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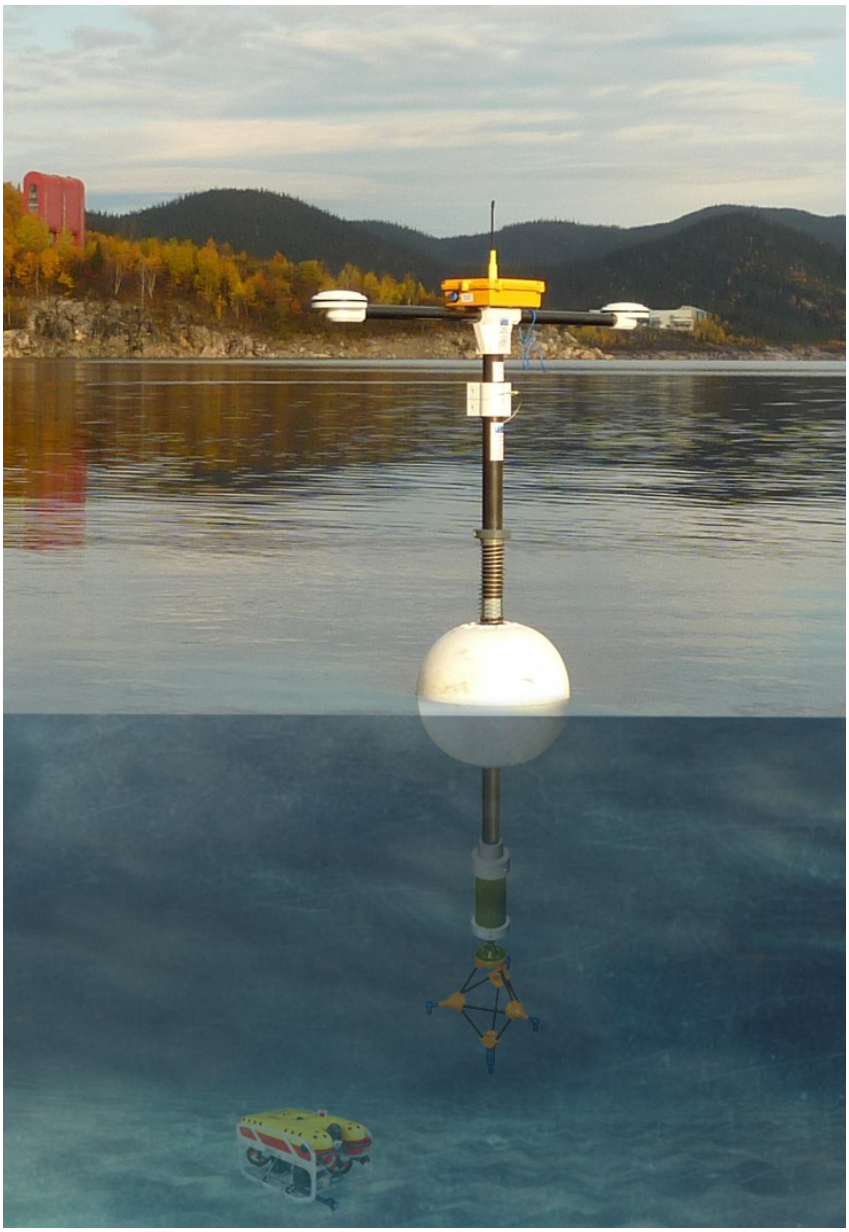
Underwater georeferenced survey using the AQUA-METRE RTKDuo System



AQUA-METRE R300NG, RTKDuo Buoy description
Document ref 0128-801-004

Content

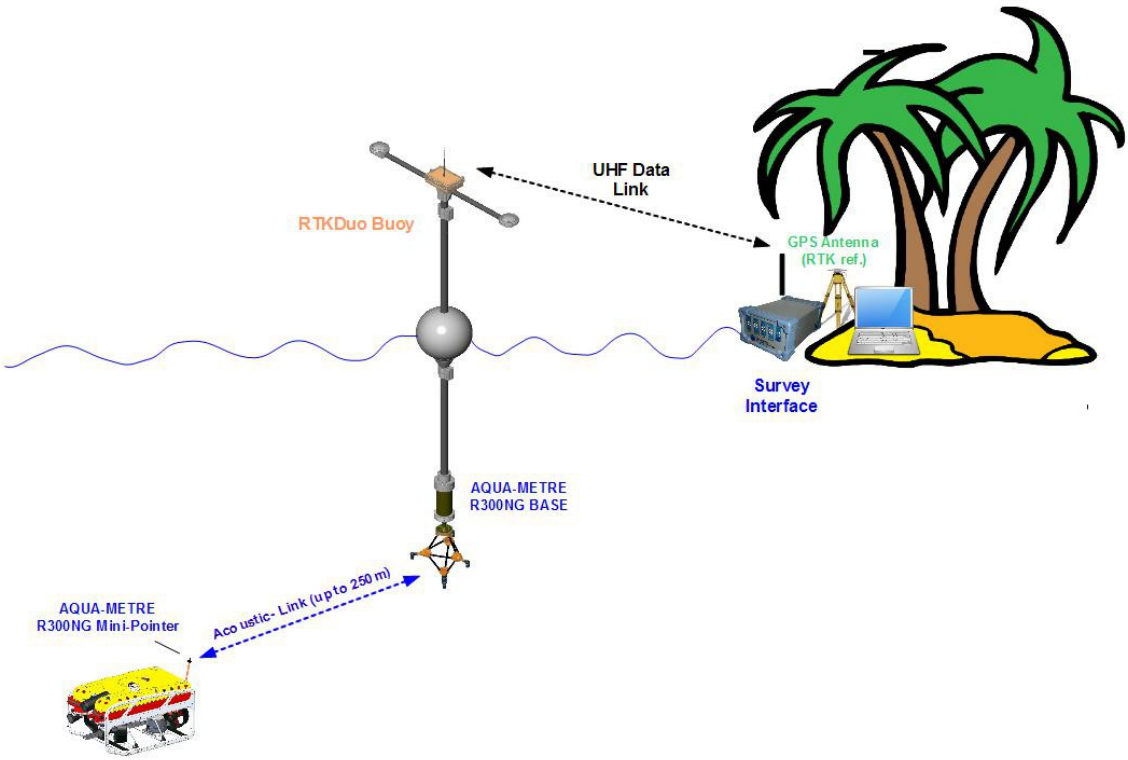
RTKDuo Buoy at Manic5 (Daniel Johnson) dam (QC, Canada)

1 RTKDuo System Configurations

Two configurations may be envisaged:

1.1 Near-shore RTKDuo configuration

The Survey Interface is set up on a fixed point (ROV pilot from the shore during dam survey for instance), the GNSS receiver inside the Survey Interface acts as the RTK reference Base:



RTKDuo near-shore configuration (dam, bridge or pier survey typically)

The system is managed from a fixed location, thus, the GNSS receiver inside the Survey Interface is set up as a RTK Reference Base in order to generate local RTCM corrections that are sent to the RTKDuo buoy.

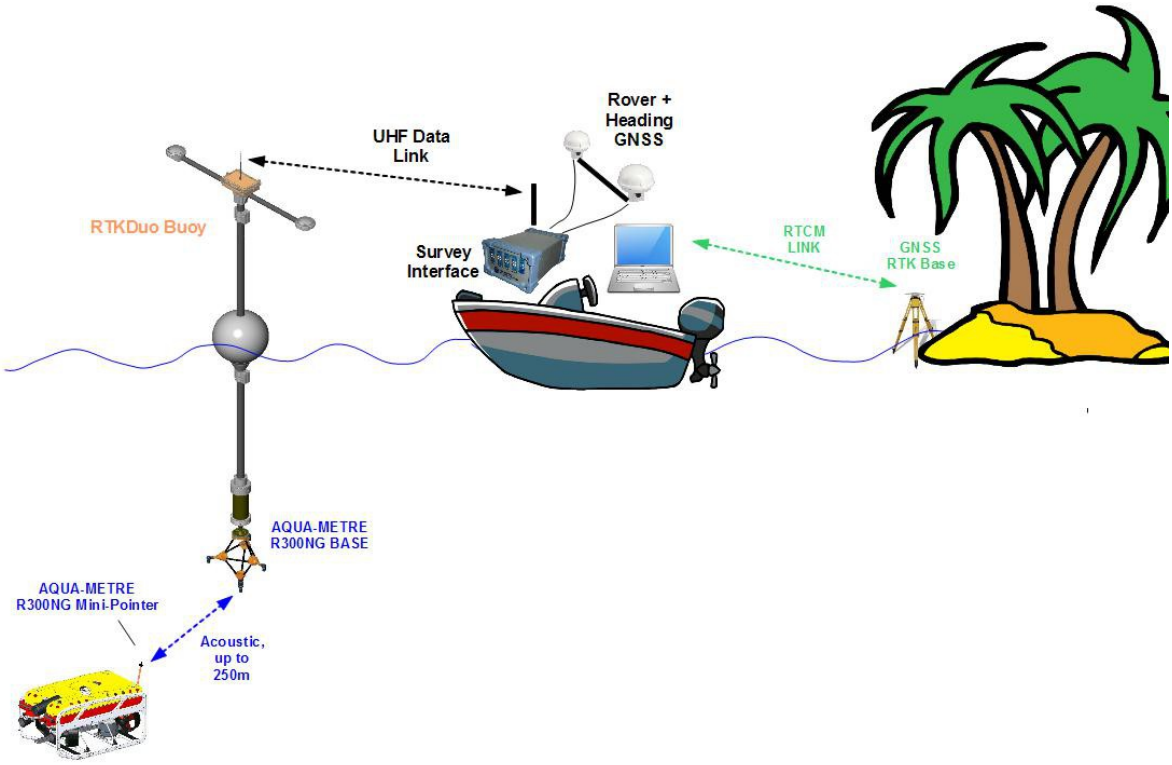
The Survey Interface communicate with the RTKDuo buoy through an UHF data link (max range 2 to 5 km, depends on radio-modem frequency option).

The R300-NG MiniPointer is supplied by its internal batteries (autonomy: 5 days of 10 working hours + sleeping mode between working periods), no need to connect it to the ROV system (however, it can be optionally supplied by the ROV in case of permanent installation).

The RTKDuo buoy is moored close to the survey area in order to lower the positioning errors, the dual antenna GNSS receiver inside the RTKDuo buoy works as a rover + heading.

1.2 Offshore RTKDuo or dual rover configuration

In offshore configuration, the Survey Interface is set up on a moving point (ROV pilot from a vessel or construction work from a barge for instance), then external RTK correction must be provided to the System by a customer's RTK Base + radio-modem, or by using RTK network corrections (NTRIP through cellular modem for instance), in this configuration it is possible to use the GNSS receiver inside the Survey Interface as a second rover with dual antenna to measure a heading and position the support vessel:



RTKDuo offshore configuration (barge construction, offshore ROV inspection typically)

Note that an offshore survey from a steady location like a jack up barge may be sometime considered as a near shore configuration.

1.3 RTKDuo buoy features

Mode of operation

All Pointers acoustic interrogations through the RTKDuo Buoy are geo-referenced using the measured RTK position of the Buoy, the internal RTK heading (smoothed by the MRU gyro) and the measured Pitch/Roll from the MRU. Thus, the local acoustic coordinates measured by the USBL AQUA-METRE R300-NG Base unit are geo-referenced and transmitted back to the Survey Interface through the radio-modem using standard $GGA NMEA messages. The $GGA messages are then transferred from the survey interface to the AQUA-CAD application software running on the survey PC. At this point, the geo-referenced coordinate may be processed by the AQUA-CAD software (the software provided by PLSM to manage the AQUA-METRE system configuration) and used to display the survey operation using the BricsCAD CAD software (.dwg compatible) or simply transferred to another final user software application through a real or virtual COM port or Ethernet network (UDP protocol).

Cartographic projections

When using the BricsCAD tool associated with AQUA-CAD to display the survey operation, it is necessary to choose a cartographic projection used to display the geographic coordinate in the local 3D Cartesian coordinate system. AQUA-CAD offers different type of cartographic projections from the very simple ENU (East/North/Up), centred on the reference RTK Base station, up to the whole UTM collection (UTM01N/S to UTM60N/S). User can also chose to convert the geographic position to a local cartographic system using the 2 points Pivot/lever calibration (refer to AQUACAD manual for more detail).

Altitude

As regular GGA messages, the GGA messages generated by the RTKDuo Buoy include the altitude above mean sea level (MSL) and the height of MSL from the WGS84 reference ellipsoid. When using the MiniPointer with the optional accurate pressure jauge (max error <0.05 % of FS, FS= 10 or 30 bars) and the AQUA-CAD software, it is also possible to measure the depth accurately (5cm) and compensate for the tide in real time. Thus, no longer need for a tide gauge, thanks to the RTK altitude measurement of the Buoy (RTK differential Tide function in the RTKDuo buoy).

RTK differential corrections

As soon as the reference position of the antenna of the RTK Base as been defined, the Survey Interface unit sends the RTK differential corrections to the RTKDuo buoy automatically and transparently. Using AQUACAD, user may also chose another source of RTK correction, among the choice list: network protocol (NTRIP).

Autonomy/sleeping mode

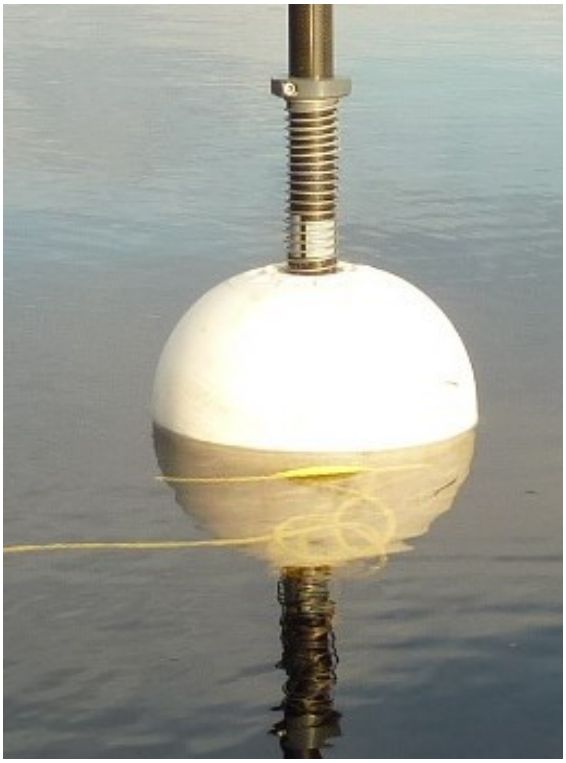
In active mode, the autonomy of the Buoy exceeds 3 working days of 12 hours, with sleeping period during nights. To put the RTKDuo Buoy in sleeping mode, just switch off the radio-modem of the

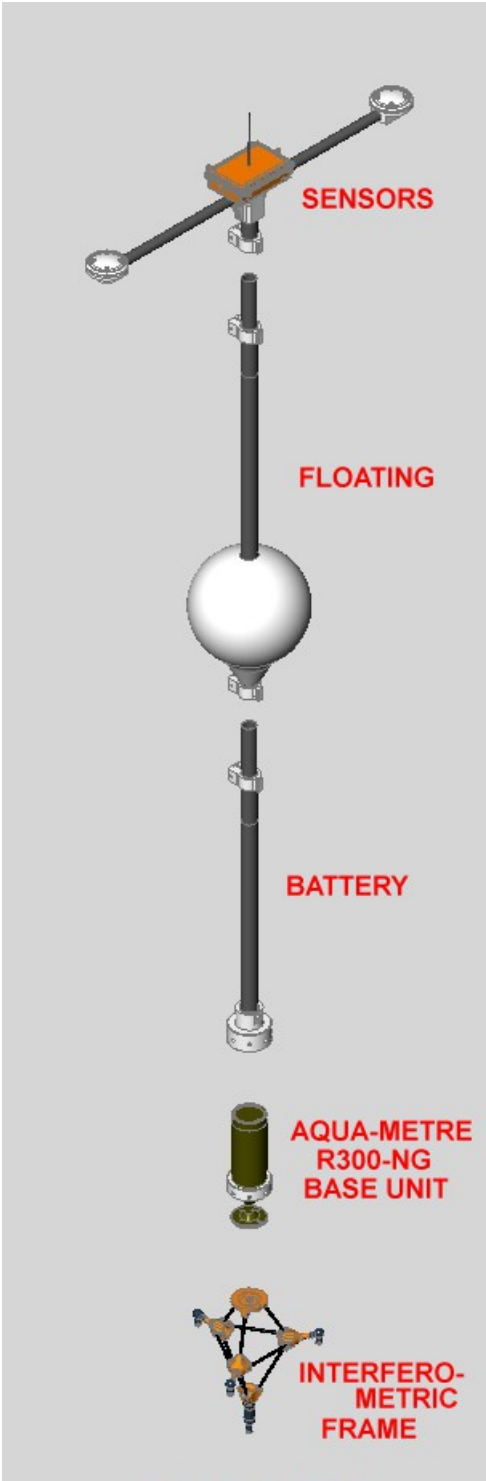
Survey Interface unit, the RTKDuo buoy will enter sleeping mode within 30 seconds after server beacon vanished. To reactivate the RTKDuo buoy, simply switch on the radio-modem of the Survey Interface unit, the RTKDuo buoy will be available within 1 minute after server beacon set up.

Swell absorber, mechanical design

The RTKDuo buoy includes a swell absorber in order to stabilize the sensors (GPS-RTK and MRU). This absorber designed by PLSM consists of a custom inox spring that mechanichally links the main frame to the flotation (see picture).

The main frame is made of carbon tubes (build from fabric not pultruded) to offer the best balance between weight and rigidity.





2 Hardware description

2.1 Survey Interface unit

The Survey Interface unit includes:

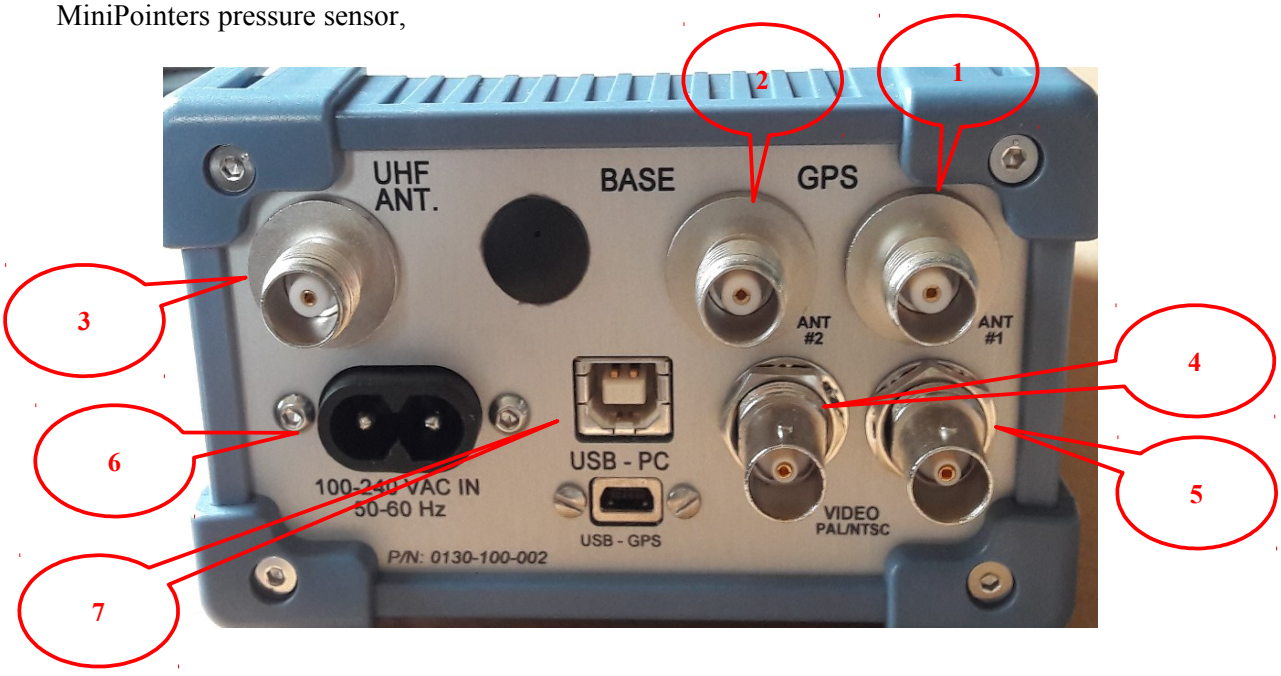
- a dual antenna GNSS RTK receiver (connectors TNC (1) + (2)), set up as a reference base station or rover+heading depending on chosen configuration,

- an UHF radio-modem (connectors TNC (3)) to communicate with the RTKDuo Buoy,

- a µ-controller with a USB interface to interface to the Survey PC,

- a video overlay unit (connectors BNC (4) + (5)) used to add date/hour and coordinate of Pointer on a video signal (video inspection by ROV for instance),

- a very accurate digital barometer in order to compensate the atmospheric variations when using the MiniPointers pressure sensor,

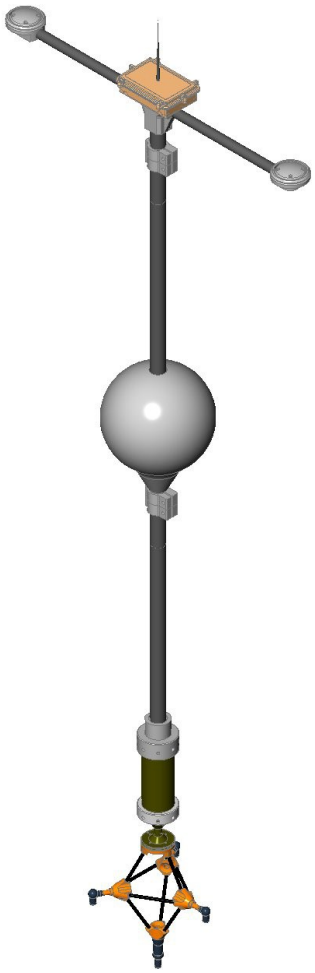


- the Survey Interface is powered through the main supply connector **(6)** (100-240VAC, power less than 8W) and linked to the survey PC through the USB (connector **(7)**).

Survey Interface unit characteristics

Parameter	*Value*
Electrical	
Supply voltage / Power:	100-240 VAC, 50/60Hz / maximum 8 Watts
Input Power connector:	IE320-C8 female cord input (EU or USA/CANADA cord available)
Interface:	USB2.0 compatible
OS compatibility:	Driver for Windows XP-SP3, Windows 7, 8 and 10
Mechanical	
Dimensions:	20x11.5x7.5 cm (L x l x h)
Weight:	1.05kg (housing alone, without cable)
Radio-modem	
Frequency band:	868 MHz (EU), 915 MHz (USA/CANADA) or 2.4GHz (International) ISM band (licence free)
Range:	868 and 915 MHz: up to 5km (line of sight conditions) 2.4 GHz: up to 2km (line of sight conditions)
Antenna connector:	TNC female
Internal GNSS Receiver	
Type:	GNSS (GPS/GLO/BEIDOU/GAL, L1/L2/L5 + SBAS)
Antenna connector:	TNC female
Antenna type:	GNSS Survey antenna (L1/L2/L5)
Internal video overlay unit	
Type:	BOB4 from Decadenet (USA)
Video standard:	PAL or NTSC (automatic detection)
Connector:	BNC 75Ω female (IN and OUT)
Display area:	Up to 22 row x 40 columns
Internal digital Barometer	
Range:	300 to 1100 hPa
Absolute accuracy	+/- 1 hPa

2.2 RTKDuo Buoy unit



The RTKDuo Buoy includes :

- a dual antenna GNSS RTK receiver in order to measure the geographic position and the true North heading of the Buoy dynamically and simultaneously,

- a Motion Reference Unit (MRU) that measures the Pitch/Roll of the Buoy and smooths the RTK heading according his internal gyros (Kalmann filter fusion algorithm),

- an UHF radio-modem to communicate with the Survey Interface,

- a batteries pack on the lower part of the buoy that supplies the Buoy electronic and the AQUA-METRE Base unit attached on the bottom of the Buoy mast,

- a µ-controller that manages the sensors synchronisation and communication with the AQUA-METRE Base unit and Survey Interface,

RTKDuo Buoy characteristics

Parameter	*Value*
Mechanical	
Dimensions:	230 x 115 x 17 cm
Weight:	13.9kg (does not include the AQUA-METRE Base unit)
Material:	Carbon-Epoxy tubes and polymer (junction parts)
Radio-modem	
Frequency band:	868 MHz (EU), 915 MHz (USA/CANADA) or 2.4GHz (International) ISM band (licence free)
Range:	868 and 915 MHz: up to 5km (line of sight conditions) 2.4 GHz: up to 2km (line of sight conditions)
Internal GNSS Receiver	
Type:	GNSS (GPS/GLO/BEIDOU/GAL, L1/L2/L5 + SBAS)
Antenna type:	Tallysman OEM GNSS multi-band active antenna
Precision:	RTK position: 2cm, RTK internal heading: 0.2° (smoothed by the MRU's gyro)
Internal MRU	
Type:	Mem's based MRU
Precision:	Pitch/Roll: 0.1° typical (depends on swell state)

Internal batteries pack

Type:	10 x NiMh cell, 10 A,h (Sanyo HRD)
Autonomy:	50 hours in active mode, >1 month in sleeping mode
Charge duration:	< 8 hours

Interfaces

Aux. Interface #1:	ON/OFF function, ext. power supply (12 to 24V) and RS232 interface, SOURIAU UTS710E6S female connector
Aux. Interface #2:	USB monitor (mainly used for the buoy controller firmware update), Mini-USB female connector
Aux. Interface #3:	USB GNSS (mainly used for GNSS firmware update), Mini-USB female connector

2.3 RTKDuo System Packaging

The whole set including the Survey Interface unit, the RTKDuo Buoy, all cables and antennae, as well as all accessories like charger,... is delivered in a PELICAN case 1770 with custom protection foam.

RTKDuo Buoy and Survey Interface in PELICASE 1770

Outside dimensions are: 146 x 47 x 29 cm, total weight: 30 kg (flotation is inflated before use to save space during freight)

2.4 The AQUA-METRE R300-NG USBL

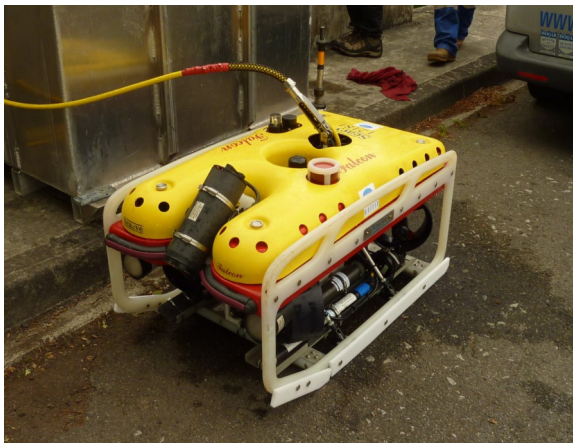
The AQUA-METRE R300-NG is a local underwater positioning system based on an acoustical interferometric scheme (mainly known as Ultra Short Base Line or USBL). It is particularly well suited to accurate local 3D locating within the range of up to 250 metres (820 feet) from the reference point (the Base).

The simplest AQUA-METRE system configuration able to measure 3D coordinates underwater is made of at least two main components:

-The measurement **Base,** which measures 3D coordinates in his local acoustic reference Cartesian coordinate system (defined by the interferometric frame geometry),

AQUA-METRE R300-NG unit attached to the RTKDuo buoy:

- At least one **Pointer** which replies to Base interrogations.



MiniPointer AQUA-METRE R300-NG (alone, right; installed on a survey ROV, left)

The MiniPointer may be operated using internal battery and fully isolated from the ROV electrical circuit (all communications through acoustic telemetry), it may also be powered by the ROV (12 to 24V, 100mA max), and/or interfaced to an RS232 bus to speed up communication link.

AQUA-METRE R300-NG characteristics (see reference manual for more details)

Parameter	*Value*
Mechanical	
Base R300-NG Weight:	3.3kg , 1.96kg in fresh water (including housing + acoustic frame)
MiniPointer R300-NG Weight:	1.17kg , 0.45kg in fresh water (including hydrophone)
Acoustic	
Acoustic frequency band:	65-75 kHz (mode #1) / 76-88 kHz (mode #2)
Range:	250m in direct line of sight
Accuracy:	Distance: +/-2.5cm (does not include celerity error)
	Angles: +/-0.1°
Resolution:	Distance: 1mm
	Angles: 0.01°
Standard deviation:	Distance: 6mm
(fixed location)	Angles: 0.03°
Pressure sensor	
Pressure sensor accuracy:	<0,05% of full scale, typically better than 0,025%
Battery autonomy	
Base R300-NG:	Power Supplied by the RTKDuo Buoy in this configuration
MiniPointer R300-NGt:	>30h in active mode, >1 month in sleeping mode

3 AQUA-METRE R300-NG USBL + RTKDuo overall accuracy

The overall positioning accuracy of the RTKDuo buoy associated with the AQUA-METRE R300-NG acoustic sensor depends on:

- the RTK accuracy (not the main source of error here),

- the error of the reference RTK base location (user responsibility),

- the Heading, Pitch & Roll angle measurements,

- the AQUA-METRE acoustic measurement error (error for distance and angles measures),

Thus, the vertical and horizontal expected accuracy has been computed for different depths and horizontal distance between the RTKDuo buoy and the MiniPointer:

Horizontal Accuracy (cm)

	Buoy to MiniPointer Horizontal Distance (m)								
Depth (m)	0	5	10	25	50	100	150	200	250
5	3,3	3,3	3,3	4,6	8,8	17,5	26,2	34,9	43,7
10	3,3	3,3	3,3	4,8	9,0	17,6	26,3	35,0	43,7
25	4,5	4,6	4,8	6,3	9,8	18,0	26,6	35,2	43,9
50	8,8	8,8	9,0	9,8	12,4	19,5	27,6	36,0	44,5
100	17,5	17,5	17,6	18,0	19,5	24,7	31,5	39,0	47,0
150	26,2	26,2	26,3	26,6	27,6	31,5	37,0	43,6	50,9

Vertical Accuracy (cm) (RTK+acoustic)

	Buoy to MiniPointer Horizontal Distance (m)								
Depth (m)	0	5	10	25	50	100	150	200	250
5	3,5	3,5	3,5	4,8	9,0	17,6	26,3	35,0	43,7
10	3,5	3,5	3,5	4,8	9,0	17,6	26,3	35,0	43,7
25	3,5	3,5	3,5	4,9	9,0	17,6	26,3	35,0	43,7
50	3,5	3,5	3,5	5,2	9,2	17,7	26,3	35,0	43,7
100	4,5	4,6	4,8	6,2	9,8	18,0	26,6	35,2	43,9
150	6,3	6,4	6,6	7,7	10,8	18,6	26,9	35,5	44,1

Also estimated below, the vertical accuracy when using the pressure sensor included in the MiniPointer (in this case, the accuracy is obviously independent of the horizontal distance):

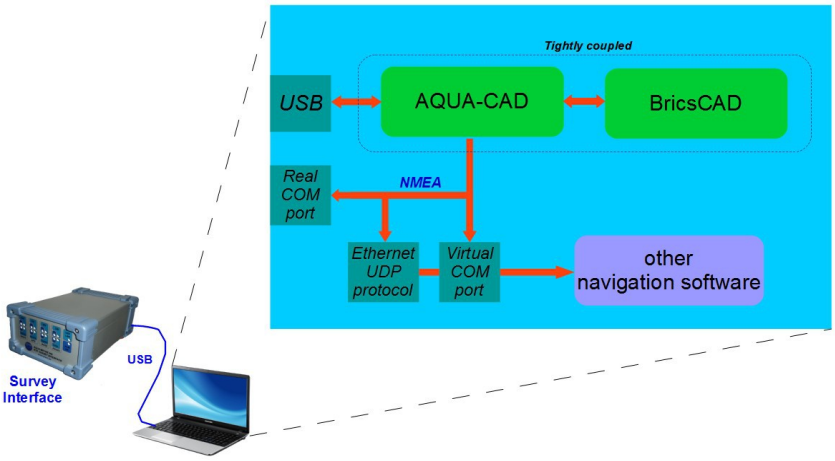
Vertical Accuracy (cm) (RTK-Tide+pressure sensor)

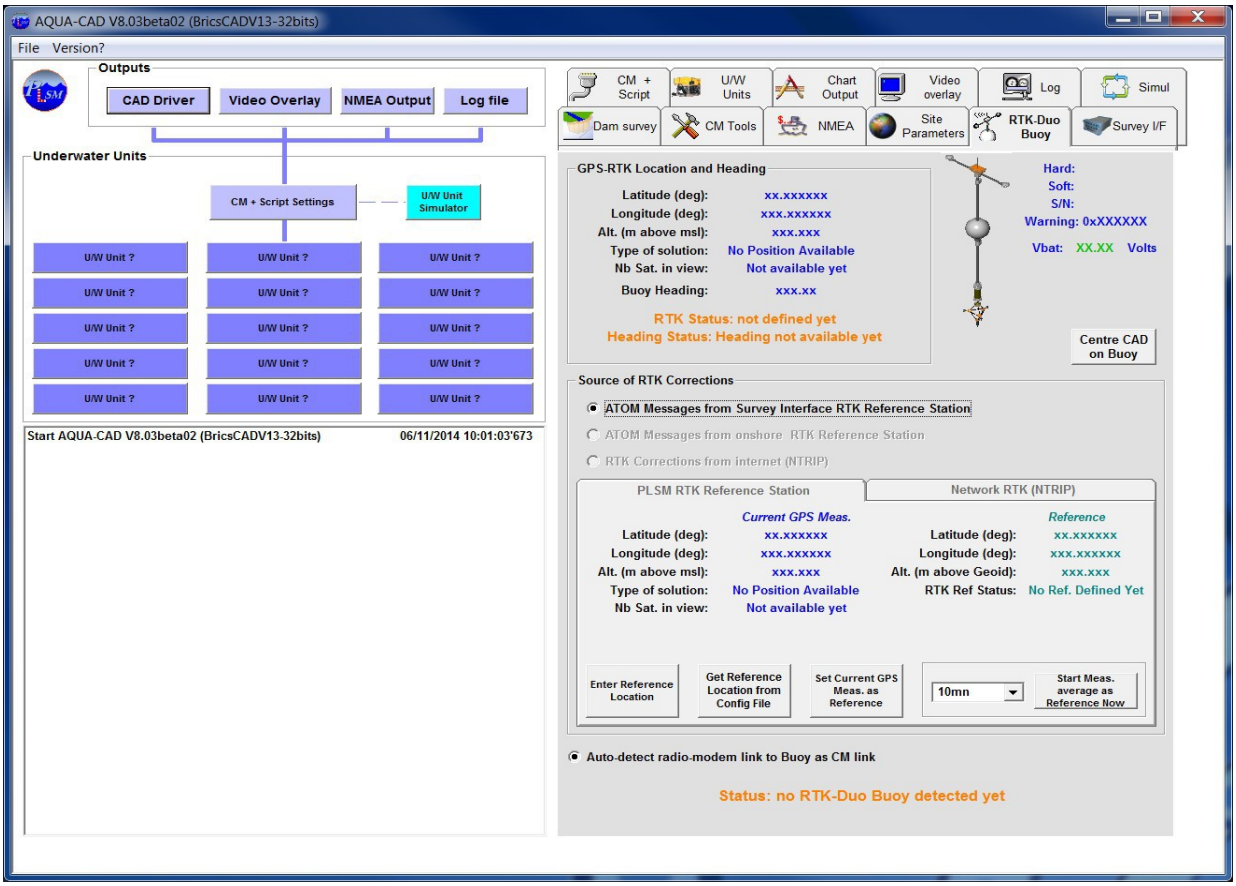
	Buoy to MiniPointer Horizontal Distance (m)								
Depth (m)	0	5	10	25	50	100	150	200	250
5	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4
10	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4
25	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4
50	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6
100	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0
150	5,8	5,8	5,8	5,8	5,8	5,8	5,8	5,8	5,8

Like every USBL system, if user needs a very accurate positioning, it is recommended to keep the RTKDuo buoy as close as possible to the Pointer location.

4 *AQUA-CAD software features*

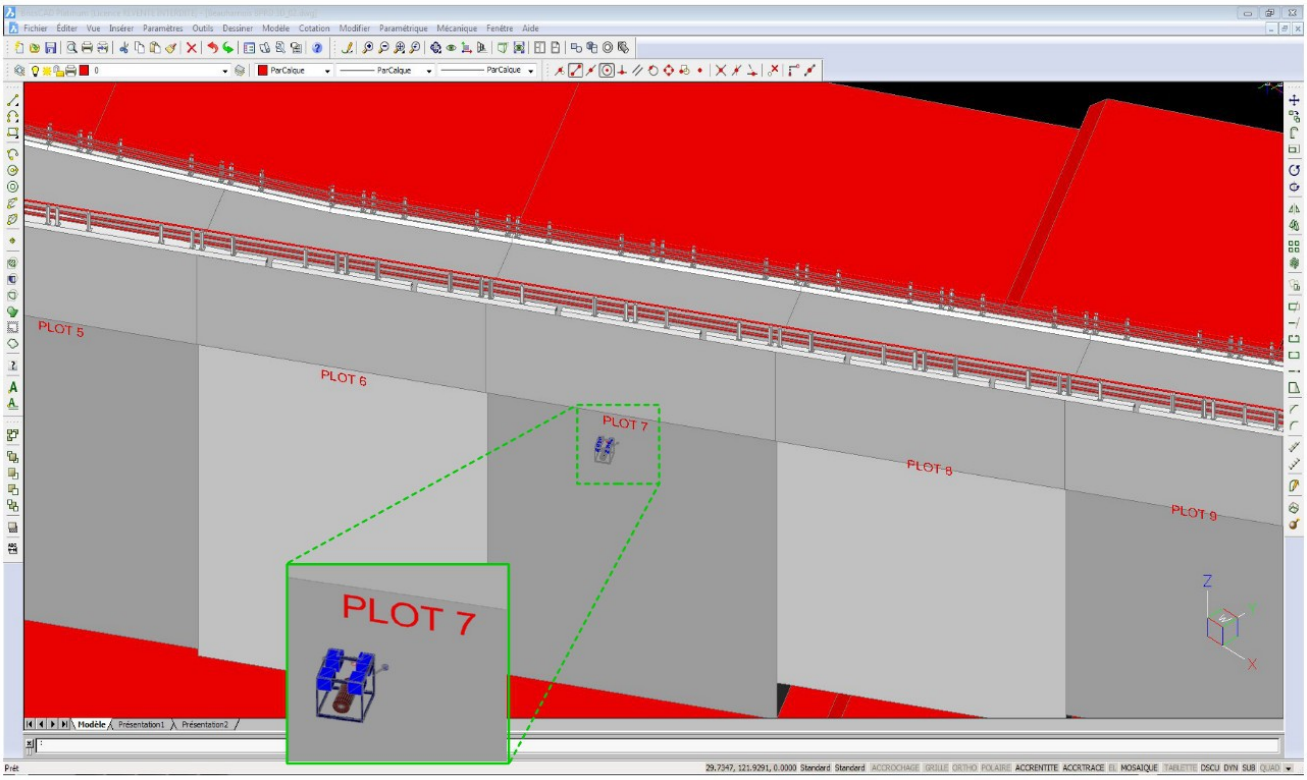
AQUACAD is a hardware specific software developed by PLSM and dedicated to the AQUA-METRE range of underwater positioning systems. AQUACAD is able to set up and manage an AQUA-METRE system configuration and report measurement in real time using a tightly coupled CAD application (BricsCAD which is fully .dwg compatible) and/or sending NMEA like output string to another navigation software. It also directly manages the PLSM's video overlay unit included in the Survey Interface.





AQUA-CAD main window (underwater units and log on the left, RTKDuo subwindow on the right)

AQUA-CAD is tightly coupled with the BricsCAD software (‚dwg fully compatible tool, see www.bricsys.com web site for more detail) used to display the measurements on the local map (simple 2D map up to a 3D structure). User can also define the ROVshape to display it in real time in the BricsCAD tool. The strong interface between AQUA-CAD and BricsCAD is not exclusive, user can work with the BricsCAD tool simultaneously (drawing entities, querying distances,...).



BricsCAD screenshot of a dam survey with 3D model (detail of the ROV zoomed)

User can also activate/deactivate the ROV trace, in this case each incoming measurement leave a small circle which center is the actual measurement value (x,y,z), the color may be selected by user.

The RTKDuo buoy and the RTK reference location are also displayed on the CAD drawing in order to check and optimize the position of the buoy.

5 Document history

Document number	Date	Modifications
0128-801-001	**22/10/2014**	Creation of the document
0128-801-002	**02/06/2015**	Minor modifications
0128-801-003	**30/11/2018**	New offshore configuration, improved performances,
0128-801-004	**30/04/2020**	New GNSS board, improved performances,