

Node and Network states	LED Background color (Node and sensor state)	LED Flash color (Network state)
Magnetometer and its active sensors are operating correctly	GREEN	WHITE flash
Sensors are operating correctly, but this node is a client and **no Master is present**	GREEN	RED flash
Sensors are operating correctly, but magnetometer is not activated in this node	GREEN	CYAN flash
Magnetometer is warming up or trying to get a signal lock	BLUE	BLUE flash
Magnetometer is warming up or trying to get a signal lock, Node is a network client and **no Master is present**	BLUE	RED flash
Magnetometer is activated but not present (no data). Network is OK: synchronized and communicating	RED	VIOLET flash
Magnetometer is activated but not present, (no data). Node is a network client and **no Master is present**	RED	RED flash

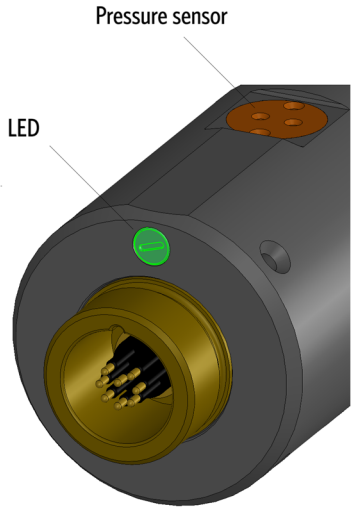


Figure 2-3 - Synapse status LED location on the magnetometer towfish

3 Gradiometer Frame Assembly

The horizontal transverse gradiometer frame consists of three main components that need to be assembled prior to deployment:

- Horizontal 'wing' with towfish collar clamps at both ends
- Vertical fin with an air-filled float pod
- Vertical fin with a weighted keel pod

The 'wing' is symmetrical and does not have a preferred orientation. However, the towfish collars contain bolts for clamping over the towfish only on one side (see Figure 3-2), that may be more convenient to adjust when facing upwards.

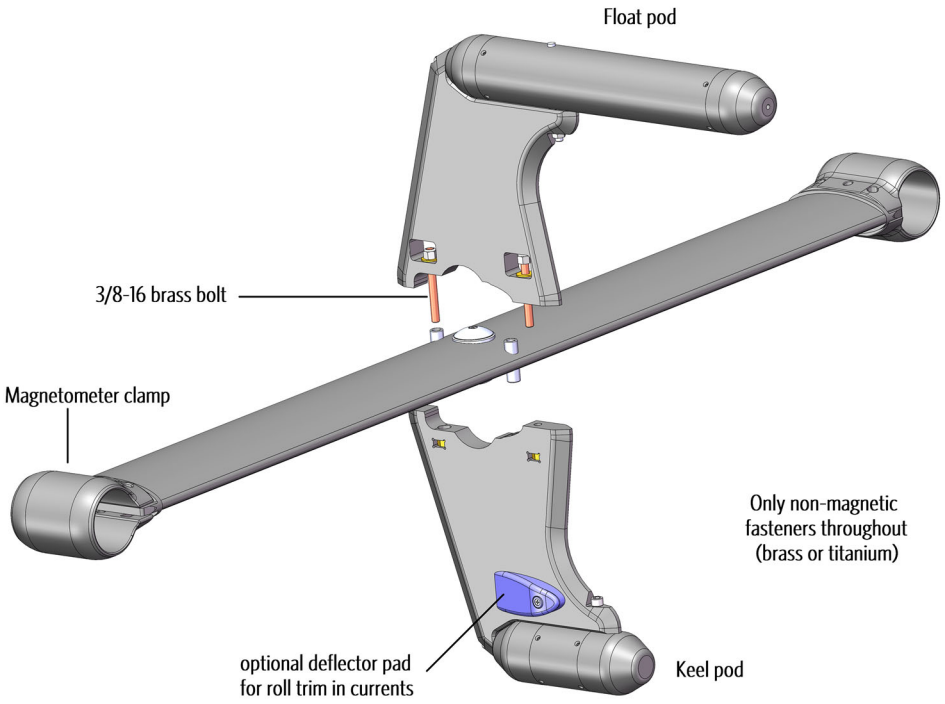


Figure 3-1 – Gradiometer frame components and assembly.

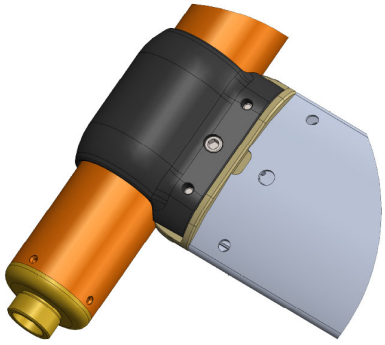


Figure 3-2 - Towfish collar clamps contain a single bolt (centered) that requires adjusting when clamping over the tube, and two bolts that affix the collar permanently to the 'wing' and do not require adjusting.

4 Layback distance estimation for optimal magnetometer positions

BOB software computes the position of the magnetometer sensor(s) during the survey using a combination of the fixed layback distance and the curve of the vessel's track. For best positional accuracy, the lengths of all system components must be included when determining the total 'layback' distance between the GPS receiver mounted on the vessel, and the magnetometer sensor.

The side-scan integration cable is 5.3m long, while the Y-split adapter cable adds 4.3m. The magnetometer sensor is located at the tail end of the towfish, adding a further 0.8m. This combined magnetometer offset from the side-scan sonar tow connection to the tail end of the magnetometer towfish (sensor location) amounts to 10.4m when the Y-split adapter cable is used with the gradiometer frame. When a single Synapse towfish is used without the Y-split adapter cable, the total magnetometer offset is 6.1m.

When used in combination with a side-scan sonar, one additional unknown dimension must be accounted for: the offset between the GPS receiver on the vessel, and the side-scan integration cable tow point. If this distance can be approximated as a constant with an accuracy of +/- 0.5m, it may serve as a sufficiently accurate initial estimate for layback calculations. Total layback can be fine-tuned during post-processing after initial magnetic field maps are generated, as part of the layback (lag) correction step.

For best results when towing the magnetometer with a side-scan sonar, it is recommended to use an acoustic positioning beacon (e.g. USBL) to determine the position of the side-scan sonar and feed that time-stamped position data into the magnetometer data logging software in combination with the magnetometer offset. Please note that the date and time included in the USBL data stream must be synchronized with the date and time of the magnetometer system data stream (i.e. they must use the same common time zone. UTC time is recommended)

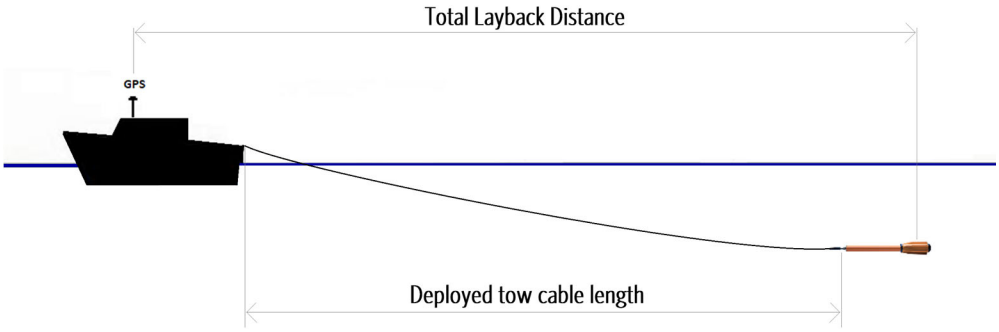


Table 4-1 – Layback distance estimation for surface towed magnetometers

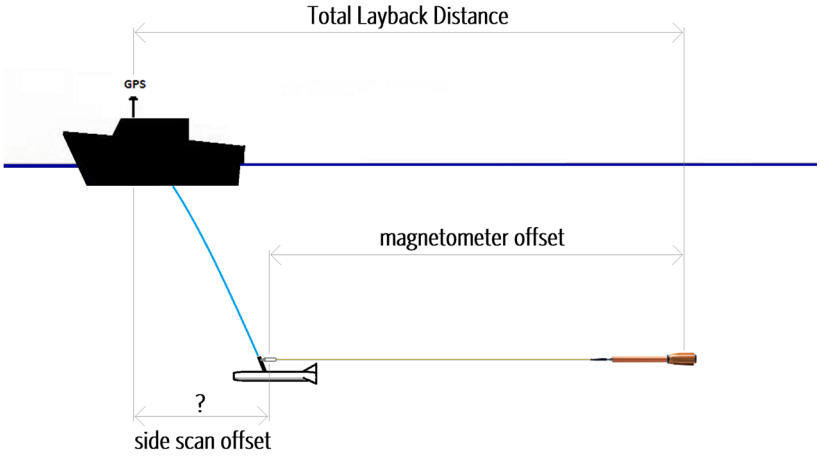


Table 4-2 - Layback distance estimation for side-scan sonar integrations

Tow cable length must be adjusted appropriately for the length of the magnetometer system before determining the magnetometer offset. The magnetometer sensor is located at the back of the Synapse towfish, increasing the effective length of the tow cable.
The use of a Y-split cable (for horizontal gradiometers) further increases the effective cable length.

Table 4-3 - Adjustment required to determine the effective tow cable length for different magnetometer models

Magnetometer model	Tow cable length adjustment
Synapse	+ 0.75 m
Synapse Horizontal gradiometer	+ 4.4 m
Synapse Array	(depends on frame dimensions)

4.1 Pressure Sensor

Pressure (depth) sensor options available in Synapse towfish are outlined in Table 4-4. The choice of the sensor affects its precision as well as the maximum pressure limit that it can withstand before sustaining permanent damage. Exceeding this pressure can cause a change in the calibration tuning of the sensor, and its accuracy may suffer as a result.

Note that the standard Synapse housing as a whole is rated to a depth of 1000m, which should never be exceeded or damage to the housing may result.

Table 4-4 - Pressure sensor options

Depth Range	Pressure Range	Precision	Housing
345 m	500 PSI	0.1 m	1000m standard
1000 m	1500 PSI	0.3 m	1000m standard

The pressure sensor is an analog device that may drift with temperature and with time. For proper operation, the pressure sensor's zero-level should be reset prior to every survey. For best results in calibration, the towfish should be submerged to allow the temperature of the pressure sensor to reach the water temperature and then retrieved back to air to calibrate the zero-depth pressure. Use either **p** or **$dzro** commands to set the zero pressure level. Please refer to the Synapse command protocol for further details.

The **P** (capital P) command will display the current pressure sensor calibration settings and will offer the option to set the full-scale pressure calibration. The full-scale calibration is factory-set and does not need to be altered by the operator unless below-nominal full-scale accuracy is suspected.

The pressure sensor may be calibrated by entering the factory full-scale calibration value, by entering a nominal value that is valid for a generic sensor of a given pressure range, or by submerging the towfish to a known depth and entering that depth.

4.2 Altimeter - Optional

A Synapse towfish may be equipped with an optional 200kHz single-beam echo sounder altimeter. This device senses the distance from the towfish to the sea bottom by emitting sound pulses and measuring the time elapsed before the echoes return. It is a self-contained digital device that does not require calibration. The altimeter continuously varies its power output gain in response to the strength of the returns it receives and can adjust to a wide range of distances automatically.

The Synapse altimeter has a range of 1m to 90m, and a resolution of 0.1m. An altitude value expressed in meters is added to every magnetic field reading and is formatted as follows 'A:015.05m' in the serial terminal.Note that the altitude data field does not appear if an altimeter is not installed in the towfish, or if the altimeter is disabled as a peripheral in the Synapse configuration menu. Please refer to the Synapse command protocol for further details.

The value 'A:599.99m' will be shown whenever the altimeter is out of range (does not detect any return), or the towfish is not submerged in water. This indicates that the altimeter cannot 'find' a surface underneath the towfish, but that the altimeter is working properly. If the altimeter were to stop functioning, the 'A:' field would disappear from the data stream completely or will be replaced with dashes.

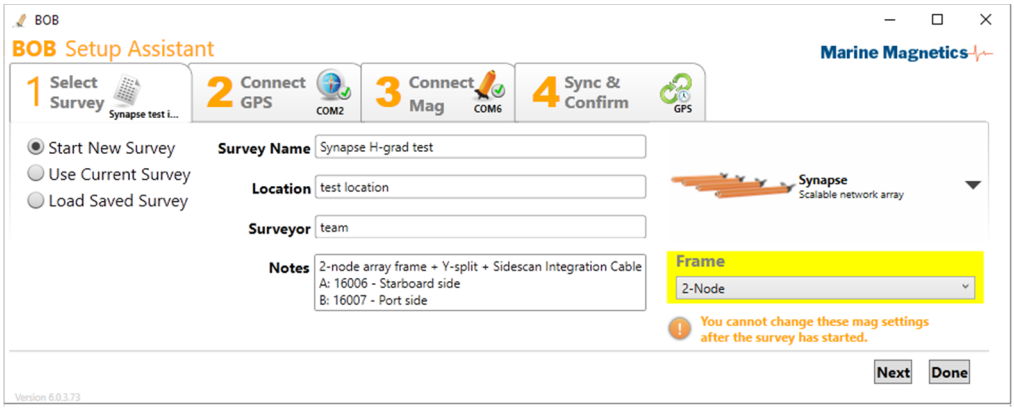
Please refer to Section 8 for details on the altimeter data format.

5 Operating the Synapse system using BOB Software

Marine Magnetics BOB is the magnetometer interface software that provides data logging, survey planning and data corrections for all Marine Magnetics products. Additional processing and data visualization features can also be activated using the BOB Analytic Module (BAM) license. Free BOB software is available from the following URL: https://bob.marinemagnetics.com/

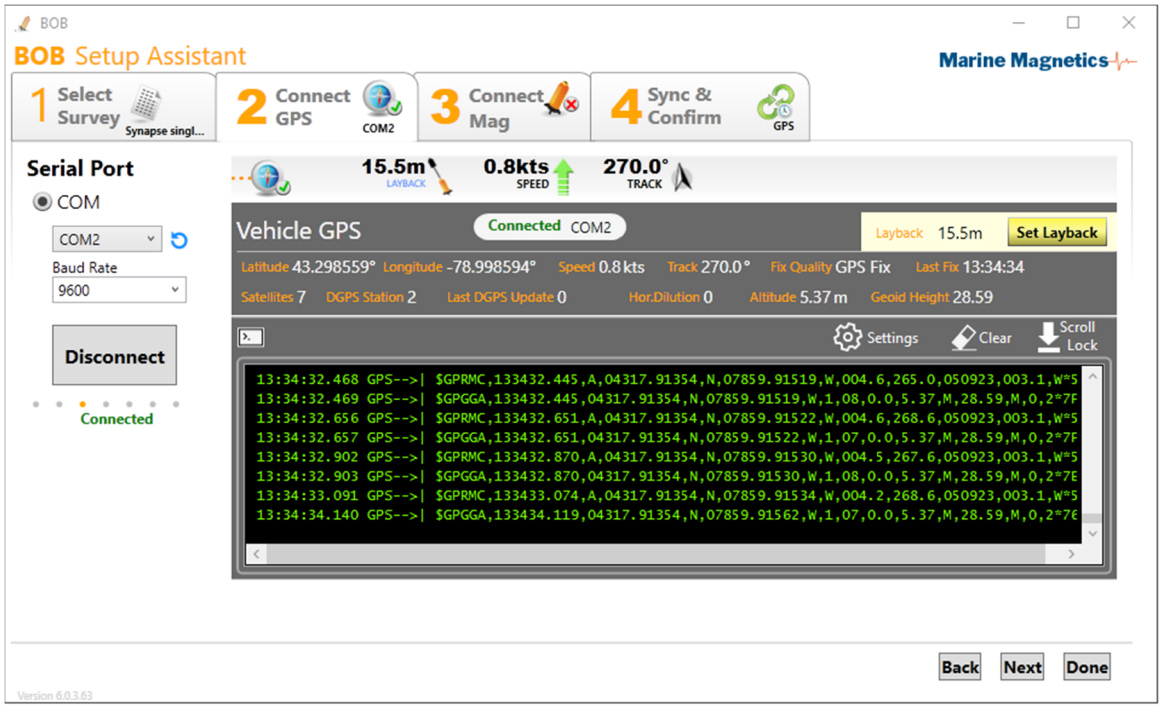
Described below are BOB Setup Assistant steps for configuring a new Synapse system survey.

1. **Create a new survey and select the appropriate magnetometer type: Synapse Array, and number of nodes**



Note that the magnetometer type cannot be changed after the survey has been created.
Once the array or a certain size is configured, the number of nodes cannot be changed without creating a new survey.

2. **Connect to the GPS via COM port.**
BOB supports RS-232 or virtual COM port GPS, and uses only GxGGA and GxRMC NMEA data strings. 5Hz or higher update rate is recommended. Default Layback is set to 15.5m, and can be modified later via the BOB GeoPlot window, as well as during post-processing.



3. **Connect to the Magnetometer via COM port.**
   BOB supports RS-232 or virtual COM port connections and communicates with the isolation transceiver.
   Use 115,200 baud rate for Synapse systems. Refer to Section 7 for details on RS-232 baud rate configuration.

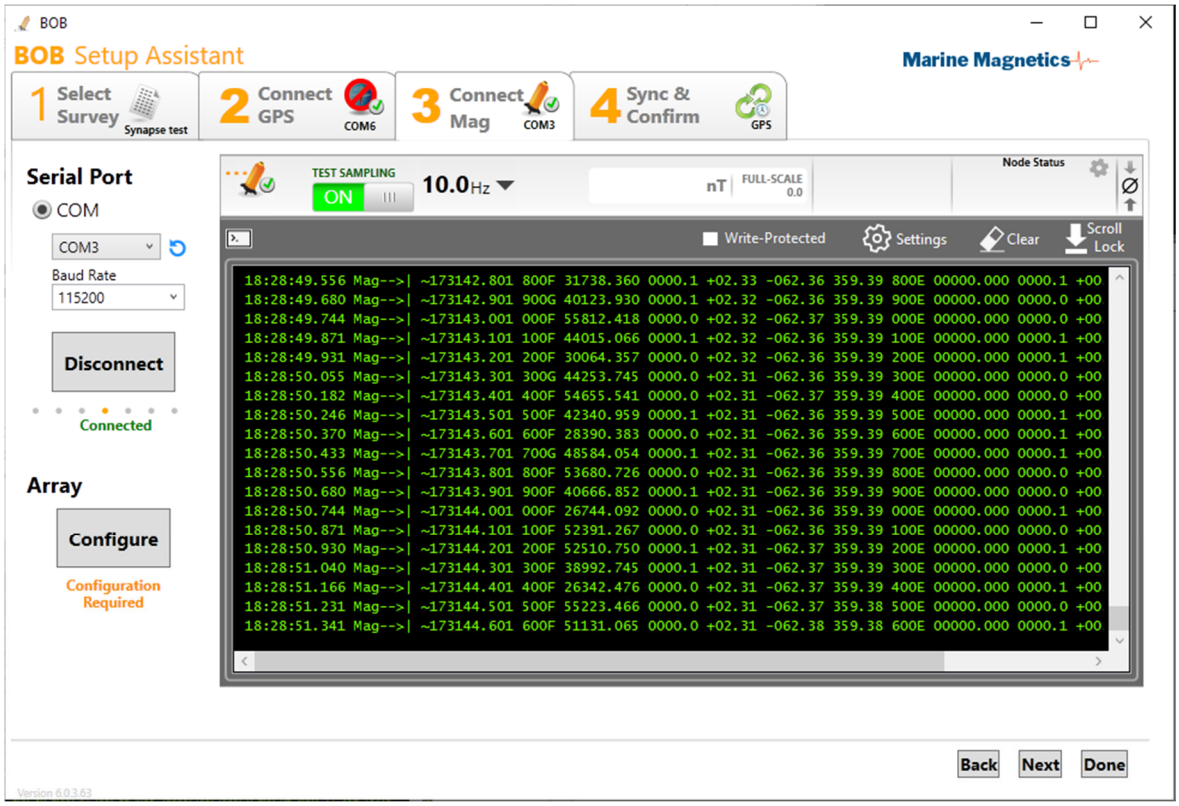


Figure 5-1 - Typical data output of a 2-node Synapse system during start-up

Synapse magnetometers are designed to start sampling at 10 Hz upon power-up.
Due to the inherent flexibility of Synapse arrays, BOB requires the array 'frame' to be configured before proceeding with data collection.
The array configuration may include 1 or more nodes and can use various frames and arrangements. At this time, three configurations are supported: a single synapse towfish, a 2-node horizontal transverse gradiometer frame and a 5-node horizontal array.

All Synapse systems also require that a single Master node be assigned. This node will collate all the data from the array and communicate with the isolation transceiver. The Master node is the only node that will respond to the transceiver commands.

Any node in the array can be assigned to act as a Master node, but only one Master node can be present in the system for communication to work. When no master node is selected, the Synapse system will not respond, and it will appear as though none of the nodes are connected to the transceiver.
When more than one master node is assigned, communication cross-talk results in 'bad data', which consists of random characters in every data string.

Please refer to Section 8 for details on Synapse Data Format.

5.1 Single Synapse configuration in BOB

To configure a Synapse system with a single node, select the single node option from the drop-down menu and ensure the node serial number is configured as Master node.
The configuration tool will appear blank if the connected Synapse unit is not configured to act as Master.
Enter the unit's serial number into the "Master Node: box and click "Assign".

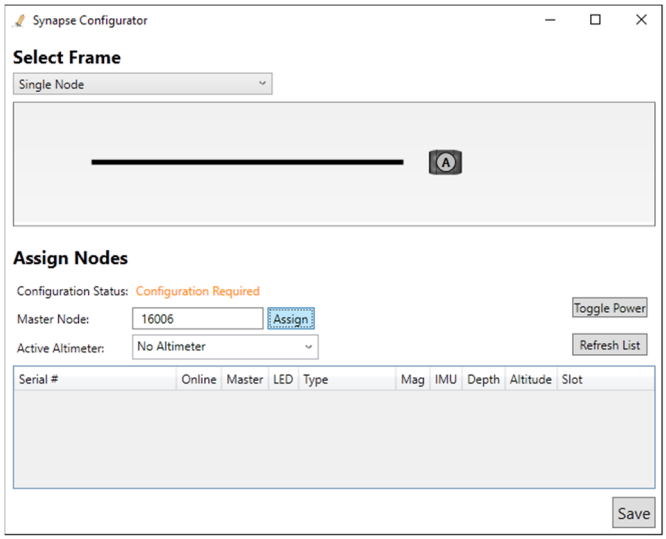


Figure 5-2 - Synapse configuration for a single node not yet configured to act as the Master node.

Once the connected Synapse node is configured to act as Master node, the list of connected nodes should get updated, and you should see incoming data in the terminal window.

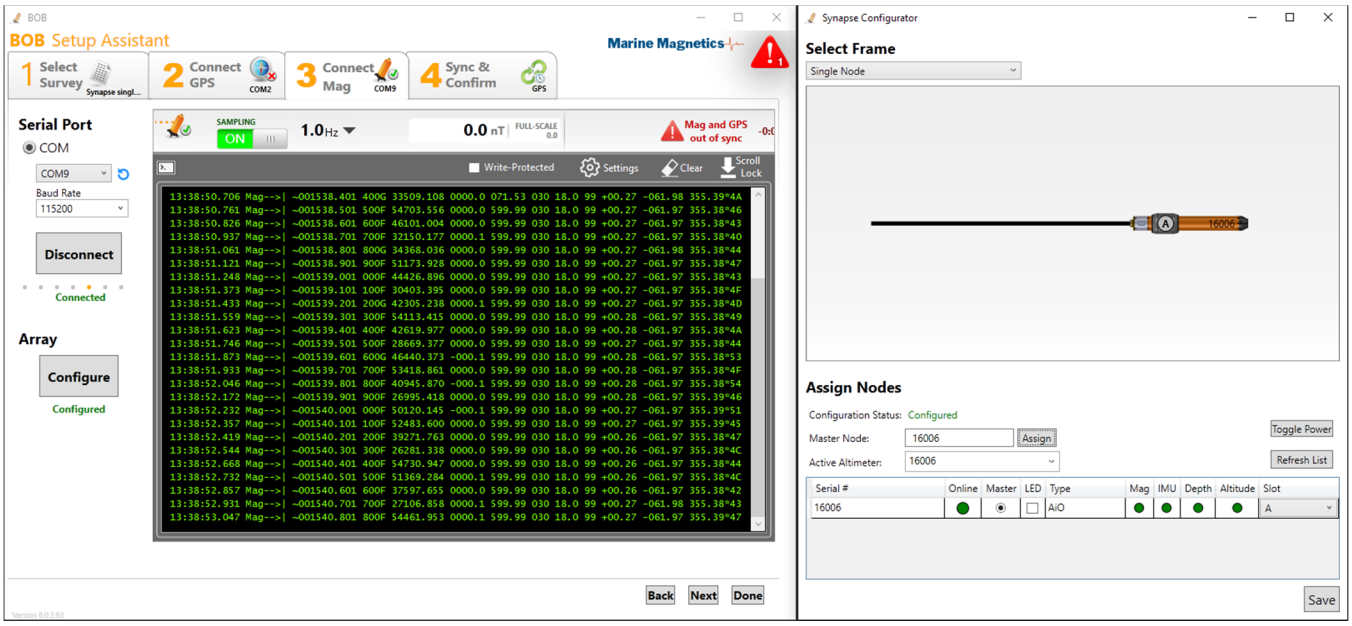


Figure 5-3 - Typical data output from a single Synapse magnetometer
containing time, magnetic field, depth, altitude and IMU sensors,
with a configuration window confirming that this unit is configured as Master node, and its altimeter is enabled.

5.2 2-Node Synapse array configuration in BOB

To configure a Synapse system with two nodes, select the Horizontal Gradiometer option from the drop-down menu. Only one node can be configured as the Master node in an array.

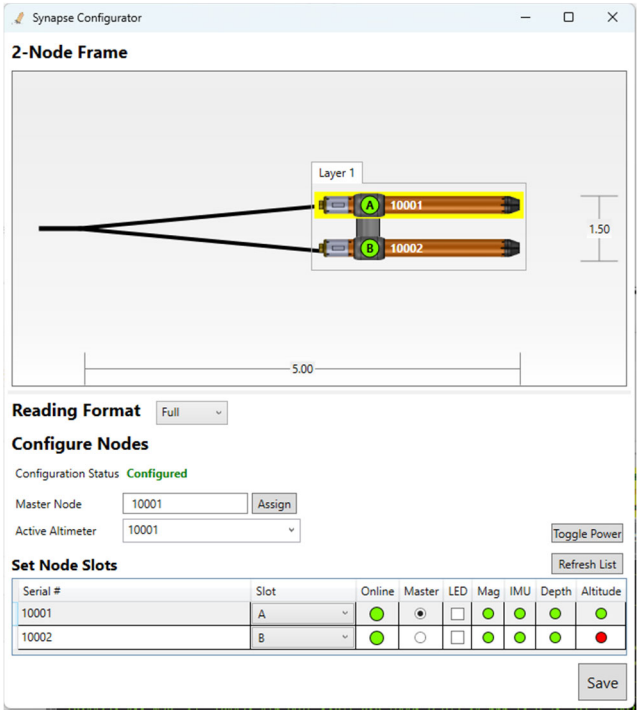


Figure 5-4 - Synapse configuration for a 2-node array with one Master node.
The offsets shown correspond to the 1.5m Horizontal Gradiometer frame attached to a 4.3m Y-split adapter.

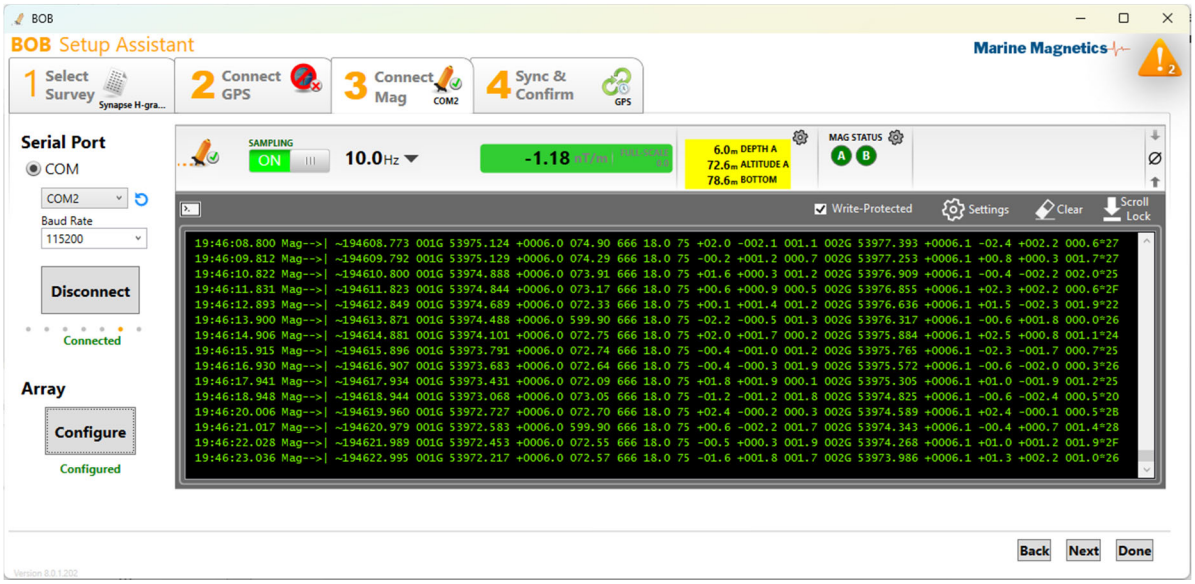


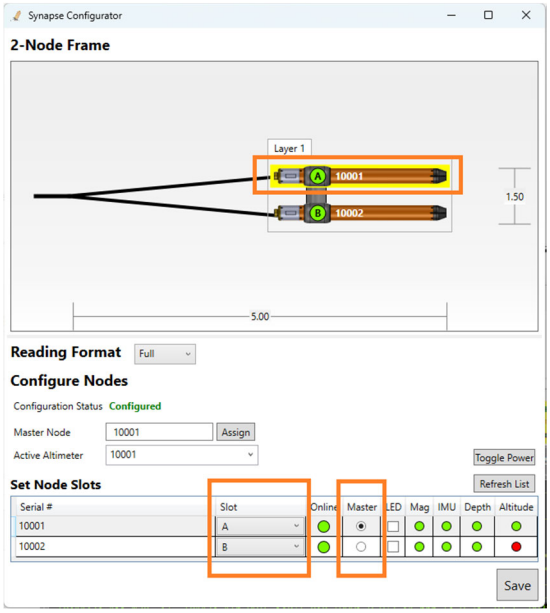
Figure 5-5 - Typical data output from a 2-node Synapse array (Horizontal Gradiometer)
containing time, magnetic field, depth, active altimeter and IMU sensor readings.
The array data string always begins with the Master node, followed by other nodes in increasing order of unit SN.

5.3 Assigning the Master node

In a Synapse system with multiple nodes, two important configuration steps must be completed:

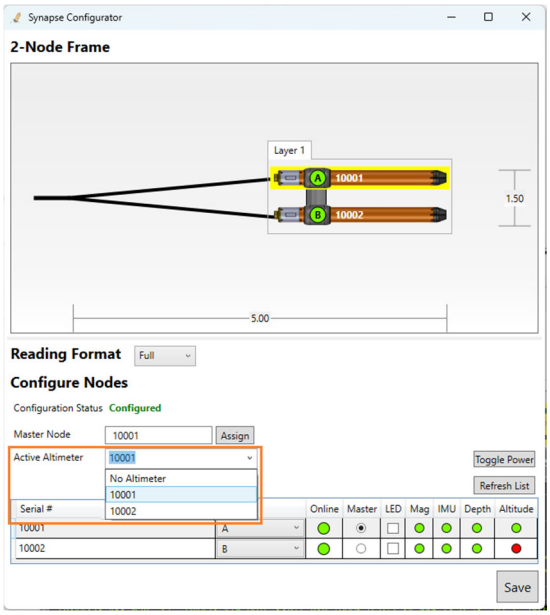
1. one unit/node must be assigned to act as Master node
2. each unit/node must be assigned a specific slot on the array frame, to keep track of the position of each magnetometer sensor

Assigning the master node can be done by clicking on the Master radio button in the list of mag units or by typing the unit's SN into the Master Node box and clicking Assign. The unit can be assigned to a specific frame slot by selecting the slot from the drop-down list.



5.4 Enabling and disabling the altimeter

The integrated altimeter transducer in all Synapse units can be disabled if necessary to prevent interference with other acoustic sensors present in the survey system. In arrays with multiple altimeters located closely (e.g., 1.5m Horizontal Gradiometer frame), only one altimeter must be activated to prevent mutual interference.



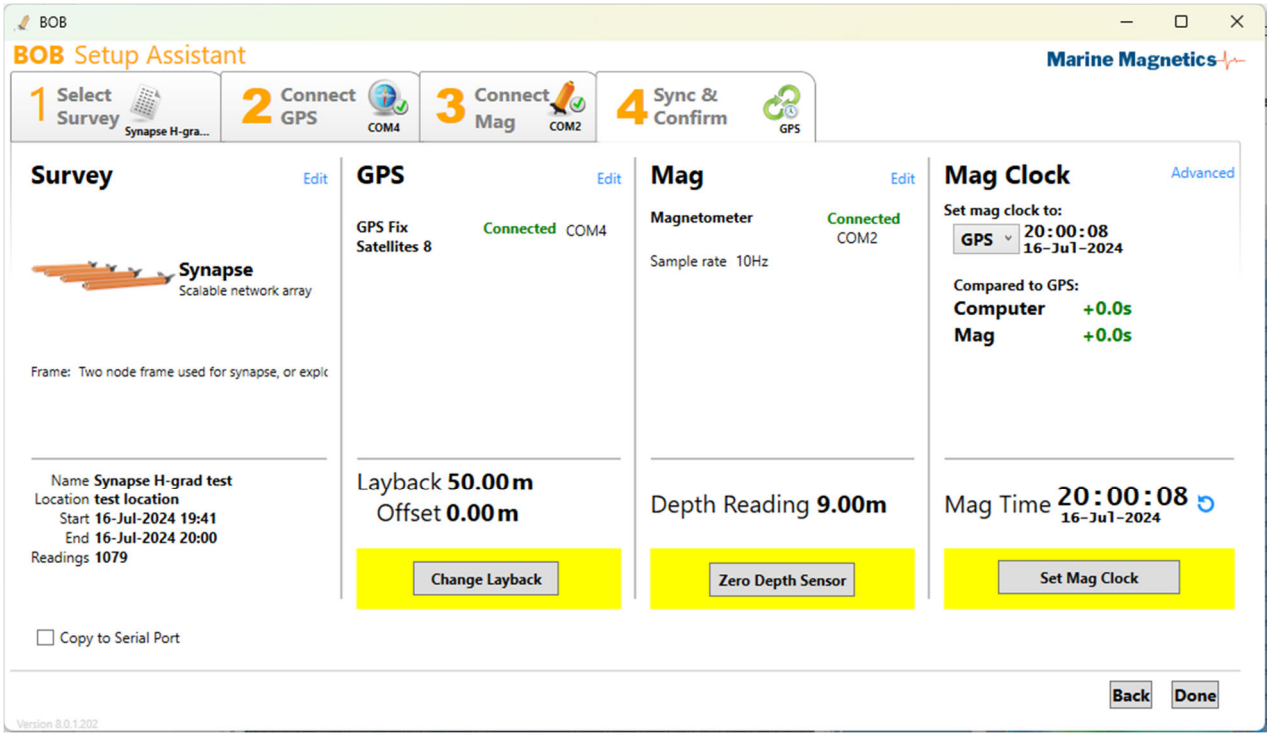
5.5 Finalizing the configuration in BOB

The final step 4 in BOB Setup Assistant summarizes the survey parameters and COM port connections, and offers options for time synchronization source for the magnetometer towfish.

For best results, the magnetometer should be synced to the GPS/UTC time. This requires a GPS connection.

Without a GPS connection, the Mag clock can be set to either PC time or entered manually. For best results ensure that your PC is configured to automatically sync its system time to the Internet.

Please note that time synchronization to UTC time is required whenever base station correction is intended to be applied during post-processing.



6 Magnetometer data display in BOB

The BOB user interface is divided into two windows: The Main BOB window, which contains the sensor profile graphs and a readings table below, and the GeoPlot window, which displays the location of the survey equipment and data points in a map view.

Synapse magnetometer data consists of the Fields, Positions, and Attitude signal groups.
The vertical scale for each signal group can be selected individually or as a group by selecting the group heading in the Layers panel and right-clicking on it. You can also multi-select individual components by holding down the *Ctrl* or *Shift* keys.
The vertical slider to the left of the Layers panel can also be used to adjust the vertical scale.

The profile traces of the Fields group can be dragged up and down with a mouse and scaled via the layers panel, for convenience and comparison. The traces in Position and Attitude groups can only be scaled but not dragged, as they have predefined reference "0" positions. The depth zero reference level is the top of the graph, representing the water's surface. The altitude zero reference level is at the bottom of the graph. The Pitch and Roll traces are centered to display both positive and negative deviations.

The sampling button at the top left of the toolbar also serves as the sampling indicator. A drop-down menu shows a selection of available sampling rates.

When sampling is enabled, the current magnetometer time and magnetic field reading from the master node are displayed above the profile plot. Depth, Altitude, and Bottom alert indicators can be configured by right-clicking and selecting the minimum and maximum thresholds.

The Array Node Status indicators and Array configuration tool are shown to the right of the Depth and Altitude alert indicators, followed by the Notifications icon and the Depth sensor zero calibration button.

The GeoPlot window features a multi-layered map view of the collected data and real-time magnetometer position. With a BAM license activated, the data can be visualized in several interpolated maps, including Total Field, Analytic Signal, and Partial Gradient maps.

Please refer to the BOB User Manual for further details on all features and functions.

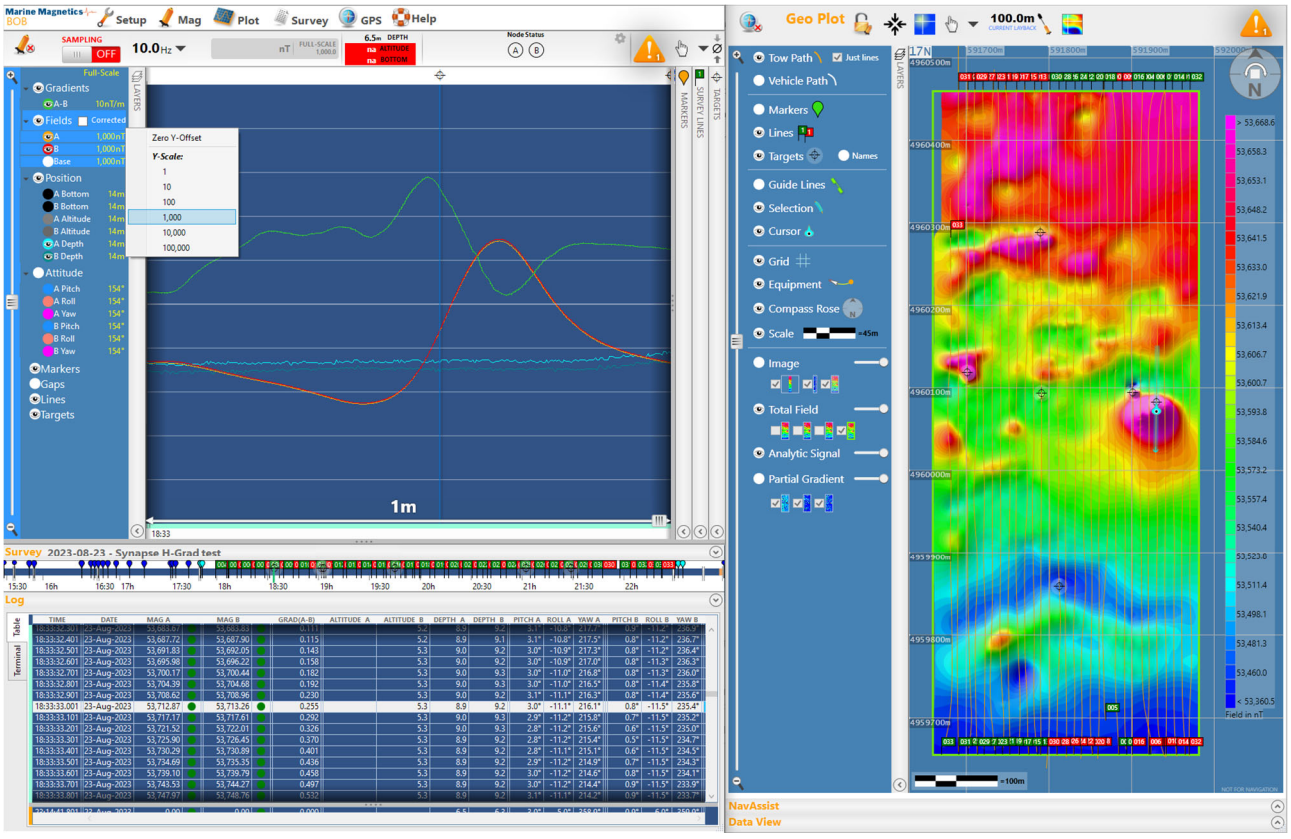


Figure 6-1 - Typical BOB user interface when reviewing existing Synapse Horizontal Gradiometer data and interpolated maps generated in BAM.

6.1 Real-time and Review panes of the Profile Plot

The Profile Plot window in BOB contains a vertical divider that can be used to split the view into the Review pane (left) and the Real-Time Readings pane (right). The Horizontal scale (time span) can be set separately for each pane using the horizontal slider at the bottom of each pane. The timeline bar below the profile plot will highlight the time interval currently displayed in the Review Pane.

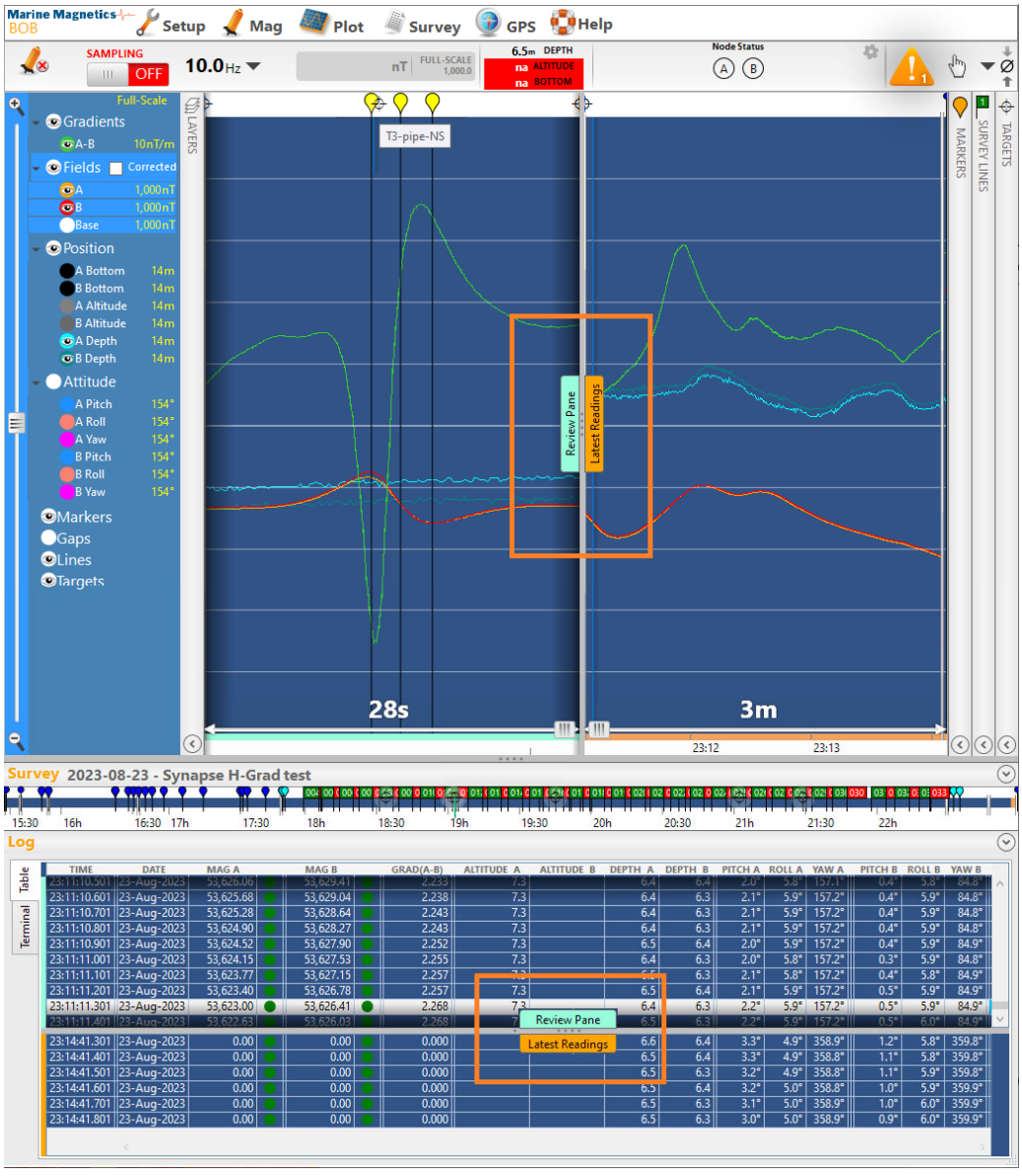


Figure 6-2 - BOB Profile Plot can be divided into Review (left) and Real-time (right) panes, with different time spans for each. The Log table below the plot can be similarly divided with a horizontal bar.

6.2 Calibrating the depth sensor zero level

Calibrating the pressure sensor's zero depth level should be done at the start of each survey, after allowing the magnetometer towfish to adjust to the water temperature and then bringing it out of the water to set the zero depth level.

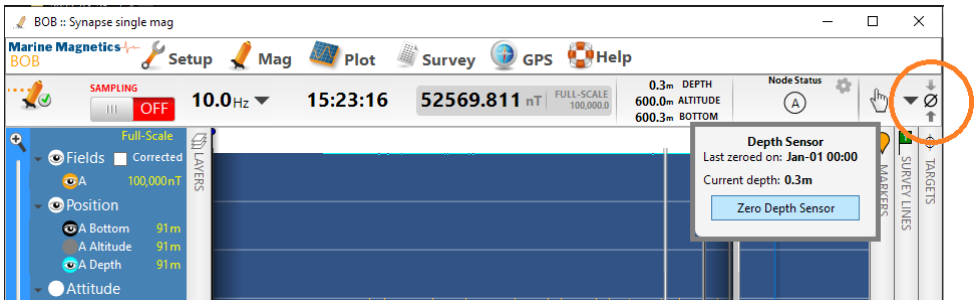


Figure 6-3 - The top-right corner of the main BOB window contains a button for setting the zero level of the depth sensor

6.3 IMU Attitude Indicator

The Attitude Indicator display, accessed through the Mag menu, can monitor the Synapse magnetometer or gradiometer's real-time orientation.

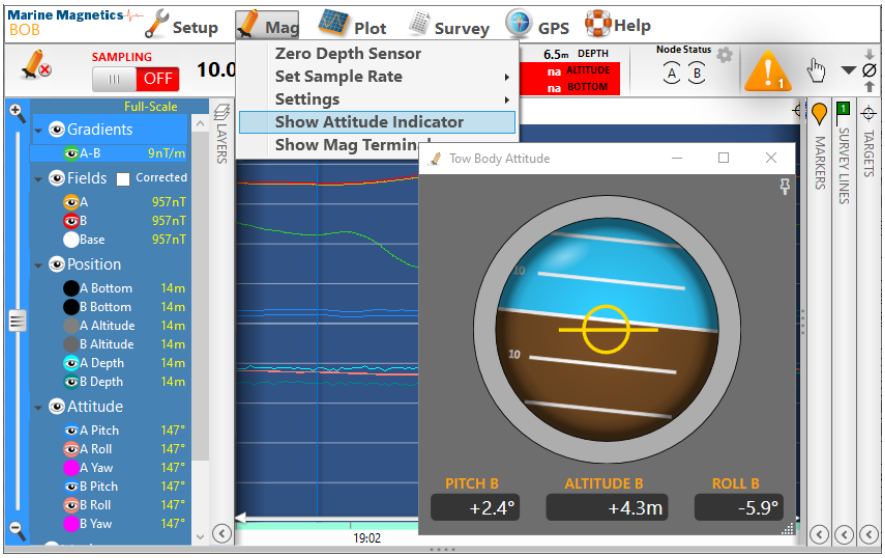


Figure 6-4 - The Attitude Indicator displays Pitch, Roll and Altitude readings from the active node whenever the Synapse magnetometer is actively sampling.

6.4 Saving and exporting survey data

All data collected by BOB are always stored in the BOB survey database whenever sampling is enabled. The database is stored internally and cannot be directly accessed, but it can be backed up to a file for archiving, or exported in CSV format for processing in 3rd party software.

To create a backup copy of the BOB survey database, use Survey > Backup to File. This will create a file with the extension .MMS, that contains all of the data logged during the survey, including all markers, targets and BAM maps. This file can be imported into a BOB installation on another computer for sharing or post processing.

To export survey data for post-processing in 3rd party software, use the menu selection Survey > Export Survey Log. This option offers a flexible interface for selecting specific data channels and corrections to be applied and exported. The resulting file will be ASCII text formatted as CSV (Comma Separated Values), or a space-separated value file.

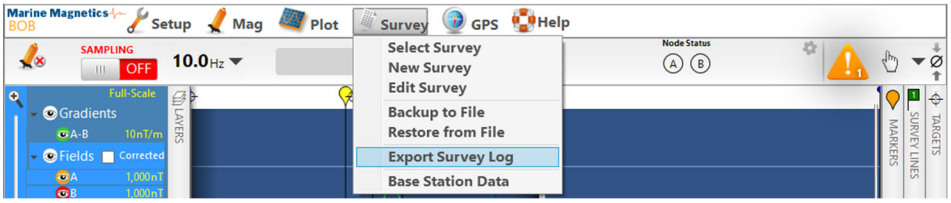


Figure 6-5 - Survey data can be backed up as a BOB-compatible backup (MMS) or exported as universal CSV format

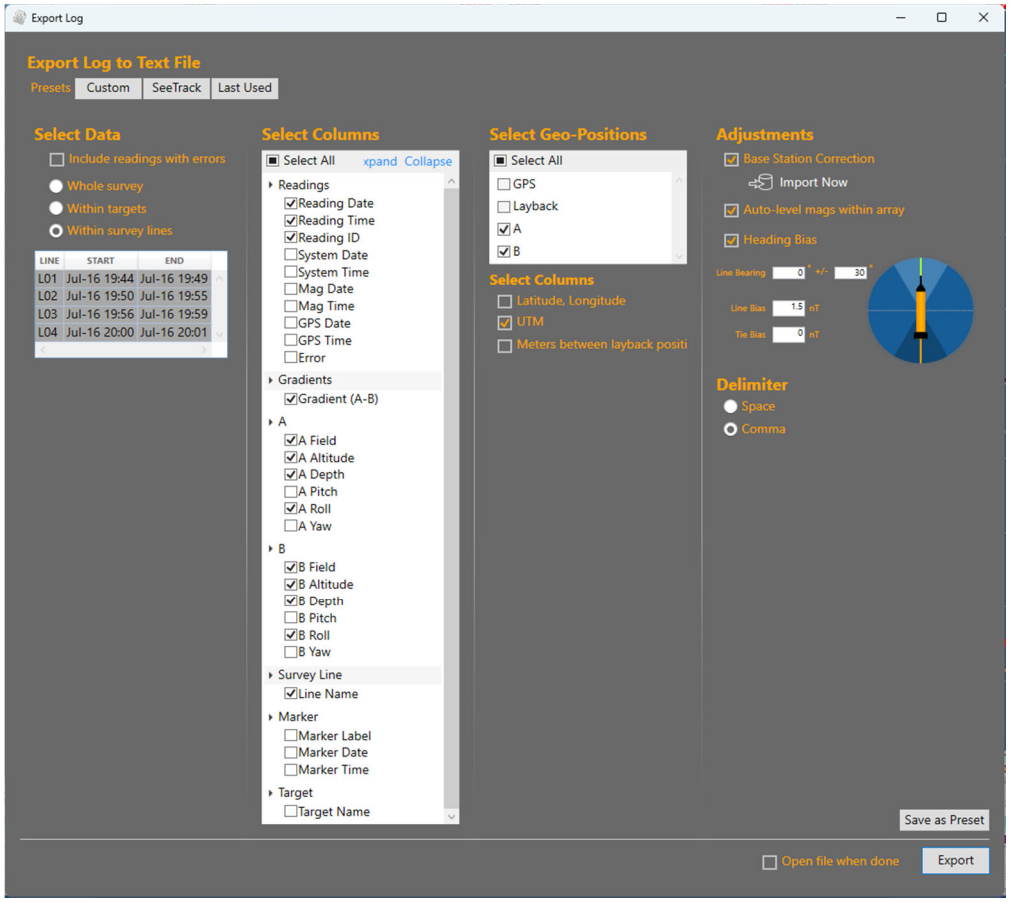


Figure 6-6 – The Data export interface offers a flexible selection of available data channels, positions and corrections. The Layback geo-position represents the end of the soft tow cable, as configured by the Layback setting in BOB. Gradiometer nodes A and B will be automatically offset relative to layback point by the frame preset dimensions.

6.4.1 Survey Export Log format – Description of all data columns and units

(*) represents n/a

Column	Value	Description
Reading_Date	23-Aug-2023	Date of the sample reading, magnetometer clock
Reading_Time	17:59:00.001	Time of the sample reading, magnetometer clock
Gradient(A-B)	-1.702	Measured gradient, nT/m (difference between raw fields at A and B slots divided by the separation between slots (frame width).
A_Field	53664.055	Magnetic field at frame slot A (nT)
B_Field	53666.608	Magnetic field at frame slot B (nT)
A_Altitude	*	Magnetometer Altitude at frame slot A (m) (if enabled)
B_Altitude	4.5	Magnetometer Altitude at frame slot B (m) (if enabled)
A_Depth	8.5	Magnetometer Depth at frame slot A (m)
B_Depth	8.6	Magnetometer Depth at frame slot B (m)
A_Pitch	2.75	IMU Pitch angle at frame slot A (deg). Positive is Nose-down. Includes IMU gyro correction.
A_Roll	-5.08	IMU Roll angle at frame slot A (deg). Positive is to Starboard. Includes IMU gyro correction.
A_Yaw	245.79	IMU Yaw angle at frame slot A (deg). Includes correction based on IMU's MEMS compass.
B_Pitch	1.85	IMU Pitch angle at frame slot B (deg). Positive is Nose-down. Includes IMU gyro correction.
B_Roll	-5.54	IMU Roll angle at frame slot B (deg). Positive is to Starboard. Includes IMU gyro correction.
B_Yaw	240.23	IMU Yaw angle at frame slot B (deg). Includes correction based on IMU's MEMS compass.
Reading_ID	74539	Unique Reading ID since start of database
System_Date	23-Aug-2023	Date of the sample reading, Windows PC clock
System_Time	17:59:01.441	Time of the sample reading, Windows PC clock
Line_Name	004	User-marked survey line (if marked)
Marker	*	Name of the note marker corresponding to current time (if marked by user)
Marker_Date	*	Date corresponding to the marker
Marker_Time	*	Time corresponding to the marker
Error		Error code identifying the magnetometer sensor operating state (A,..,F). Blank if no errors.
Target_Name	*	Name of the anomaly target corresponding to current time (if marked by user)
Fish_Latitude	44.79163057	Latitude of the towfish (end of cable) location. WGS84. See Note below on specific component positions.
Fish_Longitude	-79.83802109	Longitude of the towfish (end of cable) location. WGS84.
Fish_Easting	591913.10	UTM Easting of the towfish (end of cable) location. See Note below on specific component positions.
Fish_Northing	4960460.30	UTM Northing of the towfish (end of cable) location.
Fish_Zone	17N	UTM Zone
Boat_Latitude	44.79073146	Latitude of the GPS location. WGS84
Boat_Longitude	-79.83807075	Longitude of the GPS location. WGS84
Boat_Easting	591910.60	UTM Easting of the GPS location (m), WGS84
Boat_Northing	4960360.37	UTM Northing of the GPS location (m), WGS84
Boat_Zone	17N	UTM Zone
Heading_Bias	-0.000	Heading bias applied based on GPS heading (as configured in the heading correction dialog)
Fish_Heading	182.4	Towfish heading (based on GPS heading, corrected for layback)
Base_Station_Correction	-5.906	Base station correction (nT) (Base Station Field less the average value for the base data imported)
Base_Station_Field	53671.211	Base Station Field (nT) interpolated for this point in time using available base station readings
A_Field_Leveling	1.304	Sensor-specific levelling correction, computed individually for each marked survey line
B_Field_Leveling	-1.304	Sensor-specific levelling correction, computed individually for each marked survey line
A_Field_(Corrected)	53671.265	Corrected magnetic field at frame slot A, with all selected corrections applied (Base station, Heading bias, Automatic Sensor Levellign)
B_Field_(Corrected)	53671.211	Corrected magnetic field at frame slot B (nT).
Corrected_Gradient(A-B)	0.037	Magnetic gradient derived from corrected magnetic fields at slots A and B (nT/m). (Difference between corrected fields divided by the separation between slots (frame width)).
A_Latitude	44.79167588	Latitude of the magnetometer in slot A
A_Longitude	-79.83802706	Longitude of the magnetometer in slot A
B_Latitude	44.79167513	Latitude of the magnetometer in slot B
B_Longitude	-79.83800813	Longitude of the magnetometer in slot B

Notes: Latitude and Longitude of the Towfish and Mag nodes (slots) are computed by BOB based on the position of the GPS (Boat) and the specified layback distance, and accounting for the curve of the tow cable and the vessel path. While GPS (Boat) latitude and longitude remain fixed in the database, you can re-compute mag coordinates at any time by entering a new layback distance in BOB.

"Towfish" represents the end of the single tow cable. For gradiometers, this represents the position of the head of the Y-split cable. Use the slot-specific latitude and longitude (e.g. A_Latitude) for positions corresponding to specific magnetometer sensors.

7 Configuring the isolation transceiver

The isolation transceiver (IT) integrated into the side-scan integration contains a battery-powered clock that synchronizes the connected magnetometer. This clock is set by the top-side PC (e.g. BOB software) and should remain accurate for several days following the setting. A rechargeable lithium battery is used within the transceiver as the clock power source. The on-board battery will automatically recharge whenever the transceiver is connected to power. This battery never requires replacement under normal usage.

The transceiver communicates with the PC using a configurable baud rate (default: 115200), and with the connected towfish using a separate baud rate (default: 31200 for Synapse). Both of these can be modified through the transceiver configuration menu.
It is not necessary to have the towfish or tow cable connected to check the transceiver operation and configuration settings.

Table 7-1 - Isolation Transceiver Commands

Command	Description
SPC or t	Get Time. Requests current transceiver time. If a towfish is connected it will also check the towfish time and synchronize it to the transceiver time if there is a discrepancy.
T	Set transceiver time and date. As soon as the time is set, the IT will attempt to set the time of the towfish, provided one is connected. The IT will remember the time after it is powered off for as long as the internal battery retains charged.
d or D	Scan sensors. In addition to querying the towfish this command also displays the voltage being supplied by the IT, and the current and power consumption of the magnetometer, as well as the depth sensor reading.
?	Display command menu
!	Get towfish serial number.
Ctrl+O	Power On/Off. Toggles power to the towfish.
Ctrl+B	Change transceiver RS-232 baud rate for the top-side telemetry link (PC-Transceiver)
Ctrl+T	Resync towfish to the transceiver clock
Ctrl+X	Abort/Cancel current command
*	Enter transceiver diagnostic mode. A security code is required.

Use <Ctrl+B> to configure the transceiver's communication settings:

```
^B
Change comm settings
PC-115200bps GPS-9600bps FISH-31200bps
1- xcvr<->PC
2- xcvr<->GPS
3- xcvr<->towfish
4- xcvr<->towfish comm channel
```

Selection option 1 to change the Transceiver<->PC baud rate:

```
1
>1-Set xcvr<->PC baud rate
1:2400 2:4800 3:9600 4:38400 5:115200
```

Use <Ctrl+X> to if you need to cancel the command

```
^X
>
Aborted
-Baud rate not changed
```

8 Synapse Data Format

8.1 Standard Format – Single magnetometer

The Standard data format is the most commonly used and is usually the default setting when a Synapse magnetometer is first shipped. The data string appears as follows:

```
~HHMMSS.sss SSSL FFFFF.FFF DDDD.D AAA.AA ASG AV.V AW +PP.PP +RRR.RR YYY.YY*CS CR LF
___________ ______________ ______ __________________ _____________________ __
   TIME        MAG DATA    DEPTH   ALTIMETER DATA           IMU DATA       CHKSM
```

Example:

```
~162046.101 114G 52846.465 0000.1 599.99 030 18.0 99 -02.37 +010.07 357.07*2E
```

The first character of each data line is always ~ (ASCII code 126). This leading character is supplied for automated data collection systems that require periodic synchronization with the data stream.

The first character of each Synapse protocol command sent to the Master node is $.

The first character of each response from the Master node is #.

Each letter shown in italics stands for a digit of a particular record in the reading.

Table 8-1 - Standard data format description for Synapse magnetometers

Column	Description
HHMMSS.sss	UTC Time of transmission of the string. (Towfish time is set by the isolation transceiver) Nominally, it occurs at the even fraction of a second as determined by 1/sample-rate. However, a string can be delayed by slight differences in sync between sensor nodes, and transmission times from sensor nodes. e.g. 162406.101 transmission time corresponds to a reading that was taken at 16:24:06.100
SSS	Signal strength associated with the current magnetometer measurement e.g. 114 Range: 0-150 for Rubidium Synapse. 0-200 for Overhauser Synapse.
L	Sensor Lock Status. (G during normal sampling) Rubidium Synapse: A,B,C or D: Starting up, E: heat stabilizing, F: Scanning for signal, G: Locked. Overhauser Synapse: TBD
FFFFF.FFF	Magnetic field in nT, with a precision of 1pT. e.g 53577.252
DDDD.D	Depth sensor reading in meters, with a precision of 0.1m. e.g 0012.3 or -000.2
AAA.AA	Echo sounder altimeter reading, in meters (if installed), with a precision of 0.01m. Maximum theoretical range: 0-599.99m, where 599.99 indicates no return.
ASG	Altimeter return signal strength. 000 indicates no return.
AV.V	Altimeter output drive pulse amplitude (Volts). Range: 1-18V during normal operation. 25.5V indicates that altimeter is disabled.
AW	Altimeter output drive pulse width (µs x 10). e.g. 33 = 330 µs
+PP.PP	IMU Pitch angle (deg). e.g. -02.37
+RRR.RR	IMU Roll angle (deg). e.g. +010.07
YYY.YY	IMU Yaw reading (deg. Azimuth). e.g 357.07
**CS CR LF*	Checksum followed by Carriage Return and Line Feed (ASCII 13 and 10)

Please refer to the Synapse Array Interface Protocol for details on all commands and data format.

8.2 Compact Format – Single magnetometer

The Compact data format excludes the signal strength and optional altimeter parameters, and can be used when data bandwidth restrictions require it.

The data string appears as follows:

```
~HHMMSS.sss L FFFFF.FFF DDDD.D AAA.AA +PP.PP +RRR.RR YYY.YY*CS CR LF
___________ ___________ ______ ______ ____________________ __
   TIME      MAG DATA   DEPTH   ALT          IMU DATA       CHKSM
```

Example:

```
~162046.101 G 52846.465 0000.1 599.99 -02.37 +010.07 357.07*2E
```

The first character of each data line is always ~ (ASCII code 126). This leading character is supplied for automated data collection systems that require periodic synchronization with the data stream.

The first character of each Synapse protocol command sent to the Master node is $.

The first character of each response from the Master node is #.

Each letter shown in italics stands for a digit of a particular record in the reading.

Table 8-2 - Standard data format description for Synapse magnetometers

Column	Description
HHMMSS.sss	UTC Time of transmission of the string. (Towfish time is set by the isolation transceiver) Nominally, it occurs at the even fraction of a second as determined by 1/sample-rate. However, a string can be delayed by slight differences in sync between sensor nodes, and transmission times from sensor nodes. e.g. 162406.**101** transmission time corresponds to a reading that was taken at 16:24:06.**100**
	(no signal strength data in compact format)
L	Sensor Lock Status. (G during normal sampling) Rubidium Synapse: A,B,C or D: Starting up, E: heat stabilizing, F: Scanning for signal, G: Locked. Overhauser Synapse: TBD
FFFFF.FFF	Magnetic field in nT, with a precision of 1pT. e.g 53577.252
DDDD.D	Depth sensor reading in meters, with a precision of 0.1m. e.g 0012.3 or -000.2
AAA.AA	Echo sounder altimeter reading, in meters (if installed), with a precision of 0.01m. Maximum theoretical range: 0-599.99m, where 599.99 indicates no return.
	(no additional altimeter data in compact format)
+PP.PP	IMU Pitch angle (deg). e.g. -02.37
+RRR.RR	IMU Roll angle (deg). e.g. +010.07
YYY.YY	IMU Yaw reading (deg. Azimuth). e.g 357.07
**CS CR LF*	Checksum followed by Carriage Return and Line Feed (ASCII 13 and 10)

Please refer to the Synapse Array Interface Protocol for details on all commands and data format.

To switch between Standard and Compact data formats, the $data command can be used:

`$data,SN,F` (where SN is the node serial number, F represents the data format. 0: Standard, 1:Compact, 2:Base64 compressed)

e.g.

`$data,16022,0` (command to the Synapse master node, requesting a change to standard format (0))

`#data,16022,0` (confirmation response from the Synapse master node, showing the new data format setting)

8.3 Compressed (Base64) Format – Single magnetometer

The Base64 compressed format contains all data from the Standard format, but compresses it to a hex data string to save space.

This format offers the best data density for communication channels with limited bandwidth, but requires decoding by the top side data logger.

The data string appears as follows:

```
$data,16022,2
#data,16022,2
~185211.101 DwoC/A3FAAYABQWLAD3IMv7m9dsGow*4B
~185211.201 DwoC/A5nAAYABgWLAD3IMv7m9dsGng*41
~185211.301 DwoC/A45AAYABQUZAD3IMv7m9doGoQ*13
```

Compare to equivalent Standard data string:

```
$data,16022,0
#data,16022,0
~185211.401 102G 50073.121 0000.0 013.05 061 20.0 50 -02.83 -025.98 016.99*44
~185211.501 106G 50072.891 0000.0 005.28 064 20.0 50 -02.83 -025.98 017.00*4B
~185211.601 104G 50073.439 0000.0 005.28 064 20.0 50 -02.83 -025.98 017.01*45
```

8.4 Gradiometer and Array Data – Standard format

When more than one Synapse node is connected, their respective data strings simply get concatenated together by the Master node before being forwarded to the isolation transceiver, with only a single time stamp column at the start.

The number of connected nodes and their order of appearance in the combined data string is reported as part of the #clst response which occurs automatically every 4 minutes, and can be requested at any time using the $clst command.

Note: The master node data always appears first in the string, followed by all other connected nodes in order of increasing serial numbers. This is indicated in the #clst response, which lists the connected nodes:

```
#clst,0,02,16022-F/F,16023-F/F *03
```

Data format: 0 (standard)

Nodes connected: 2

Master node SN: 16022, with all peripherals installed and enabled (-F/F)

2nd node SN: 16023, with all peripherals installed and enabled (-F/F)

Example: A 2-node horizontal gradiometer with both altimeters enabled:

```
~185304.502 099G 50074.376 0001.1 599.99 000 20.0 50 -02.71 -025.98 016.81 102G 50074.645 0001.1 599.99 000 20.0 50 -02.64 -025.92
018.28*48
```

Please refer to the Synapse Array Interface Protocol for details on all commands and data format.

8.5 Missing sensor measurements in data

Missing data measurements are replaced by the dashes as placeholders, and may indicate an issue with one or more internal sensors.
Example:

In this example the magnetometer is warming up and still reporting zeros, preceded by the 000 signal strength and C status (warming up).

However the altimeter data is missing as indicated by the dashes; while the Depth and IMU data are present.

```
#clst,01,16022-F*72
~155727.915 000C 00000.000 0000.1 ---.-- --- --.- -- +00.71 -004.10 359.99*53
~155728.015 000C 00000.000 0000.2 ---.-- --- --.- -- +00.70 -004.09 359.99*55
~155728.115 000C 00000.000 0000.1 ---.-- --- --.- -- +00.70 -004.09 359.99*55
```

TIME	MAG DATA	DEPTH	ALTIMETER DATA	IMU DATA	CHKSM

9 Troubleshooting

For normal operation, the Synapse system relies on the master node to communicate with the isolation transceiver at the correct baud rate of 31200, and on the isolation transceiver to communicate with the top-side data logging system at a correct baud rate of 115200.
See Section 7 for details on configuring the transceiver baud rates.

The isolation transceiver should still communicate with the top-side data logger via RS-232 whether the towfish or tow cable are connected or not. If you cannot communicate with the isolation transceiver (integrated into the side-scan integration cable), check the baud rate and the power supply.

The Synapse system requires one of the array nodes (units) to be assigned as the master node. If no master node is assigned, it will appear as though the towfish is not connected. Refer to Section 2.3 for the diagnostic information indicated by the Synapse status LED.

If more than one master node is assigned, the data seen in the RS-232 terminal will contain unreadable text and non-ASCII characters. Assign one of the nodes to act as the master node (see Section 5.3).

Please refer to the Synapse Array Protocol section on front bulkhead LEDs for a summary of system states, which is helpful in identifying the system's state.

If you need additional support, please do not hesitate to contact Marine Magnetics. We will be happy to help!

Contact Us:

Tel:	+1 905 479-9727	Fax:	+1 905 479-9484
Email:	support@marinemagnetics.com	URL:	www.marinemagnetics.com

9.1 Examples of data with indications of various potential issues:

Synapse data string will contain dashes as placeholders for all sensor measurements that are missing or not working properly, making it easy to tell how many data fields one should expect. However, if a specific sensor is not installed or is disabled (in the configuration menu), there will be no dashes for it.

1) Single Synapse connected: SN 10002:

ALL SENSORS OK – NORMAL OPERATION

MAG TRANSITIONS FROM WARM-UP (E) TO SCANNING (F) TO SAMPLING (G)

```
Marine Magnetics Corp.
SSIM Network Node rev2.29
(C) June, 2023
Press '?' for list of commands

Peripherals: Mag Depth Alt IMU
Powering up peripherals
Ready
Setting Towfish Time...
Towfish time was set
Time: 23.180/15:57:26.0
Setting Rb to 10Hz
Starting Rb Datastream
Syncing Network...
#clst,01,10002-F*72
Syncing Rb Mag...
~203828.401 000E 00000.000 0000.0 599.99 030 18.0 75 -01.25 +005.34 002.37*4E
~203828.501 000E 00000.000 0000.1 599.99 030 18.0 75 -01.25 +005.34 002.37*4F
~203828.601 000E 00000.000 0000.1 599.99 030 18.0 75 -01.25 +005.34 002.37*4F
~203828.701 000E 00000.000 0000.1 599.99 030 18.0 75 -01.25 +005.34 002.37*4F
~203828.801 000F 14064.086 0000.1 599.99 030 18.0 75 -01.25 +005.34 002.37*45
~203828.901 000F 47356.584 0000.1 599.99 030 18.0 75 -01.25 +005.34 002.37*46
~203829.001 000F 33406.056 0000.1 599.99 030 18.0 75 -01.25 +005.34 002.36*4D
~203829.101 084G 32455.675 0000.1 599.99 030 18.0 75 -01.25 +005.34 002.36*4C
~203829.201 082G 48755.684 0000.1 599.99 030 18.0 75 -01.25 +005.33 002.37*4A
~203829.301 083G 48812.688 0000.1 599.99 030 18.0 75 -01.25 +005.34 002.36*4C
~203829.401 085G 48812.205 0000.1 599.99 030 18.0 75 -01.26 +005.34 002.36*4E
~203829.501 084G 48812.122 0000.2 599.99 030 18.0 75 -01.25 +005.34 002.36*48
~203829.601 081G 48812.109 0000.1 599.99 030 18.0 75 -01.25 +005.33 002.36*45
~203829.701 084G 48811.700 0000.1 599.99 030 18.0 75 -01.25 +005.33 002.36*49
~203829.801 082G 48811.991 0000.1 599.99 030 18.0 75 -01.26 +005.33 002.36*4C
_____________ _______________ _______ ____________________ ____________________ __
   TIME         MAG DATA    DEPTH    ALTIMETER DATA           IMU DATA        CHKSM
```

2) Single Synapse connected: SN 10002: Some of the sensor measurements are missing

Mag, depth and IMU are OK, altimeter is not working (dashes)

```
~155948.101 110G 51138.583 -000.3 ---.-- --- --.- -- +00.75 -004.58 359.61*46
~155948.201 111G 51138.652 -000.2 ---.-- --- --.- -- +00.76 -004.58 359.61*4E
~155948.301 108G 51138.618 -000.3 ---.-- --- --.- -- +00.74 -004.57 359.61*4D
```

Mag and Altimeter are not working, but depth and IMU OK

```
~155948.101 ---- -----.--- -001.3 ---.-- --- --.- -- +00.75 -004.58 359.61*46
~155948.201 ---- -----.--- -001.3 ---.-- --- --.- -- +00.75 -004.58 359.61*4E
~155948.301 ---- -----.--- -001.3 ---.-- --- --.- -- +00.75 -004.57 359.61*4D
```

Only depth sensor is working

```
~155948.101 ---- -----.--- -001.3 ---.-- --- --.- -- ---.-- ----.-- ---.--*46
~155948.201 ---- -----.--- -001.3 ---.-- --- --.- -- ---.-- ----.-- ---.--*4E
~155948.301 ---- -----.--- -001.3 ---.-- --- --.- -- ---.-- ----.-- ---.--*4D
_____________ _______________ _______ ____________________ ____________________ __
   TIME         MAG DATA    DEPTH    ALTIMETER DATA           IMU DATA        CHKSM
```