Calculating Calibration Coefficients for C-Star Transmissometer

The procedures in this application note are valid for Seasave V7 and SBE Data Processing version 7.21d and later. The Seasoft V2 software (Seasave V7 and SBE Data Processing) can produce the following transmissometer results:

Light transmission [%] = (M * voltage output) + B
Beam attenuation coefficient c = - (1 / z) * ln (light transmission [decimal] **)**

where

M and B are the calibration coefficients.
z is the transmissometer path length (meters).
M, B, and z are input to the CTD configuration (.xmlcon) file.
Light transmission [decimal] is light transmission [%] divided by 100.

M and B are listed on the sensor's Calibration Sheet, and are calculated as follows:

M = (Tw / [W0 – Y0]) * (A0 - Y0) / (A1 - Y1)
B = -M * Y1

the parameters listed on the Calibration Sheet:

- A0 = factory output in **air**, V_{air}
- Y0 = factory **dark or zero** (blocked path) output, V_d
- W0 = factory output in pure **water**, V_{ref}
- Tw = % transmission in pure water
  For transmission **relative to water** (light transmission in pure water = 100%), set Tw = 100%. **or**
  For transmission **relative to air** (light transmission in air = 100%), set Tw to a value from Table 1 in this document.
- A1 = current (most recent) output in **air**
- Y1= current (most recent) **dark or zero** (blocked path) output

Values for V_{air}, V_d, and V_{ref} are supplied in terms of both voltage and counts.

- Use the **voltage values** in the software if using an analog (voltage) sensor.
- Use the **counts values** in the software if using a digital (RS232) sensor (compatible only with SBE 16*plus* V2, 16*plus*-IM V2, or 19*plus* V2 CTDs).

Because obtaining a good pure water calibration can be difficult in the field, the output in air is used as the reference to track the instrument drift over time. By comparing the original output in air to subsequent outputs in air in the field, the initial instrument slope (derived from the pure water calibration) can be adjusted to correct for instrument drift.

The initial calculation of M and B is based on A1 and Y1 measured at the factory using Tw=100% (providing transmission measurements relative to water). These values are tabulated on the Calibration Sheet, and are input to the CTD configuration (.xmlcon) file by the manufacturer.

Example: The Calibration Sheet shows the following values for a voltage output C-Star with a 25 cm pathlength:
A0= 4.743 volts Y0 = 0.002 volts W0 = 4.565 volts Tw = 100% (for transmission relative to water) z = 0.25 m
The current calibration provides the following voltages: A1 = 4.719 volts Y1 = 0.006 volts
Calculating the calibration coefficients:
M = (100 / [4.565 – 0.002]) * (4.743 - 0.002) / (4.719 - 0.006) = 22.046 B = -22.046 * 0.006 = -0.132

The transmissometer is deployed and outputs 3.56 volts. Seasave V7 (or SBE Data Processing) calculates:
Light transmission [%] = (M * voltage output) + B = (22.046 * 3.56) – 0.132 = 78.351%
Beam attenuation coefficient c = - (1 / z) * ln (light transmission) = - (1 / 0.25) * ln (0.78351) = 0.976

Setting up Configuration (.xmlcon) File in Seasave or SBE Data Processing

Use the Configure Inputs menu in Seasave V7 (real-time data acquisition software), or the Configure menu in SBE Data Processing (post-processing software), to create or modify the .xmlcon file (see software Help files).

- For the voltage (analog) output C-Star: Select *Transmissometer – WET Labs C-Star* for one of the **external voltage channels** on the CTD. The software prompts for M, B, and pathlength (m).
- For the RS-232 (digital) output C-Star (SBE 16*plus* V2, 16*plus*-IM V2, or 19*plus* V2 CTDs only): Select *Transmissometer – WET Labs C-Star* for one of the **RS-232 channels on the CTD**. The software prompts for M, B, and Path length (m).

Note: The configuration file can only be saved as an .xmlcon file (not a .con file) if the C-Star is one of the sensors.

Field Recalibration

For field recalibration, connect the transmissometer to the CTD, run Seasave V7, and view the C-Star output with the light path in air (A1), and then with the light path blocked (Y1). Recalculate M and B, using the new values for A1and Y1 and the original factory values for A0, Y0, and W0, and enter M and B in the .xmlcon file. Refer to the Configuration Sheet in your CTD manual to determine the appropriate output channel for the transmissometer.

- To obtain the in-air reading, verify that the C-Star lenses are clean and dry. Consult the C-Star manual for recommendations on cleaning the lenses.
- To obtain the blocked voltage reading, use an opaque material.

Discussion of Transmission and Beam Attenuation Coefficient Relative to Water vs. Relative to Air

Many optical oceanographers prefer reporting transmissometer measurements relative to water, because they are not based on (currently accepted) values of Tw relative to air, which are subject to interpretation and may change in the future (see Table 1). The manufacturer calculates M and B relative to water, and indicates those values on the Calibration Sheet and in the configuration file. If desired, you can calculate M and B relative to air, and input those values in the configuration file.

The relationship between measurements relative to air and relative to water is:

Light transmission (relative to air) = Light transmission (relative to water) * Light transmission of pure water (relative to air)

But,

$c = -(1 / z) * \ln(\text{light transmission [decimal]})$

Therefore, rewriting the light transmission equation in terms of the beam attenuation coefficient c:

c (relative to air) = c (relative to water) + c of pure water (relative to air)

If M and B are calculated and entered in the configuration file relative to water, the light transmission and beam attenuation are calculated by the software relative to water. Conversely, if M and B are calculated and entered in the configuration file relative to air, light transmission and beam attenuation are calculated by software relative to air.

Light transmission of pure water relative to air is dependent on the transmissometer's pathlength and wavelength. Table 1 lists pure water percent transmission values (Tw), **relative to air**, for transmissometers with various wavelengths and pathlengths. The values have been derived with help from transmissometer manufacturers and references in the literature, and seem to be generally accepted. However, variations of several percent in reported coefficients exist in the literature. Therefore, these values may be subject to change or debate; consult the literature, and calculate M and B using your desired value of Tw.

Table 1. Nominal values of % transmission in pure water, **relative to air**, for transmissometers of listed wavelength and pathlength.

Wavelength	10 cm	25 cm	Reference
488 nm (blue)	99.8%	99.6%	1, 2
520 nm (green)	99.5%	98.8%	1, 2
650 nm (red)	96.0%	90.2%	1, 3
650 nm (red)	96.4%	91.3%	4 ***(historical value)***

References:

1. Pope and Fry, Applied Optics, Vol. 36.
2. Morrel, 1994 as communicated by WET Labs.
3. Smith and Baker, 1998, Applied Optics, Vol. 20, No. 2.
4. Original Sea Tech Transmissometer manual.