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HYSWEEP Angular Offsets – Static Pitch and Roll Values

By Joe Burnett

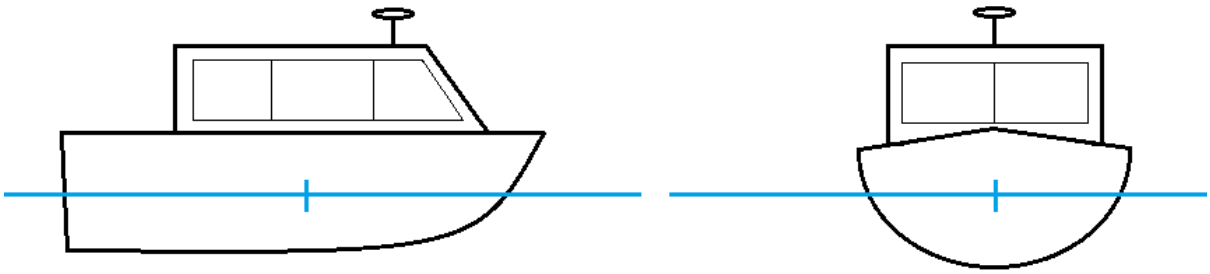
Recently, and more frequently, multibeam and LIDAR (laser) users are finding small, but significant vertical 'shifts' in their data. After asking some questions, we are finding that they are not compensating and correcting for the static (at rest) pitch and roll values of their motion device (MRU or IMU) in their system setup.

When setting up a multibeam, LIDAR, or even a single beam system (that is being motion compensated), it is important to enter the proper starboard, forward, and vertical offsets for each piece of equipment, with respect to the vessel center of gravity. Likewise, the static pitch and roll offsets of the motion device is an important part of the offsets of the system. These values allow for proper lever arm corrections, when motion data (heave, pitch, and roll) is collected from your MRU or IMU sensor and applied to the echosounder draft and the RTK GPS tide data.

It is here, that the static pitch and roll values need to be known, with respect to the level of the vessel, when it is at this static position.

WHAT DO WE MEAN BY 'STATIC' AND 'LEVEL'?

The **static** description is fairly simple and straightforward. When the vessel is in its normal, loaded state of fuel, cargo, equipment, and crew, and has *all* of its survey equipment deployed, and *all* personnel are at their respective stations on the vessel, and, the vessel is in as 'calm' of water as possible, it is now at its static position. This is when you should measure and enter the static pitch and roll offset values. (More on this later).



Pitch Roll

The **level** of the vessel is a bit more difficult than may be imagined. Typically, when a person thinks of a vessel being level, they understand it to be level both alongship and athwartship, or Fore-Aft and Port-Starboard. Where this becomes difficult, is designating the part of the vessel where you measure the horizontal plane. Is it the upper deck, the lower deck, some in-between deck, the gunwale… This differs by opinion.

It becomes much simpler, when we look at the first part of this equation—the static position. When the vessel is in its static position (as mentioned above), this is when you should measure the vertical offset of the sonar, as the vessel is now in its level position.

In a perfect world, if a vessel is sitting in the water in its static position, and is sitting perfectly flat in the alongship and athwartship planes, the MRU or IMU measures exactly 0.00 degrees for both the pitch and roll values (as shown above).

In the 'Real World', your vessel is, more than likely, going to have some degree of pitch and/or roll values, and they may even be fairly significant values, such as 5 degrees or more. How is this possible, you ask ?

FIGURE 1. *Pitch*

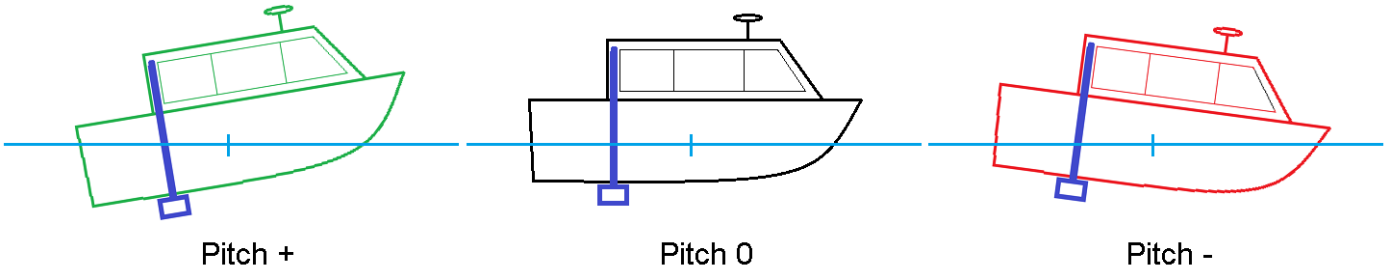
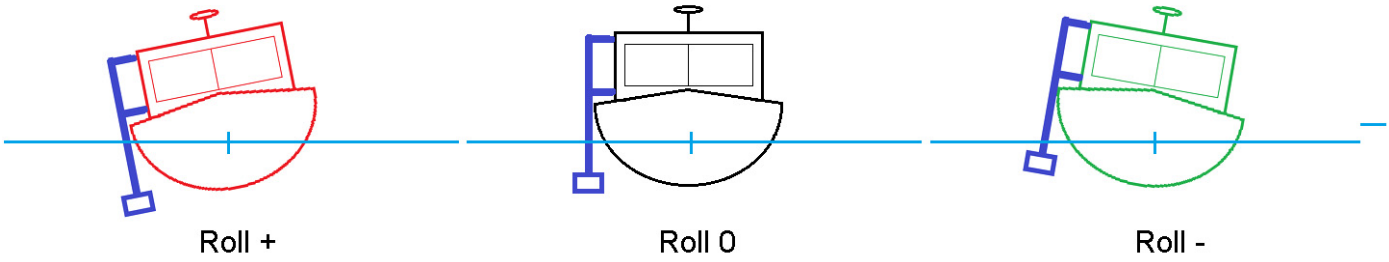


FIGURE 2. *Roll*



Well, when you mount your MRU or IMU, you mount it to the deck or bulkhead, that you assume was level. However, once your vessel is in the water, and at its static position, these horizontal mounting planes may not be level at all and the pitch and/or roll values output by the MRU or IMU, are *not* at 0.00 degrees. More than likely, your vessel is going to have a slight 'list' (roll); due to a weight imbalance caused by the placement of equipment, fuel, cargo, and personnel on the vessel; and a slight upward bow orientation (pitch), again, due to more weight located more to the aft in the vessel.

Therefore, it can be assumed that you will have pitch and roll offsets that are not 0.00 degrees. It is these values that will be considered your static pitch and roll values.

HOW DO YOU DETERMINE THESE VALUES (ACCURATELY) ?

Even when your vessel is in the water in its static position, if you watch the pitch and roll values displayed from your MRU or IMU, you will notice that they are changing faster than you can keep up with them (mainly because they are updating at 20-100 Hz). This is why our

programmer added two special boxes to the ‘Bar Check’ window in the HYSWEEP® SURVEY program.

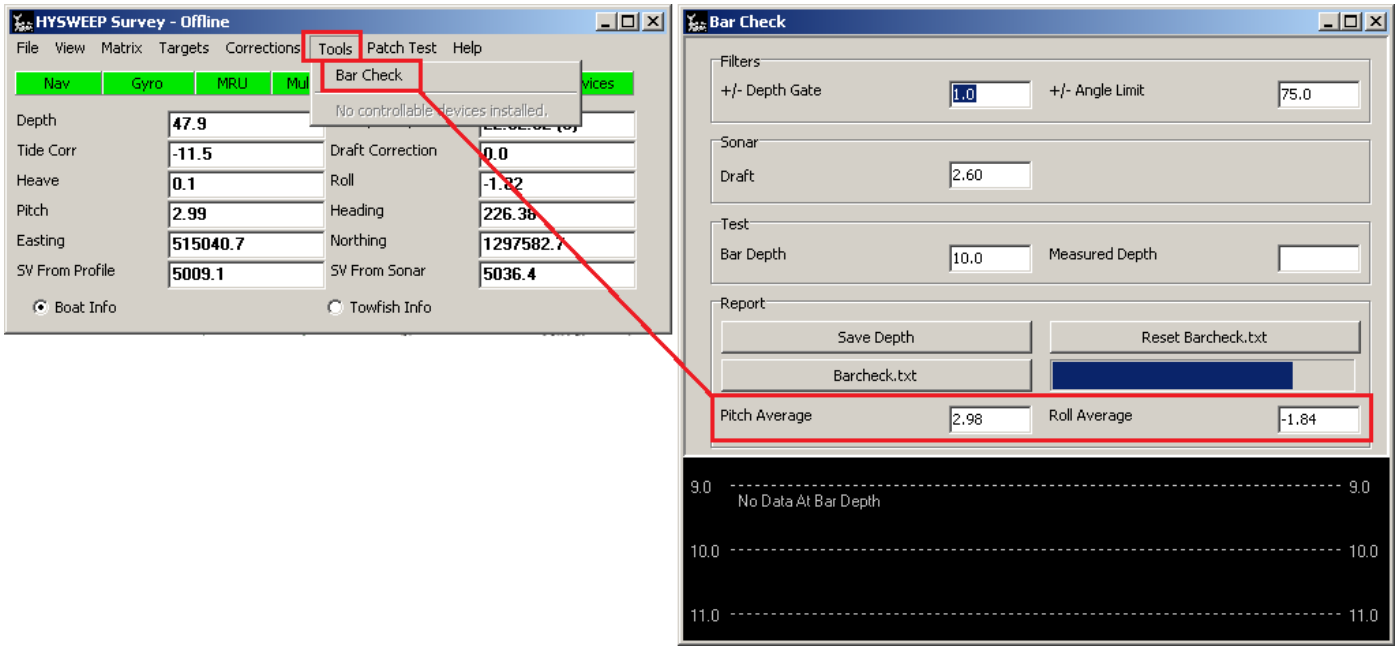
(And NO ! A ‘Bar Check’ does not take place at your local Pub.)

Once you have deployed all of your equipment, gotten the vessel into calm water, and all personnel seated at their respective stations:

1. **Start the HYSWEEP® SURVEY program.** (It is not necessary to start HYPACK® SURVEY.)
2. **Select TOOLS - BAR CHECK** and watch the Pitch Average and Roll Average values in the display. (These values are continually averaged.)

   After approximately 30-60 seconds, you should have a good static value for both pitch and roll.
3. **Write the static pitch and roll values down** or take a screen capture of the Bar Check window.

FIGURE 3. *Measuring the Static Pitch and Roll in the Bar Check Tool*



4. **Enter these values in the HARDWARE program** for the pitch and roll offsets for the MRU or IMU.

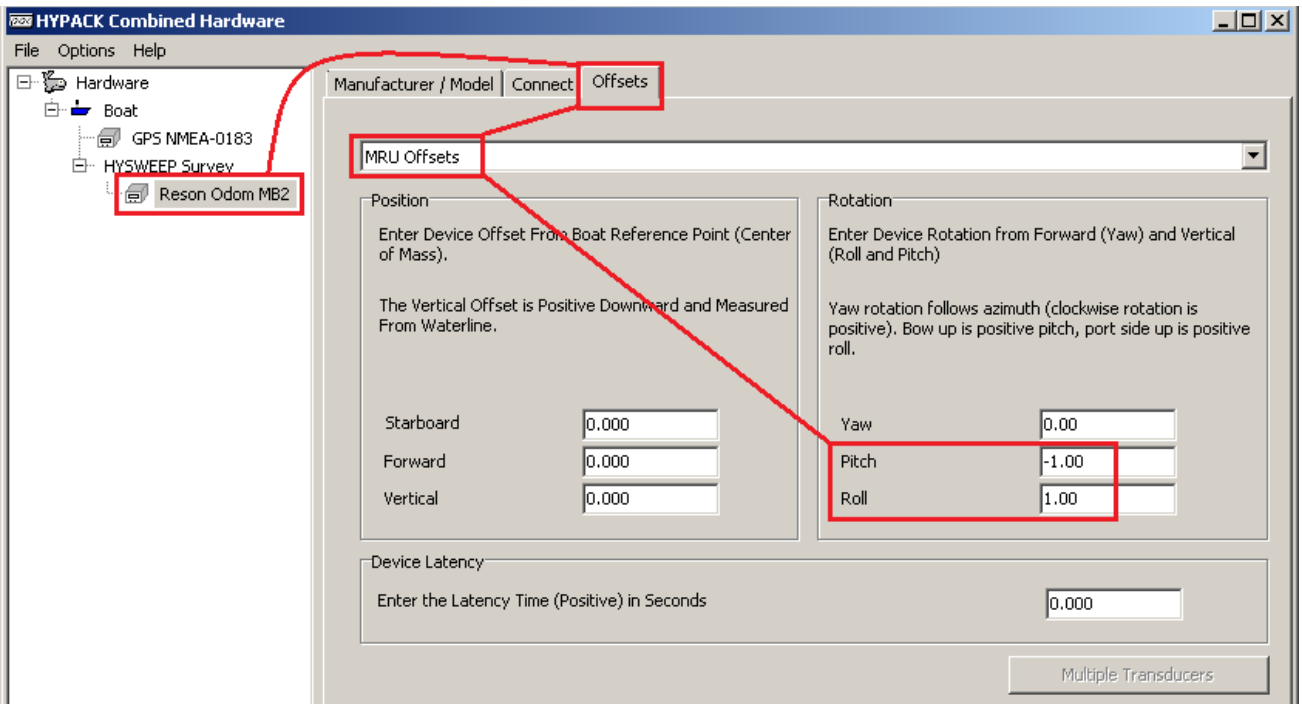
NOTE: If the vessel experiences a significant attitude change due to a sea state change or personnel movement, simply close and reopen the Bar Check Tool to restart the test.

IMPORTANT: These values should very closely, represent the static pitch and roll values for the vessel, even when there are slight changes to the amount of fuel, cargo, and crew currently on board. If you believe that your static pitch and roll values change/will change significantly, due to changes in any of these parameters, this procedure should be performed and recorded for all possible fuel, cargo, and crew loadings. With this information, you will be able to modify the static pitch and roll values, for each and every survey. If you do modify these values, the pitch and roll values for your Patch Test, will also need to be modified. (More on this later.)

WHAT DO I DO WITH THE STATIC PITCH AND ROLL VALUES ?

1. **Open the HARDWARE program**.
2. **Highlight the device that is providing your motion data**.
3. **In the Offsets tab, enter the static pitch and roll values**.

FIGURE 4. Entering the Static Pitch and Roll Offsets



WHAT IS THIS DOING FOR ME?

Because your vessel's attitude at its static position, is not perfectly level (the MRU or IMU pitch and roll are not 0.00), we need these values as 'correctors', so the motion sensor output can be adjusted to be as close to 0.00 degrees, as possible.

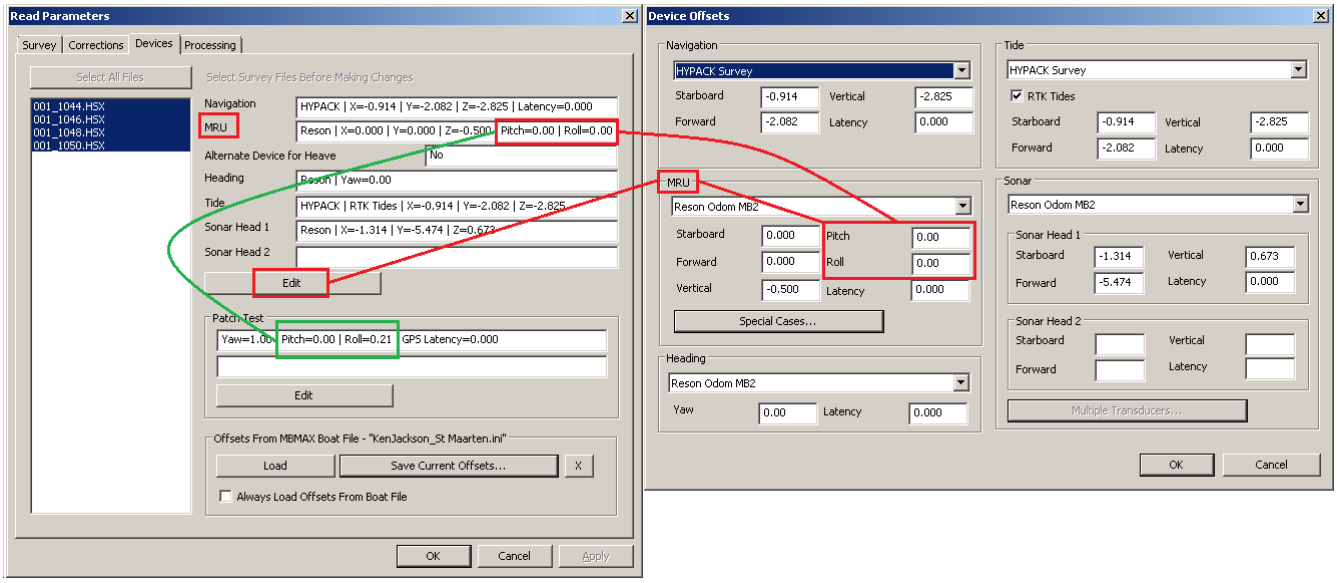
In effect, we are making the system and software 'think' that the vessel is perfectly level.

WILL THIS AFFECT MY CURRENT PATCH TEST VALUES ?

Absolutely !! Since you have 'changed the mounting orientation' of the MRU or IMU relative to the sonar with the offsets, you should perform a new Patch Test for pitch and roll to determine how much this 'manual change' has modified their current values.

If your original static pitch and roll values and Patch Test values are as shown here:

FIGURE 5. *Original Static and Patch Test Values*

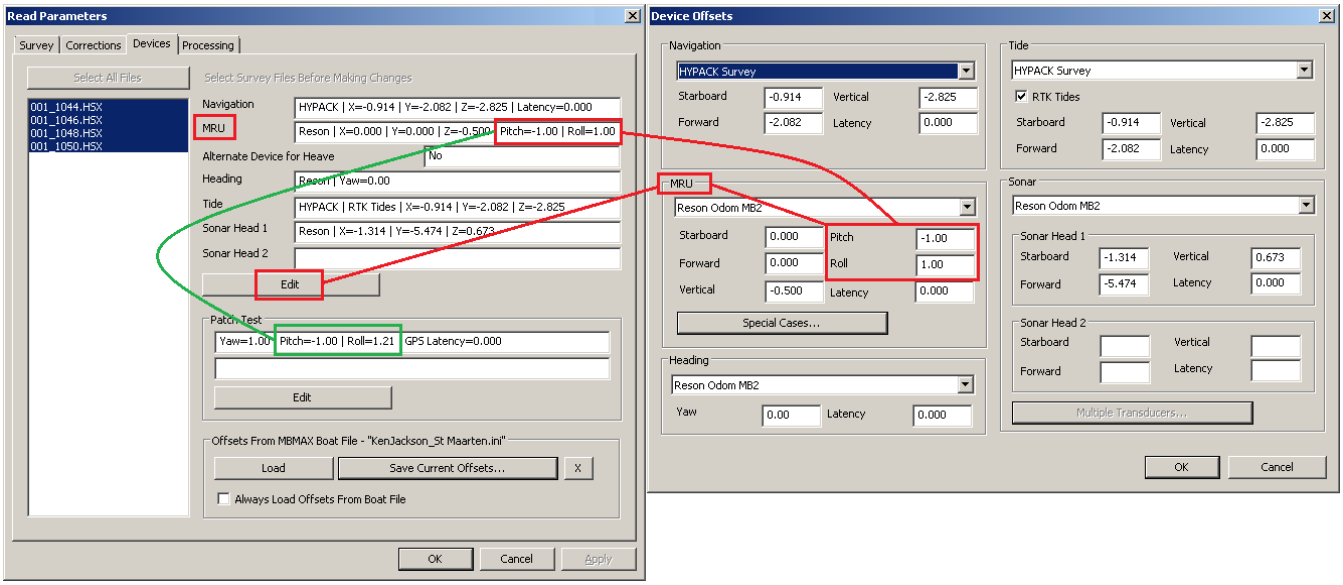


And now, you 'manually change' the static pitch and roll values (based on the results from the 'Bar Check' window), the Patch Test pitch and roll values should change by 'adding' the amount of the 'manual change' to the Patch Test's values.

In this example, the 'manual change' to the static Pitch was -1.00 degrees.

(It went from 0.00 to -1.00) Therefore, you should be able to 'add' -1.00 to the Patch Test's Pitch value.

The 'manual change' to the static Roll was +1.00 degrees. (It went from 0.00 to +1.00) Therefore, you should be able to 'add' +1.00 to the Patch Test's Roll value.



IMPORTANT: You should ALWAYS perform a proper Patch Test, just to verify the change.

AGAIN…. WHY AM I DOING THIS ??

This is being done, in order that, the lever arm corrections to the (1) vertical offset of the sonar (draft) and (2) vertical readings from the RTK device are properly calculated.

Here are examples of each:

VERTICAL OFFSET OF THE SONAR

- Static roll value of a the MRU or IMU is +5.00 degrees
- Vertical offset of the sonar is 1.00 meters (in the static position)
- Starboard offset of the sonar is 2.00 meters

If you did *not* enter the +5.00 degrees as a static roll offset for the motion sensor, and collected data while the vessel was stationary in its static position, the following calculation would be applied to the vertical offset of the sonar in MBMAX64 (64-bit HYSWEEP® EDITOR):

2.00 meters * TAN(+5.00 degrees) = +0.175 meters modification downward will be applied to the sonar vertical offset, *even though the draft of the sonar did not change*. This is because the editor is being told that the vessel is 'Rolling' by +5.00 degrees.

NOTE: If the static Roll value had been -5.00 degrees, this would have been an upward modification, or -0.175 meters 'addition', to the vertical offset of the sonar.

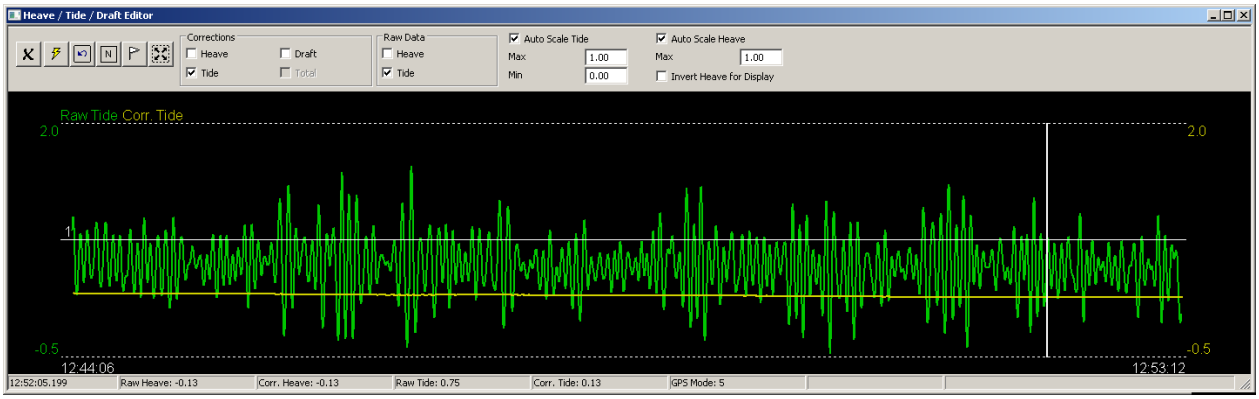
If the static value of +5.00 degrees *had* been entered in the roll offset for the motion sensor, and the vessel incurred a slight increase in the roll value to +6.00 degrees, the +5.00 degrees would be subtracted from the +6.00 degrees causing a 'true' +1.00 degree roll lever arm to be applied to the draft of the sonar, then the resulting modification of 2.00 meters * TAN(+1.00 degrees) = +0.035 meters downward would be correct.

Basically, the +5.00 roll value has become the "0.00" about which all roll values will be corrected.

VERTICAL READINGS (TIDE DATA) FROM RTK DEVICE

In a recent case, a user had a question of why their 'normalized' RTK tide values (yellow) were appearing below their raw tide values (green), instead of 'splitting' the middle of the raw tide values, as one would expect.

FIGURE 6. *Raw Tide Values (green) vs Normalized RTK (yellow)—Motion Sensor Offsets = 0*



Since they had 0.00 entered for the static pitch and roll values for the MRU, MBMAX assumed that these values represented the vessel when it was in its static position in the water and applied the pitch and roll data from the MRU, in the lever arm calculations for the RTK tide values.

After receiving the file from the user, it was noticed that their RTK GPS device was mounted near the bow of the vessel and had a forward offset of +16.257 meters and a starboard offset of -2.727 meters. When looking at the pitch and roll data collected during the survey line, it was noticed that it had an average pitch value near -1.2 degrees and an average roll value near 0.4 degrees.

FIGURE 7. Pitch = 1.2

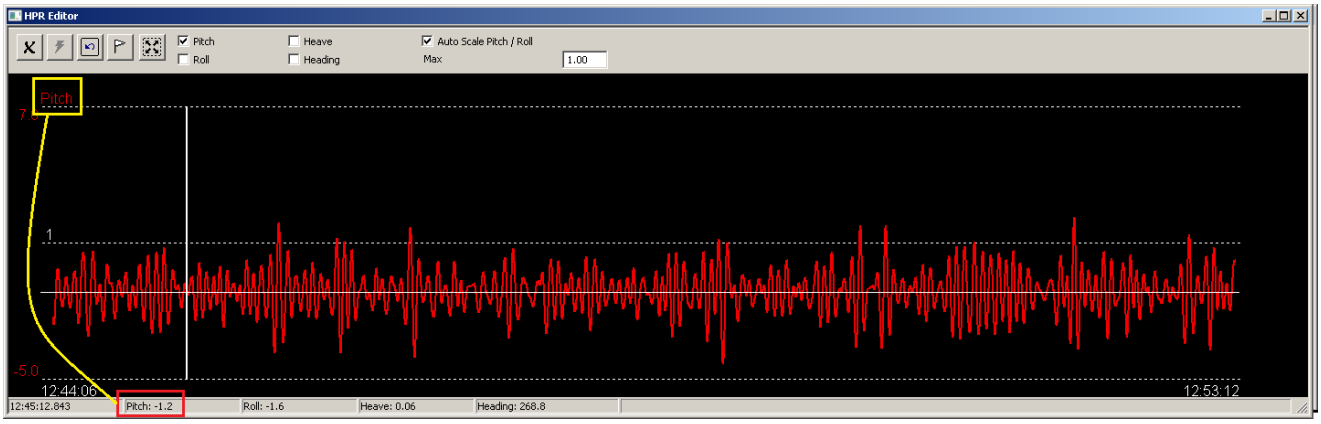
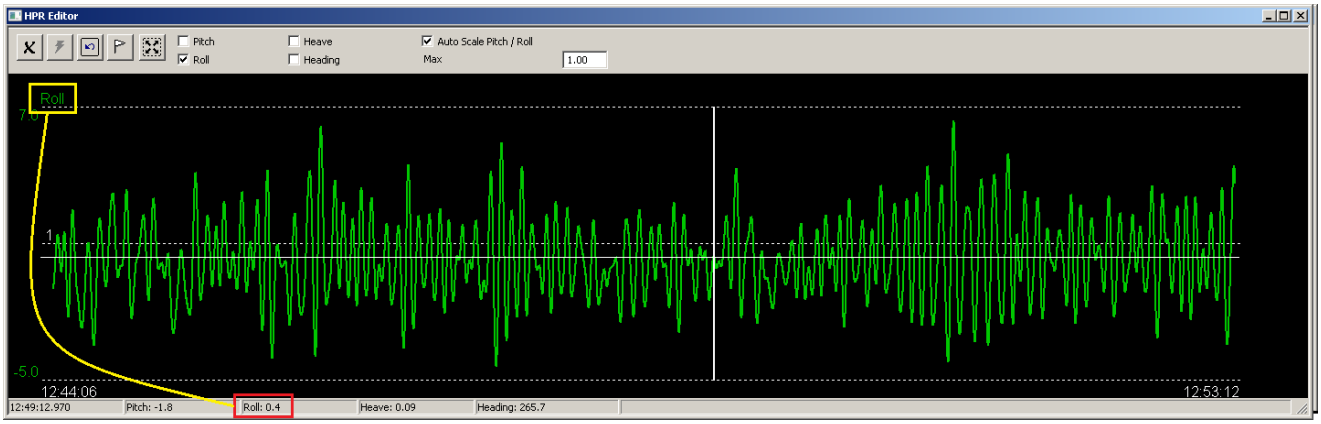


FIGURE 8. Roll = 0.4



Using these values and assuming that these average 'in motion' pitch and roll values approximated what the static values should be, the adjustments to the RTK Tide values would be the following:

Pitch: 16.257 meters * TAN(-1.2 degrees) = -0.312 meters (downward modification), in addition to,

Roll: -2.727 meters * TAN(0.4 degrees) = +0.019 meters (upward modification),

for a total approximate 'adjustment' of -0.293 meters (downward modification) to the RTK Tide data that was being calculated.

In HYPACK®, RTK tide values are inverted and called 'Tide Corrections'; therefore, in the displays, the adjustment would be an upward modification.

When these values were entered into the pitch and roll offsets for the MRU, the RTK Tide values (Tide Corrections) displayed like this:

FIGURE 9. *Raw Tide Values (green) vs Normalized RTK (yellow) with Motion Sensor Offsets*

MORAL OF THE STORY

If you have ever done surveys where you have compared single beam data to multibeam data and there seems to be a slight unresolvable 'vertical shift' between the two, it's very possible that this may be the issue.

Or, if you are comparing two multibeam surveys against each other (from two different vessels and systems) and there is a slight 'vertical shift' between the two surveys. It could be that one vessel had the static offsets and the other did not.

CONCLUSION

I know this may have been a lot to take in, and hopefully, my explanation did not confuse you, but I feel you are asking yourself, "Why haven't I been told about this before??"

Well, I know that in the Multibeam Training Courses that I have given over the past 9 years, I try to make it a point to discuss this issue and its importance. The 'Average Pitch' and 'Average Roll' boxes have been in the Bar Check window for as long as I can remember (15 years +). Again, they were put in this window for the very point that this article has been written.

If you have any questions, please don't hesitate to email me at joe@hypack.com