Optimizing EM302 Settings for Water Column Imaging

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**Introduction**

In Aug/Sept of 2011, several researchers from CCOM/JHC took part in a water column mapping expedition onboard the NOAA Ship Okeanos Explorer in the Gulf of Mexico. The purpose of the cruise was to assess the capability of the Okeanos Explorer’s 30 kHz Kongsberg Maritime EM302 multibeam echosounder to detect, and ultimately map, mid water targets such as natural seabed seeps in the Gulf of Mexico. As the echosounder is designed for seabed mapping, it was necessary to spend some time assessing the impact of various system settings on the quality of mid water imagery data. It is the intent of this short report to augment the formal cruise report by documenting some of the considerations that must be made when “tuning” this type of echosounder for mid water mapping operations. A list of recommendations is compiled at the end of this report.

**TVG offset**

The water column data has its own unique time-varying gain (TVG) function applied that is independent of the TVG applied for bottom detection and seabed imagery data. The nominal range of the water column data, as stored on disk, is -64 dB to 63 dB. Signals below or above this range are clipped. It is possible to avoid clipping the weak scatters that we are seeking to image by modifying the TVG parameters for the water column data. This is done by starting a telnet session to the TRU cabinet from the SIS machine:

1. Click the Windows button on the taskbar and choose “Run”.
2. Type “telnet 157.237.14.60”, this will open a DOS command window with a telnet session actively connected to the TRU.
3. Type the following: x_log_offset=30  This will update the TVG to use an additional 30 dB gain (the default is 0 dB). The TRU should report back the typed command the value being used for the TVG offset
4. Type “exit”.

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**Notes:**

- For detailed instructions, refer to the Okeanos Explorer documentation.
- Regular maintenance and calibration are crucial for optimal performance.
- Always consult with the expedition team for specific recommendations and procedures.
The above procedure must be repeated whenever the power is cycled on the TRU. If this procedure is not completed, then data whose level falls below -64dB will be lost.

**Runtime Parameters**
**Sector Coverage**

Setting the Angular Coverage Mode to “Automatic” will displace, grow or shrink the receiver beam fan to optimize the bottom detection quality across the swath. Though this is desirable from a bathymetric mapping point of view, it can be make further water column signal processing difficult as one can no longer assume that a given receive beam is at a fixed angle with respect to the vertical or within the same transmitter sector. For water column data acquisition, it is helpful to set the angular coverage mode to “Manual” with “Max. angle” values appropriate to the water depth. It is noteworthy that when the system runs in “Automatic” angular coverage mode that it will shrink the receiver coverage sector when faced with weak bottom returns at the outer edges of the swath. If water column mapping is the primary focus of the mission, then it may instead be desirable to allow for increased angular coverage despite the fact that the system cannot track the seabed at these angles. For example, in automatic mode you may find that the system selects +/-55° based on seabed return signal quality, however, water column imaging may still be possible over a much wider sector, e.g. +/-65°. Increasing the angular coverage must be balanced against a decrease in along-track density that comes with the reduced ping rate associated with large angular coverage.
**Depth Settings**

Dual swath sounding allows for increased along-track data density and/or faster survey speeds by essentially firing a second ping shortly after the first. The swaths are adjusted in the fore-aft direction such that one ensonifies an area slightly aft of the vessel and the other ensonifies an area slightly forward. The FIXED mode will set the fore and aft swaths at a fixed angle whereas the DYNAMIC mode will adjust the angular spacing to ensure a fixed along track sampling density to account for changes in vessel speed and water depth. The DYNAMIC mode is likely the better of the two as it attempts to maintain a constant along-track sampling density on the seafloor, however, it should be noted that this is not necessarily the case for water column targets, especially those in the upper part of the water column.

With the Ping Mode set to automatic, the system will choose an appropriate mode of operation depending on the water depth and return signal quality. In our experience, water column imaging artifacts can vary slightly or even dramatically between the various modes and some experimentation should be done to find a mode of operation that produces data of sufficient quality for the purpose of the mission. For our particular mission (mapping natural gas seeps), we desired a long pulse length to increase our chances of detecting weak scatterers in the water column so we chose to run in DEEP mode regardless of the water depth. Other water column mapping missions may have other priorities though and the table of mode characteristics should be consulted since the pulse length, number of transmit sectors and their operating frequencies all vary with Ping Mode. Furthermore, test data should be acquired using FM mode enabled and disabled (for the modes of operation that support both pulse waveforms) to determine if water column imagery quality varies with waveform type. Given the variety of data quality from one mode to the next, it is important to set aside time early in the cruise to assess the different Ping Modes and determine which is best suited for the mission at hand.

**Transmit Control**

Pitch and yaw stabilization is desirable as these both lessen the uncertainty in positioning with water column imagery that is not corrected for motion of the vessel. Currently, there is no commercially available software to fully geo-register water column imagery and it is thus advantageous to have the data compensated for motion in real-time such that the ensonified volume closely approximates a plane orthogonal to the vessel track.

**Real-Time Visualization**

Real-time visualization parameters can be optimized to increase the utility of the water column data display for quality control such that watch standers can monitor data quality for problems such as ship noise, interference from other sounders or weather related signal degradation. Suggested settings are a fixed depth and across
track scale with integer tickmarks such that the operator can quickly ascertain the
vessel relative coordinates of any water column targets. When attempting to find
water column targets, it is inconvenient if the reference frame in the image changes
from ping to ping. Fixing the image scale may be of particular importance for
operations where the water column display imagery is used to help coordinate
other operations such as CTD or ROV.

Fixing the image scale can be done through the “Show/Hide” interface which is
accessed via the top left button in the water column imagery display. The “Depth
Start Range Mode” and “Depth Stop Range Mode” should be set to fixed with
reasonable scale values entered (e.g. image should stretch vertically from X meters
to Y meters). The same is done for the “Across Start Range Mode” and “Across Stop
Range Mode”. The number of grid lines are then set for both the X and Y Axes. This
particular procedure is non-intuitive and some experimentation will be required to
get a particular combination of Start/Stop range and number of grid lines to give
reasonable (and usable) scales on the image. A more intuitive procedure would be
to set the grid interval, however, this is not currently possible in SIS.

The color scaling for the image should be set to “Fixed” as well to maintain
consistent imagery coloring from ping to ping that is visually easier to maintain
watch over. The Data Range should be adjusted to avoid visually clipping the
weaker targets, such as plumes, from the display (-80dB in the case below).
Bringing the upper end of the scale down below or near the level of the bottom
returns allows for an increase in contrast for water column scatterers at the expense
of visually clipping the stronger seabed returns. Note that these settings affect the
display only and do not affect the data.
Once the settings are optimized, it is suggested that the current frame layout and settings are saved as a new set of settings for water column mapping operations.

**System Tuning**

As mentioned earlier, there may be a particular set of system settings that provide optimal data quality for the task at hand. It is suggested that the following parameters be considered:

1) Ping Mode: dictates pulse lengths, transmit sector geometry and angular coverage (deeper modes may restrict the angular coverage even when used in water depths where the system is not attenuation limited at the outer edges of the swath)

2) Pulse wave form: CW and/or FM, some modes allow for both waveforms with the “FM disable” setting in the runtime parameters tab forcing the use of CW.

3) Dual swath versus single swath: water column artifacts, interference and noise levels may vary with the two modes of operation. Single swath may afford cleaner imagery however dual swath allows for increased along-track
resolution at the expense of potential degradation of imagery quality due to imperfect normalization between the swath pairs (e.g. strobe-like effects).

4) Transmitter beamwidth. Though not mentioned in the configuration documentation above, it is possible to modify the beamwidth of the transmitter array. Depending on the nature of the mission, it may be desirable to increase the beamwidth to improve probability of detection. Though dual swath technology can virtually guarantee 100% along-track coverage on the seafloor, the same cannot be said of targets in the water column, especially if the system is actively optimizing transmitter steering to maintain coverage on the seafloor.

Though we can optimize the water column imagery display for real-time Q/A, this display is of limited use, particularly for system tuning, for several reasons:

1) The only mechanism to compare and assess data quality between different modes of operation is through screen grabs. This does not permit quantitative analysis of the data itself, only of the real-time display imagery.

2) Only one swath of the dual swath is displayed. Noise levels, artifacts and interference patterns cannot be assessed in the second swath.

3) The low ping rate in deep water can make this a particularly tedious and subjective exercise.

For these reasons, it is critical to assess data quality using post-processing software tools such as FM Midwater or SonarScope.

**Opportunities for Software Improvement**

During the three week mission, a list of recommendations was compiled by the science party based on the few frustrations encountered during acquisition and post-processing. This list is presented below.

1. The water column TVG parameters should be configurable through a dialog box instead of by telneting to the TRU. The chosen values should persist when the TRU is de-energized.

2. The sampling rate of the water column data should be configurable by the user. An automatic (and default) mode would be to do what has been done to date: downsample the data to approximately the range resolution afforded by the pulse bandwidth. We had assumed that this would mean a constant sampling rate for a particular mode of operation, e.g. DEEP mode with 5 ms CW pulses, however, we have found that the sampling rate can vary. Having a varying sampling rate can hamper post-processing algorithms such as
filtering as the data must be resampled. We recommend that the user should be able to choose a constant sampling rate.

3. Understandably, the real-time display of the water column imagery can display the data from only of swath when running in dual swath mode. For quality assessment and system parameter tuning, it would be advantageous to be able to choose to instead display the second swath in the dual swath pair.

4. Setting the number of grid lines in the water column display is not intuitive and it would be much more intuitive to set the grid interval instead, e.g. 100 meters. Further to this, the auto scaling of depth and across track values chooses values that make it difficult to use the grid to accurately interpolate the position of a water column target in real-time. It is recommended that the automatic mode choose multiples of 10m, for example, for start/stop ranges and grid intervals. The same can be said about the “Cross track” display.

5. The water column display should be able to show the selected beam for the scope display. This would allow for better real-time assessment of water column signal quality with varying system parameters. The water column display should also display the min/max depth gates such that watch standers can assess whether the depth gates are appropriate with a quick glance.