Calibration Accuracy for Aanderaa DCS Products

Introduction

The Aanderaa Doppler Current Sensors (DCS) are Doppler, backscatter based current sensors. The sensors transmit an acoustic pulse at a given frequency. If the pulse hits a scattering water volume, some of the acoustic energy is reflected and sent back to the instrument. The Doppler principle utilizes the frequency shift that occurs to the reflected signal if the scattering water volume is moving at a given speed relative to the current meter. The frequency shift increases if the scattering volume moves faster and decreases if the scattering volume moves slower. If there is no relative movement between the instrument and the water volume, the returned signal will have no frequency shift and contain the same frequency as was transmitted.

The frequency shift may be both positive and negative. If the water volume moves towards the sensor, the frequency shift will be positive, and if the water volume moves away from the sensor, the frequency shift will be negative.

The basic equation used to derive the current speed is dependent on the transmitted frequency, the received frequency and the speed of sound in the water volume. The equation is shown below:

$$Csea := (Fr - Ft) \cdot \frac{Cw}{Ft \cdot 2}$$

where

- *Ft* is the frequency of the transmitted pulse
- *Fr* is the frequency of the received signal
- *Cw* is the speed of sound in water

The above equation may be rearranged as follows:

$$Csea := \left[\left(\frac{Fr}{Ft} \right) - 1 \right] \cdot \frac{Cw}{2}$$

By looking at the equation above, it is clear that the only elements that may cause errors in the current speed estimation are the three parameters; *Ft*, *Fr* and *Cw*.

Inaccuracy Caused by Oscillator Drift

If we analyze the equation for current speed given above, we notice that the equation is sensitive to a transmitting frequency or sampling frequency that vary from unit to unit or with time. Aanderaa Instruments employs a design technique where the same oscillator is used to derive the transmitting frequency and the sampling frequency for the received signal. As a consequence, both *Fr* and *Ft* will be influenced proportionally by a frequency error in the oscillator circuitry. *The net result will therefore be zero, and full accuracy for the current speed estimation is still maintained, independent of oscillator accuracy*.

Inaccuracy Caused by Speed of Sound

The DCS assumes a speed of sound that equals 1500m/s. This figure is included in the software as a constant. If the speed of sound is not 1500m/s, an error will occur. However, this error may be corrected for in the post-processing software if the actual figure for the speed of sound is known.

The Aanderaa Data Reading Program 5059 allows you to correct the current speed estimates by means of technique called *virtual sensors*. The virtual sensor feature enables you to define a new virtual channel that derives its values from the figures of a measured channel and an applied equation.

The correcting equation is outlined below:

$$\text{Csea\_corrected} := \frac{\text{Csea\_measured} \cdot \text{Cw\_actual}}{\text{Cw\_assumed}}$$

where

- *Cw_actual* is the actual speed of sound present when the measurement took place.
- *Cw_assumed* is the speed of sound assumed by the instrument (1500m/s).
- *Csea_measured* is the current speed measured by the instruments, and
- *Csea_corrected* is the current speed corrected for difference in speed of sound

An even more elegant solution, when the instrument is equipped with pressure, temperature and conductivity sensors, is to let the 5059 derive the actual speed of sound itself. This may also be achieved using the program's virtual sensor feature. In this way every record may be corrected for the speed of sound that was present at the time the recording took place.

Other Matters Influencing Calibration Accuracy

Most Aanderaa DCS products produce 10-bit SR-10 data outputs. This is a 10-bit raw data format with an absolute resolution. The new DCS MkII series employ floating-point accuracy, and will as such have minimum round off errors. When converting to the 10-bit raw data format, a quantification error occurs. This error is equal to ±½LSB, or ±0.15cm/s. The latter error is not present in the RS-232 or CAN-Bus version since the measured current then is read out as a floating-point value.

Backscatter based Doppler Current sensors also suffer from statistic noise. The noise is modulated on top of the main signal and appears as a high frequency component. The mean value of this noise is zero, and it may therefore effectively be removed by means of a moving average filter. When the noise is *not* filtered out (none processed data), the DCS MkII series still achieves statistical noise with standard deviation as low as 0.5cm/s.