Tilted Sonar Head Offsets

February 2021

Introduction

NORBIT sonars provide a swath width of up to 210°. When surveying close to the shoreline or object of interest, it allows users to ensonify an area up to the draft of the sonar. For certain applications, surveying close to the area of interest is not possible due to safety or other limiting factors. In such scenarios, mounting the sonar at an angle is often preferred. This setup yields greater range and higher SNR soundings, enabling vessels to survey at a safe distance from the target.

Configuring integrated NORBIT sonars in such a way requires adjustments to be must be made to the INS setup. The adjustments factor in additional mounting angle offsets and provide adjusted offset values to add to the antenna lever arms.

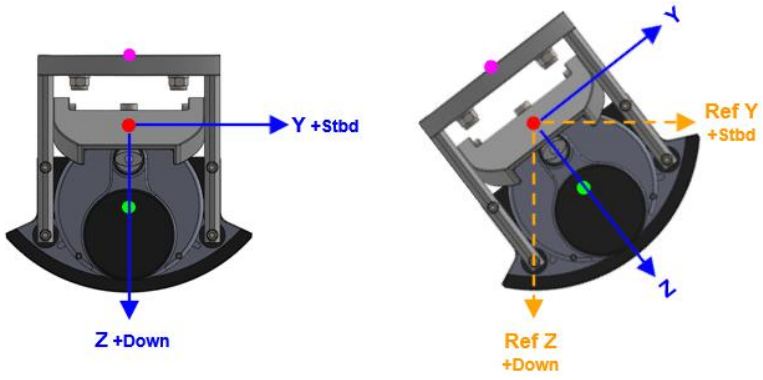


Figure 1. iWBMS looking from rear with no rotation (left) and rotation to starboard (right). Offsets between Sonar Ref. Point, IMU Ref. Point and Top Center of Bracket, within the Reference Frame, change depending on mounting angle.

1 WINGHEAD i77h / iWBMS / iWBMSh / iWBMSe

1.1 Mounting Angles

The internal mounting angles of the IMU (non-rotated) are found in the user manual. It depends on both the iWBMS model and IMU type. The IMU type can be viewed in **INS Tools → Version Info**

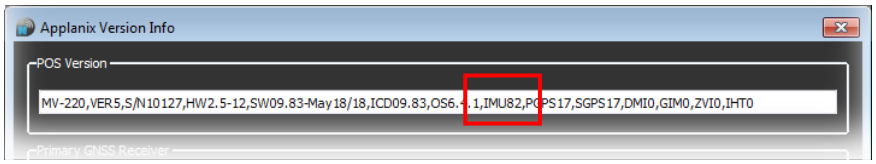


Figure 2. INS Version Info

1.1.1 IMU Type 89 (WINGHEAD i77h or iWBMSh)

If the sonar is rotated, X and Z becomes +90. The rotation angle is calculated as 90 plus the rotation angle (e.g. 90 + 10 = 100, for a 10.0° rotation to starboard) and is entered as a Y rotation. It is always positive.

No Rotation	
X (+ Port Up)	0.00
Y (+ Bow Up)	90.00
Z (+ Clockwise)	0.00

10.0° Rotation to Port	
X (+ Port Up)	90.00
Y (+ Bow Up)	80.00
Z (+ Clockwise)	90.00

10.0° Rotation to Stbd	
X (+ Port Up)	90.00
Y (+ Bow Up)	100.00
Z (+ Clockwise)	90.00

1.1.2 IMU Type 89 (WINGHEAD i77h, using standard WINGHEAD dual head bracket)

With the standard WINGHEAD dual head bracket, each sonar is rotated ±10° and pitched ±1° to optimize sounding distribution. In this case the following rotations apply, depending on which side the IMU is located:

10.0° Rotation to Port	
X (+ Port Up)	89.00
Y (+ Bow Up)	80.00
Z (+ Clockwise)	89.00

10.0° Rotation to Stbd	
X (+ Port Up)	91.00
Y (+ Bow Up)	100.00
Z (+ Clockwise)	91.00

1.1.3 IMU Type 42 (iWBMS) or 64 (iWBMSh)

Enter the mounting angle as a Y-rotation, e.g. if the iWBMS is mounted 37.5º to port, enter +37.5° for Y.

No Rotation	
X (+ Port Up)	90.00
Y (+ Bow Up)	0.00
Z (+ Clockwise)	-90.00

37.5° Rotation to Port	
X (+ Port Up)	90.00
Y (+ Bow Up)	37.50
Z (+ Clockwise)	-90.00

37.5° Rotation to Stbd	
X (+ Port Up)	90.00
Y (+ Bow Up)	-37.50
Z (+ Clockwise)	-90.00

1.1.4 IMU Type 82 (iWBMS)

If the sonar is rotated, X becomes 90 and Z becomes -90. The rotation angle is calculated as -90 plus the rotation angle (e.g. -90 + 37.5 = -52.5, for a 37.5° rotation to port) and is entered as a Y rotation. The Y rotation is always negative.

No Rotation	
X (+ Port Up)	0.00
Y (+ Bow Up)	-90.00
Z (+ Clockwise)	0.00

37.5° Rotation to Port	
X (+ Port Up)	90.00
Y (+ Bow Up)	-52.50
Z (+ Clockwise)	-90.00

37.5° Rotation to Stbd	
X (+ Port Up)	90.00
Y (+ Bow Up)	-127.50
Z (+ Clockwise)	-90.00

1.1.5 IMU Type 69 (iWBMSe)

The rotation angle is entered as an X rotation, with the sign reversed due to the 180° Z-rotation:

No Rotation	
X (+ Port Up)	0.00
Y (+ Bow Up)	0.00
Z (+ Clockwise)	180.00

37.5° Rotation to Port	
X (+ Port Up)	-37.50
Y (+ Bow Up)	0.00
Z (+ Clockwise)	180.00

37.5° Rotation to Stbd	
X (+ Port Up)	37.50
Y (+ Bow Up)	0.00
Z (+ Clockwise)	180.00

1.2 Offset Adjustments

1.2.1 WINGHEAD i77h

For dual head offsets in the standard WINGHEAD dual head bracket, refer to the user manual. For single head rotations, refer to the table below. The *Sonar Ref. Point to IMU Ref. Point* and *Sonar Ref. Point to Measure Point* must be adjusted for the mounting angle. Note, the X offsets are unaffected.

The table below shows the required adjustments from 5º up to 50º. Enter the offsets in **INS Tools → INS Setup Wizard**, selecting both **Custom** System and **Custom** Measure Point. Note, these tables only show the values for a rotation to port; if mounted to starboard, the sign of the Y offsets **MUST** be reversed.

Sonar Ref. Point to IMU Ref. Point			
Rotation to Port	**X +Fwd**	**Y +Stbd**	**Z +Down**
0.0°	Refer to User Manual Offsets & Reference Points Chapter	0.000 m	0.004 m
2.5°		-0.002 m	0.004 m
5.0°		-0.003 m	0.004 m
7.5°		-0.005 m	0.004 m
10.0°		-0.007 m	0.039 m
12.5°		-0.009 m	0.039 m
15.0°		-0.010 m	0.039 m
17.5°		-0.012 m	0.038 m
20.0°		-0.014 m	0.038 m
22.5°		-0.015 m	0.037 m
25.0°		-0.017 m	0.036 m
27.5°		-0.018 m	0.035 m
30.0°		-0.020 m	0.035 m
32.5°		-0.021 m	0.034 m
35.0°		-0.023 m	0.033 m
37.5°		-0.024 m	0.032 m
40.0°		-0.026 m	0.031 m
42.5°		-0.027 m	0.029 m
45.0°		-0.028 m	0.028 m
47.5°		-0.029 m	0.027 m
50.0°		-0.031 m	0.026 m

Sonar Ref. Point to Measure Point / Top Center of Bracket			
Rotation to Port	**X +Fwd**	**Y +Stbd**	**Z +Down**
0.0°	Refer to User Manual Offsets & Reference Points Chapter	0.000 m	-0.027 m
2.5°		0.001 m	-0.027 m
5.0°		0.002 m	-0.027 m
7.5°		0.004 m	-0.027 m
10.0°		0.005 m	-0.027 m
12.5°		0.006 m	-0.026 m
15.0°		0.007 m	-0.026 m
17.5°		0.008 m	-0.026 m
20.0°		0.009 m	-0.025 m
22.5°		0.010 m	-0.025 m
25.0°		0.011 m	-0.024 m
27.5°		0.012 m	-0.024 m
30.0°		0.014 m	-0.023 m
32.5°		0.015 m	-0.023 m
35.0°		0.015 m	-0.022 m
37.5°		0.016 m	-0.021 m
40.0°		0.017 m	-0.021 m
42.5°		0.018 m	-0.020 m
45.0°		0.019 m	-0.019 m
47.5°		0.020 m	-0.018 m
50.0°		0.021 m	-0.017 m

* NOTE: If the sonar is mounted with a rotation to starboard, the sign of the Y offsets must be reversed

1.2.2 iWBMS / iWBMSh / iWBMSe, 400kHz, Bracket 35021

Sonar Ref. Point to IMU Ref. Point			
Rotation to Port	**X +Fwd**	**Y +Stbd**	**Z +Down**
0.0°	Refer to User Manual Offsets & Reference Points Chapter	0.000 m	0.079 m
2.5°		-0.003 m	0.079 m
5.0°		-0.007 m	0.079 m
7.5°		-0.010 m	0.078 m
10.0°		-0.014 m	0.078 m
12.5°		-0.017 m	0.077 m
15.0°		-0.020 m	0.076 m
17.5°		-0.024 m	0.075 m
20.0°		-0.027 m	0.074 m
22.5°		-0.030 m	0.073 m
25.0°		-0.033 m	0.072 m
27.5°		-0.036 m	0.070 m
30.0°		-0.040 m	0.068 m
32.5°		-0.042 m	0.067 m
35.0°		-0.045 m	0.065 m
37.5°		***-0.048 m***	***0.063 m***
40.0°		-0.051 m	0.061 m
42.5°		-0.053 m	0.058 m
45.0°		-0.056 m	0.056 m
47.5°		-0.058 m	0.053 m
50.0°		-0.061 m	0.051 m

Sonar Ref. Point to Measure Point / Top Center of Bracket			
Rotation to Port	**X +Fwd**	**Y +Stbd**	**Z +Down**
0.0°	Refer to User Manual Offsets & Reference Points Chapter	0.000 m	-0.070 m
2.5°		0.003 m	-0.070 m
5.0°		0.006 m	-0.070 m
7.5°		0.009 m	-0.069 m
10.0°		0.012 m	-0.069 m
12.5°		0.015 m	-0.068 m
15.0°		0.018 m	-0.068 m
17.5°		0.021 m	-0.067 m
20.0°		0.024 m	-0.066 m
22.5°		0.027 m	-0.065 m
25.0°		0.030 m	-0.063 m
27.5°		0.032 m	-0.062 m
30.0°		0.035 m	-0.061 m
32.5°		0.038 m	-0.059 m
35.0°		0.040 m	-0.057 m
37.5°		***0.043 m***	***-0.056 m***
40.0°		0.045 m	-0.054 m
42.5°		0.047 m	-0.052 m
45.0°		0.049 m	-0.049 m
47.5°		0.052 m	-0.047 m
50.0°		0.054 m	-0.045 m

* NOTE: If the sonar is mounted with a rotation to starboard, the sign of the Y offsets must be reversed

2 iWBMSc (NovAtel)

It is important to bear in mind the NovAtel sign convention. Y is +Forward, X is +Starboard and Z is +Up. For this mounting configuration we are only concerned with rotation of the Y-axis, where positive is port up.

The two lines in the batch file that must be adjusted are `setinsoffset` and `vehiclebodyrotation`.

```
SETINSOFFSET 0.000000 -0.061150 0.1025000
VEHICLEBODYROTATION 0 0 0
```

It is advised that a separate batch file be saved indicating that this is a non-traditional mounting arrangement. By including `;;` prior to a line in the batch file, comments may be added. This helps to avoid mistakes in future. Remember to reload the batch file once the changes have been finalized.

2.1 Mounting Angles

When the iWBMSc is mounted in a standard configuration, there are no mounting angles applied in the configuration. When the sonar is mounted at a rotation, the mounting angle must be applied to the Y-axis. For instance, if the iWBMSc is mounted at a 37.5º to starboard, -37.5° must be entered in the configuration. The -37.5° must be entered as the first value of the `VEHICLEBODYROTATION` command, thus in this example it would be `VEHICLEBODYROTATION` -37.5 0 0.

2.2 Offset Adjustments

When mounting the iWBMSc at an angle, the `SETINSOFFSET`, `SETIMUTOANTOFFSET`, and `SETIMUTOANTOFFSET2` values must change accordingly. The Y adjustment of -0.061150 m remains the same regardless of mounting angle.

The following table gives the required adjustments from 5º up to 50º. Note, these tables only show the values for a rotation to port; if mounted to starboard, the sign of the X offsets **MUST** be reversed.

SETINSOFFSET from IMU to REF			
Rotation to Port	**X +Stbd**	**Y +Fwd**	**Z +Up**
0.0°	0.000 m	Refer to User Manual Offsets & Reference Points Chapter	0.102 m
2.5°	0.004 m		0.102 m
5.0°	0.009 m		0.102 m
7.5°	0.013 m		0.101 m
10.0°	0.018 m		0.100 m
12.5°	0.022 m		0.100 m
15.0°	0.026 m		0.099 m
17.5°	0.031 m		0.097 m
20.0°	0.035 m		0.096 m
22.5°	0.039 m		0.094 m
25.0°	0.043 m		0.092 m
27.5°	0.047 m		0.090 m
30.0°	0.051 m		0.088 m
32.5°	0.055 m		0.086 m
35.0°	0.059 m		0.084 m
37.5°	***0.062 m***		***0.081 m***
40.0°	0.066 m		0.078 m
42.5°	0.069 m		0.075 m
45.0°	0.072 m		0.072 m
47.5°	0.075 m		0.069 m
50.0°	0.078 m		0.066 m

Top Center of Bracket to IMU			
Rotation to Port	**X +Stbd**	**Y +Fwd**	**Z +Up**
0.0°	0.000 m	Refer to User Manual Offsets & Reference Points Chapter	-0.125 m
2.5°	-0.005 m		-0.125 m
5.0°	-0.011 m		-0.125 m
7.5°	-0.016 m		-0.124 m
10.0°	-0.022 m		-0.123 m
12.5°	-0.027 m		-0.122 m
15.0°	-0.032 m		-0.121 m
17.5°	-0.038 m		-0.119 m
20.0°	-0.043 m		-0.117 m
22.5°	-0.048 m		-0.115 m
25.0°	-0.053 m		-0.113 m
27.5°	-0.058 m		-0.111 m
30.0°	-0.063 m		-0.108 m
32.5°	-0.067 m		-0.105 m
35.0°	-0.072 m		-0.102 m
37.5°	***-0.076 m***		***-0.099 m***
40.0°	-0.080 m		-0.096 m
42.5°	-0.084 m		-0.092 m
45.0°	-0.088 m		-0.088 m
47.5°	-0.092 m		-0.084 m
50.0°	-0.096 m		-0.080 m

* NOTE: If the sonar is mounted with a rotation to starboard, the sign of the X offsets must be reversed.

3 Calculating Offsets for Custom Mounting Angles

Should the tables above not contain the desired mounting angle, this section shows how to calculate the offsets for any mounting angle and relevant fixed offsets.

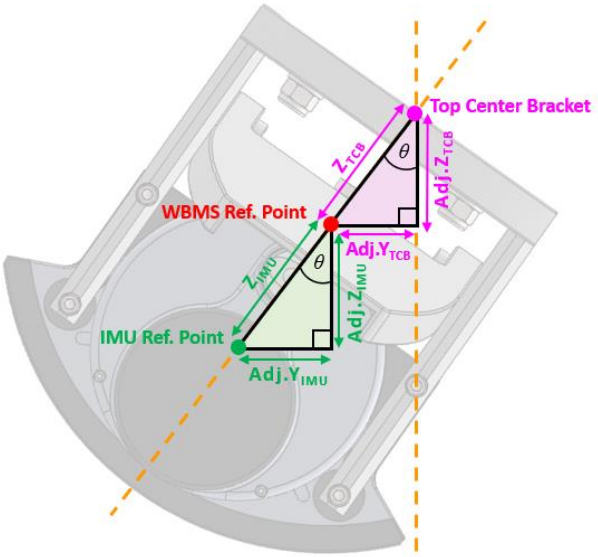
Fixed Offsets:

Z_{IMU}	Sonar Ref. Point to IMU Ref. Point in Z (no tilt)
Z_{TCB}	Sonar Ref. Point to Top Center Bracket in Z (no tilt)
θ	WBMS Mounting Angle

Unknowns:

Adj. Y_{IMU}	Adjusted Sonar Ref. Point to IMU Ref. Point in Y
Adj. Z_{IMU}	Adjusted Sonar Ref. Point to IMU Ref. Point in Z
Adj. Y_{TCB}	Adjusted Sonar Ref. Point to Top Center Bracket in Y
Adj. Z_{TCB}	Adjusted Sonar Ref. Point to Top Center Bracket in Z

Refer to Section 3 of the user manual for the fixed offsets of the relevant system.



$Adj.\ Y_{TCB} = Z_{TCB} \times \sin\theta$

$Adj.\ Z_{TCB} = Z_{TCB} \times \cos\theta$

$Adj.\ Y_{IMU} = Z_{IMU} \times \sin\theta$

$Adj.\ Z_{IMU} = Z_{IMU} \times \cos\theta$

Figure 3. Rear perspective of iWBMS/iWBMSh with a rotation to port, showing all known and unknown offsets.

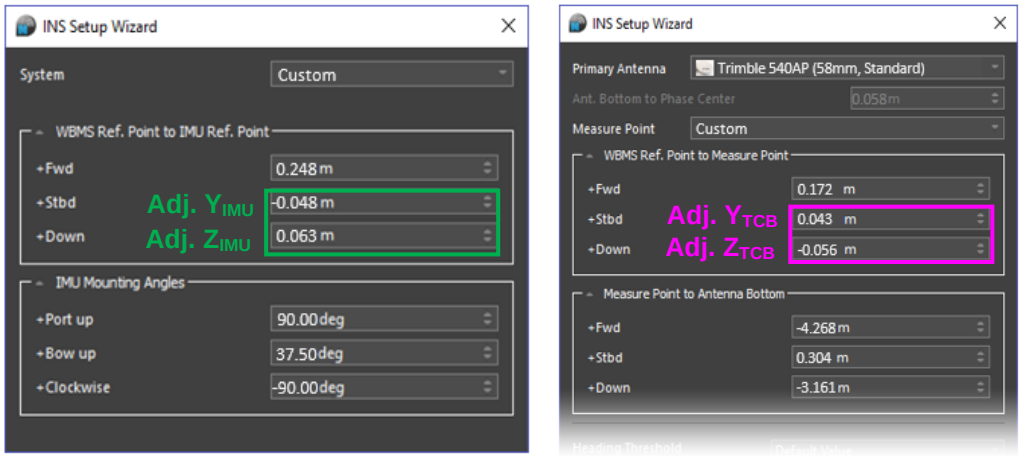


Figure 4. Example showing INS Setup Wizard for iWBMSh (1º TX with IMU Type 42) with 37.5º rotation to port.

4 Dual Head Example (iWBMSh with 1º TX, IMU Type 42, ±37.5° Tilt)

Step 1 Suppose that the system is mounted in the standard dual head bracket with ±37.5° rotation.

Step 2 The table in Section **Error! Reference source not found.** indicates that two offsets must be a djusted: *Sonar Ref. Point to IMU Ref. Point* and *Sonar Ref. Point to Measure Point.*

Step 3 Referring to the User Manual, we know that the standard offsets (with zero rotation) are as follows:

Sonar Ref. Point to IMU Ref. Point	**Sonar Ref. Point to Top Center of Bracket**
X: 0.248 m +Fwd	X: 0.172 m +Fwd
Y: 0.000 m +Stbd	Y: 0.000 m +Stbd
Z: 0.079 m +Down	Z: -0.070 m +Down

Step 4 Referring to the table in Section 1.2.2, we know that the Y and Z offsets must be adjusted as follows for a rotation of 37.5° to port:

Sonar Ref. Point to IMU Ref. Point	**Sonar Ref. Point to Top Center of Bracket**
X: 0.248 m +Fwd (No adjustment)	X: 0.172 m +Fwd (No adjustment)
Y: -0.048 m +Stbd	Y: 0.043 m +Stbd
Z: 0.063 m +Down	Z: -0.056 m +Down

Recall that, for a rotation to starboard, the Y sign must be reversed.

Step 5 With dual head it may be more convenient and practical to use Top Center of Dual Head Bracket as the Measure Point. Thus, the *Sonar Ref. Point to Top Center of Bracket* offset can be adjusted to change the Measure Point, using the offsets on the drawing on the next page.

Sonar Ref. Point to Top Center of Dual Head Bracket
X: 0.172 m +Fwd (No adjustment)
Y: 0.215 m +Stbd
Z: -0.210 m +Down

Note, this has no effect on where the data output is valid; it simply means that the antenna offset should now be measured from the top of the dual head bracket, which is easier. Note also, these offsets are only valid for the *NORBIT dual head bracket*, with ±37.5° rotation.

Step 6 Update the configuration in the GUI with the revised offsets.

1. In **INS Tools** → **INS Setup Wizard**, select System: **Custom** and enter the revised *Sonar Ref. Point to IMU Ref Point* offset, depending on whether the IMU is mounted to port or starboard.
2. Enter 37.5° rotation in the "+Bow Up" field of the IMU Mounting Angles section if the IMU is rotated to port, or -37.5° if rotated to starboard.
3. Finally, enter the revised *Sonar Ref. Point to Measure Point* offset, selecting Measure Point: **Custom**.
4. Save the configuration.

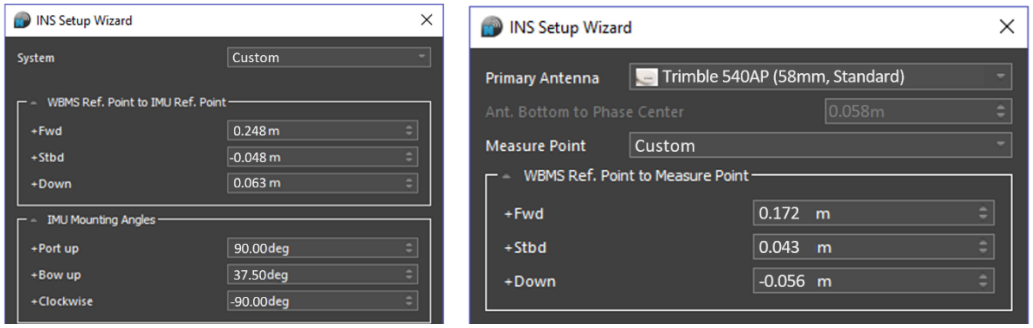


Figure 5 The adjusted offsets should be applied in **INS Tools** → **INS Setup Wizard.**

Step 7 Configure the offsets in the data acquisition software. This depends on where your chosen reference point (0,0,0) is located.

1. The system is configured by default so that position and attitude data are valid at the Sonar Ref. Point. Thus, multibeam, position and attitude data are valid at the same location.
2. If your chosen reference point is the vessel COG, apply a 'COG to Sonar Ref. Point' offset to the multibeam data (only the sonar which contains the IMU), as well as position and attitude data. Multibeam data from the second sonar requires a new offset, 'COG to Secondary Sonar Ref. Point'.
3. If your chosen reference point is the Sonar Ref. Point for the sonar containing the IMU, then your reference points are equal and no offsets are required for position, attitude and multibeam data for the primary head. Only the offset for the secondary head is required, i.e. apply an offset from 'Sonar Ref. Point (Primary) to Sonar Ref. Point (Secondary)'.

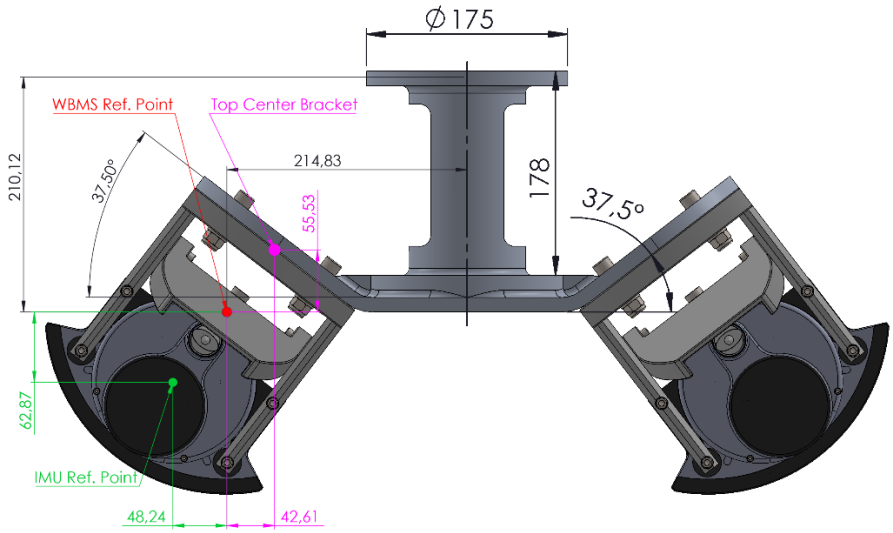


Figure 6. Rear view of iWBMS/iWBMSh (1° TX) in the standard dual head bracket with dimensions to center of flange.

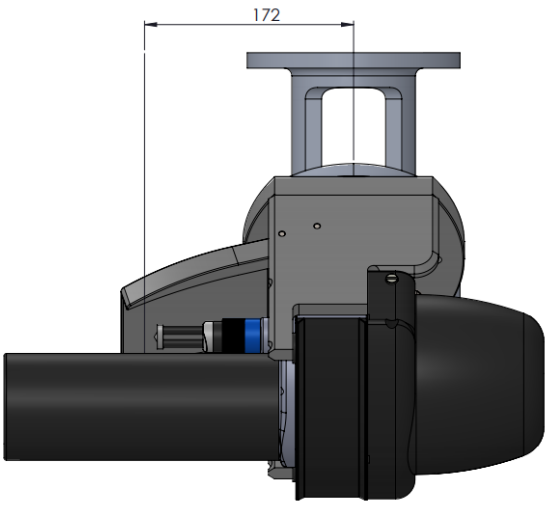


Figure 7. Side view of iWBMS/iWBMSh (1° TX) in the standard dual head bracket with dimensions to center of flange.

5 Operator Settings

In addition to the adjustments described previously, users should enter the sonar rotation angle under Advanced settings to normalize the gates and seabed profile, otherwise a flat seabed will appear to be sloping. However, note that this is only for display and does not affect data output.

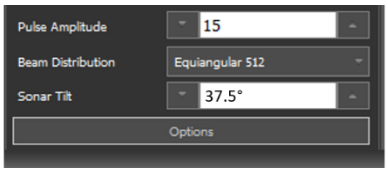


Figure 8. Enter the rotation angle in the GUI

6 Special Considerations for Angled Mounting

While mounting the NORBIT sonar with a rotation can be beneficial in some applications, it does not come without some tradeoffs. One issue is that users will experience a loss of range on one side of the swath. Users should adjust the line spacing to account for this. While the sonar is capable of a 210° swath angle, using the maximum swath angle in a rotated configuration is not practical. Issues of limited range and increased outer beam noise may negate any perceived benefit of operating with the wider swath.

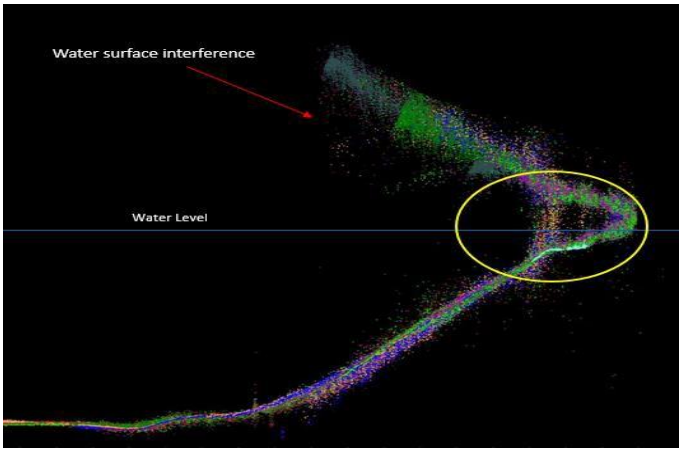


Figure 9. Surface reflections

A second issue that arises is surface reflections. Noise forming a horizontal V-shape near the surface may be apparent on the sonar display, and false soundings may be detected above waterline. Adjustments to sonar swath angle and gates can reduce this problem.

Users should also be aware of the impact of sound velocity. When surveying in an environment with a stable SV profile, impacts will be minimal. However, more complex SV environments can be challenging to model and correct for, therefore it is advised that additional SV casts be recorded when a tilted configuration is employed.