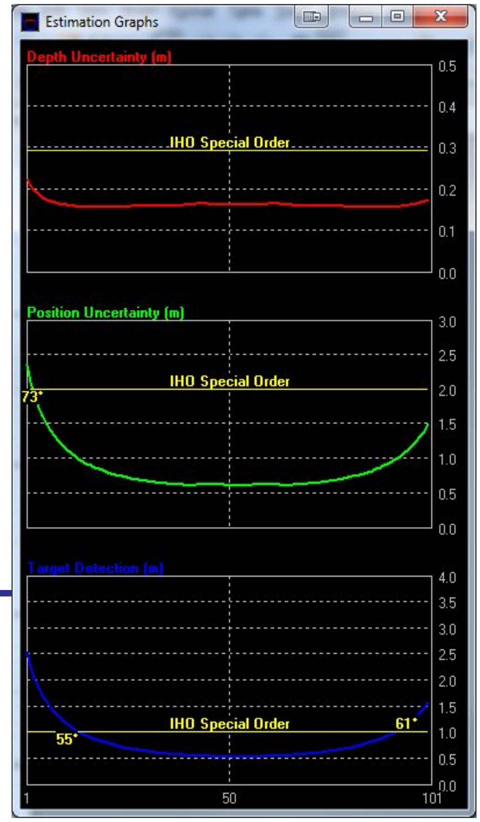
Total Propagated Uncertainty: A Primer — Part 1, TVU

By David Maddock



Welcome to the first in a multi-part series on Total Propagated Uncertainty (TPU). TPU is a method used to quantify the uncertainty of survey measurements developed by Rob Hare of the Canadian Hydrographic Service. HYPACK® can calculate and display TPU in several places—in a survey-planning calculator, during data acquisition in HYPACK® SURVEY and HYSWEEP®, and in post-processing tools like MBMAX (HYSWEEP® EDITOR).

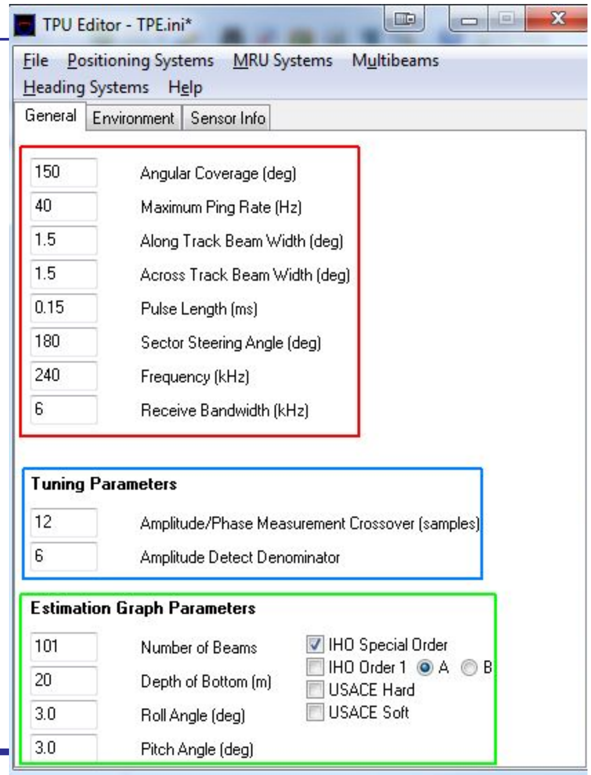
However, the trickiest part of implementing TPU is the configuration. There are many parameters to set up and it is not always clear what they mean or how they affect the uncertainty calculation. I hope that this series of articles will shed some light on this complicated, yet important, topic.

THE BASICS

The TPU algorithm makes three primary calculations per beam: a depth uncertainty (TVU), a position uncertainty (THU), and the minimum size target that can be detected. The general approach is to identify each potential source of uncertainty (equipment limitations, environmental factors, etc.) and combine them as a quadratic sum of squares. Each sum of squares can itself be a component in a higher-order sum and so on. The calculation "propagates" up a dependency tree to the top-most node which represents the total uncertainty for the beam.

TPU EDITOR

FIGURE 1. TPU EDITOR, General Tab

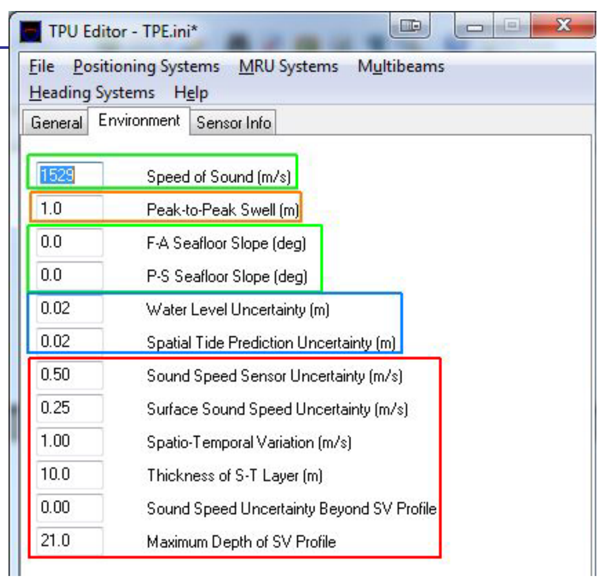


The TPU Editor is used to set the input parameters for these calculations and will display the results for a single hypothetical ping as a set of three graphs. If an accuracy standard is selected, it will be drawn as a yellow line and the angle of the first beam to violate the standard is noted.

Because the calculations take, as input, some real-time values during your survey (eg. roll, pitch, depth, beam angle, and so on), the TPU Editor expects you to enter a reasonable estimation of these values in the *Estimation Graph Parameters* section (see General tab). Also in this category are the *Speed of Sound* and *Seafloor Slope* fields (see Environment tab) and Survey Speed (see Sensor Info tab). During survey real-time values are used here.

THE COMPONENTS OF TOTAL VERTICAL UNCERTAINTY (TVU)

FIGURE 2. TPU EDITOR—Environment Tab



For this article, let's focus on the vertical or depth uncertainty. It is has four major components:

- Water level error
- Dynamic draft error
- Heave error
- Depth measurement error

The first three items are fairly straight-forward. These are tide, draft, and heave-related. The key fields that affect tides are outlined in blue (see Environment tab). The key fields for draft are outlined in purple (see Sensor Info tab). Heave is outlined in orange. These values are *a priori* uncertainties that can be found in the specification documents for your equipment or otherwise estimated.

The final component, depth measurement error, is by far the most complicated. It quantifies all the errors that are in some way a function of the measured depth:

- Pitch & roll measurement error
- Refraction errors
- Sounder errors

Typically this means that as depth increases, so does the uncertainty.

The pitch and roll component is governed by the fields outlined in yellow (see Sensor Info tab). These also can be found in the manual for your MRU.

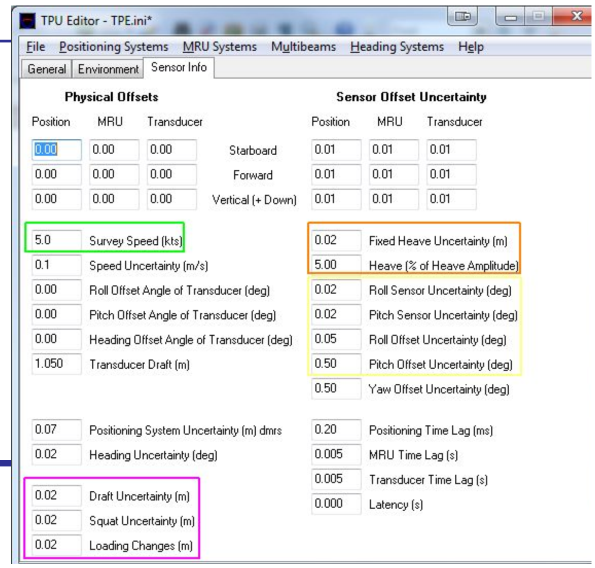


***FIGURE 3.** TPU EDITOR—Sensor Info Tab*

Refraction has to do with sound velocity corrections. These fields are outlined in red on the Environment tab. The Sound Speed Sensor Uncertainty can be found in the manual to your sound velocity probe. The final two fields deal with the case of soundings that go deeper than your SV profile does. If this doesn't pertain to your dataset, leave uncertainty beyond SV profile set to zero.

SOUNDER ERRORS

The final components we will discuss are those of the echosounder itself. There are three major factors:

- Along-track beam resolution
- Across-track beam angle measurement error
- Range measurement error

These are determined by the remaining fields of the General Tab.

As the name implies, the along-track beam resolution depends on the *Along-track Beam Width*.

The range measurement error is determined by *pulse length*.

IMPORTANT: Using a larger pulse length when it is not needed can have a serious effect on your TPU budget. Pay attention to this field!

Finally, across-track beam angle measurement depends on the *Across-track Beam Width*, but this one is tricky. TPU uses two different calculations depending on whether the sonar uses amplitude or phase detection. The *Amplitude/Phase Measurement Crossover* is used to tell the TPU Editor when to switch from using amplitude mode to phase mode. The *Amplitude Detect Denominator* tweaks the scale factor for amplitude mode. (Phase mode scaling is tied to the calculated phase sample count.) Only change these fields under advisement of your sonar manufacturer.

Tune in next time and we will cover the horizontal component (THU).